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Coastal Hazard Management Study – Byron Bay Embayment

WRL Technical Report 2013/28
March 2016

By J T Carley, I R Coghlan, C D Drummond, P Dean-Jones and D Anning

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Project Details

Report Title	Coastal Hazard Management Study - Byron Bay Embayment
Report Author(s)	J T Carley, I R Coghlan, C D Drummond, P Dean-Jones and D Anning
Report No.	2013/28
Report Status	Final
Date of Issue	March 2016
WRL Project No.	2013088.01
Project Manager	James Carley
Client Name	Byron Shire Council
Client Address	70-90 Station Street, Mullumbimby NSW 2482
Client Contact	Catherine Knight
Client Reference	

Document Status

Version	Reviewed By	Approved By	Date Issued
Interim Draft V 1.0			24/12/2013
Interim Draft V 2.0	R J Cox	G P Smith	03/03/2014
Interim Draft V 3.0	R J Cox	G P Smith	09/07/2014
Draft V 4.0	R J Cox	G P Smith	10/12/2014
Draft V 5.0	R J Cox, I R Coghlan	G P Smith	17/07/2015
Final	R J Cox	G P Smith	05/11/2015
Final Revision 1.0	G P Smith	G P Smith	21/03/2016

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Byron Shire Council has prepared this document with financial assistance from the NSW Government through its Coastal Management Program. This document does not necessarily represent the opinions of the NSW Government or the Office of Environment and Heritage.

Executive Summary

ES.1 Introduction

The Water Research Laboratory (WRL) of the School of Civil and Environmental Engineering at UNSW Australia was engaged by Byron Shire Council to undertake a Coastal Hazard Management Study for the Byron Bay embayment. The study area extends northward from Cape Byron to the southern extremity of Tyagarah Beach (Figure ES.1).

The NSW North Coast is the traditional country of the Bundjalung people. The Byron Bay embayment has had a long history of coastal development since European colonisation. Belongil spit was subdivided into 200 lots with 33 feet (approximately 10 m) frontages in 1886. The first jetty was constructed off Jonson Street in 1888 and was removed in 1949. A second jetty was built (between Don and Manfred Streets) in 1928, was severely damaged in 1954 and was removed in 1972. The war memorial pool near Jonson Street was opened in 1966, with the pool, adjacent car park and surf life saving club protected by a seawall. All private development on Belongil spit now has some form of rock, concrete or geotextile container coastal protection – with most of these structures not designed to contemporary engineering standards. A partial seawall also fronts the Marine Parade foreshore at Wategos Beach.

The most recent study (BMT WBM, 2013) indicates that Belongil is receding at approximately 0.45 m/year, with additional recession expected to occur due to projected sea level rise.

ES.2 Assets at risk

Table ES.1 details the principal assets vulnerable in 2050 to coastal erosion/recession based on the "best estimate" hazard lines produced by BMT WBM (2013) for a retreat scenario involving removal of all seawalls except Jonson Street. Approximately $189 million of private land and buildings are potentially affected to 2050. Additional scenarios and probabilities were considered in the economic analysis, and substantial urban infrastructure is also vulnerable.

Table ES.1: Assets Vulnerable to Erosion/Recession in 2050 with Seawall Removal

	Number or m^2 of Vulnerable Structures or Assets				
Asset	**Clarkes Beach**	**Main Beach**	**Cavvanbah (First Sun to Border St)**	**Belongil (Border St to Creek)**	**Total (No or m^2)**
Houses (No)	4	0	0	56	60 No
Cabins & amenities (No)	16	2	0	0	18 No
Road reserve (m^2)	0	0	0	9,458 m^2	9,458 m^2
Railway corridor (m^2)	0	0	25,275 m^2	0	25,275 m^2
Private land	0	0	0	71,332 m^2	71,332 m^2

ES.3 Shortlisted Management Options

In addition to the status quo, five shortlisted management options were developed in conjunction with stakeholders and Councillors as part of this study. These options were:

1. Status quo.
2. Planned Retreat (Public-Private).
3. Groynes, seawall, nourishment.
4. End Control, seawall, nourishment.
5. End Control, seawall, NO nourishment.
6. Adaptive scheme comprising seawall, groynes and small scale nourishment.

The Public-Private model of Planned Retreat means that landowners who purchased prior to 1988 would be compensated with public funds for losses associated with Planned Retreat, while landowners who purchased after 1988 would bear their own losses (Private). The justification for this split is Council's 1988 development control plan which advised of the vulnerability of some properties to coastal erosion and recession, and therefore those who purchased after this date should have been aware of coastal hazards.

ES.4 Previous Studies

Three coastal management studies have been undertaken in the past.

The Gordon, Lord and Nolan (PWD 1978, 243 pages) study recommended:

- Groynes + nourishment.

The Geomarine (Lord and Nielsen, 1989, 65 pages) study recommended the following actions (the majority of which have since been undertaken):

1. Commitment by Council to protect/upgrade town centre.
2. Reassess hazard lines in town centre and Clarkes Beach.
3. Redefine erosion escarpment.
4. Adopt soft management for Clarkes Beach.
5. Train Belongil Creek.
6. Dune works and beach nourishment along Belongil.
7. Reassess hazard lines for Belongil.
8. Rock groynes between Belongil Creek and the town centre, at:
    a. Manfred St;
    b. The second jetty site;
    c. The town centre (possibly in conjunction with a tourist jetty.
9. Dune maintenance.

The WBM (Patterson and Witt, 2003, 433 pages) study recommended the following option for Belongil:

- Seawall + nourishment + end control structure.

WBM recommended Planned Retreat if sand nourishment was not found to be viable, but noted many impediments to its implementation, and therefore recommended further alternative protection options.

ES.5 Economics of Options in this WRL Study

A cost benefit analysis (CBA) was undertaken in accordance with NSW Treasury guidelines and recent draft guidelines supporting a revised draft NSW Coastal Management Manual, for a planning horizon to 2050. A Benefit to Cost Ratio (BCR) greater than one and/or a Net Present Value (NPV) greater than zero means a project is economically viable. A summary of the CBA results is shown in Table ES.2. Within this table, the consultants' best estimate values are based on values for inputs determined by WRL and/or GCCM, together with interpretation and advice provided by OEH. Byron Shire Council (resolution 16-028) also directed WRL and GCCM to adopt certain values for variables within the CBA, with the results of these also shown in Table ES.2. Details of this analysis are shown in Appendix N. It can be seen that the best economic option is 6.1, the adaptive scheme with engineered seawall only.

Table ES.2: Summary of CBA Results

		NPV ($ million)		BCR	
Option	**Description**	**Best Estimate**	**BSC Base Case**	**Best Estimate**	**BSC Base Case**
2	Planned retreat	-28.26	-40.79	0.35	0.40
3	Groyne Seawall Nourishment	-23.13	11.62	0.56	1.22
4	End Control Seawall Nourishment	-16.45	15.88	0.63	1.36
5	End control Seawall no Nourishment	-2.10	25.15	0.92	1.91
6	Adaptive management - all components	-7.25	22.51	0.79	1.66
6.1	Adaptive management-seawall only	7.24	31.94	1.42	2.87
6.2	Adaptive management - Seawall + single groyne	5.19	31.86	1.26	2.59
6.3	Adaptive management - Seawall + groyne field	-3.76	24.42	0.87	1.82

Transfer payments (e.g. Council rates or land tax) were not included in the CBA, however, this revenue stream is of interest to stakeholders.

Council rates revenue for properties in the Byron Bay embayment (virtually all in Belongil precinct) potentially affected by erosion/recession to 2050 is:

- Present rates revenue: $407,000 per annum
- NPV of present rates revenue to 2050: $7 million

The potential range of land tax revenue for properties in the Byron Bay embayment (virtually all in Belongil precinct) potentially affected by erosion/recession to 2050 is:

- Present land tax revenue: $0.6 to $2.4 million per annum
- NPV of present land tax revenue to 2050: $10 to $41 million

ES.6 WRL Comments on Planned Retreat (Public-Private)

Planned Retreat most closely aligns with the NSW Coastal Policy 1997 and *Coastal Protection Act 1979*, however, this is not unequivocal. Planned Retreat was the preferred management option by Byron Shire Council in the draft 2010 CZMP and has appeared within development control plans since 1988, but it has not been adopted within an operational CZMP.

Planned Retreat has received backing in court rulings regarding setbacks for new development and removable buildings. However, during this time, coastal protection works (seawalls of varying coastal engineering standard) have proliferated. Seawalls now protect all private Belongil beachfront properties and are the status quo. Planned Retreat could only be implemented with the orderly removal of all seawalls on Belongil.

Planned Retreat (Public-Private) offers the main advantages of:

- Restoration of a more natural ecological environment (however, human use is likely to remain medium to high); and
- Improved alongshore pedestrian access and beach amenity.

Planned Retreat (Public-Private) also offers economic benefits due to increased beach availability, but this would be outweighed by property losses. The predominant economic benefits of Planned Retreat accrue to tourists/tourism and the general public in the form of enhanced natural beaches, but the Public-Private model involves this being funded predominantly by landowners.

The main disadvantages of Planned Retreat (Public-Private) are:

- Low economic viability:
    - NPV -$28 million and BCR = 0.35 (consultants'/OEH best estimates),
    - NPV -$41 million and BCR = 0.40 (BSC inputs);
- Funding inequity;
- Likely protracted resistance from affected landowners, including attribution of recession hazard to Jonson Street works and/or climate change; and
- High probability of a breakthrough of Belongil Spit at Manfred Street during a major storm.

Subject to funding agreements being reached, the predominant distribution of costs and benefits for Planned Retreat (Public-Private) relative to the status quo would be:

• Funding (costs):	Private Landowners:	69% ($31 M)
	Public sector	31% ($12 M)
• Beneficiaries:	Council	63% ($9.5 M)
	Tourists:	34% ($5.5 M)

That is, the Planned Retreat (Public-Private) option would require $12 million of public funding relative to the status quo. If a 20 m buffer (from the face of the erosion escarpment) is applied to Planned Retreat, private property losses would increase by approximately $30 million.

A range of useable public beaches, from urban to nature reserve wilderness will still be available within the 37 km of coastline in Byron Shire without Planned Retreat.

ES.7 WRL Recommended Option for Belongil

WRL recommends that as a minimum, the status quo be improved with Stage 1 (engineered seawall with walkway) of Option 6, the adaptive scheme. This sub option as a standalone measure has the best economic performance. Many parties who participated in the consultation process expressed a view that no form of coastal protection works were acceptable for Belongil, however, protection was supported by many other parties involved. The engineered seawall with walkway offers an improvement on the status quo. The full three stage adaptive management protection scheme has components of:

- Stage 1: Seawall with walkway (Figure ES.2);
- Stage 2a: An initial self-filling trial groyne;
- Stage 2b: Additional groynes; and
- Stage 3: Small scale sand nourishment.

Progress to later stages would be warranted if triggers within the adaptive scheme are reached, however, economic modelling indicates that, relative to the status quo, the cost of increasing beach width (above the status quo) over a 1 km stretch of Belongil is not economically viable.

The adaptive management scheme is flexible and staged, without large scale nourishment, and aims to minimise the financial commitment of Council and the State, while providing engineered protection to the built environment and alongshore access to residents and visitors.

Stage 1 of Option 6 staged adaptive management protection scheme offers the main advantages of:

- Technical feasibility;
- Economic feasibility;
- Funding equity – beneficiaries are predominant funders;
- Low financial commitment from Byron Shire Council and the State;
- Improved alongshore pedestrian access; and
- An improvement on the status quo for all parties.

The approximate capital funding requirements for the adaptive scheme (subject to funding negotiations) are:

- Stage 1 (year 1): Seawall with walkway
    - Landowners: $12 M (80%)
    - Council: $1 M (7%)
    - State Government coastal program: $1 M
    - State Government other: $1 M

- Total (over approximately 10 years, if latter stages are undertaken):
    - Landowners: $21 M (62%)
    - Council: $6 M (18%)
    - State Government coastal program: $6 M
    - State Government other: $1 M

Provided that a funding model, public access and a wall alignment can be negotiated, the outlay from Council and the State for Stage 1 of Option 6 staged adaptive scheme is only about 15% of other options including Planned Retreat (public-private). The scheme offers benefits to all parties compared with the status quo.

Subject to the realisation of more extreme scenarios of projected global climate change and sea level rise, ongoing recession of the beach and ongoing monitoring, there may be a time in the future when protection options are no longer viable.

Retreat may then become a viable option, however, this may be more than 100 years into the future. Climate, environmental, economic, social, political, regulatory and technological change over this time means that accurate planning of coastal management on a century timescale may be unrealistically speculative.

ES.8 Recommendation for other Areas in Byron Bay Embayment to 2050

Wategos

The following actions are recommended:

- Accurately map the bedrock surface and existing seawall extent;
- Check the stability of the existing seawall; and
- Consider rebuilding the seawall and/or partial retreat of Marine Parade which may involve conversion to one way traffic flow.

The Pass to Clarkes Beach

BMT WBM (2013 Figure 4-41) noted that "the erosion hazard at The Pass extends to bedrock". The erosion hazard lines extend into the Captain Cook car park (slightly by 2050) and Lighthouse Road for 2100, however, bedrock levels there are uncertain. Due to the requirement for road access to Wategos, additional geotechnical works to retain Lighthouse Road may be required. Given the proximity to bedrock, these would not displace substantial portions of sandy beach and would not be required prior to 2050.

Options for the Captain Cook car park are minor retreat by 2050 or similar works to those suggested for Lighthouse Road. These would not be needed immediately.

The following actions or considerations are recommended:

- Accurately map bedrock surface to confirm hazard lines relative to structures.
- The small number of structures potentially vulnerable to hazards may make retreat of these structures more justifiable than more intensely developed areas.

Main Beach

Generally continue dune management to allow natural processes to prevail, in conjunction with upgrading the Jonson Street seawall structure. Monitor beach change, particularly if modifications are undertaken to Jonson Street works.

Cavvanbah

Future changes to this beach will be affected by management options for Belongil. There are no buildings within the erosion/recession hazard zone to 2050. The railway corridor is within the erosion/recession hazard zone in 2050 but not in the immediate hazard zone. If nourishment is undertaken for Belongil, Cavvanbah would be a potential placement site. Based on present land use, there is no economic justification for protection of Cavvanbah with a seawall (north from First Sun towards Border Street) to 2050. However, reopening or alternative use of the railway line/corridor would necessitate a review of the need for protection in the future.

North Beach

Future changes to this beach will be affected by management options for Belongil, however, there are no structures within the coastal erosion/recession hazard zones to 2050 or 2100. Impacts on North Beach need to be considered in the design of any (groyne) structures for Belongil. Some existing or future developed areas may be vulnerable to coastal lake or watercourse entrance instability and wave propagation across the entrance of Belongil Creek. This could be managed through monitoring and/or the groyne schemes proposed, and is presently partially managed through the existing Belongil creek entrance opening management procedures.

ES.9 Overall Summary

The Byron Bay embayment has had a long history of development within the active coastal zone, with jetties, seawalls, groynes, shipwrecks and dune management on the open coast, and bridges (road and rail), seawalls and entrance management for Belongil Creek having altered coastal processes for over 100 years. Land subdivisions undertaken in the 1880s still remain.

Planned Retreat as a response to this legacy would allow a return to a more natural ecological beach state. The Planned Retreat (Public-Private) model option within this study would also involve high economic cost, low economic viability, social disruption and unresolved, funding, equity and logistical issues. A publically-funded Planned Retreat (Public) model (effectively a "buyout") may resolve many of these issues, but would involve substantially higher economic cost to the public sector.

All management options including Planned Retreat will involve sand being transferred from one location to another. Due to the predominantly developed nature of much of the urban environment in the Byron Bay embayment, engineered management which improves upon the status quo is recommended in the most vulnerable locations, with continued soft management (through dune works and planning controls) recommended for those areas where sufficient buffer exists to separate urban areas from coastal hazards.

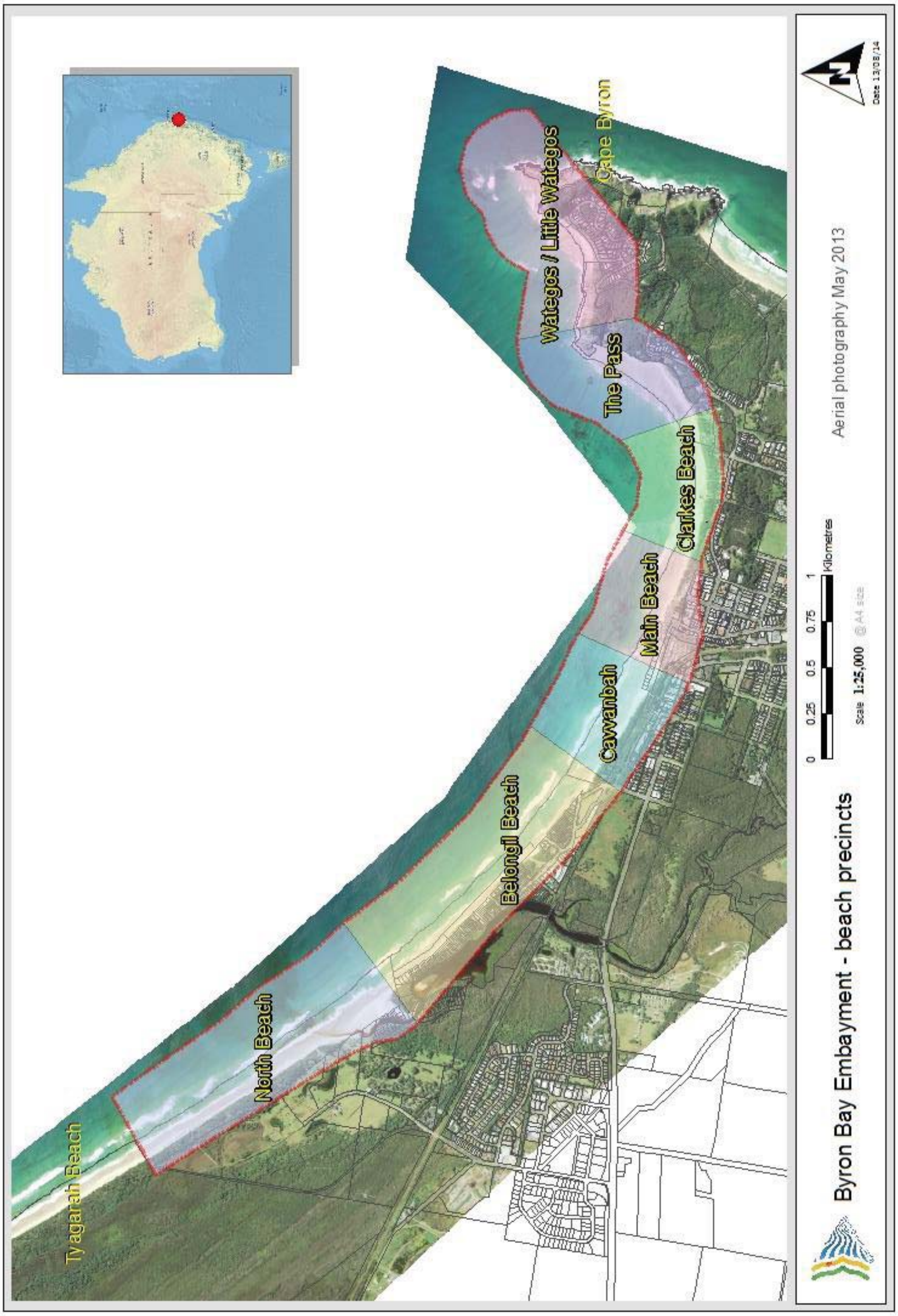


Figure ES.1: Study Area (Source BSC)

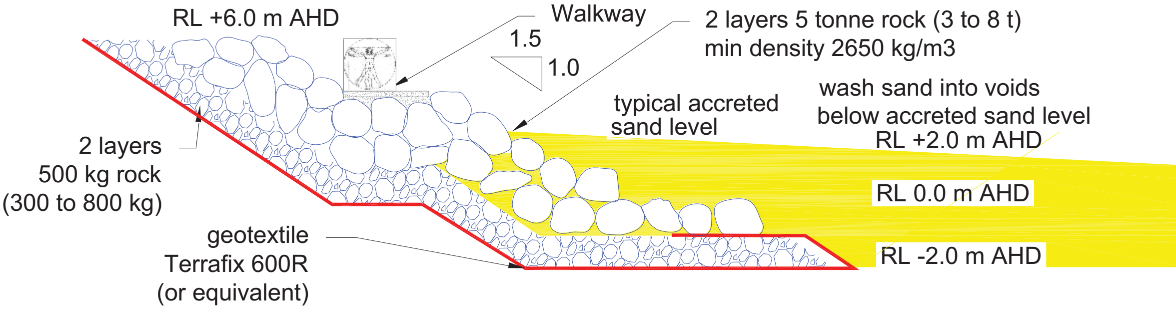


Figure ES.2: Preliminary Seawall Design incorporating Alongshore Pedestrian Access

Contents

List of Tables

List of Figures

1. Introduction

The Water Research Laboratory (WRL) of the School of Civil and Environmental Engineering at the UNSW Australia was engaged by Byron Shire Council (BSC) to undertake a Coastal Hazard Management Study (CHMS) for the Byron Bay Embayment. WRL sub-contracted Umwelt Australia (Umwelt) and the Griffith Centre for Coastal Management (GCCM) to provide additional specialist input to the CHMS.

The study area extends northward from Cape Byron to the southern extremity of Tyagarah Beach as shown in Figure 1.1. The area extends landward and seaward from the coast to sufficiently cover all extents that may require coastal hazard management between the immediate time (nominally 2010, as per BMT WBM, 2013) and 2050 to 2100.

This study assessed and determined feasible options for managing the identified coastal hazard risks within the BBE for 2050 and 2100 planning horizons. The risks posed by coastal hazards were assessed and a range of potential management options were considered that seek to balance the competing priorities associated with managing the coastline.

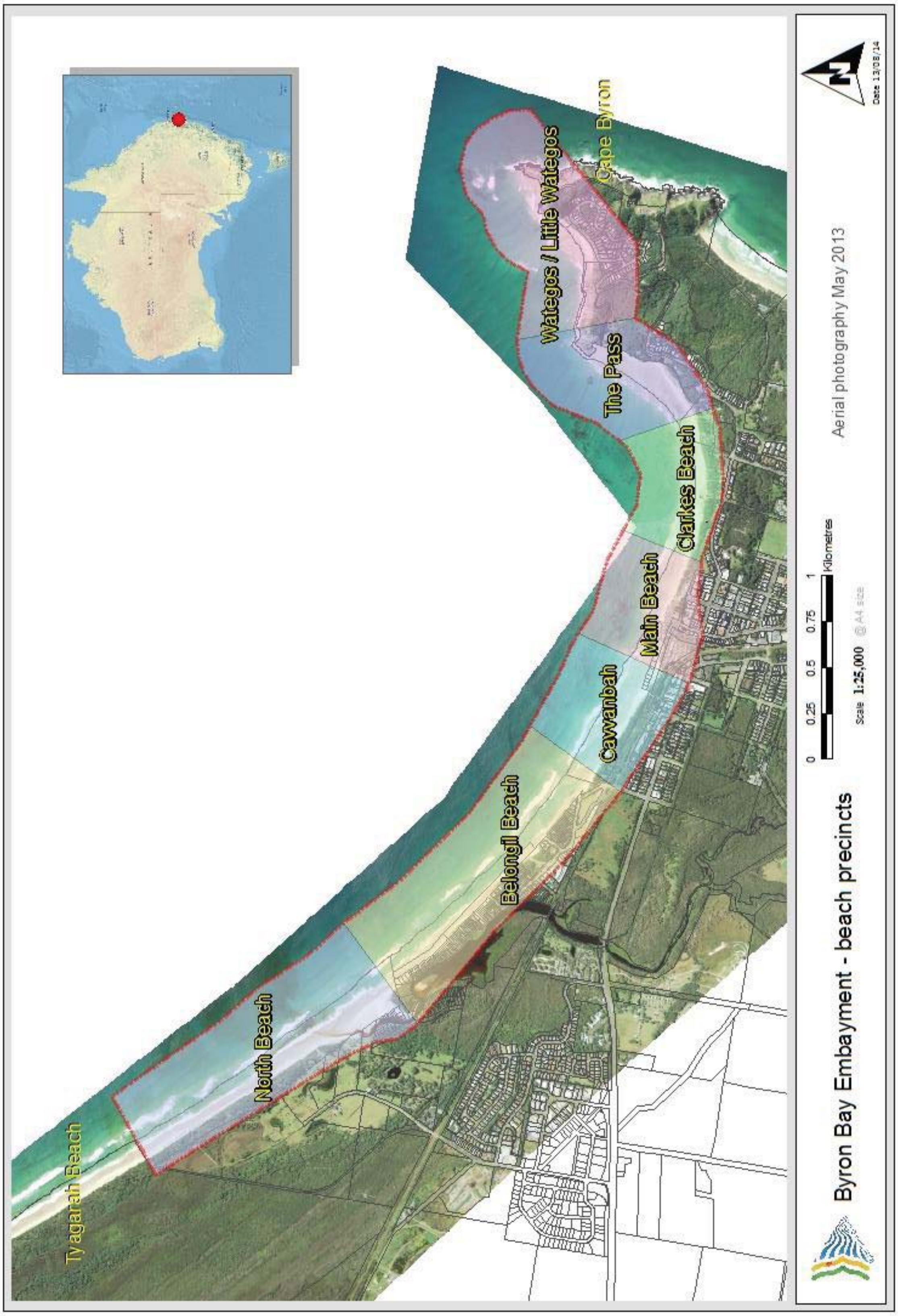


Figure 1.1: Study Area (Source BSC)

2. Coastal Hazards and Risk

A detailed database of assets potentially vulnerable to erosion was provided electronically to BSC based on information contained in BSC's GIS database. This Section summarises vulnerable assets, with additional details provided in Appendix H and I for each scenario.

2.1 Overview

Coastal hazards for the Byron Bay Embayment were assessed in BMT WBM (2013) with Version 3 dated 19/9/2013.

The NSW Coastal Protection Act 1979 (as at 3 January 2014) states: "coastal hazard" means the following:

(a) beach erosion;
(b) shoreline recession;
(c) coastal lake or watercourse entrance instability;
(d) coastal inundation;
(e) coastal cliff or slope instability;
(f) tidal inundation;
(g) erosion caused by tidal waters, including the interaction of those waters with catchment floodwaters.

OEH (July 2013) *Guidelines for Preparing Coastal Zone Management Plans* lists the following hazards:

- Beach erosion;
- Shoreline recession;
- Coastal lake or watercourse entrance instability;
- Coastal inundation (including estuaries);
- Coastal cliff or slope instability;
- Tidal inundation (including estuaries);
- Erosion within estuaries caused by tidal waters, including the interaction of those waters with catchment floodwaters.

BMT WBM produced hazard lines for the combined hazards of beach erosion, shoreline recession and (sea level rise recession due to) climate change for three planning horizons, namely:

- Immediate;
- 2050; and
- 2100.

These hazard lines are shown in Appendix L. For the shoreline recession hazard, BMT WBM (2013) produced three estimates, namely "min", "best estimate" and "max". In order to reduce the permutations, WRL with the concurrence of BSC and OEH, undertook a count of assets potentially affected by coastal hazards for WBM's "best estimate" of the shoreline recession hazard.

BMT WBM's (2013) hazard lines also considered two scenarios, namely:

- Scenario 1: Retain/maintain/upgrade all existing coastal protection structures (continuous from Border St to northernmost Belongil private property);
- Scenario 2: Remove all existing coastal protection structures except Jonson Street (which would need to be maintained/upgraded).

Therefore, six hazard lines were considered by WRL for counting assets potentially vulnerable to coastal hazards. Due to presence of rock outcrops, headlands, existing coastal protection structures and the entrance to Belongil Creek, the BMT WBM hazard lines were not continuous for the entire Byron Bay embayment. Future upgrades to protection structures and minor inaccuracies in hazard line plotting may alter the count of affected assets near the ends of the hazard lines.

Note that Scenario 1 assumes that the existing seawalls function to protect assets, however, this cannot be assured in their present condition (WorleyParsons, 2013). Some assets are vulnerable to erosion under Scenario 1 because the existing seawalls do not cover the entire coast of the Byron Bay embayment.

The technical definition of *risk* is *likelihood* times *consequence*. The BMT WBM hazard lines were estimated using contemporary NSW engineering practice, but do not consider quantitative probabilities for a range of input parameters, but rather consider "design", 100 year ARI or "best estimate" for these. Therefore, a wide range of likelihoods (and consequences) cannot be used to analyse risk for this study. This is further addressed in Appendix J of this study.

2.2 Assets Potentially Vulnerable to Erosion Hazard

Cadastre parcels potentially vulnerable to erosion and recession based on "best estimate" hazard lines in BMT WBM (2013) are summarised in Table 2.1.

Table 2.1: Properties Potentially Vulnerable from Erosion

Planning Horizon	Recession Hazard	Scenario	Total Number of Vulnerable Cadastre Parcels
Immediate	n/a	1 (retain seawalls)	54
Immediate	n/a	2 (remove seawalls)*	134
2050	Best estimate	1 (retain seawalls)	58
2050	Best estimate	2 (remove seawalls)*	166
2100	Best estimate	1 (retain seawalls)	84
2100	Best estimate	2 (remove seawalls)*	230

*Retain Jonson St works only

The structures potentially vulnerable from erosion are summarised in Table 2.2. In this context a structure is defined as a freestanding building which appears to be for habitation, commercial or community use. This would include houses, attached apartments (counted as one structure), freestanding cabins and public amenities. Within the limits of the aerial photographs used to count structures, garden sheds and detached garages or carports have not been counted as a structure in this assessment. For the purposes of assessing management options to 2050, a further breakdown of potentially vulnerable structures is provided in Table 2.3 for Scenario 2 (remove seawalls except Jonson St). Note that this would also apply for Scenario 1 (retain seawalls) for all locations except Belongil (Border St to northern Belongil Spit). Note that individual asset values were considered in assessing avoided losses in Appendix N and Section 12.

Table 2.2: Structures Potentially Vulnerable from Erosion

Planning Horizon	Recession Hazard	Scenario	Number of Vulnerable Structures
Immediate	n/a	1 (retain seawalls)	2
Immediate	n/a	2 (remove seawalls)*	36
2050	Best estimate	1 (retain seawalls)	22
2050	Best estimate	2 (remove seawalls)*	78
2100	Best estimate	1 (retain seawalls)	60
2100	Best estimate	2 (remove seawalls)*	161

*Retain Jonson St works only

Table 2.3: Structures and Assets Potentially Vulnerable from Erosion to 2050 for Scenario 2

	Number or m^2 of Vulnerable Structures or Assets				
Asset	Clarkes Beach	Main Beach (a)	Cavvanbah (First Sun to Border St)	Belongil (Border St to Creek)	Total (No or m^2)
Houses (No)	4	0	0	56	60 No
Cabins & amenities (No) (a)	16	2	0	0	18 No
Road reserve (m^2)	0	0	0	9,458 m^2	9,458 m^2
Railway corridor (m^2)	0	0	25,275 m^2	0	25,275 m^2
Private land (m^2)	0	0	0	71,332 m^2	71,332 m^2

(a) The assets are at the extremities of the Jonson St works (cabin in First Sun and SLSC building) and may be protected in an upgrade (WorleyParsons, 2014)

Other infrastructure potentially at risk from erosion is summarised in Table 2.4. Note that no sewer vacuum mains or water mains are potentially affected by erosion. Services such as Telstra and Electricity are also located within erosion hazard zones but are not documented on Council's GIS system.

Table 2.4: Other Infrastructure Potentially Vulnerable from Erosion

Planning Horizon	Recession Hazard	Scenario	Number of Vulnerable Assets: Sewer Gravity Mains	Sewer Pressure Mains	Sewer Rising Mains	Stormwater Drains	Stormwater Mains	Sewer Vacuum Mains	Water Mains	Other (Public Assets)
Immediate	n/a	1	0	0	1	0	1	0	0	2
Immediate	n/a	2	12	0	1	0	1	0	0	5
2050	Best estimate	1	3	0	1	0	4	0	0	3
2050	Best estimate	2	28	1	1	0	6	0	0	6
2100	Best estimate	1	12	2	1	0	10	0	0	19
2100	Best estimate	2	64	36	1	3	19	0	0	34

2.3 Value of Assets Vulnerable to Erosion and Recession

Asset values were determined in Appendix N. A summary of the value of assets potentially vulnerable to erosion and recession to 2050 is shown in Table 2.5.

Table 2.5: Value of Assets Potentially Vulnerable to Erosion and Recession

Timeframe	Rateable Value of affected private property (2016 $million)	Value of affected private buildings (2016 $million)	Total (market) value of affected assets (2012 $million)
With no buffer			
Scenario 2 (remove seawalls*): 2050 Projection	107	32	138
With 20 m buffer			
Scenario 2 (remove seawalls*): 2050 Projection	128	59	187

* Except Jonson Street

2.4 Probabilistic Assessment of Assets Vulnerable to Erosion and Recession

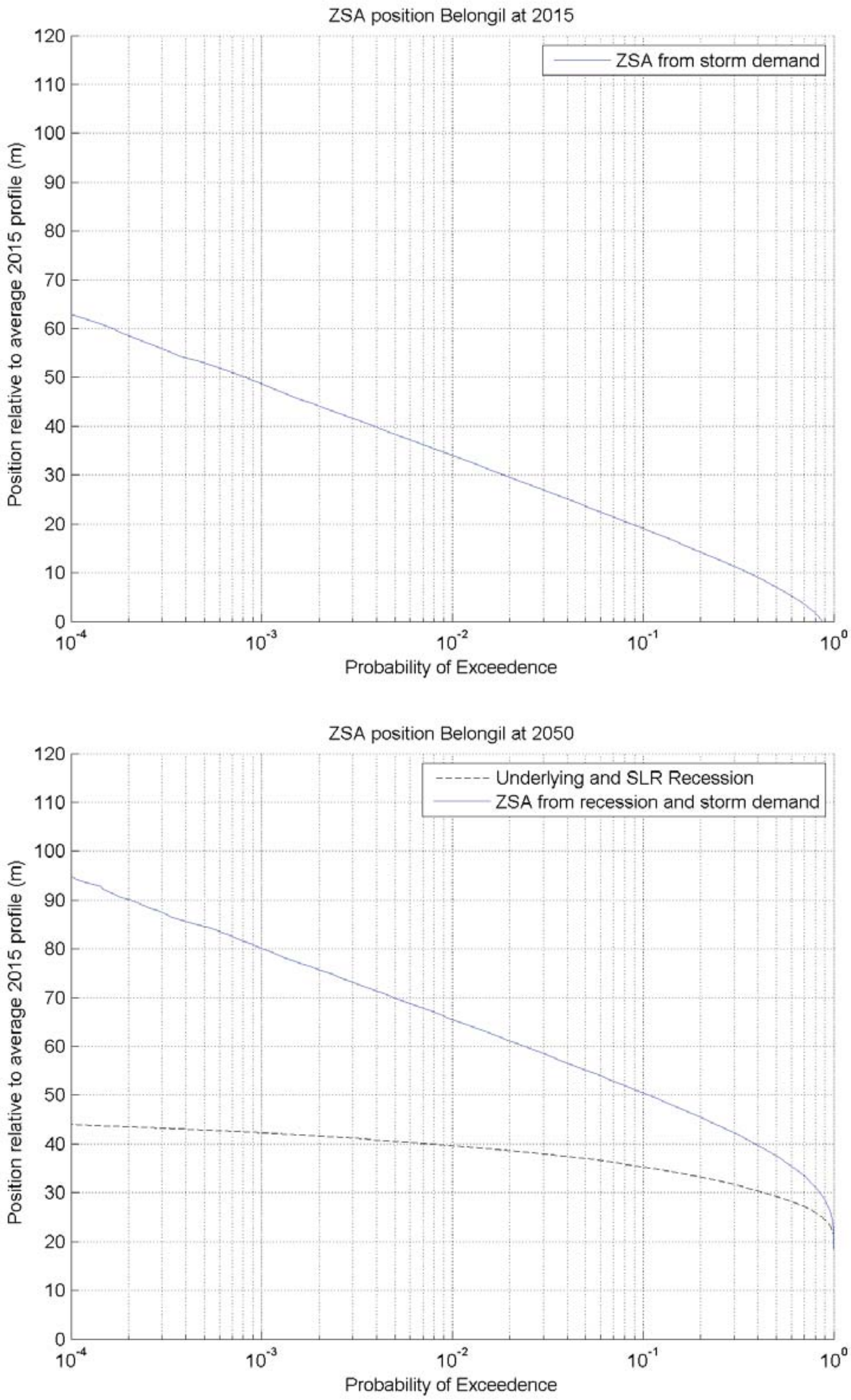
Detailed methodology regarding the probabilistic assessment of assets Vulnerable to erosion and recession is presented in Appendix J.

In the conventional approach described above, each of the input variables is assigned a single value and a single estimate (prediction) of recession and erosion is produced. This is usually a "design", "100 year ARI", "best estimate" or "conservative" value. In a probabilistic approach, each independent input variable is allowed to (randomly) vary over a range of values pre-defined through probability distribution functions (pdf). This range covers both uncertainty and error in a heuristic manner. By implementing a stochastic method to the recession model (Monte Carlo simulations) a probabilistic range of estimates (forecasts) of future recession is produced. Probabilities of storm demand are also included in this assessment by combining them randomly with the recession probabilities in a further Monte Carlo simulation. Note that by assuming that the storm demand represents a deviation from the long term average trend, and by expressing the combined probability as an AEP, the probability (AEP) of an eroded shoreline position each year does not need to consider beach recovery. The bounding still relies somewhat on engineering judgement and experience.

In the Land and Environment Court judgement "John Van Haandel v Byron Shire Council [2006] NSW LEC 394", Commissioner Brown accepted that the erosion escarpment for application of a 20 m setback was the historical erosion escarpment from the 1970s or 1980s. That is, recovery of the beach (whether natural or through mechanical intervention) did not advance the setback line in a seaward direction. Furthermore, Commissioner Brown noted that *"… the 20 m requirement must be applied cumulatively with the requirement for relocation otherwise it would have no purpose."*

Therefore, for the purposes of the probabilistic assessment of coastal hazards for the economic assessment of planned retreat, progradation/accretion following storm events is not considered to be a "gain" of private land, since this land has reached its planned retreat trigger and cannot be redeveloped.

Present day erosion hazard distances are shown in Figure 2.1 for Belongil, with the present day line presented in BMT WBM (2013) based on an AEP of 10^{-2} (1%). For 2050, each of the above variables were considered to be independent, and were combined through a *Monte Carlo* (Mariani et al 2013) simulation using 10^{6} iterations.



Note: BMT WBM 2050 best estimate 2050 ZSA hazard line is y = 75 m

Figure 2.1: Probabilities of Erosion and Recession Hazard – Belongil

2.5 Assets Impacted by Probabilistic Erosion and Recession Hazards under Planned Retreat

This Section is an abbreviated version of that contained in Appendix J.

The probabilities of eroded land and buildings were assessed for the purpose of economic assessment of risk under a Planned Retreat scenario.

As detailed in Appendix N, only the privately held land has high economic value. Areas of eroded/receded privately owned land for a range of probabilities are shown in Table 2.6. Note that since the 2050 values include a combination of erosion and recession, the probabilities can only be expressed as an AEP, and cannot be correctly expressed as an ARI, however, for the present day 63% AEP is equivalent to 1 year ARI and 9.5% AEP is equivalent to 10 year ARI. These areas are relative to the following initial 2015 areas and are almost exclusively in the Belongil precinct:

- Cadastral area of private land potentially impacted by erosion: 109,227 m^2;
- Useable area (excludes areas seaward of seawalls, private road, creek): 106,441 m^2.

Based on BSC's coastal audit (2011), there are 14 private properties at Belongil subject to coastal hazards to 2050 that were purchased prior to 1988 and would therefore be subject to publicly funded retreat under a Planned Retreat (Public-Private) model. These pre-1988 properties have the following initial 2015 areas:

- Cadastral area of private land potentially impacted by erosion: 23,227 m^2;
- Useable area (excludes areas seaward of seawalls, private road, creek): 21,777 m^2.

Table 2.6: Area of Eroded/Receded Private Land for Retreat Scenario

	Eroded land (m^2) for AEP (%)				
	63%	**9.5%**	**1%**	**0.1%**	**0.01%**
2015	11,372	32,075	43,041	51,313	62,271
2050	39,553	48,515	60,783	71,332	81,877

Note: Almost all land is within Belongil precinct, with small areas in Cavvanbah for rare AEP events in 2050

Table 2.7 presents the number of buildings where the zone of slope adjustment (with no additional buffer) would cause retreat of buildings to be triggered. For economic assessment, it has been assumed that the building replacement value is written off if the building is not designed to be relocatable, while relocatable structures can be moved landward at a cost of $10,000 provided there is sufficient land remaining, with an additional $10,000 for reconnection of services. Non-relocatable buildings have been allocated a value of $2500 per m^2 of building floor area. This is based on Rawlinsons (2015) for Tweed Heads "High standard framed house with no air conditioning". GIS processing was used to determine building footprints, with high resolution oblique aerial photos used to classify each building as 1, 1.5 or 2 storeys.

Table 2.7: Number of Buildings Impacted under Retreat Scenario

	Building numbers for AEP (%)				
	63%	9.5%	1%	0.1%	0.01%
2015 relocatable	1	6	9	9	9
2015 non relocatable	9	16	25	34	44
2015 total	10	22	34	43	53
2050 relocatable	6	9	9	9	9
2050 non relocatable	23	29	41	47	49
2050 total	29	38	50	56	58

Note: Almost all buildings are within Belongil precinct, with a small number in Cavvanbah for rare AEP events in 2050

The value of land and buildings at Belongil relative to distance from the present seawall face (with and without a 20 m buffer) is shown in Figure 2.2.

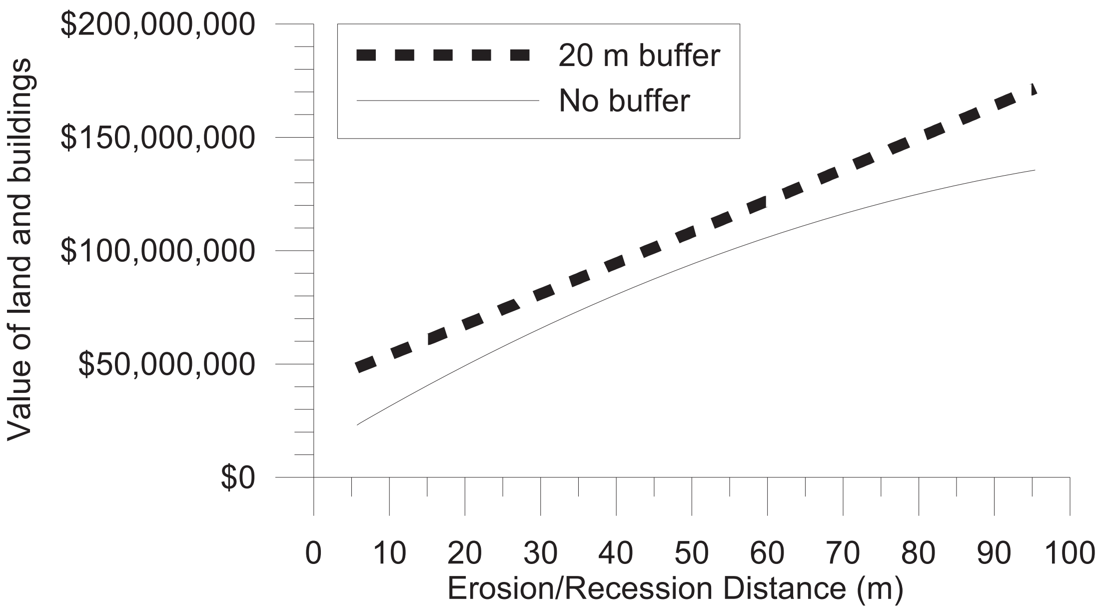


Figure 2.2: Value of Land and Buildings

For floodplains, the NSW Floodplain Management Manual (NSW Government, 2005) recommends that damage is expressed as "average annual damages" (AAD). The AAD method in the Floodplain Manual assumes complete rebuilding after each major event, whereas under a Planned Retreat scenario, once a loss has occurred, it is assumed that the land asset value is written off, conventional buildings are written off and relocatable buildings are moved (where space is available). Therefore, while there are no precedents available, a concept of incremental average annual damages was considered for the Byron Bay embayment.

Incremental AAD was calculated by combining the following information:

- The probabilities of future shoreline recession and storm erosion (Figure 2.1 for Belongil), that is, the AEP of shoreline position for each year; and
- The economic consequence of damage through erosion/recession (Figure 2.2 for Belongil).

The combination was undertaken by considering the probabilities of erosion events for each year using a Monte Carlo simulation technique with 1,000,000 iterations per year. Only events which move the erosion scarp further landward than its otherwise most landward position (over the planning/economic assessment period – not geological time) will trigger planned retreat and its consequential economic loss. The Monte Carlo results were then averaged to produce incremental AAD as shown in Figure 2.3. Note that the future dollar values are not discounted in this figure, but discounting is undertaken in Appendix N. It can be seen that substantial economic damage occurs in the early years following implementation of Planned Retreat, with approximately $28 million of damages occurring in the first year of implementation if no buffer is adopted, rising to $52 million if a 20 m buffer is adopted. This is because of the substantial loss of land and buildings which would occur in even a minor erosion event (e.g. 1 year ARI) following removal of the existing seawalls. Towards the end of the assessment period, the incremental AAD asymptotes towards the component driven predominantly by the long term recession.

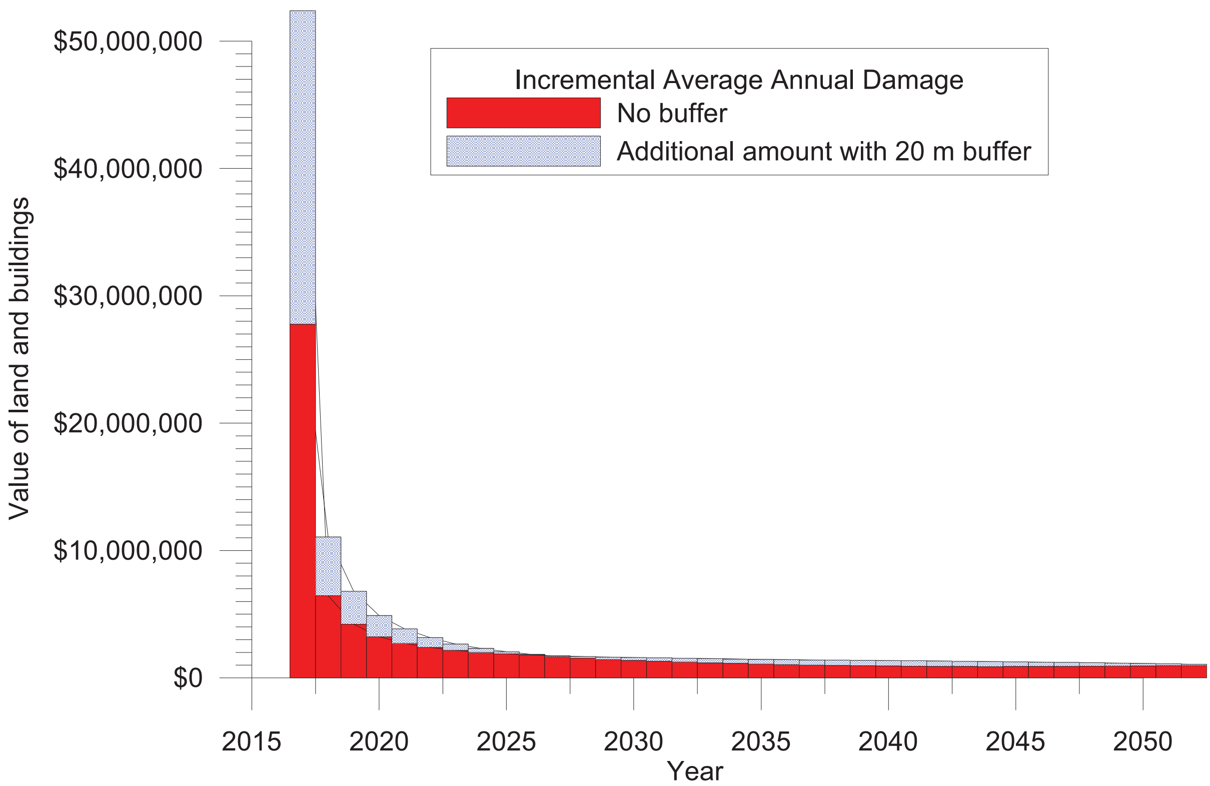


Figure 2.3: Incremental Average Annual Damages

The incremental AAD is shown cumulatively in Figure 2.4. Note that the future dollar values are not discounted in this figure, but discounting is undertaken in Appendix N. The cumulative incremental AAD is approximately $94 million (undiscounted) to 2050 if no buffer is adopted, rising to $115 million if a 20 m buffer is adopted. This compares with an estimated value of approximately $189 million (Appendix N) for the total value of private land and buildings potentially affected by coastal hazards to 2050.

The BMT WBM (2013) best estimate 2050 coastal hazard line was undertaken to contemporary coastal engineering practice, but is inherently conservative because it was based on a sea level rise of 0.4 m and assumes that a 100 year ARI erosion event occurs in 2050. Note, however, that it is not implausible for major erosion events (exceeding 100 year ARI) to occur early in the implementation period.

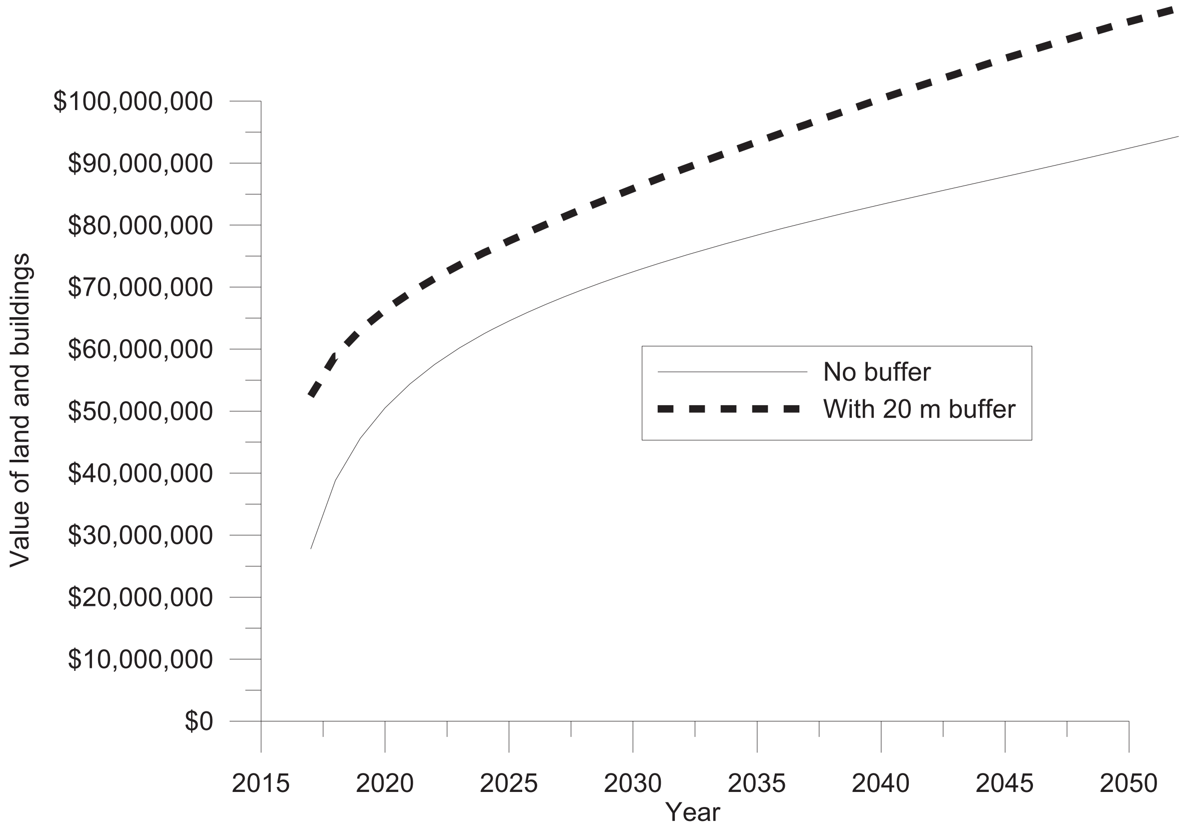


Figure 2.4: Cumulative Incremental Annual Damages

2.6 Inundation Hazard

BMT WBM (2013) indicated that there was an inundation hazard for areas of Byron Bay, however, most dunes were sufficiently elevated to prevent overtopping. BMT WBM noted that potential dune overtopping could occur at the northern end of the Jonson Street protection works, Manfred Street and northern Belongil Spit (beyond the northernmost house). They noted that the dune heights at North Beach north of Belongil Creek were high and therefore not subject to overtopping. They also noted that the berm fronting the Belongil Creek mouth was low and therefore subject to overtopping, however, assessment did not extend into the Belongil Creek mouth and any assessment of inundation through wave propagation across the entrance to the dune on its landward side. The inundation hazard (excluding wave runup) within Belongil Creek was also addressed in the BMT WBM (2014) Belongil Creek Floodplain Risk Management Study Report. The mapping produced by BMT WBM (2013) indicates areas of potential inundation, however, substantial additional work and analysis would be required to extend this into a risk assessment. Such work would include mapping of the depth of inundation and an inventory of the floor levels of vulnerable structures.

2.7 Coastal Entrance or Watercourse Entrance Instability

BMT WBM (2013) did not map hazard zones at the Belongil Creek entrance, however, a zone of estuary entrance instability was noted. Detailed modelling of this has not been undertaken, however, the presence of the bridges on Ewingsdale Road and the disused railway line serve to reduce the spatial extent of the instability. The instability is presently somewhat managed within the existing opening procedures for the estuary, through the location of the initial channel cut.

2.8 Probability of Breakthrough at Manfred Street

It was assumed in the modelling of BMT WBM (2013) and in this WRL report that Planned Retreat would involve the removal of all coastal protection works except Jonson Street. This could result in a breach of Belongil Spit, particularly in the vicinity of Manfred Street.

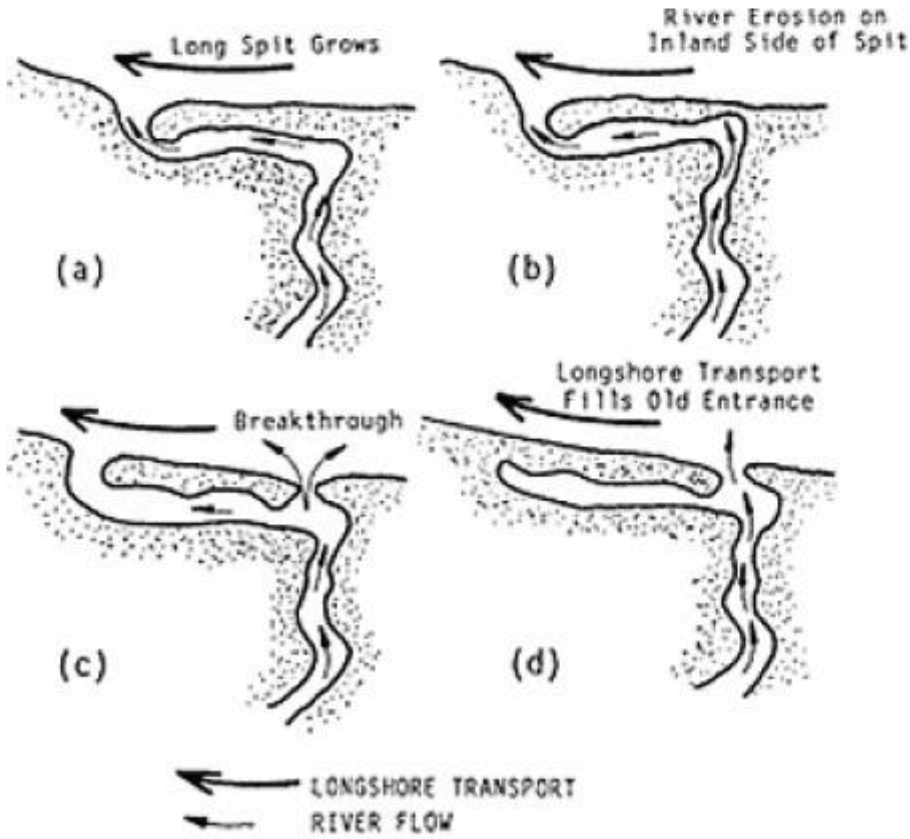
As stated previously, BMT WBM adopted nominally 100 year ARI, "design" and conservative conditions in their assessment. For the purposes of economic assessment, additional probabilities were developed by WRL.

The concept of a breach is shown in Figure 2.6. Such a breach could be initiated from the creek or ocean side. An assessment of the potential for a breach was undertaken by Moratti/PWD (1990) who found that storm erosion of 200 m^3/m (about 80% of the design storm demand adopted by BMT WBM, 2013) would effectively remove the land comprising Manfred Street, from the ocean through to Belongil Creek.

WRL repeated the analysis of Moratti/PWD (1990) for the most recent (2012) photogrammetry profile (Figure 2.6). WRL found that for the latest available dune profile (2012):

- There was sufficient volume in the dune to withstand 1 year and 2 year ARI erosion events; and
- The dune would be breached under a 5 year ARI erosion event.

While detailed modelling was not undertaken, it is likely that dune overwash would damage both Manfred and Childe Streets. The damage to Childe Street would potentially compromise vehicle access to approximately 15 properties to the north. Further details of these calculations are presented in Appendix J.



WRL note: Breach can initiate from ocean side as well as estuary/creek side.

Figure 2.5: Concept of a Breach of Sand Spit (NSW Government, 1990)

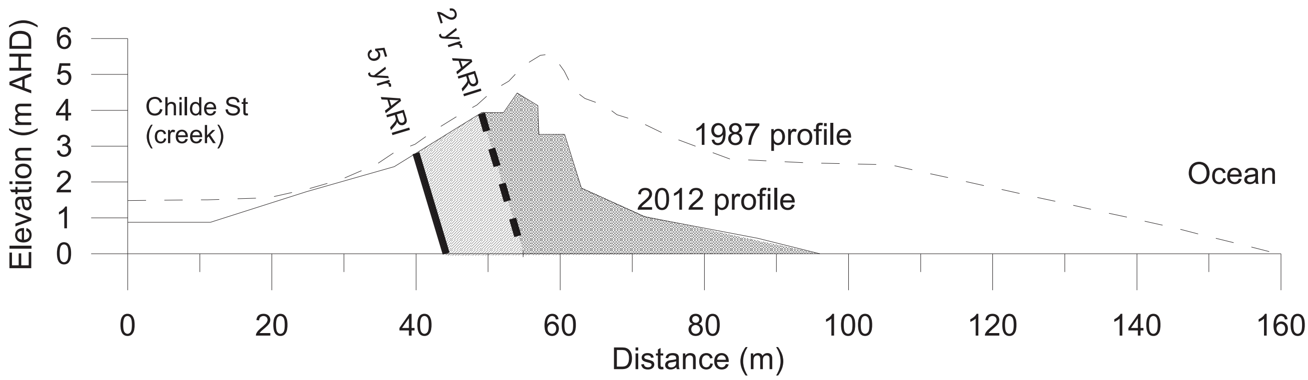


Figure 2.6: Potential Erosion Breach at Manfred Street

3. Guidelines for Evaluating Management Options

In determining the feasibility of a range of coastal hazard management options for risks identified within the Byron Bay Embayment, WRL considered the *Coastal Management Principles* outlined in the NSW *Guidelines for Preparing Coastal Zone Management Plans* (NSW OEH, 2013). More detailed consideration of policy on shortlisted options is contained in Section 14. The two principles most relevant to this options assessment are reproduced below.

> ***Principle 6***
> *Adopt a risk management approach to managing risks to public safety and assets; adopt a risk management hierarchy involving avoiding risks where feasible and mitigation where risks cannot be reasonably avoided; adopt interim actions to manage high risks while long-term options are implemented.*
>
> ***Principle 7***
> *Adopt an adaptive risk management approach if risks are expected to increase over time, or to accommodate uncertainty in risk predictions.*

WRL also considered additional guidance within NSW OEH (2013) for the process of evaluating potential management options. These guidelines indicate that the scale of the recommended coastal management options should be consistent with the amount of funding reasonably likely to be available over their implementation period. That is, the recommended options should focus on managing the highest risks (coastal hazards), be reasonable and achieve optimal long-term outcomes for the expected available funding. The process of options evaluation should consider that:

- A combination of options may achieve the best outcomes; a single option will often not provide a total solution to an issue;
- Options that achieved multiple objectives should be considered; and
- Both existing and potential new management options should be evaluated.

Further to this, NSW OEH (2013) states that the general approach that should be followed in managing risks from coastal hazards is:

- Management of high public safety risks takes priority over risks to built assets;
- If risks from a hazard are low, maintain this level of risk through appropriate land-use, development approval and infrastructure planning decisions; and
- If the risks from a coastal hazard are high:
    - avoid further development in the area or ensure the development can accommodate the hazard, including any likely increase in the severity of the hazard over time (e.g. due to projected sea level rise);
    - ensure appropriate emergency management arrangements are in place; and
    - consider works to reduce risk levels, focusing on the highest risks.

If coastal protection works are a recommended option, NSW OEH (2013) states that any adverse impacts from the works, including increased off-site erosion or flood levels, reduced beach access and environmental impacts should be considered. The potential for coastal protection works to address more than one hazard (e.g. the works may address both erosion and recession), the maintenance arrangements for these works and the management arrangements for any associated impacts from the works should also be considered.

The non-exhaustive list of coastal management options set out in NSW OEH (2013) are reproduced in Table 3.1. Note that BMT WBM (2013) examined each of the coastal hazards in Table 3.1 within the Byron Bay Embayment except for coastal cliffs instability and tide/flood risk.

Table 3.1: Potential Options for Managing Risks from Coastal Hazards (Source: NSW OEH, 2013)

Option Category	Option	Coastal Hazard					
		Beach Erosion/ Recession	Estuary Entrance Instability	Coastal Inundation	Coastal Cliffs Instability	Tidal Inundation	Tide/ Flood Risk
Avoiding the Risk	Building setbacks (planning and development controls e.g. through environmental planning instruments through time or trigger dependent consent conditions)	✔	✔	✔	✔	✔	✔
	Infrastructure setbacks	✔	✔	✔	✔	✔	✔
	Building design criteria (e.g. footings and floor levels)	✔	✔	✔	✔	✔	✔
Changing the Likelihood	Coastal or flood protection works (short or long term)	✔	✔	✔		✔	✔
	Beach nourishment	✔	✔	✔			✔
	Re-vegetation programs (e.g. dunes)	✔	✔	✔	✔		✔
	Compliance action relating to illegal works on beaches	✔	✔	✔			✔
	Cliff and slope stabilisation works				✔		
Changing the Consequence	Building and infrastructure relocation or modification	✔	✔	✔	✔	✔	✔
	Catch walls*			✔	✔	✔	
	Access control				✔		
	Public education				✔		✔
Sharing the Risk With Another Party	Insurance				✔		✔
Retaining the Risk by Informed Decision	Emergency management (including monitoring and warning)	✔	✔	✔	✔	✔	✔

* The term "catch walls" is not defined in OEH (2013), but normally refers to walls installed near the base of cliffs to "catch" rock falls and prevent fallen boulders from travelling further.

4. Previous Coastal Hazard Management Studies

4.1 Previous Studies

The following previous studies relevant to coastal management in Byron Bay have been undertaken. Brief reviews are provided in either this section or Appendix A.

- Byron Bay – Hastings Point Erosion Study (Gordon et al. PWD, 1978);
- Geomarine (1989);
- Byron Shire Coastline Hazard Definition Study Final Report (WBM, 2000);
- Byron Coastline Values Study (Byron Shire Council, 2000);
- Byron Shire Coastline Management Study (WBM, 2003);
- Scoping Study on the Feasibility to Access the Cape Byron Sand Lobe for Sand Extraction for Beach Nourishment (Patterson Britton & Partners, 2006);
- Modelling Byron Bay Erosion and Effects on Seawalls (Patterson, D., 2010);
- Peer Review of Report on Byron Bay Coastal Modelling by Dean Patterson (University of New South Wales Water Research Laboratory, 2010);
- Draft Coastal Zone Management Plan for Byron Shire Coastline (BSC, 2010)
- Results of the Byron Shire coastal audit conducted May 2010 to May 2011, Ordinary Meeting 30 June 2011, Report No.12.19;
- Byron Shire Coastline Hazards Assessment Update (BMT WBM, 2013);
- Investigating the Re-design of the Jonson Street Protection Works (WorleyParsons, 2014);
- Byron Bay Erosion Protection Structures – Risk Assessment (WorleyParsons, 2013);
- Design of Interim Beach Access Stabilisation Works – Belongil, Byron Bay (WRL. 2013).

4.2 WBM Coastline Management Study (2003)

The *Byron Shire Coastline Management Study* (WBM, 2003) developed coastal hazard management options for risks identified within the Byron Bay Embayment. The proposed management strategy was fivefold depending on the coastal risks to individual areas of the BBE. The risk classifications used for areas of the embayment were as follows:

1. Undeveloped Areas with No Beach Erosion/Recession Threat.
2. Areas with Existing Development under Long Term Beach Erosion/Recession Threat.
3. Areas with Existing Development under Immediate or Mid-Term Beach Erosion/Recession Threat.
4. Undeveloped Areas with No Coastal Inundation Threat.
5. Areas with Existing Development under Coastal Inundation Threat.

4.3 WBM Recommendations for Undeveloped Areas with No Beach Erosion/Recession Threat

For areas which are presently undeveloped or where there is a sufficient buffer zone to accommodate the potential short term (immediate) erosion and long term recession without any threat to development prior to 2100, WBM (2003) primarily recommended an *avoiding the risk* strategy. This included building and infrastructure setbacks (see Table 3.1) considering the 2100 beach erosion/recession hazard line. A secondary recommendation was *changing the likelihood* of beach erosion/recession by undertaking dune re-vegetation programs.

Within the study area, the majority of the foreshore of Clarkes Beach, the majority of the foreshore of Main Beach and the southern end of Tyagarah Beach were included in this category.

WBM (2003) also indicated that the area between Cape Byron and The Pass (including Little Wategos Beach and Wategos Beach) was developed but the beach erosion/recession threat was limited by bedrock and protections works.

4.4 WBM Recommendations for Areas with Existing Development under Long Term Beach Erosion/Recession Threat

For areas with existing development which are not under immediate threat from beach erosion/recession, but which may be under threat between 2050 and 2100, WBM (2003) proposed a similar strategy to undeveloped areas, that is, primarily *avoiding the risk*. This included building and infrastructure setbacks considering the 2050 beach erosion/recession hazard line. A secondary recommendation was *changing the likelihood* of beach erosion/recession by undertaking dune re-vegetation programs.

Within the study area, isolated areas of the foreshores of Clarkes Beach and Main Beach were included in this strategy.

4.5 WBM Recommendations for Areas with Existing Development under Immediate or Mid-Term Beach Erosion/Recession Threat

4.5.1 Preamble

For areas with existing development which are under immediate threat from beach erosion/recession or may be under threat prior to 2050, WBM (2003) primarily recommended a *changing the likelihood* strategy. After considering nine alternative strategies, WBM recommended coastal protection works (seawall and an end control structure – single groyne), in combination with beach nourishment and dune re-vegetation programs.

For Belongil, WBM's recommendation was: *"The preferred option at Belongil Beach is to implement beach nourishment to retain the amenity of the beach. Given the magnitude of the long term recession trend, it is recommended that an end control structure be incorporated to provide added stability and longevity to the works together with an upgrade of the existing seawalls to give an added factor of safety as terminal protection. This option (C2) provides high financial benefits which outweigh the costs related primarily to capital and operational works with minimal consequential costs. It also overcomes the difficulties associated with the current planning instruments and the resultant tensions with respect to property protection."*

Within the study area, an isolated area of the foreshore of Main Beach (seaward of the Byron Bay Surf Life Saving Club, BBSLSC) and the entire foreshore of Belongil Beach (Jonson Street to Belongil Spit) was included in this strategy.

WBM (2003) indicated that there were exceptions to this recommended strategy where existing development is under threat prior to 2050. At Clarkes Beach, the recommended management strategy was *changing the consequence* for the Byron Beach Cafe, the North Coast Holiday Parks Clarkes Beach and an isolated dwelling between them. This strategy included the relocation of buildings and infrastructure (i.e. planned retreat) but a recommended approach was not specified (i.e. public ownership, private ownership or private and public ownership). This alternative coastal management strategy was recommended due to the limited amount of development along Clarkes Beach.

Each of the nine coastal hazard management options evaluated by WBM (2003) for areas within the Byron Bay Embayment where existing development is under threat prior to 2050 is summarised below for reference.

4.5.2 Seawall Alone

This coastal hazard management option includes a seawall between Jonson Street and Belongil Spit. Since beach nourishment was not included in conjunction with the seawall, the required structural capacity of the seawall would be significant as it would rarely be partially covered with sand and would frequently encounter wave impacts.

4.5.3 Groynes Alone

This management option includes a groyne field between Jonson Street and Belongil Spit. WBM (2003) asserted this field would be a series of six groynes with an orientation perpendicular to the coast. The objective of the groynes would be to provide indirect protection to property fronting Belongil Spit by providing assistance in developing a more stable shoreline and sand buffer. While not included in the initial coastal protection works scope, WBM (2003), noted that an additional groyne may need to be constructed on the northern side of Belongil Creek to reduce erosion/recession impacts downdrift of the field.

4.5.4 Nourishment with Single Groyne

For this option, imported sand which matches the native sand within the embayment is to be placed on the beach, dune and nearshore zone between the Jonson Street and Belongil Spit. To minimise losses of this placed sand via gradual dispersion to adjacent beaches and ongoing underlying recession, the use of an end control (single groyne) structure was also included. The end control structure was to act as an artificial headland and be a substantial groyne-type structure, likely in a "T" groyne arrangement. WBM (2003) asserted that this structure should have a larger cross-sectional footprint than a conventional groyne to retain a wider beach on its updrift side.

4.5.5 Nourishment with Single Groyne and Seawall (Recommended)

This coastal hazard management option is the same as the previous option, but with the inclusion of a seawall to mitigate the risk that property could be threatened by erosion prior to re-nourishment campaigns. The seawall would provide protection against further erosion until re-nourishment was carried out. The structural capacity of the seawall was to be inversely commensurate with the extent of beach nourishment. That is, the overall cross-shore geometry of the seawall could be reduced if significant volumes of borrowed sand could be placed seaward of the structure.

4.5.6 Nourishment with Groynes

This option includes sand nourishment of the beach, dune and nearshore zone between the Jonson Street and Belongil Spit in conjunction with the construction of a groyne field. The initial nourishment volume required to provide erosion protection was asserted to be less than the previous two options with an end control structure (WBM, 2003) due to the stabilising effect of the groynes. The option also included only four groynes with an orientation perpendicular to the coast. While not detailed by WBM (2003), WRL expects that this option adopted a wider groyne spacing (i.e. less number of groynes) than the *groynes only option*, because the groynes which are combined with nourishment would be comparatively longer. This assumes that the adopted groyne spacing is a function of groyne length and equivalent for both options and that the water depth at the head of the groyne is also equivalent for both options.

4.5.7 Nourishment with Single Groyne and Offshore Breakwaters

This coastal hazard management option is the same as the recommended option which included beach nourishment in conjunction with an end control structure and a seawall, except that offshore breakwaters replace the seawall. WBM (2003) asserted this option would be composed of a series of three offshore breakwaters with an orientation parallel to the coast. The objective of the offshore breakwaters was to increase the longevity of the imported sand by reducing wave impacts, and beach erosion accordingly. WBM (2003) indicated that the offshore breakwaters may be either emergent or a submerged reef type but did not indicate a preferred arrangement for this option.

4.5.8 Retreat Under Public Ownership

This is the first of three coastal hazard management options which include planned retreat. Each differs by the ownership of the land and the responsibility for removal of any structures on the land. This option involves the upfront transfer of ownership of all land to the Crown via a voluntary or compulsory acquisition process (essentially a “buyout”) by government so that it is under public ownership as recession occurs.

4.5.9 Retreat Under Private Ownership

This second planned retreat option involves land remaining in private ownership as recession occurs. Private individuals will be responsible for their own planning in terms of loss of buildings; infrastructure and relocation.

4.5.10 Retreat Under Private and Public Ownership

This third planned retreat option assumes a robust legal framework is in place to achieve retreat in public and private ownership. This option is designed to overcome deficiencies in the two previous planned retreat options. The framework centres around the introduction of the 1988 Development Control Plan (DCP) No. 1 by BSC (1988). Part J of this plan formally made the public aware of the coastal hazards within the Byron Bay Embayment for the first time. On this basis, land with buildings which existed prior to 1988 would be transferred to the ownership of the Crown. Conversely, land with buildings which were constructed later than 1988 would remain in private ownership as recession occurs. An alternative application of this management option was also described by WBM (2003) whereby land ownership would only be transferred to the Crown if the land was presently owned by the same owner prior to 1988.

4.6 WBM Recommendations for Undeveloped Areas with No Coastal Inundation Threat

The consideration of the coastal inundation hazard was not separated into planning periods as with the assessment of the beach erosion/erosion hazard; only the immediate planning period was considered. WBM (2003) considered that exposed sites with dune elevations of at least

5.6 m AHD were not under threat from coastal inundation though inundation mapping was not undertaken. Minimum dune elevations to prevent inundation at more sheltered sites were not determined. For areas which are presently undeveloped and there is no immediate threat from coastal inundation, WBM (2003) recommended a do nothing strategy.

Within the study area, the area between Cape Byron and The Pass (excluding Wategos Beach), the majority of the foreshores of Clarkes Beach, Main Beach and Belongil Beach and the southern end of Tyagarah Beach were included in this strategy.

4.7 WBM Recommendations for Areas with Existing Development under Coastal Inundation Threat

WBM (2003) recommended: *"In areas where development is under threat from inundation (and where no other works are proposed) it is recommended that the dunes be strengthened to provide sufficient height and volume of sand to accommodate storm erosion and overtopping."*

WBM (2003) considered that exposed sites with dune elevations less than 5.6 m AHD were under immediate threat from coastal inundation. For areas with existing development which may be potentially threatened by coastal inundation, WBM (2003) primarily recommended a changing the likelihood strategy. This strategy included dune re vegetation programs, beach nourishment and/or beach scraping to provide sufficient height in the dune system to prevent dune overtopping. WBM Oceanics envisaged that these works would be undertaken in conjunction with efforts to manage the beach erosion/erosion hazard (assuming that areas are potentially threatened by both inundation and erosion/recession). For areas which are potentially threatened by coastal inundation but not beach erosion/recession, WBM asserted that the same management strategy (re-vegetation/nourishment/scraping) would be used.

Within the study area, the entire foreshore of Wategos Beach and isolated areas of the foreshores of Clarkes Beach, Main Beach and Belongil Beach were included in this strategy.

4.8 Implementation of WBM Recommendations

While WBM (2003) recommended the implementation of beach nourishment with an end control (single groyne) structure and a seawall, it was noted that beach nourishment is subject to uncertainties regarding the suitability of marine sand from the likely offshore "borrow" source and approval to extract it. To reduce these uncertainties, WBM (2003) recommended that a substantial investigation into beach nourishment be undertaken. If such an investigation found that suitable marine sand was not available for extraction for beach nourishment, WBM Oceanics (2003) alternatively recommended that the following secondary coastal hazard management options be implemented in order of decreasing preference:

2. Planned retreat under private and public ownership;
3. Planned retreat under private ownership; or
4. Seawall alone or groynes alone.

There were numerous sub components to all the above options including dune management.

With regard to planned retreat and its funding, WBM noted: *"However, this is subject to higher social costs as it entails property loss, social dislocation and strict control over land use by the State. A consequence of a planned retreat policy would also be the loss of part of the Casino/Murwillumbah Railway Line. Furthermore, it can not be part funded by land owners as* *their properties are lost to erosion. The political acceptance of such an approach is also uncertain."*

The sand scoping study (summarised in Appendix A) by Patterson Britton & Partners (PBP, 2006) was commissioned in partial response to the recommendation for a beach nourishment investigation. It is understood that based on the PBP study, BSC concluded that suitable marine sand at acceptable cost was not available for beach nourishment. As such, BSC adopted planned retreat as the primary coastal hazard management strategy (except for Jonson Street and the town centre) for inclusion in the draft CZMP (BSC, 2010).

4.9 Peer Review Panel for WBM (2003)

A peer review of WBM (2003) undertaken by Professor Bruce Thom, Mr Angus Gordon and Mr Phil Watson is summarised in a letter dated 27 November 2003. The peer review concluded that the WBM (2003) study represented *"… a useful body of professional information upon which Council can build in selecting a long term management strategy…"*. The peer review also recommended that the following actions be undertaken:

- Additional legal advice;
- Further exploration of funding options; and
- Additional consultation;

As stated above, the peer review panel's input was also partially responsible for the Patterson Britton & Partners (2006) sand scoping study being undertaken.

5. WRL Physical and Technical Feasibility of Options

5.1 Preamble

5.1.1 Introduction

In assessing the physical and technical feasibility of a range of coastal hazard management options for hazards identified within the Byron Bay Embayment, WRL considered the coastal processes and hazards within the study area and the immediate and projected (2050 and 2100) coastal hazard risks (beach erosion/recession and coastal inundation). The coastal hazards were informed by BMT WBM (2013).

It should be noted that the typical design life for structures is approximately 50 years. Horton et al (2014) noted that the cost of new residential development is amortised for tax purposes over 40 years based on Subdivision 43-25 of the Income Tax Assessment Act 1997. They also compiled the following list from Australian Standards regarding design life:

- AS 1170 (structural design): 50 years;
- AS 2870 (residential slabs and footings): 50 years;
- AS 3600 (concrete): 40 to 60 years;
- AS 4678 (earth-retaining structures): 60 years;
- AS 4997 (maritime structures): 50 years for a normal commercial structure.

For areas with existing development which are under immediate threat from beach erosion/recession or may be under threat prior to 2050, twelve physically and technically feasible coastal hazard management options are considered possible to safely implement and maintain over the intended design life. Reasons supporting this assessment of feasible options are presented in Section 5.4.

Each of the twelve feasible options was defined as a *changing the likelihood* strategy or a *changing the consequence* strategy. The shortlist included the nine coastal hazard management options evaluated by WBM (2003), although WRL split the beach nourishment with end control structure and offshore breakwaters option into two options (emergent offshore breakwaters and submerged reef offshore breakwaters), an eleventh option including coastal protection works (seawall and a groyne field), in combination with beach nourishment and dune re-vegetation programs (Section 4.1.2), and a twelfth option with submerged reef offshore breakwaters alone (Section 4.1.3).

The feasibility assessment is largely based on desktop assessment and WRL's professional experience, including the Churchill Fellowship of WRL engineer Alessio Mariani, (Mariani, 2012). The feasibility assessment considers previous studies, WRL's experience with other locations, and has not undertaken specific modelling. It does not purport to be a design study for all options, however, preliminary design of shortlisted options is developed further in Section 9. Additional investigations would be needed to progress the preferred option prior to implementing in a CZMP.

The options below relate primarily to the erosion/recession hazard between First Sun Caravan Park and North Beach. Management of other hazards and other parts of the study area is addressed in Section 10.

5.1.2 WRL Additional Option 1: Nourishment with Groynes and Seawall

This coastal hazard management option is the same as the option recommended by WBM (2003) which included beach nourishment in conjunction with an end control structure and a seawall, except that a groyne field replaces the end control structure.

5.1.3 WRL Additional Option 2: Offshore Breakwaters (Submerged Reef) Alone

This coastal hazard management option includes a field of submerged reef offshore breakwaters between Jonson Street and Belongil Spit. This option would be composed of a series of approximately three offshore breakwaters with an orientation parallel to the coast. However, beach nourishment and an end control structure are not proposed in conjunction with the submerged breakwaters. The objective of the breakwaters would be to reduce wave impacts, and beach erosion accordingly.

5.1.4 Additional Option 3: Adaptive Scheme comprising Seawalls, Groynes and Sand Transfer

While the potential for staging is implicit in many options, BSC and OEH requested that greater consideration be given to a staged adaptive management scheme. A suggested sequence of adaptive stages for the Belongil section of the Byron Bay embayment is:

- Seawalls (initially from Border Street to the northernmost private Belongil property);
- An initial trial groyne;
- Additional groynes;
- A small scale sand transfer plant or nourishment.

5.1.5 Design Life for Coastal Hazard Management Options

Based on discussions with BSC, consideration of AS 4997-2005 and ISO 21650:2007, and WRL's experience with the existing coastal protection works within the BBE, a 50 year design life has been adopted for evaluation of the physical and technical feasibility of all coastal hazard management options. However, notwithstanding this, the standard discount rate within the NSW Treasury Guidelines for Economic Appraisal (2007) means that economic factors beyond 30 years do not affect the economic feasibility of a project. Nevertheless, the likely performance of the preferred option beyond 2050 is considered qualitatively later in this report.

5.2 Coastal Hazard Management Options Literature Review

To inform the feasibility assessment of coastal hazard management options within the Byron Bay Embayment, WRL undertook a review of literature pertaining to worldwide implementation of seawalls, groynes, offshore breakwaters (emergent and submerged reef) and beach nourishment. Literature reviewed for each of these options is presented in Appendices B, C, D, E and F, respectively.

5.3 Coastal Processes and Coastal Erosion/Recession Hazards (Current and Projected)

BMT WBM (2013) updated the coastal erosion/recession hazards assessment for the entire Byron Shire (Figure 5.1), with updated hazard lines for the Byron Bay embayment shown in BMT WBM's Figures 4-41 to 4-45. For the Byron Bay embayment, this update considered photogrammetry from 13 dates between 1947 and 2012. Two scenarios were considered for Belongil (and North Beach), namely:

1. All existing seawalls are retained (continuous from Border Street to the northernmost private property on Belongil; and
2. All seawalls (except Jonson Street) are removed.

Figure 5.1: Summary of Coastal Hazards Within the Byron Bay Embayment (Source: BMT WBM, 2013)

It is well established that net littoral drift due to waves is northward in the Byron Bay embayment. Based on Patterson (2010), BMT WBM estimated the following sand transport rates:

- Northward net littoral drift from Tallow Beach: ~400,000 to 450,000 m^3/year;
- Southward loss from East Australian Current off Cape Byron: ~50,000 m^3/year;
- Net littoral Drift from the Pass to Belongil: ~200,000 m^3/year; and
- Cross embayment transport between Cape Byron and Belongil: ~200,000 m^3/year.

The following components combine to define coastal hazard lines:

- Storm erosion;
- Dune stability: 11 m was adopted by BMT WBM (for a dune crest of 5 m AHD), but this component was not incorporated into the hazard lines due to its width varying with dune

height. WRL notes that for the more typical prevailing dune height of 7 m AHD, BMT WBM suggested a value of 14 m;

- Underlying recession;
- Recession due to sea level rise (a shoreline evolution model, as distinct to the Bruun Rule, was used to estimate this component, however, BMT WBM noted that an indicative Bruun Factor of 45 was applicable to the study area).

The following sea level rise benchmarks **relative to 1990** were used by BMT WBM:

- 2050: 0.4 m; and
- 2100: 0.9 m.

In allowing for approximately 0.06 m of sea level rise between 1990 and the present (2010), the following sea level rise benchmarks **relative to 2010** were used by BMT WBM:

- 2050: 0.34 m; and
- 2100: 0.84 m.

BMT WBM also considered fluctuations associated with El Niño Southern Oscillation. Furthermore, BMT WBM noted that ongoing recession on North Belongil is likely to create a breakout of Belongil Creek further south than its present position.

Best estimate allowances from BMT WBM (2013) for the various components of coastal setbacks are shown in Table 5.1. Note that some of these components were calculated by WRL from BMT WBM's work and were not directly stated in the format presented in Table 5.1.

Discussion regarding other coastal hazards is provided in Sections 2.6, 2.7 and 2.8.

Table 5.1: BMT WBM (2013) Coastal Hazard Line Components

	Storm demand		Dune Stability (a)	Recession			SLR recession		Hazard distance (a)		
		SD	DS		R	R	SLR	SLR	SD+DS+R+SLR		
	m³/m above AHD	(m) for 7 m AHD dune	(m) for 7 m AHD dune	(m/yr)	2050 (m)	2100 (m)	2050 (m)	2100 (m)	Pres (m)	2050 (m)	2100 (m)
Scenario 1: Retain seawalls											
Clarkes	150	21	14	0.20	8	18	35	73	35	78	126
Main Beach	150	21	14	0.09	4	8	15	28	35	54	71
N of Jonson	250	36	14	0.24	12	22	33	65	50	95	137
Kendall St	250	36	14	0.17	11	15	22	39	50	83	104
Border St	250	36	14	0.11	10	10	15	18	50	75	78
N Belongil	250	36	14	0.46	21	41	20	72	50	91	163
North Beach	250	36	14	0.44	20	40	18	50	50	88	140
Scenario 2: Remove seawalls except Jonson St											
Clarkes	150	21	14	0.20	8	18	35	73	35	78	126
Main Beach	150	21	14	0.09	4	8	15	28	35	54	71
N of Jonson	250	36	14	0.44	19	40	33	65	50	102	188
Border St	250	36	14	0.43	18	39	24	39	50	92	160
N Belongil	250	36	14	0.41	16	37	17	18	50	83	136
North Beach	250	36	14	0.39	14	35	16	72	50	80	123

a. DS component not included in BMT WBM hazard line plots – WRL adopted value for 7 m AHD dune.

5.4 Physical/Technical Feasibility Assessment for Management Options

5.4.1 Availability of Materials

This section briefly outlines the availability of materials insofar as this may influence the physical/technical feasibility of options. The main anticipated materials would be:

- Rock;
- Concrete;
- Geotextiles; and
- Sand.

Seawalls and the trunk of groynes are likely to be constructed from rock. Many coastal structures on the north coast have been constructed from *greywacke*. Basalt is another type of rock favoured for coastal structures. Preliminary enquiries by WRL indicate that substantial quantities of greywacke armour rock up to 5 to 8 tonnes was available in several quarries, but that sufficiently large basalt was more limited. Potentially suitable quarries are located near Ballina (NSW, ~30 km away), Corndale (NSW, ~35 km away), Tumbulgum (NSW, ~60 km away), Piggabeen (NSW, ~75 km away) and West Burleigh (QLD, ~80 km away), with additional quarries servicing the Gold Coast.

Quarries have historically supplied rock for the existing Byron Bay structures, the more than 20 training walls from Ballina to Noosa, and the more than 30 km of boulder wall on the Gold Coast. As described above, access to rock larger than 8 tonnes is now more limited.

Groyne heads may need to be constructed from armour units larger than 8 tonnes subject to detailed design. If required, these would likely be constructed from concrete which is a readily available construction product. Concrete armour could also replace smaller rock armour in the future, should suitable rock supplies become limited, however, presently in NSW, concrete armour is more expensive than rock.

Geotextiles would likely be used for filtration in coastal structures. This is a readily available construction product.

Minor quantities of sand are readily available as a construction product or through beach scraping. Potential sources for more substantial quantities are discussed in Appendix A and K.

5.4.2 Seawall Alone

WRL considers that the implementation and maintenance of a seawall alone between Jonson Street or Border Street and Belongil Spit is physically and technically feasible. It could be designed to withstand wave impacts and erosion/recession over a 50 year design life and suitable construction materials are readily available. Land-based implementation and maintenance would be rendered most safe by ensuring that an adequate vehicular easement is allowed for landward of the seawall crest. A seawall alone would provide a high level of certainty in performance for erosion protection, but would not enhance beach amenity over the status quo unless accompanied by additional management measures. A walkway along the wall could partially mitigate the reduced amenity.

Figure 5.2 presents a typical configuration of an existing coastline without implementation of any management options. It has been included as a reference to a typical configuration with a seawall (alone) and all subsequent coastal hazard management options. Figure 5.3 presents a typical configuration of this coastal hazard management option in association with an example location where it has been implemented. Note that these illustrations are conceptual in nature and neither suitable for construction nor specific to the Byron Bay Embayment.

5.4.3 Groynes Alone

WRL considers that the safe implementation and maintenance of a groyne field alone between Jonson Street and Belongil Spit is physically and technically feasible. The Byron Bay Embayment has a net northward littoral drift which is a necessary pre-requisite for implementation of a groyne field. There is a lower level of certainty in performance for erosion protection for this management option unless the structures were extremely long, as the groynes primarily alter recession rather than erosion. Beaches would be widened on the southern side of the groynes, while there would be substantial recession to the north of the last groyne. Figure 5.4 presents a typical configuration of this coastal hazard management option in association with an example location where it has been implemented.

5.4.4 Offshore Breakwaters (Submerged Reef) Alone

WRL considers that a field of submerged reef offshore breakwaters alone between Jonson Street and Belongil Spit is physically and technically feasible. Implementation and maintenance would be boat-based. However, as noted in Appendix E, a relatively large number of submerged reef offshore breakwaters built to date are underperforming in their coastal protection objectives. In relative terms, there is a lower level of certainty in performance (erosion protection, design life and beach amenity) for this management option. Figure 5.5 presents a typical configuration of this coastal hazard management option in association with an example location where it has been implemented.

5.4.5 Nourishment with Single Groyne

WRL considers beach nourishment between Jonson Street and Belongil Spit in conjunction with an end control structure (single groyne) is physically and technically feasible. Implementation and maintenance of beach nourishment campaigns would likely be boat-based. The level of certainty in performance (erosion protection and beach amenity) for this management option is directly linked to the certainty of undertaking maintenance beach nourishment campaigns, however, large nourishment volumes would be needed to provide erosion protection to private property. That is, if ongoing beach nourishment campaigns can be implemented shortly after storm events, in relative terms, there is a high level of technical certainty in performance, however, numerous planning and logistical barriers are likely. A single groyne would somewhat prolong the life of the nourishment, but would have substantial effects to the north and would be unlikely to stabilise the beach for the required distance to the south. Figure 5.6 presents a typical configuration of this coastal hazard management option in association with an example location where it has been implemented.

5.4.6 Nourishment with Single Groyne and Seawall

Further to the previous option, WRL considers that beach nourishment and a seawall between Jonson Street and Belongil Spit in conjunction with an end control structure (single groyne) is physically and technically feasible. By incorporating a seawall, this option has the equal highest level of certainty in performance for erosion protection, but less certainty regarding beach amenity unless maintenance sand nourishment can be assured. As discussed above, the use of only one groyne would have substantial effects to the north and would be unlikely to stabilise the beach for the required distance to the south. Figure 5.7 presents a typical configuration of this coastal hazard management option in association with an example location where it has been implemented.

5.4.7 Nourishment with Groynes

WRL considers that beach nourishment in conjunction with a groyne field between Jonson Street and Belongil Spit is physically and technically feasible. The level of certainty in performance (erosion protection) for this management option is directly linked to the certainty of undertaking maintenance beach nourishment campaigns. This is unlikely to have sufficient planning certainty to remove the erosion hazard to private property. Figure 5.8 presents a typical configuration of this coastal hazard management option in association with an example location where it has been implemented.

5.4.8 Nourishment with Groynes and Seawall

Further to the previous option, WRL considers that the safe implementation and maintenance of beach nourishment in conjunction with a groyne field and a seawall between Jonson Street and Belongil Spit is physically and technically feasible. In relative terms, this management option has the equal highest level of certainty in performance for erosion protection and would provide engineered beach amenity. Figure 5.9 presents a typical configuration of this coastal hazard management option in association with an example location where it has been implemented.

5.4.9 Nourishment with Single Groyne and Offshore Breakwaters (Emergent)

WRL considers that beach nourishment in conjunction with a field of emergent offshore breakwaters between Jonson Street and Belongil Spit is physically and technically feasible. Implementation and maintenance would be boat-based. Implementation and maintenance methods for beach nourishment and the end control structure have not been repeated for brevity. In relative terms, if fully emergent this management option has a high level of certainty in performance for erosion protection, but would likely cause socially unacceptable changes (reduction) to the beach wave climate (the surf). Figure 5.10 presents a typical configuration of this coastal hazard management option in association with an example location where it has been implemented. In practice there would be numerous precedent, planning and logistical obstacles to this option.

5.4.10 Nourishment with Single Groyne Structure and Offshore Breakwaters (Submerged Reef)

Further to the previous option, WRL considers that the safe implementation and maintenance of beach nourishment in conjunction with a field of submerged reef offshore breakwaters between Jonson Street and Belongil Spit is physically and technically feasible. In relative terms, there is a low level of certainty in performance for erosion protection and beach amenity for this management option, with the certainty of performance for submerged reef structures lower than emergent structures. Figure 5.10 presents a typical configuration of this coastal hazard management option in association with an example location where it has been implemented. In practice there would be numerous precedent, planning and logistical obstacles to this option.

5.4.11 Retreat Under Public Ownership, Private Ownership, and Private and Public Ownership

WRL considers that the safe implementation of planned retreat is physically and technically feasible and is not influenced by its ownership arrangement. Low maintenance is expected to be required. Relocation of services infrastructure, realignment of roads and modification of the Casino to Murwillumbah railway corridor would also need to be implemented. In relative terms, this management option does not purport to provide erosion protection, but there is a high level of certainty that removal of buildings and infrastructure will avoid them being damaged by the erosion/recession hazard ("avoiding the risk"). Setbacks and relocatable buildings have been implemented on some landholdings on Belongil, however, continued occupation of some landholdings is unlikely under this option due to the required setbacks covering all of the land. This option would provide the highest certainty that a natural beach can be obtained, however, considerable effort would be required to achieve this. Planned retreat does not directly deal with a potential breakthrough at Manfred Street, which in turn may accelerate the retreat process. Figure 5.12 presents a typical configuration of this coastal hazard management option in association with an example location where it has been implemented. The orderly removal of existing protection works would be required to implement this option, which is likely to meet substantial landowner resistance.

5.4.12 Unfeasible or Marginally Feasible Coastal Hazard Management Options

A further 22 coastal hazard management options were assessed by WRL and found to be unfeasible or marginally feasible on a physical and/or technical basis. These are tabulated in Appendix G and were not explored further.

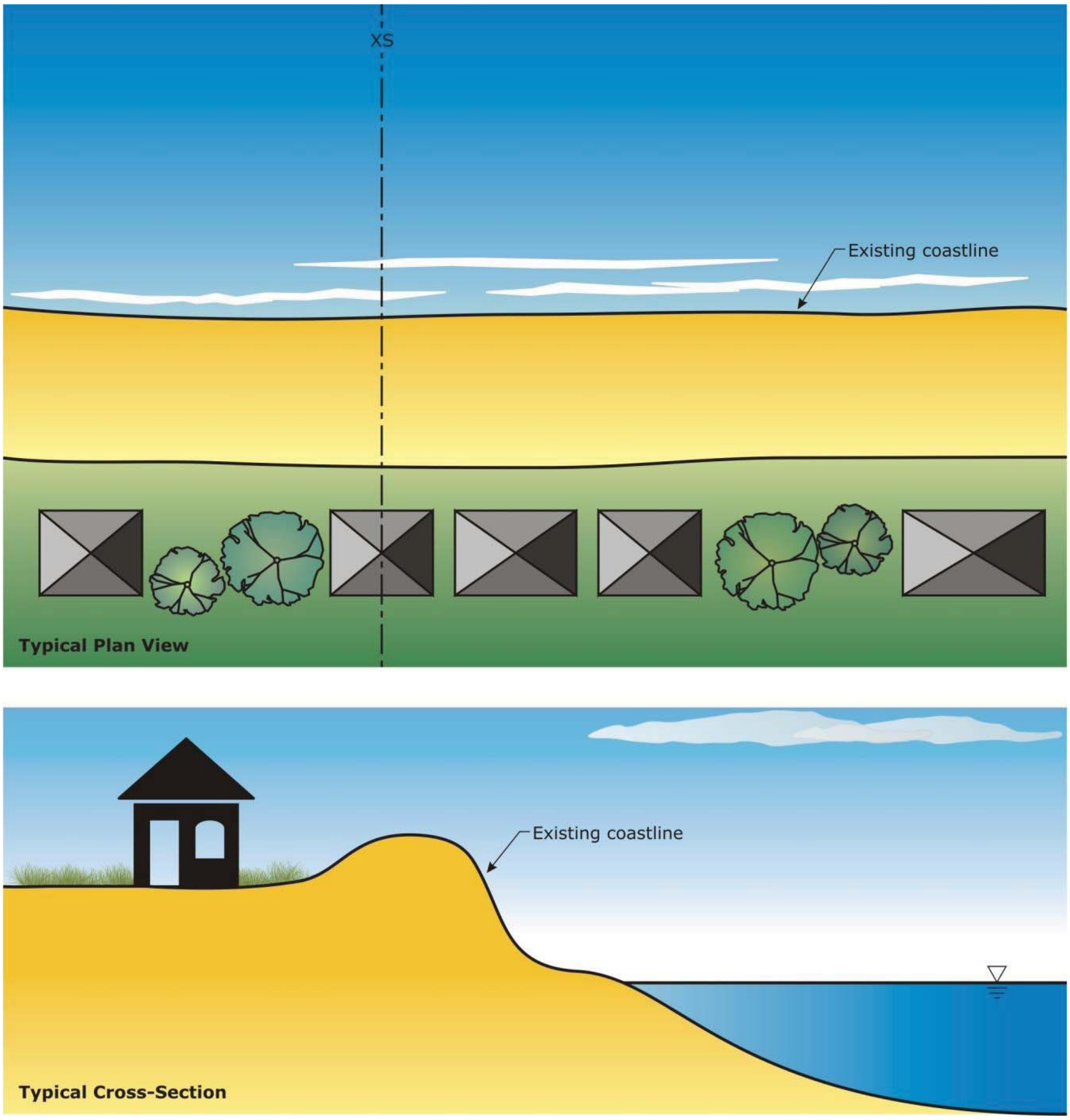
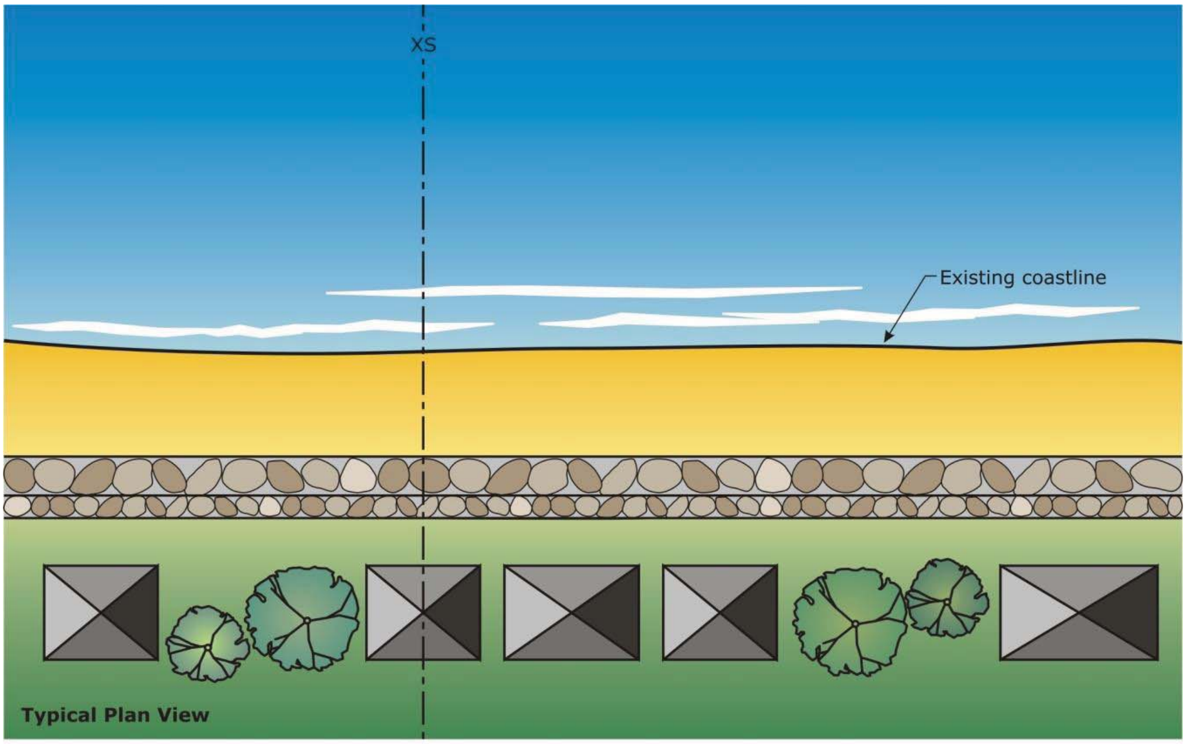


Figure 5.2: Existing Coastline Without Management Options



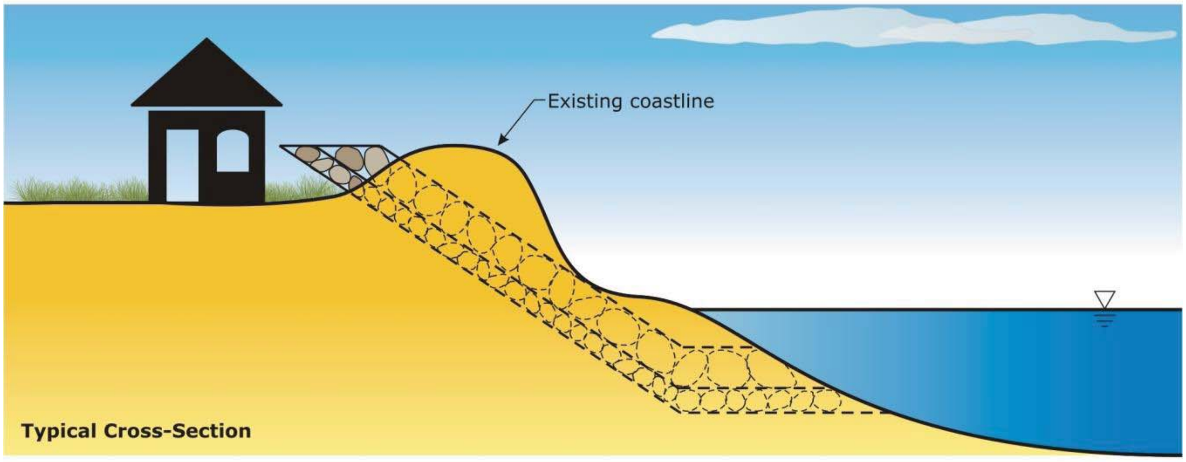


Figure 5.3: Terminal Seawall Alone

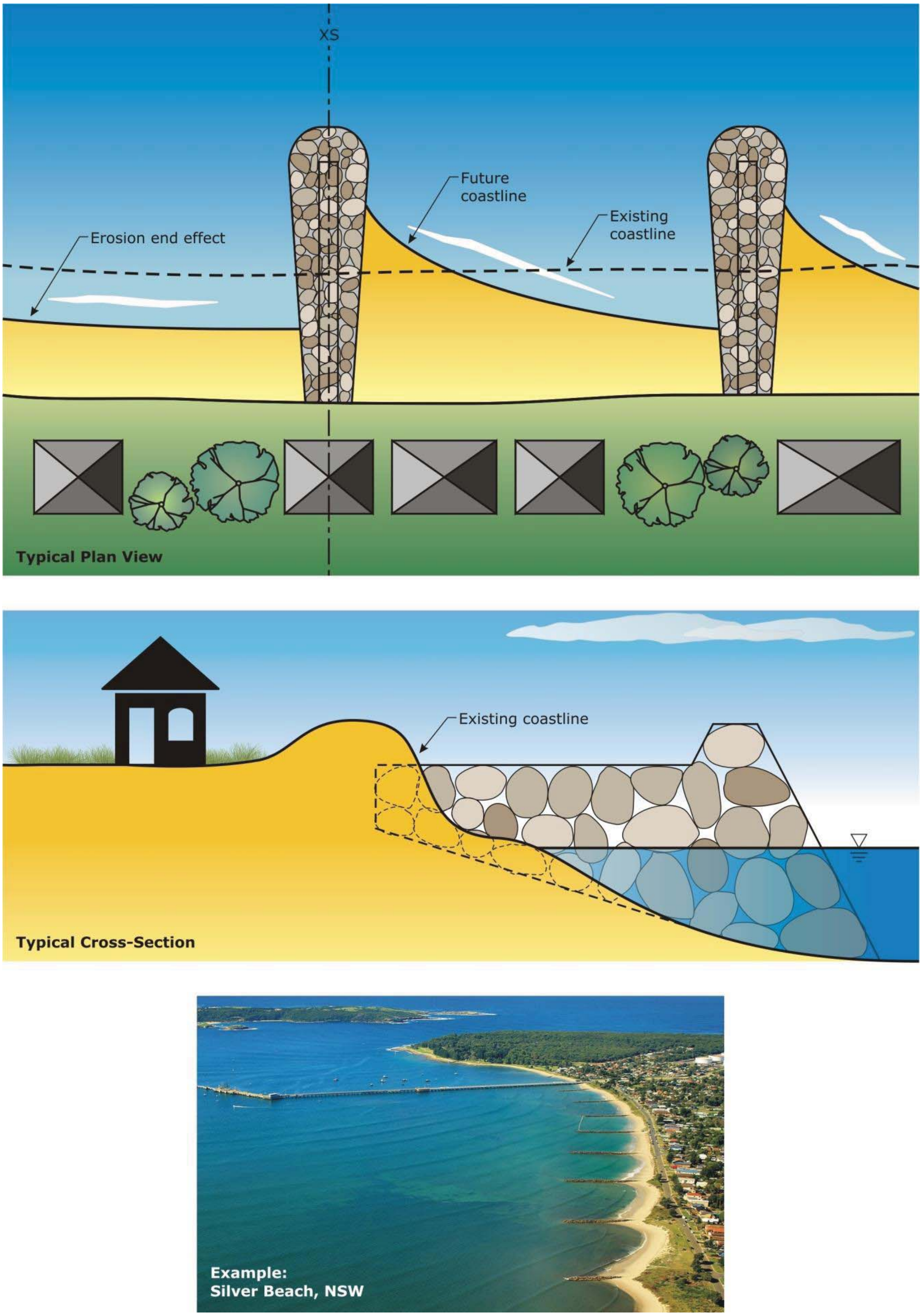


Figure 5.4: Groynes Alone

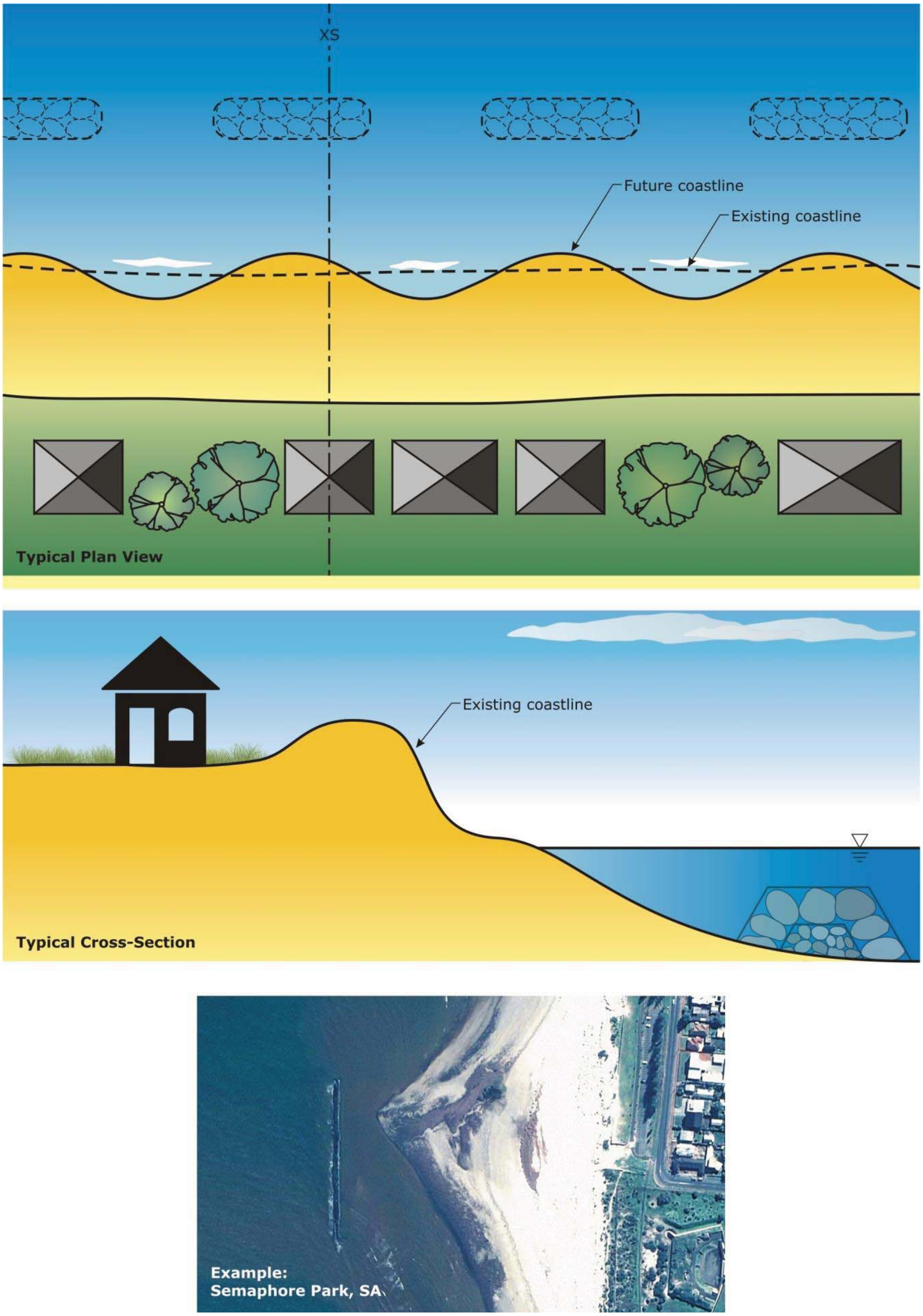


Figure 5.5: Offshore Breakwaters (Submerged Reef) Alone

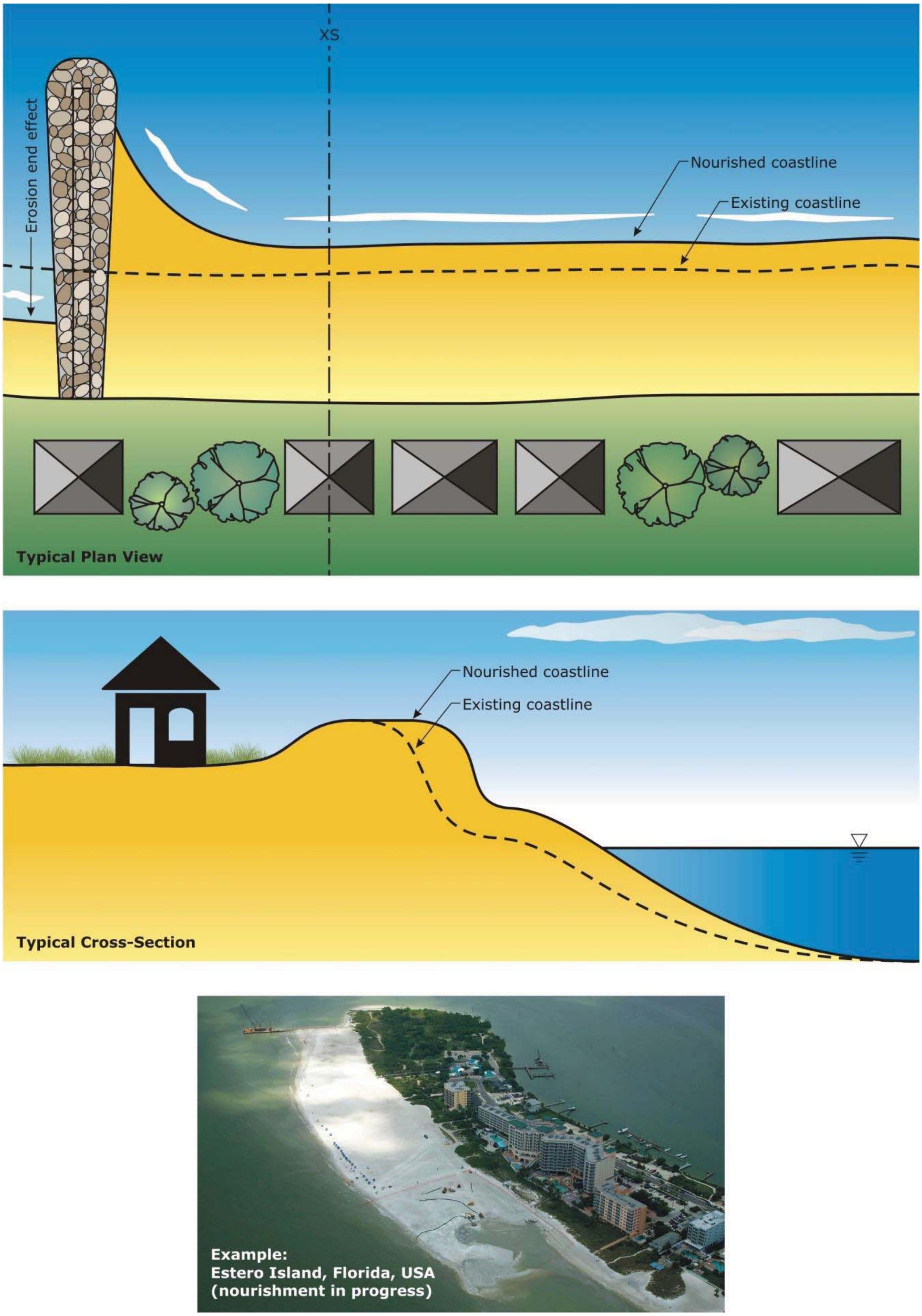
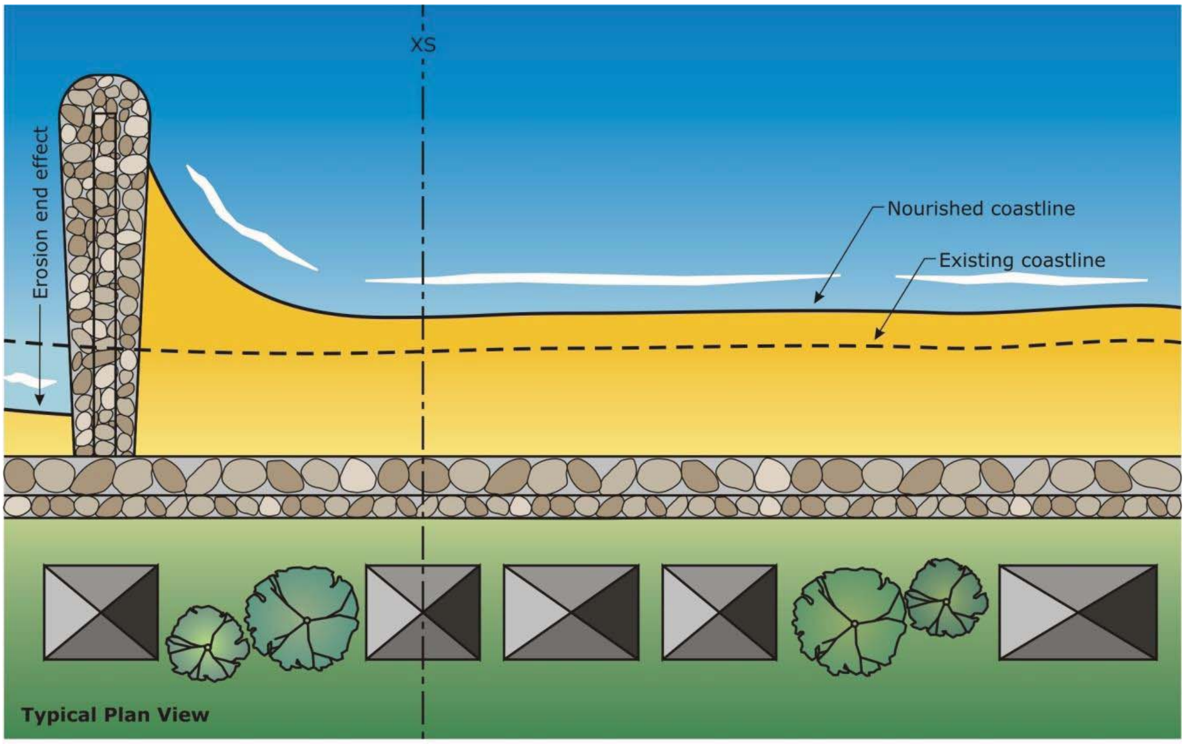


Figure 5.6: Nourishment with Single Groyne



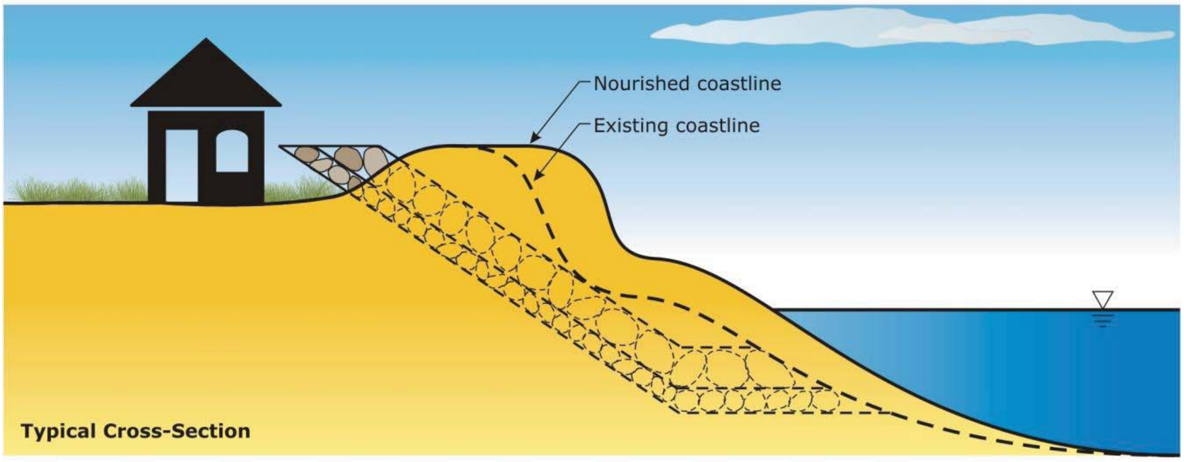
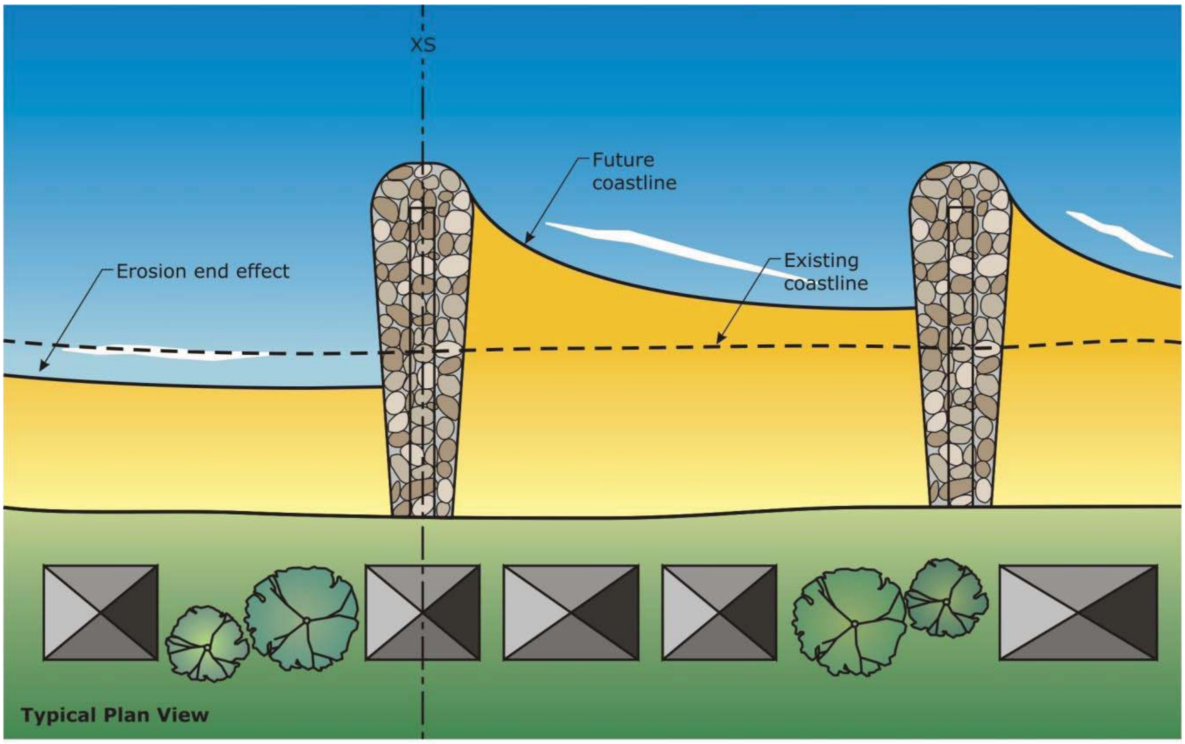


Figure 5.7: Nourishment with Single Groyne End Control Structure and Seawall



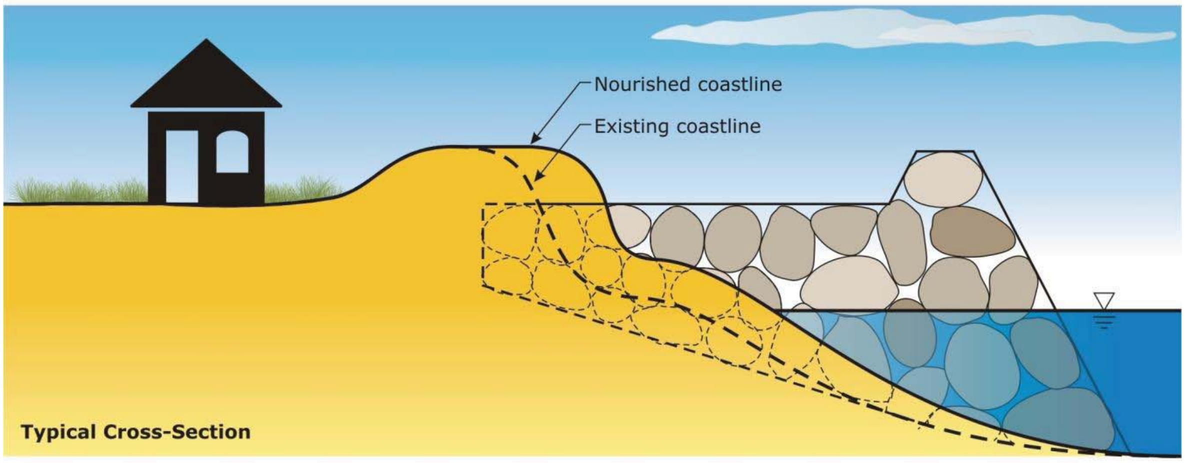
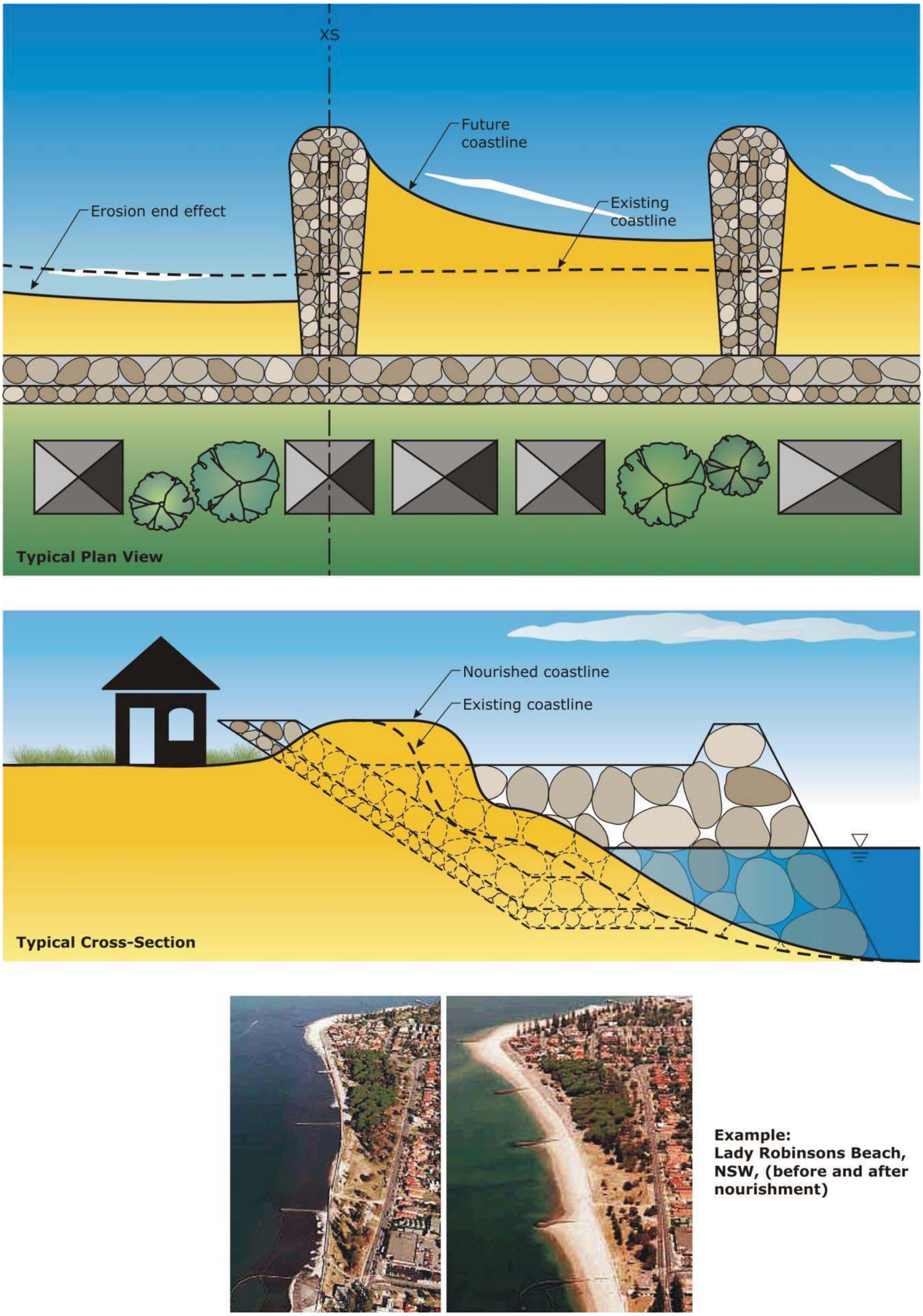
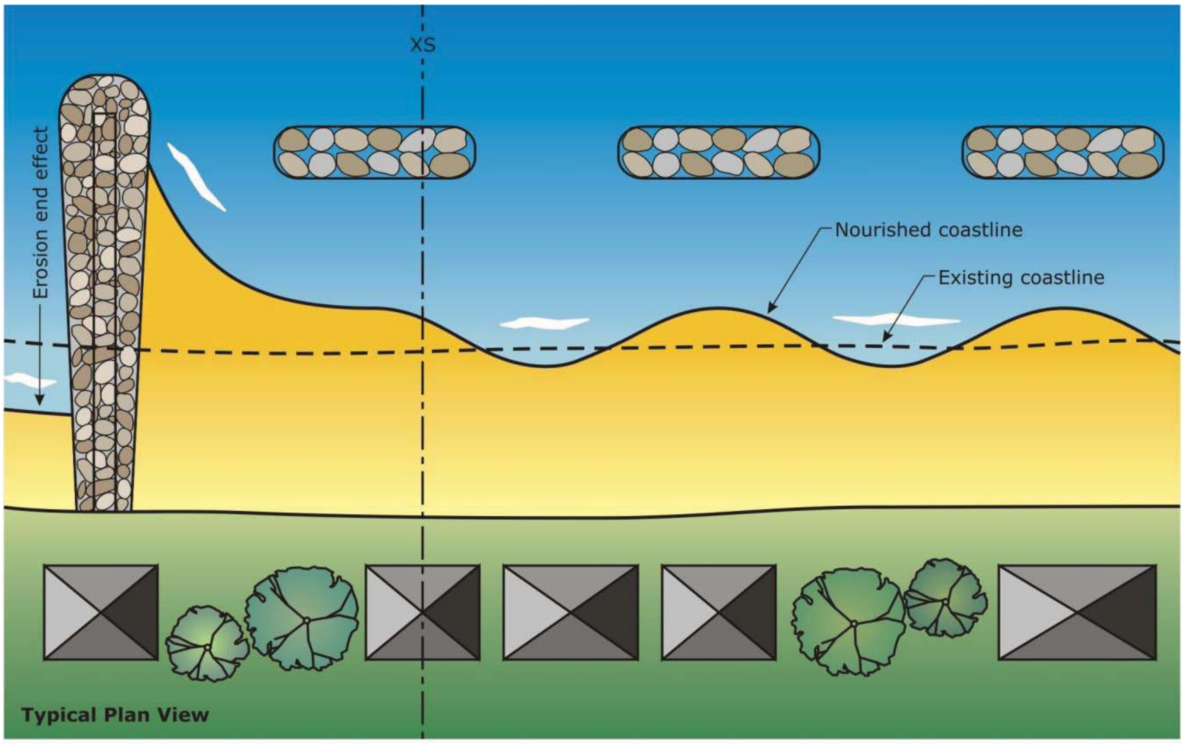


Figure 5.8: Nourishment with Groynes



Example: Lady Robinsons Beach, NSW, (before and after nourishment)

Figure 5.9: Nourishment with Groynes and Seawall



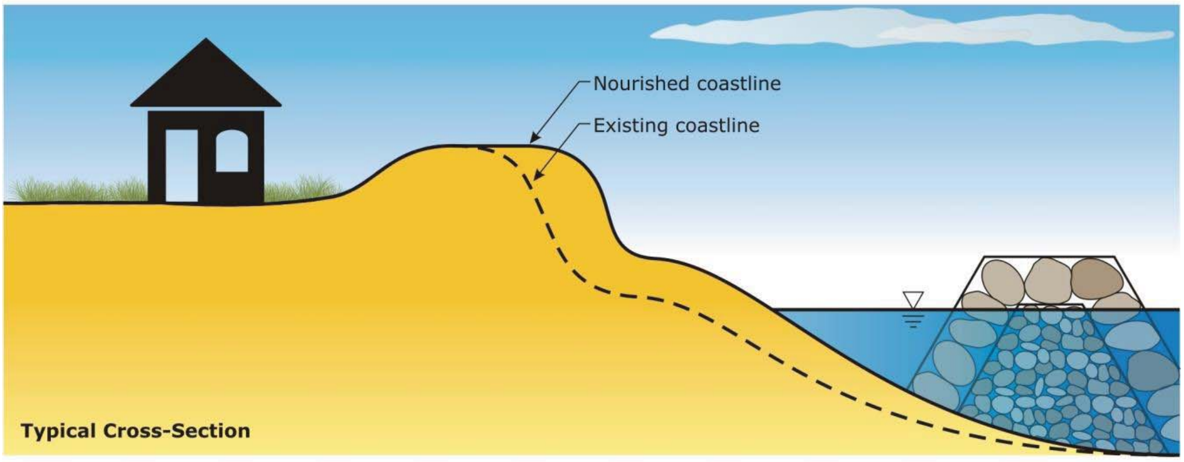
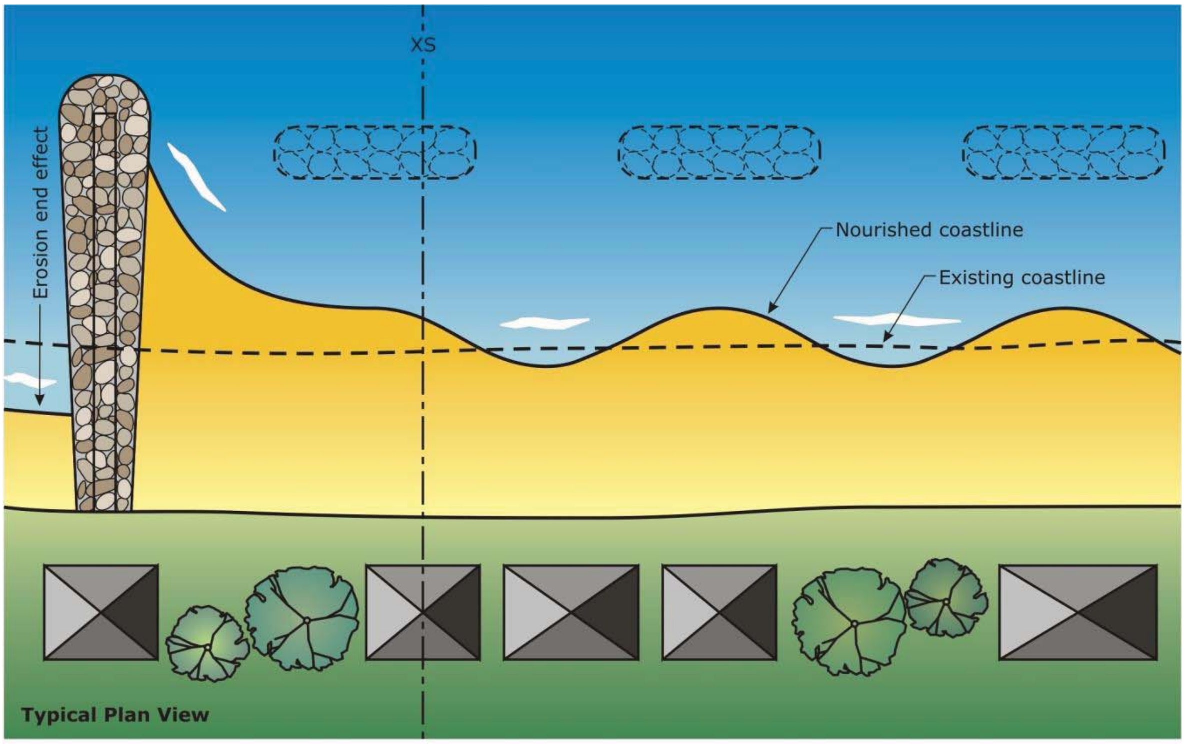


Figure 5.10: Nourishment with Single Groyne and Offshore Breakwaters (Emergent)



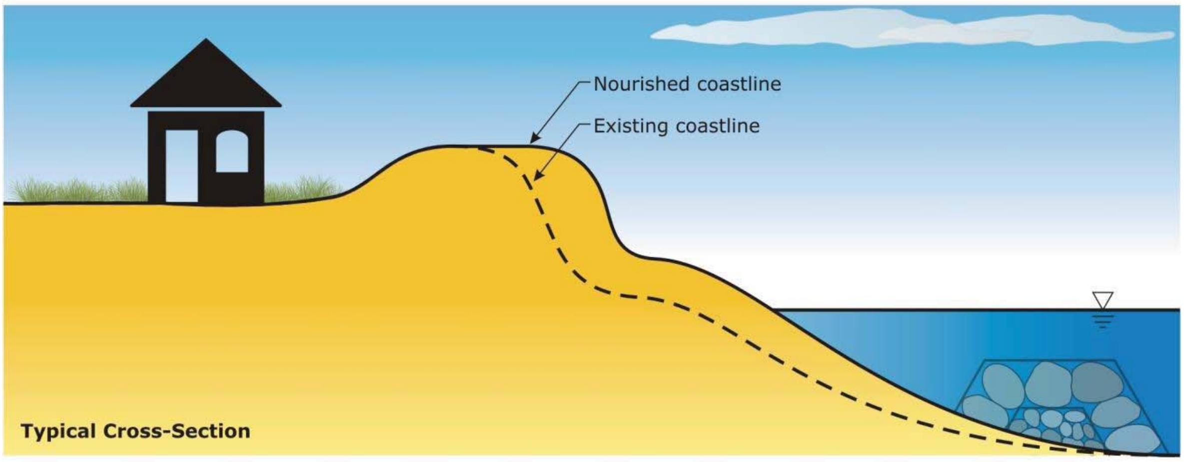
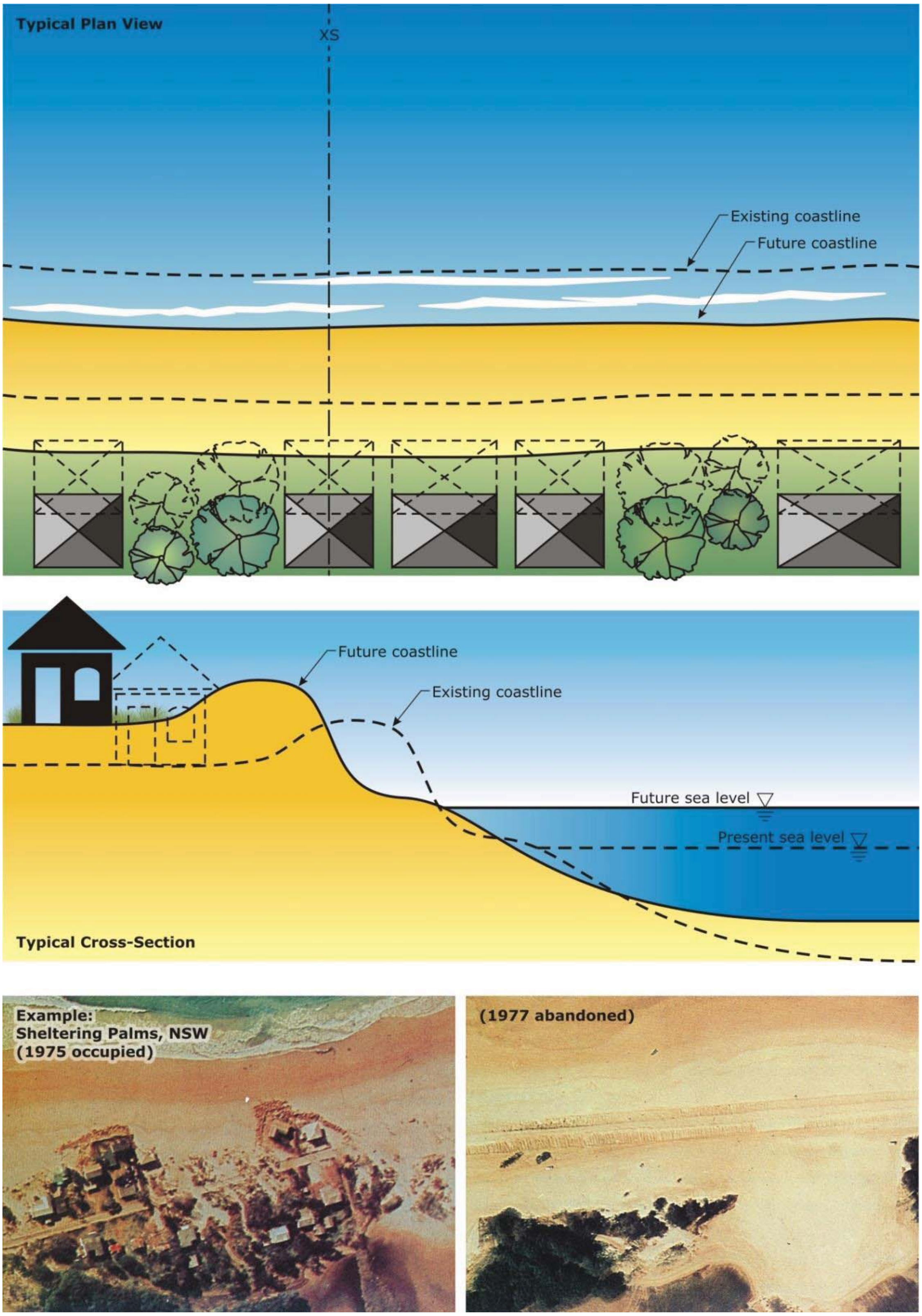


Figure 5.11 Nourishment with (Natural) End Control Structure and Offshore Breakwater (Submerged Reef)



Note: Retreat may be triggered by storm erosion, underlying recession or SLR recession, or all.

Figure 5.12: Retreat

6. Funding Considerations

6.1 Overview

Projects can comprise variable proportions of capital and maintenance expenditure. Funding for works can be in the following forms:

- Pre-emptive – where the project is planned and funded well ahead;
- Adaptive – where smaller steps and lead times are involved, with flexibility retained; and
- Reactive – which is usually an unplanned situation or extreme event.

As part of the reasonableness assessment, it is necessary to consider the amount of funding likely to be available over the design life of the coastal hazard management options. That is, it is necessary that the preferred option be financially feasible with a reasonable prospect of funding. This includes both the initial cost to implement the preferred option and the ongoing cost of maintaining the management option. Funding could be in the form of grants or assistance to undertake design, construction or retreat, or could be in reaction to a natural disaster.

Potential sources of funding include:

- Commonwealth government;
- State government;
- Local government (BSC);
- Visitors; and
- Landowners.

Funding for coastal works in other jurisdictions was investigated as part of this study. Note that this investigation was not an exhaustive worldwide review, but rather investigated a limited range of jurisdictions known to have potential relevance to Byron Shire. This generally took the form of interviews with experienced coastal managers or engineers practising in the jurisdiction with a summary provided in Table 6.1.

Table 6.1: Summary of Funding Used in Other Jurisdictions

Jurisdiction	Typical Funding for Hard Coastal Protection	Typical Funding for Beach Nourishment
California USA	100% landowners	Typically 60% Federal in some circumstances (public land), but may be 0% Federal if only private property affected. Balance or full amount by local government, which comprises bed taxes and contributions by landowners who have hard coastal protection structures.
Netherlands	Funded 100% by federal government where critical (sand is now generally the preferred method of protection.	Shoreline generally fixed to 1990 position. Funded 100% by Federal government.
QLD	100% landowner Typically funded as loan by local government to be repaid with interest over 10 years as rates levy.	25% state 75% local government
SA	100% state for existing approved development. 100% landowner for new or intensified development. 100% by state instrumentality for public infrastructure.	100% state for nourishment as protection. Variable state (0 to 100%) and local government. (0 to 100%) for nourishment for amenity.
VIC	Unspecified state contribution. Unspecified local government for existing development (rarely undertaken on open coast). Funding models not well developed.	Funding models not well developed.
WA	100% landowner. Redevelopment generally triggers surrender of foreshore reserve buffer to crown at owners' expense where there is sufficient space remaining on lot.	Sometimes provided as beneficial reuse by ports from dredging (funded from boating licence and commercial lease fees). Minor ports 100% state govt. Generally 50% state government 50% local government.

6.2 Commonwealth Funding

Commonwealth funding may be available through the:

- National Partnership on Natural Disaster Resilience Program (NPA), https://www.em.gov.au/npa
- Natural Disaster Relief and Recovery Arrangements (NDRRA), http://www.disasterassist.gov.au/factsheets/pages/naturaldisasterreliefandrecoveryarrangements.aspx

6.2.1 NPA Program

The NPA program is administered by states to enhance the nation's resilience to natural disasters through mitigation works (adaptation) and preparedness. Three NPA grant categories are listed for local government, namely:

- Auxiliary Disaster Resilience Grants Scheme (ADRGS);
- Bush Fire Programs; and
- Floodplain Programs

Under the ADRGS Scheme, types of eligible projects include:

- Research or technical studies of disaster risk, community vulnerability, resilience measures etc.;
- Development of community engagement strategies;
- Structural works to protect against damage (e.g. disaster proofing of existing buildings at risk and other engineered works that offer protection from natural disasters);
- Disaster warning systems;
- Geographic Information Systems (GIS) data for disaster resilience purposes; and
- Non-recurrent capability development activities.

The NPA program provides approximately $110 million over 4 years, however the ADRGS Scheme had a budget of approximately $338,000 for NSW in the 2012-13 financial year. Funding contributions in this scheme are generally apportioned in thirds between all three levels of government.

6.2.2 NDRRA Program

According to the web site listed above: "The Natural Disaster Relief and Recovery Arrangements (NDRRA) represent a comprehensive national policy and financial framework for disaster relief and recovery. Through the long-standing NDRRA, the Australian Government provides partial reimbursement to states and territories for eligible expenditure on certain disaster events."

For disasters requiring expenditure of between $240,000 and $103,036,500, the Commonwealth Government would contribute 50% towards the following costs (the items listed are of most relevance to the Byron coast, with numerous others listed on the web site):

- Category A:
  - Essential repairs to housing to a habitable condition;
  - Demolition or rebuilding to restore housing to a habitable condition;
  - Removal of debris from residential properties.
- Category C:
  - A community recovery fund.

For disasters requiring expenditure of between $103,036,500 to $180,313,875, the Commonwealth Government would contribute 50% towards the following costs (the items listed are of most relevance to the Byron coast, with numerous others listed on the web site):

- Category B:

- Restoration or replacement of essential public assets (that are not operating on a commercial basis) such as roads, bridges and schools to their pre-disaster standard;
- Concessional loans, subsidies or grants (e.g. economic assistance to industry) to small businesses, primary producers, voluntary non-profit bodies and needy individuals;
- Counter disaster operations for the protection of the general public.

Since this program specifically includes roads and bridges damaged due to natural disasters, funds may be available from this scheme in the event of a breakthrough of Belongil spit and/or damage to Childe, Manfred, Don or Border Streets.

6.3 NSW Government Funding

6.3.1 OEH Coastal Program Funding

The NSW Office of Environment and Heritage provides funding to local government on a dollar-for-dollar basis to investigate, design and implement coastal management. The annual budget for the entire state for this program is approximately $2 million per annum, and has remained at this level for decades, which has been a reduction in real terms. This is equivalent to a net present value of approximately $26 million over 35 years at 7%. The funds are generally allocated on the basis of $1 from the state for $1 from Council.

This amount is inadequate to fund the scale of works being considered for the Byron Bay embayment.

6.3.2 NSW Government Natural Disaster Funding

NSW Government funding for natural disaster relief is listed at:

http://www.emergency.nsw.gov.au/nddassistance

Under NSW Public Works' administration:

"Grants are available to meet the additional costs of emergency work to restore essential services, including the provision of emergency levee banks, which are in excess of normal operations. Grants are available to meet 100 per cent of eligible emergency works and 75 per cent of eligible restorations works up to $116,000 with 100 per cent cost recovery beyond that level."

Under NSW Roads and Maritime Services' administration:

"Grants are available to help Councils to permanently restore roads and bridges to pre-disaster standards. These grants meet 75 per cent of the first $116,000 expenditure and 100 per cent beyond that level. This assistance is administered by the NSW Roads and Maritime Services."

Repairs to the road ends (Manfred, Don, Border Streets) and Childe Street due to a natural disaster may therefore be eligible for 75 to 100% of funding. This amount would comprise a contribution from the Commonwealth under the NDRRA Program.

6.3.3 TRESBP Funding

Although these funds would not be available for coastal management in the Byron Bay embayment, funding for the Tweed River Sand Bypass Project (TRESBP) is noteworthy. The Heads of Agreement within the Tweed River Entrance Sand Bypassing Project Agreement Act 1998 - Schedule 2 indicates that at planning stage, the Benefit to Cost Ratio for the project was 2.4.

Ware et al (2015) reported: *"The TRESBP project was designed and built by McConnell Dowell (Australia) with finance provided by the ANZ banking group. The ongoing operation and maintenance of the project is through a subsidiary of McConnell Dowell under a 24 year contract with the State of NSW and Queensland which concludes in 2025 [NSW Government, 2001]. At the conclusion of the 2011/12 financial year payments of $AUD106.4 million which included establishment and operations and maintenance costs had been made by the Government Parties."*

The TRESBP funding agreement (Queensland Government, 1998), was:

- Design and Construction:
    - NSW: 75%
    - QLD and City of Gold Coast: 25%
- Maintenance and operations:
    - NSW: 50%
    - QLD and City of Gold Coast: 50%

6.3.4 NSW Land Tax

Although these funds may not be available for coastal management, Appendix N estimates that the value of land tax collected for properties in Byron Bay potentially affected by coastal erosion/recession to 2050 is approximately $400,000 to 1.6 million per year, which (based on assumptions in Appendix N) is equivalent to a net present value of $7 to $27 million to 2050.

6.3.5 NSW Floodplain Management Grants

Although not directly related to the erosion/recession hazard of coastal management, the NSW Government stated: "On 22 December 2014, $16,338,131 million funding was announced for 51 projects to local councils and other authorities to undertake priority projects to assess the risks and reduce the impacts of flooding in NSW." Among a range of projects which can be funded generally on the basis of $2 from the State for every $1 from Council, are: "voluntary purchase or house raising". This may be applicable for managing the inundation hazard.

6.4 Council Funding

Potential available funds for Council include:

- Loans for capital works;
- Sale of Council owned land;
- General rates income;
- Special rates levies for benefiting parties (which may include the entire community);
- Parking revenue; and
- Special purpose grants.

All of these options would require detailed consideration and negotiation, however, there are numerous precedents.

Council funds could be allocated towards funding some or all of the following:

- Beach access works;
- The public portion of Planned Retreat (public-private) in the form of property compensation or the engineering works required to restore degraded land;
- Seawall structures fronting roadheads;
- Sand nourishment;
- Sand retaining structures such as groynes;
- Maintenance of the above and.

6.4.1 Loans for Capital Works

Capital works are commonly funded through loans. Potential sources of funds to repay such loans are detailed below.

6.4.2 Sale of Council Owned Land

Council owns land near the end of Manfred Street. The sale of this land may be able to realise of the order of $2 million if protected by engineered coastal protection works.

6.4.3 General Rates Income

It has been reported to WRL that some Queensland Councils pay for beach nourishment and/or maintenance of seawalls on the basis that by doing so, the rateable values of (and hence rate revenue from) benefitting properties will be increased or remain high. This is done without a special rates levy, but indirectly, since the high land valuations increase/preserve their high rateable value.

Byron Shire Council's total revenue for 2013-14 was approximately $63 million.

The contribution from properties in Byron Bay potentially affected by coastal erosion/recession to 2050 is approximately $276,000 per year, which (based on assumptions in Appendix N) is equivalent to a net present value of $4.74 million to 2050.

6.4.4 Property-Specific Special Rates Levies

Special levies for a range of justified projects are common in Australia.

Bed taxes on temporary accommodation in tourist areas are common in the USA and Europe. It is reported that they are popular with local ratepayers, since the ratepayers do not bear the direct impost. Such taxes have been proposed for the Gold Coast. Typical rates in California are 10 to 12%.

Appendix N estimates that beach tourism expenditure is approximately $115 million per annum for Byron Shire, of which $32 million is attributed to the beaches between First Sun Caravan Park and the northern end of Belongil.

If it is assumed that approximately half of this ($115 million/2 = $58 million) is spent on accommodation, a special rates levy covering 10% of this amount could yield up to $6 million per annum for Byron Shire.

Within NSW, a special rates levy may be covered under Section 495 of the Local Government Act 1993. Section 495 which states:

> "(1) A council may make a special rate for or towards meeting the cost of any works, services, facilities or activities provided or undertaken, or proposed to be provided or undertaken, by the council within the whole or any part of the council's area, other than domestic waste management services.
> (2) The special rate is to be levied on such rateable land in the council's area as, in the council's opinion:
> (a) benefits or will benefit from the works, services, facilities or activities, or
> (b) contributes or will contribute to the need for the works, services, facilities or activities, or
> (c) has or will have access to the works, services, facilities or activities.
>
> Under section 495, a council could, for example make and levy:
>
> [] different special rates for different kinds of works, services, facilities or activities
> [] different special rates for the same kind of work, service, facility or activity in different parts of its area
> [] different special rates for the same work in different parts of its area.
>
> The amount of special rate will be determined according to the council's assessment of the relationship between the cost or estimated cost of the work, service, facility or activity and the degree of benefit afforded to the ratepayer by providing or undertaking the work, service, facility or activity."

6.4.5 General Rates Levies

General rates increases beyond permitted annual amounts can be applied for to the Minister, for between 1 and 7 years under Section 508 and 508A of the Local Government Act 1993.

6.4.6 Parking Revenue

Many Sydney Councils collect parking revenue from beaches and utilise some of these funds for coastal management. Due to the simultaneous prevalence of paid parking in commercial/shopping precincts for many local government areas, the contribution of beach parking revenue is not easily separated from overall parking revenue, however, Warringah Council is an exception to this.

Warringah Council in northern Sydney has approximately 14 paid car parking areas, 13 of which are for beach parking (adjoining but slightly discontinuous car parks are classed as one), servicing five beach compartments covering about 10 km of coast. Car parking fees are payable from 7 AM to 7 PM, 7 days a week, however, ratepayers, residents and life savers are exempt. Annual permits can also be purchased. Furthermore, there is ample nearby untimed free street parking available outside of peak beach use times. Fees in 2014-15 are $6 per hour, or $10 for all day on weekdays and $26 for all day on weekends.

Warringah Council presently collects approximately $1.2 million per annum in parking revenue and $2.6 million per annum in parking fines. The proportion of parking fine revenue associated with beach parking is not known, but anecdotally is high.

Pittwater Council in northern Sydney presently collects approximately $2.4 million per annum in parking revenue and $2.8 million per annum in parking fines, however, the parking revenue is also obtained from car parks on the Pittwater estuary for boat ramps and wharves servicing water-only access communities and ferries. There are 11 beach parking areas and eight paying car parks on the Pittwater estuary. Car parking fees are payable from 6 AM to 9 PM, 7 days a week, however, ratepayers, residents and life savers are exempt. There is generally ample nearby untimed free street parking available. Fees are $3.40 per hour, or $20 for all day.

Manly Council in northern Sydney, which has a mixture of paid town centre and beach parking (not dissimilar to Byron Bay) reported parking revenue of $6.2 million in 2013-2014, with fine revenue of $3.0 million. The proportion of fine revenue attributable to parking was not published, but anecdotally is high, and is likely the predominant contributor to the revenue.

Waverley Council in Sydney's east includes Bondi Beach. The Waverley LGA has a mixture of paid town centre and beach parking in several locations. In 2014 it reported parking revenue of $26.7 million, comprising $7 million in parking scheme fees, $8.9 million in meter revenue and $10.7 million in parking fines.

6.4.7 Special Purpose Grants or Loans

Special grants or loans are frequently provided by both Commonwealth and State Governments in a range of circumstances. These are sometimes in response to political or community pressure, or natural disasters. Negotiations would need to be undertaken if this was to be relied upon.

6.5 Landowner Funding

6.5.1 Structures

During stakeholder workshops for this project, some beachfront property owners have expressed a willingness to pay for protective works. However, some landowners also attribute recession of their land to the impacts of coastal stabilisation to the south (Jonson Street and Main Beach) and to global sea level rise. This section presents options for landowner funding, however, detailed negotiations would need to be undertaken to secure such arrangements.

Provisions for compensation similar to "bio banking" or "land banking" schemes operating in NSW are also in place in California, whereby compensation payments by landowners are required to purchase coastal land elsewhere in exchange for the right to construct coastal protection works which may adversely impact public recreational land or environmental habitat. Protracted court processes have been involved in California in determining suitable payments (Lester, Coast to Coast, 2014). Furthermore, the California Coastal Act allows landowners to construct seawalls to protect "existing" structures provided certain conditions are met. It is still unresolved whether "existing" refers to those in place prior to enactment of the Act in 1976, or simply prior to the construction of the seawall. The latter is adopted in practice by landowners.

Numerous Queensland Councils undertake seawall construction on behalf of benefitting landowners on the basis of a special rates levy covering the full cost of the works to be repaid (including interest) over typically 10 to 15 years. Examples of this include the Gold Coast and Toogoom, Hervey Bay (Ware et al, 2015). These schemes allow economies of scale in design, construction, professional contract management and structures which are uniform and consistent alongshore.

6.5.2 Contribution for Sand Nourishment

The California Coastal Commission requires private landowners who have hard protection structures to contribute towards a beach nourishment fund via an explicit formula which considers local recession rates and the amount of sand impounded by structures. This is in addition to owners funding the protection works 100%. Such a scheme is potentially feasible, and analogous to NSW legislation (see below), however, as yet there is no precedent in Australia, and it would require substantial negotiation or court determination.

Dean (1986) proposed the "approximate principle" for offsetting the sand lost from the littoral system through being impounded by a seawall. For a wall extending from -2 m AHD to +6 m AHD, with an underlying recession rate of 0.45 m/year (Belongil in BMT WBM, 2013), Dean's principle estimates that the wall would deprive the littoral system of 3.6 m^3/m per year (36 m^3 per year for a 10 m frontage).

For a sand supply cost of $10 to $20 per cubic metre, this would equate to an annual cost of $360 to $720 for a 10 m allotment, noting that many Belongil landholdings comprise more than one allotment. For the approximately 850 m of private Belongil frontage, this would amount to an ongoing contribution of $30,600 to $61,200 per year for sand nourishment from all combined Belongil landowners. With the coastal audit (BSC, 2011) identifying 41 beachfront properties, this would equate to an average of approximately $750 to $1,500 per landowner per year. Whether this should be backdated would be the subject of further negotiation, as would contribution from second row landowners who may also benefit from beachfront seawalls. If the 15 second row owners were included, this would reduce to $550 to $1,100 per landowner per year.

Given their lack of control over the phenomena, there are equity concerns regarding whether landowners should be liable for additional recession caused by sea level rise.

6.5.3 Planned Retreat

Landowners would be required to contribute to the costs of Planned Retreat under a private or public-private model. This may be in the form of a loss of assets and/or the funding of engineering works to demolish structures and restore degraded land. Under the public-private model, owners who purchased after 1988 would be expected to fund their component of retreat on the basis that their property was purchased with an awareness of coastal erosion/recession hazards (*caveat emptor* – let the buyer beware).

6.6 Coastal Protection Service Charge

Information regarding the Coastal Protection Service Charge (CPSC) is contained in the following documents:

- NSW Coastal Protection Act 1979;
- NSW Local Government Act 1993;
- NSW DECCW (2010): "Coastal Protection Service Charge Guidelines".

Specific legal advice would be needed to interpret the provisions of these Acts and guidelines, however, as detailed below, levying of a CPSC appears to be dependent on Council agreeing to provide coastal protection services, rather than private landowners undertaking their own works.

Section 55 M of the NSW Coastal Protection Act 1979, as amended contains specific provisions (CPSC) regarding funding ("restoration and maintenance", "maintain and repair", "manage the impacts") of coastal works benefiting coastal landowners. However, detailed schemes for such funding are not well developed.

Section 496B of the NSW Local Government Act 1993 as amended contains additional information on CPSCs:

> "496B Making and levying of annual charges for coastal protection services
> (1) A council may, in accordance with this Act and the regulations, make and levy an annual charge for the provision by the council of coastal protection services for a parcel of rateable land that benefits from the services, being services that relate to coastal protection works constructed:
> (a) by or on behalf of the owner or occupier (or a previous owner or occupier) of the parcel of land, or
> (b) jointly by or on behalf of:
> (i) the owner or occupier (or a previous owner or occupier) of the parcel of land, and
> (ii) a public authority or a council.
> (2) An annual charge for the provision of coastal protection services must be calculated so as to not exceed the reasonable cost to the council of providing those services (including any legal, insurance, engineering, surveying, project management, financing and similar costs associated with providing those services). The coastal protection services for which an annual charge may be made and levied are services:
> (a) to maintain and repair coastal protection works, or
> (b) to manage the impacts of such works (such as changed or increased beach erosion elsewhere)."

Clearly, the NSW Local Government Act 1993 contains some provisions for charging benefitting landowners for direct structural protection works and for beach nourishment, however:

- The precedent for such charges has not yet been well developed;
- The Act states that the quantum may need to be determined in the Land and Environment Court;
- The payment of a CPSC may depend upon on which entity (Council, private landowner) constructed the works and when this occurred. The payment of a CPSC is voluntary in some circumstances.

An example of an issue which would need to be determined includes the quantum of contributions from landowners without direct beach frontage, as they may still benefit from their seaward neighbour or access road having engineered protection works – which may also be covered in property-specific special rates levies. The DECCW (2010) guidelines (Section 2.1) partially address this when referring to protection works on neighbouring land, but exclude this situation in Section 2.2.

Guidance on an appropriate charge for the sand locked up by a structure is covered by the discussion above regarding Dean's (1986) "approximate principle".

6.7 Summary of Funding Options

A summary of potential funding sources is shown in Table 6.2 Many funding options are only reactive, so do not offer certainty or any ability to pre-emptively manage the coast. All suggested funding schemes below will require substantial development and negotiation. They are presented so that the search for a solution can be narrowed.

There are insufficient funds available via conventional avenues to undertake major capital works, unless substantial contributions are negotiated with landowners. These negotiations may substantially delay implementation.

Table 6.2: Summary of Potential Funding Sources

Source	Type	Potential One off Capital Amount	Recurrent Amount (NPV to 2050)
Commonwealth NPA Program	Pre-emptive Adaptive	Unknown but low	
Commonwealth NDRRA Program	Reactive	Uncapped	
NSW Government Natural Disaster Funding	Reactive	Uncapped	
NSW Government Coastal Program	Pre-emptive Adaptive	$$2 M/year for State	$2 M/year for State NPV = $26 M to 2050
Belongil land tax contribution			$400 k to 1.6 M/year $7 to 27 M
Loans for capital works	Pre-emptive Adaptive Reactive	Uncapped subject to repayment ability	
Sale of Council owned land	Pre-emptive Adaptive	~$2 million	
General rates income	Pre-emptive Adaptive Reactive		BSC total revenue 2013-14 approx. $63 M NPV = $819 M
Belongil rates contribution			$276 k/year NPV = $4.7 M
Special rates levies (bed tax)	Pre-emptive Adaptive		Potentially $6 M per year at 10% NPV = $78 M to 2050
Parking revenue	Pre-emptive Adaptive Reactive		Potentially $1 to $3 M per year NPV = $13 to 39 M
Coastal Protection Service Charge	Pre-emptive Adaptive		
Landowner contributions	Pre-emptive Adaptive Reactive	Subject to negotiation, but ~$12 million for walls	$30 k to 60 k/yr sand NPV = $390 k to 780 k to 2050 $100,000 per year for seawalls NPV = $1.3 M to 2050
Indicative totals		>$16 M	>$12 M p.a. excl. general rates NPV >$155 M excl. general rates NPV >$969 M incl. general rates

7. Preliminary Reasonableness of Coastal Hazard Management Options

The document *Guidelines for Preparing Coastal Zone Management Plans* (NSW OEH, 2013), sets out the following criteria regarding reasonableness:

- Adverse impacts from the feasible options (including increased off-site erosion or flood levels and reduced beach access);
- The potential for feasible options to address more than one coastal hazard;
- The feasibility of not only construction *but* ongoing maintenance requirements; and
- How feasible options implemented in the future will interface with existing coastal structures and beach access stabilisation works.

A comprehensive assessment of these criteria requires additional preliminary design and economic assessment. Consultation with stakeholders on 12 March 2014 (Appendix N) presented the following preliminary lists of positives and negatives for each of 12 initially shortlisted options.

Apart from formatting, the lists below in Table 7.1 are unaltered from those presented to facilitate stakeholder selection of five options for more detailed assessment – a sixth option was later developed in conjunction with OEH. The more detailed assessment (Section 9 to Section 14) is required to undertake a "reasonableness" assessment with rigour.

Table 7.1: Preliminary Positives and Negatives of 12 Options

	Main Factors	Economic	Social	Environmental	Policy
	Hybrid: Seawall + Nourishment + End Control Structure				
Positives	Staged protection and amenity	BCR 3 to 8	High certainty and performance High protection High amenity Potential surf break Popular for walking	Natural erosion accretion Dune restoration Preservation of mangroves and bird habitat	Multiple objectives and staged Soft component Enhanced access
Negatives	Expense of three options	High cost	Public safety	Disturbance	Permit to access sand Off site impacts Hard structures
	Hybrid: Seawall + Nourishment + Groynes				
Positives	Staged protection and amenity Reduced sand requirement	BCR 3 to 7 Reduced nourishment needed	High certainty and performance High protection High amenity Potential surf break Popular for walking	Natural erosion accretion Dune restoration Preservation of mangroves and bird habitat	Multiple objectives and staged Soft component Enhanced access
Negatives	Expense of three options	High cost	Public safety	Disturbance	Permit to access sand Off site impacts Hard structures
	Hybrid: Nourishment + Groynes				
Positives	Sand protection buffer, amenity, surfing	BCR 2 to 5 Reduced nourishment needed	Mod certainty and performance High amenity Some protection Potential surf break Popular for walking	Natural erosion accretion Dune restoration Preservation of mangroves and bird habitat	Multiple objectives and staged Soft component Enhanced access
Negatives	No structural protection	Moderate to high cost Higher cost than single groyne	Public safety Lower protection	Disturbance	Permit to access sand Off site impacts Hard structures

Preliminary Positives and Negatives of 12 Options

	Main Factors	Economic	Social	Environmental	Policy
	Nourishment + End Control				
Positives	Natural beach without seawall	BCR 2 to 6	Mod certainty and performance High amenity Some protection Potential surf break Popular for walking	Natural erosion accretion Dune restoration Preservation of mangroves and bird habitat	Multiple objectives Soft component Enhanced access
Negatives	Less physical protection	Moderate to high cost	Public safety Lower protection	Disturbance	Permit to access sand Off site impacts Hard structures
	Hybrid: Nourishment + Groynes				
Positives	Sand protection buffer, amenity, surfing	BCR 2 to 5 Reduced nourishment needed	Mod certainty and performance High amenity Some protection Potential surf break Popular for walking	Natural erosion accretion Dune restoration Preservation of mangroves and bird habitat	Multiple objectives and staged Soft component Enhanced access
Negatives	No structural protection	Moderate to high cost Higher cost than single groyne	Public safety Lower protection	Disturbance	Permit to access sand Off site impacts Hard structures
	Seawall Alone				
Positives	High certainty of protection	BCR 3 to 7	High Protection Long life Builds on existing Status quo	Habitat	
Negatives	Loss of beach amenity	Moderate performance Moderate cost	Low amenity subject to detailed design	Off site recession Limits erosion-accretion	Less consistent with Coastal Policy 1997 Single objective, not staged

Preliminary Positives and Negatives of 12 Options

	Main Factors	Economic	Social	Environmental	Policy
	Groynes Alone				
Positives	Natural processes shape coast at less cost	BCR 3 to 8 Low – mod performance	Some protection Potential surf break Popular for walking	Natural erosion accretion Dune restoration Preservation of mangroves and bird habitat	Some objectives
Negatives	Less physical protection	Moderate cost	Some protection	Off site recession	Off site impacts Hard structures Not staged
	Retreat (Private/Public Ownership)				
Positives	Natural processes prevail Informed acceptance of hazards	BCR 0.5 to 1.5	Some amenity	Potential return to natural state	Consistent with Coastal Policy 1988, 2010 BSC DCP Staged
Negatives	Spatial and social limits	High cost to govt. and landowners Replacement of infrastructure High litigation costs	No protection Displaced landowners Social and spatial limits	Substantial clean up needed Breakthrough of spit	Single objective Legal challenges
	Retreat (Public Ownership)				
Positives	Natural processes prevail	BCR 0.5 to 1.5	Some amenity	Potential return to natural state	Consistent with Coastal Policy 1997 Staged
Negatives	Spatial and social limit High burden to tax/rate payers	High cost to govt. Replacement of infrastructure High litigation costs	No protection Displaced landowners Social and spatial limits	Substantial clean up needed Breakthrough of spit	Not consistent with 1988, 2010 BSC DCP Single objective Legal challenges
	Retreat (Private Ownership)				
Positives	Natural processes prevail	BCR 0.5 to 1.5	Some amenity	Potential return to natural state	Consistent with Coastal Policy 1997 Staged
Negatives	Spatial and social limits High burden to landholders	High cost to landowners Replacement of infrastructure High litigation costs	No protection Displaced landowners Social and spatial limits	Substantial clean up needed Breakthrough of spit	Not consistent with 1988, 2010 BSC DCP Single objective Legal challenges

8. Stakeholder Consultation

Stakeholder consultation is detailed in Appendix M.

In summary, stakeholder consultation resulted in five options being shortlisted for economic assessment. Following additional consultation with OEH, a sixth option was developed. The six options for economic assessment were:

- Option 1 Status Quo
- Option 2 Retreat (public-private);
- Option 3 Nourishment with seawall and single end control structure;
- Option 4 Nourishment with seawall and groyne field; and
- Option 5 Seawall with end control structure (no nourishment) – this was an additional option developed by Councillors.
- Option 6 Staged Adaptive scheme comprising a seawall, a trial and subsequent groynes, and a sand transfer system.

This list applies primarily to Belongil, for which the risk assessment indicates that the majority of vulnerable assets are located. Alternative options (or different options to Belongil) may be more relevant to other parts of the Byron Bay embayment and are discussed in Section 17.

9. Preliminary Design Development of Shortlisted Options

As stated in Section 8, the following options were shortlisted for further economic assessment following stakeholder consultation:

- Planned Retreat (public-private);
- Nourishment with seawall and single end control structure;
- Nourishment with seawall and groyne field;
- Seawall with end control structure (no nourishment) – this was an additional option developed by Councillors;
- Staged Adaptive Scheme – this was an additional option developed by OEH.

9.1 Option 1 Status Quo (Base Case)

For economic assessment, a status quo base case was also considered, giving six options for economic assessment. The following factors are noted for the status quo for Belongil:

- Planned retreat planning controls have existed since 1988. These include notification of new purchasers and restrictions on development which require new structures within erosion hazard zones to be relocatable. Buildings which become located inside a trigger distance of the erosion scarp are required to be moved or demolished. In the majority of cases the trigger for retreat of existing structures has not been enforced. This is covered in Development Control Plan 2010 – Chapter 1 Part J – Coastal Erosion Lands, Adopted 3 March 2011 Effective 31 March 2011 (#1068732).
- Despite the existence of planned retreat as the status quo, rock/hard and/or geotextile structures front all private properties on Belongil Spit from Border Street to the northernmost private property (the second jetty site remains predominantly unprotected). WorleyParsons (2013) estimated that these walls would fail in 1 year ARI to 10 year ARI or larger events. Based on the WRL authors' long-term observations of the site, failure at 10 year ARI has been adopted for economic assessment (but this does not imply any endorsement of the structures).
- Interim geotextile structures are present at the ends of Border, Don and Manfred Streets. WorleyParsons (2013) estimated that these walls would fail in less than 1 year ARI events. Based on the WRL authors' long-term observations of the site, failure at 5 year ARI has been adopted for economic assessment (but this does not imply any endorsement of the structures). BSC has spent an average of $130,000 per year on these structures since 2001 (range nil to $465,000 in any given year).
- BSC spends approximately $30,000 per year on beach access and dune maintenance.
- Suggested replacement costs for the existing rock structures (not to an engineered standard) are $5,000 per m and the geotextile structures $4,000 per m.

Existing protection works between Belongil Creek and Byron Bay SLSC are detailed in Table 9.1. These were obtained from Cantys (2009), WorleyParsons (2013), Google Earth and the authors' familiarity with the site. The actual crest length may be longer than the alongshore length due to curvature and/or flanking protection.

The following information can be extracted from Table 9.1.

- The southern vegetation line at Belongil Creek mouth to Byron Bay SLSC is approximately 2657 m;
- There are erosion limiting structures on this foreshore for approximately 1317 m (50%);

- The foreshore consists of sandy beach backed by semi-exposed coffee rock for approximately 450 m (18%); and
- The foreshore consists of sandy beach backed by a sand dune for approximately 850 m (32%).

Table 9.1: Existing Protection Works and Foreshore Type between Belongil Creek and Byron Bay SLSC

North-West Boundary	South-East Boundary	Predominant Foreshore Type	Approximate Alongshore Length (m)
Belongil Creek mouth southern vegetation line	Northernmost Belongil spit private property	Natural sand	450
Northernmost Belongil spit private property	Northern Manfred St works	Predominantly rock walls	230
Northern end of Manfred St works	Southern end of Manfred St works	Engineered interim rock wall (constructed 2015)	100
Southern end of Manfred St works	Northern end of Old Jetty site	Predominantly rock walls	310
Northern end of Old Jetty site	Southern end of Old Jetty site	Natural sand with loose boulders and remnant structures	80
Southern end of Old Jetty site	Northern end of Don St site	Natural sand backed by coffee rock with loose boulders and remnant structures	40
Northern end of Don St site	Southern end of Don St site	Sandbag wall	22
Southern end of Don St site	Northern end of Border St site	Predominantly rock/concrete walls	225
Northern end of Border St site	Southern end of Border St site	Sandbag wall	40
Southern end of Border St site	Southernmost coffee rock outcrop	Natural sand backed by exposed coffee rock	410
Southernmost coffee rock outcrop	Northern end of Jonson St works	Natural sand	400
Northern end of Jonson St works	Southern end of Jonson St works (Byron Bay SLSC)	Rock walls with small groyne	350
Belongil Creek mouth southern vegetation line	Southern end of Jonson St works (Byron Bay SLSC)	Total for various	2657

9.2 Planned Retreat (Public-Private) Implementation

Planned Retreat is covered in Byron Shire Council's Development Control Plan 2010 – Chapter 1 Part J – Coastal Erosion Lands, Adopted 3 March 2011 Effective 31 March 2011 (#1068732).

The following is largely drawn from BSC's Draft CZMP (2010). Planned Retreat is also referred to as Managed Retreat in some literature.

"*Planned retreat is carried out by managing the duration, type and intensity of development within the identified coastal hazard areas (i.e. Coastal Planning Precincts). When coastal development is approved, a condition is specified that consent only remains valid while the erosion escarpment does not encroach within a specified distance from a development. Council* *will impose a covenant on the title of the land under the provisions of Section 88E of the Conveyancing Act, 1919, requiring the relocation or removal of the development. Once the escarpment does move within that specified distance, the development consent lapses and the structure must be moved back, relocated or demolished*."

"*These management requirements are based on the recognised and projected risk to coastal lands and development over a 90-year planning period. Those lands identified as potentially being subject to risk from coastline hazards over a planning horizon to year 2100 are included in the Byron Shire Coastal Planning Precincts, first adopted by Byron Shire Council in DCP No.1 (1988) …"*

"*In accordance with planned retreat and associated risk management, the overall objective … is to maintain a 20 m development-free buffer landward of the coastal erosion escarpment. The essential purpose of the buffer is to … [prevent damage to property] in the event of coastal erosion, and to accommodate natural coastal processes."*

The development free buffer distance of 20 m was previously adopted in BSC's Draft CZMP (2010) based on:

- It accommodates a significant storm bite;
- Its historical application in development consents; and
- It allows maintenance of natural processes.

However, it should be noted that under BSC DCP No.1 (1988) and BSC DCP (2010) Chapter 1, Part J, buffer distances of up to 50 m apply in some circumstances, while some approved structures have retreat trigger distances of less than 20 m.

Under the BSC Draft CZMP (BSC, 2010) early relocation of development was to be encouraged.

Given that all private property on Belongil is presently fronted by some form of protection works, these works would need to be removed to implement Planned Retreat. The BSC Draft CZMP (2010) included the action: "*Develop a plan that describes how to remove structures*" and "…*Develop a plan that describes how to remove structures and works, which will be ranked according to the impacts and issues identified in the risk assessment in accordance with the objectives of Planned Retreat as described in this CZMP*."

While the risk assessment has been completed (WorleyParsons, 2013), a plan for the orderly removal of seawalls has not been developed. Such removal would be further complicated by the approval status of some seawalls and the end effects/off site impacts of any remaining seawalls on neighbouring properties with seawalls removed.

A major issue to be resolved with the implementation of Planned Retreat is how to manage a breakthrough of Belongil Spit (most likely at Manfred St). Under this scenario, houses to the north may be set back sufficiently landward of the planned retreat trigger, but would be without road and service access. Due to the required duration of implementation, a repairs of a breach at Manfred Street have been allowed for in WRL's costings (Section 11) and Appendix N.

The following activities would need to be undertaken as part of the implementation of planned retreat:

- Removal of rock walls and cart;

- Demolition or moving of houses;
- Dune stabilisation and planting;
- Construction of beach accesses;
- Removal of roads and restoration;
- Removal of rail corridor and restoration; and
- Removal of services: Telstra, Water, Sewer, Electricity.

Unit rates for engineering activities associated with planned retreat are shown in Table 9.2 based on the immediate erosion hazard for Scenario 2 (remove all seawalls except Jonson St) only.

Table 9.2: Unit Rates for Planned Retreat

Item	Unit	Rate ($)
Removal of rock walls and cart	m	3,000
Demolition of houses	No	25,000
Dune stabilisation and planting	m	600
Construction of beach accesses	No	10,000
Removal of roads and restoration	m^2	60
Removal of rail corridor and restoration	m^2	60
Replacement value of existing buildings	m2	2,500
Cost to move relocatable buildings	No	10,000
Removal of services: Telstra, Water, Sewer, Electricity	Not costed	

9.3 Seawall Design Development

Further design development would be required if this option is to be adopted. The designs presented in this WRL report are for preliminary costing purposes only and are based on the authors' broad coastal engineering experience.

Section 55M of the Coastal Protection Act (1979 as amended) states that the consent authority must be satisfied that proposed works should not: "*unreasonably limit or be likely to unreasonably limit public access to or the use of a beach or headland*". This is a reason for including nourishment and/or sand retaining groynes within several shortlisted options.

However, since the works are intended to be staged and may involve delays in sand nourishment, alongshore pedestrian access during times of beach erosion has been incorporated into the seawall crest (Figure 9.1).

Subject to determination of the wall alignment, portions of the seawall (including the walkway) may be on road reserve, crown land or private land. Where the walkway is proposed to be located on what is presently private land, negotiations with landowners would need to be undertaken. Note that there are differing views on legitimacy of fixed boundaries on a receding/eroding coast (Coleman 2010, Corkill 2013), the resolution of which is beyond the scope of this report.

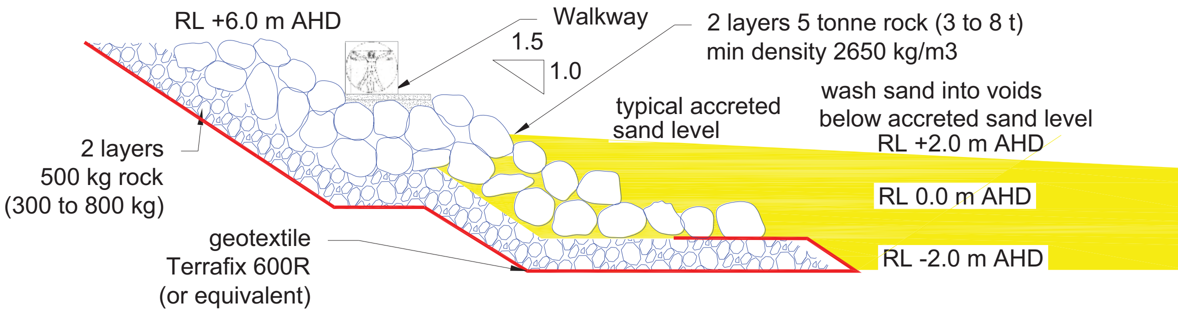


Figure 9.1: Preliminary Seawall Design incorporating Alongshore Pedestrian Access

9.4 Beach Width

9.4.1 Literature on Beach Width

For all structural protection options, erosion protection for a 1 in 100 year ARI event would be provided by the terminal seawall. That is, beach nourishment is not required to provide erosion protection or maintain the integrity of the seawall. Beach nourishment would be undertaken to assist with providing an acceptable beach width to increase and then maintain beach amenity, and may be required to manage impacts associated with coastal protection works under the Coastal Protection Act 1979. To design the nourished profiles for this option, it was first necessary to review and define an acceptable beach width for the Byron Bay Embayment.

Beach width is an important criterion when considering the community's enjoyment of the beach. While wider beaches are not always better, within reason, people prefer wider beaches (King, 2006). Anning (2012), investigating the economic value of selected Sydney beaches, highlighted that while beach width has been used extensively in the valuation literature as a proxy for beach quality, determining what is acceptable to a community for recreation use is complex. Dr Anning was contacted as part of this investigation and confirmed that the majority of beach width studies investigated have been based on housing market impacts, rather than recreational use (Anning, 2012). Some references were suggested by Dr Anning and have been included in the following discussion.

"Acceptable beach width" varies greatly depending on usage patterns and personal preference. Parsons *et al.* (2000), considering beaches in the mid-Atlantic region of the USA (primarily Delaware and New Jersey), suggested that beaches can be both too narrow and too wide. It was proposed that the ideal beach width was between 75 and 200 ft between the dune toe and the berm (approximately 23 – 61 m). Morgan (1999) investigated acceptable beach width in Wales, finding the optimal beach width to fall between 50 and 200 yards at low tide (46 - 183 m) and 20 to 50 yards at high tide (18 – 46 m), similar values to those of Parsons *et al.* (2000). King (2006) suggested that the ideal beach width is approximately 100 - 250 ft (30 – 76 m), without reference to the tidal stage of the beach.

King (2006) also highlighted that it is possible that a beach could be so wide that access is restricted. Furthermore, the quality of the beach also depends on the sand; a wide, fine sandy beach is always preferred to a beach with cobbles (King, 2006). Furthermore the US Army Corps of Engineers, responsible for beach nourishment programs in the USA, often follow a policy that 100 ft^2 (approximately 9 m^2) of beach area is desirable per person for a beach

(King, 2006). Subsequently, ideal beach widths can be determined by both general beach width, and user numbers and associated beach area per user.

Large scale nourishment of the southern Gold Coast beaches has been occurring as part of the Tweed River Entrance Sand Bypassing Project (TRESBP). A number of dredging campaigns of the Tweed River entrance have taken place and a permanent sand bypass system was introduced in 2001. This has resulted in significant changes in the Coolangatta Bay morphology, with the southern beaches of the Gold Coast thought to be the only Gold Coast beaches able to manage a high succession of large wave events (Castelle *et al.*, 2006). However, some of these beaches are now very wide. A seaward migration of the shoreline by more than 200 m has occurred at Kirra Beach, compared to the shoreline prior to the TRESBP. Some local stakeholders and tourists consider that the beaches are too wide, especially at Kirra, and that surfing, swimming, fishing, diving and beach use amenity has been compromised as a result of over nourishment (Castelle *et al.*, 2006). This highlights the importance of not making a beach 'too wide'.

Carley *et al.* (2003) and Short and Trembanis (2004) each analysed one of Sydney's Northern beaches, Manly Ocean Beach and Collaroy-Narrabeen Beach, respectively. Carley *et al.* (2003) assessed the average mid-tide beach width of Manly Ocean Beach, seaward of the wall to 0 m AHD between 1930 and 2001. The average mid tide width of the entire beach over this period was 48 m, ranging between 32 m at the southern end, to 75 m at the northern end. Their qualitative observations are that the northern end is almost always acceptably wide for the community, but the southern end is too narrow at times. Along Collaroy-Narrabeen Beach between 1976 and 2001, Short and Trembanis (2004) observed an overall mean width of 78 m, considering five different profiles spaced along the beach. The mean of the maximum widths observed was 119 m and the mean of the minimum widths was 46 m.

9.4.2 Beach Width for Belongil

Considering the above findings, a minimum dry beach width of 20 m at +2 m AHD (elevation derived below) was adopted to maintain beach amenity. To design the nourished profiles required to maintain this dry beach width, it is also necessary to consider the following:

- Frequent erosion events;
- Recession;
- Tidal action;
- Wave runup; and
- The elevation at which the minimum dry beach width is defined.

It was considered necessary to include an allowance for erosion from frequent storm events in the design nourished profiles, so that beach amenity was not completely removed following reasonably regular storm events. Using the Gordon (1987) statistical erosion model (Figure 9.2), the predicted 1 in 1 year ARI erosion volume for a high demand rip head is ~40 m^3/m above 0 m AHD. WRL adopted this erosion volume as an allowance in the design nourished profiles. Furthermore, Nielsen *et al.* (1992) suggested that following this storm event the beach slope can be idealised as a slope of 1V:10H (steepened from 1V:25H prior to the storm).

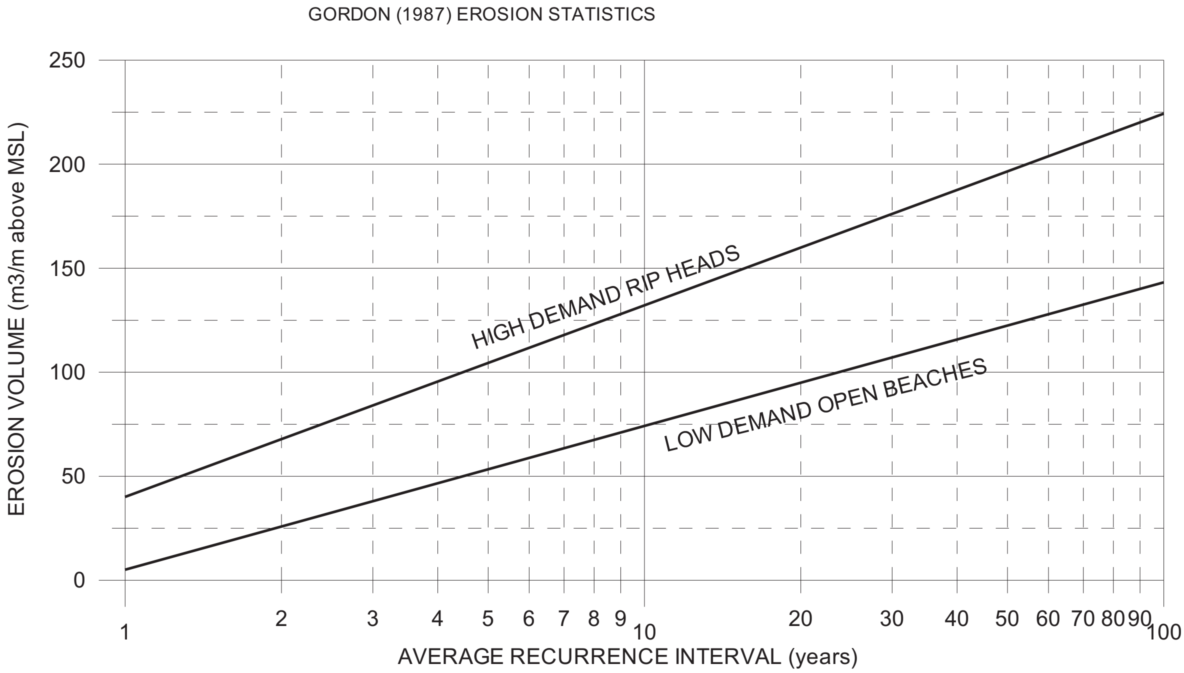


Figure 9.2: Gordon (1987) Erosion Statistics

It is important to also consider tidal action and wave run-up on the beach, as it is the dry beach that is generally used for recreational purposes. A still water level (SWL) of 0.64 m AHD (Mean High Water Springs, Table 9.4) was adopted for consideration of coincident wave runup.

The median offshore wave conditions for the wave buoy at Byron Bay and two adjacent wave buoys at Brisbane and Coffs Harbour are tabulated in Table 9.3 (Shand et al. 2010). WRL adopted the median wave conditions (H_s = 1.50 m, T_p = 9.50 s) from the Byron Bay wave buoy for consideration of typical wave conditions at Belongil, though it should be noted that nearshore waves will often be smaller than the offshore conditions due to wave refraction.

Table 9.3: Median Offshore Wave Conditions (All Directions) (Source Shand et al, 2010a)

Wave Parameter	Brisbane	Byron Bay	Coffs Harbour
Median H_S (m)	1.47	1.50	1.43
Median T_P (s)	9.31	9.50	9.50

A range of wave run-up statistics on pre-storm and post-storm nearshore beach face slopes (1V:25H and 1V:10H, respectively) were calculated using the adopted median wave conditions and a coincident SWL of 0.64 m AHD and are shown in Table 9.4. These wave runup levels were used to assist selection of the elevation at which the minimum dry beach width is defined.

Table 9.4: Wave Run-up Levels at Mean High Water Springs

Run-up Statistic	Runup Level (m AHD with MHWS tide of 0.64 m AHD)	
	1V:25H pre-storm beach slope	1V:10H post-storm beach slope
Max Run-up	2.32	4.04
2%	2.06	3.37
Average of highest 1/10	1.94	3.13
Average of highest 1/3	1.71	2.66
Average	1.33	1.93

WRL adopted an elevation of 2 m AHD to define the minimum dry beach width of 20 m. That is, following a 1 in 1 year ARI erosion event, the horizontal distance between the 2 m contour on the seaward face of the seawall and the 2 m AHD contour on the beach slope would be at least 20 m. For a mean spring high tide under median wave conditions, the average of the highest 1/10th of waves will not reach the 2 m AHD contour elevation for a pre-storm nourished profile. With the steeper post-storm beach slope, the average wave run-up at high tide will still not reach this elevation. Note that wave run-up will reach higher elevations on the beach (resulting in a beach width less than 20 m at 2 m AHD) for more energetic wave conditions coupled with higher water levels.

Table 9.5 displays the beach width at 0 m AHD (the horizontal distance between the 0 m contour on the seaward face of the terminal seawall and the 0 m AHD contour on the beach slope) and 2 m AHD as well as sand volume above 0 m AHD relative to the seawall. Note the difference between the sand volumes is 42 m^3/m, which approximates the 40 m^3/m determined by Gordon (1987).

Table 9.5: Beach Widths and Volumes Seaward of Seawall

Profile	Beach Width (m)		Dune and Beach Volume (m^3 above AHD)
	0 m AHD	2 m AHD	
Design Nourished (Pre-storm)	70	27	117
Eroded (Post-storm 1 in 1 Year ARI)	37	20	75

Note that the ARI of the erosion event (approximately 120 m^3/m) which would result in zero beach width for the design nourished profile at +2 m AHD is between approximately 5 and 25 years. Alongshore beach access in these circumstances may still be provided by means of a walkway on the seawalls such as shown in Figure 9.1.

9.5 Design Nourishment Volumes

It should be noted that this WRL study is not a detailed nourishment feasibility exercise, however, plausible assumptions are needed to assess the costs of each option in a fair and rational manner.

Previous estimates of the required nourishment volume were undertaken in WBM (2003) and Patterson Britton & Partners (PBP, 2006). It should be noted that in the WBM study, nourishment was an option considered within a report covering a broad scope, whereas the PBP report was specifically focussed on nourishment from the Cape Byron sand lobe. Both these studies were premised on introducing 250 m^3/m of sand above AHD (plus a subaqueous component, which is about twice the subaerial component) over a 2 km length of beach. This 250 m^3/m of sand above AHD would notionally offset the adopted 100 year ARI storm demand from WBM (2000), hypothetically making structural protection unnecessary. However, due to the need for periodic renourishment and the logistics and timing involved, reliance on nourishment alone for protection introduces high uncertainty, and preservation and/or upgrades to the existing seawalls were still incorporated in the WBM and PBP studies.

Three of the four shortlisted options for this study involve a seawall as the primary protection, with nourishment added to two of the options primarily for beach amenity and to reduce downdrift impacts. While detailed data is not available, on the premise that following a minor to moderate storm (approximately 1 year ARI), the sand levels against the seawalls (without nourishment) would be approximately 0 m AHD, as shown in Table 9.6, a sand volume of approximately 120 m^3/m above AHD (with 240 m^3/m below AHD, 360 m^3/m total added native volume) would be needed to provide acceptable dry beach amenity following a 1 year ARI erosion event. As previously stated, alongshore access would still be provided by means of a walkway on the seawall.

Quantities and factors used in beach nourishment calculations are shown in Table 9.6.

Table 9.6: Quantities Used in Nourishment Calculations

	WBM (2003)	**PBP (2006)**	**This WRL study**
Dune crest elevation	+6 m AHD	+6 m AHD	+5 m AHD
Closure depth	-10 m AHD	-8.5 m AHD	-10 m AHD
Native nourishment volume above AHD	Not stated	250 m3/m	120 m3/m
Native nourishment volume to closure	500 m3/m	750 m3/m	360 m3/m
Alongshore length	2 km	2 km	2 km
Initial native volume	1,000,000 m3	1,500,000 m3	720,000 m3
Overfill factor (a)	Not stated (1.0)	1.5	1.5
Initial borrow volume (b)	1,000,000 m3	2,850,000 m3	1,080,000 m3
Frequency of renourishment	25 years	5 to 10 years realistic 25 years adopted	1 to 10 years
Renourishment native volume (c)	500,000 m^3 20,000 m^3/year	750,000 m^3 30,000 m^3/year	30,000 m^3/year
Renourishment borrow volume (m^3)	20,000 m^3/year	45,000 m^3/year	30,000 to 45,000 m^3/year

Notes

a. Based on limited data, PBP found that available (borrow) sand was finer than that present (native) on Belongil, which would necessitate the use of an "overfill factor". If additional studies are able to identify and access more compatible borrow sand, the overfill factor may reduce to 1.0 (no overfill), which would result in a 33% reduction in the required borrow sand volume.
b. Due to the cost of project dredge establishment, detailed studies may find that it is more economical to increase the initial volume. Establishment costs may also be able to be reduced through cost sharing of dredger establishment with nearby sites.
c. Note that the BMT WBM (2013) Byron Shire Coastline Hazards Assessment Update estimated that there was a deficit of approximately 50,000 m^3/year of sand in the Byron Bay embayment. The renourishment requirement could only be ascertained with ongoing monitoring, however, the use of end control structures would reduce this loss in the built up areas.

Unit rates adopted for nourishment are shown in Table 9.7. The WBM (2003) and PBP (2006) studies were adjusted to 2014 dollars by means of the Australian Bureau of Statistics consumer price index.

Table 9.7: Unit Rates Used in Nourishment Calculations

	WBM (2003)	WBM (2003) in 2014 $	PBP (2006)	PBP (2006) in 2014 $	This WRL study 2014 $
Initial borrow quantity	1,000,000 m^3		2,850,000 m^3		1,080,000 m^3
Establishment	$5M	$6.6M	$3.8M	$4.6M	$5M
Cost per m^3	$8	$10.50	$5	$6	$7

Costs adopted for nourishment are shown in Table 9.8.

Table 9.8: Quantities and Costs for Preliminary Nourishment Scheme

Item	Unit	Quantity	Rate	This WRL study 2014 $	Potential Rate range 2014 $
Initial design, investigations and approvals				1,000,000	500k to 1.5M
Establishment	Item	1	5,000,000	5,000,000	1M to 6M (a)
Dredge and place	m^3	1,080,000	7.00	7,560,000	4.00 to 40.00
Dune stabilisation and planting (b)	m	2,000	300	600,000	100,000 to 700,000
Sub total (c)				$14,160,000	

Notes

(a) Shared establishment costs may be possible with other locations.

(b) Often done on a voluntary or community basis, but commercial rates are shown. Rates developed in consultation with specialist contractor.

(c) Other components of options are shown below.

9.6 Renourishment

As stated above, the BMT WBM (2013) Byron Shire Coastline Hazards Assessment Update estimated that there was a deficit of approximately 50,000 m^3/year of sand in the Byron Bay embayment. The renourishment requirement could only be ascertained with ongoing monitoring, however, the use of end control structures would reduce this loss.

Previous studies (WBM, 2003 and Patterson Britton & Partners, 2006) proposed major repeat dredging campaigns for ongoing nourishment. For this study, the alternative of a small sand transfer or small scale nourishment is proposed. This could be in the form of a transfer system from either Tallow Beach to Clarkes Beach or North Belongil-Tyagarah to Cavvanbah, small scale dredging from intermediate depths, or opportunistic dredging of nearby rivers. Sand transfer systems have operated successfully at Noosa Queensland, Portland Victoria, Lakes Entrance Victoria, Adelaide, and Mandurah Western Australia. A more detailed assessment of the feasibility is provided in Appendix K. Additional work would be required to assess the permissibility of all sand transfer options.

Costs adopted for renourishment from a transfer scheme are shown in Table 9.9. If opportunistic use of dredgers becomes available, lower costs may be possible.

Table 9.9: Quantities and Costs for Preliminary Renourishment Scheme

Item	Unit	Quantity	Rate	This WRL study 2014 $ best estimate
Capital costs				
Initial design, investigations and approvals				200,000
Establishment, pipework, pumps	Item	1	1,500,000	1,500,000
Sub total				1,700,000
Contingency			20%	120,000
Total Capital				2,000,000
Ongoing costs				
Sand pumping costs	m^3/year	30,000	10.00	300,000
Monitoring	Item/year	1	30,000	30,000

9.7 Design Considerations for Groynes

USACE (1992) stated that prior to the design of a groyne field, an inventory of the condition and effectiveness of existing, nearby structures should be prepared. The best indication of how a proposed structure will perform is the performance of a similar structure in a similar physical environment. An evaluation of how nearby groynes and training walls (which are effectively long groynes) are performing will provide an indication of how a proposed groyne field will perform.

This section has been compiled to provide an overview of groynes and training walls that have been constructed along the northern NSW and southern Queensland coast. Summarising these groynes and training walls provides information and guidance for the concept design.

Along the coast between Noosa and Byron Bay nine entrances with training walls (some with two training walls, others with just one) and eleven groynes (including four at Maroochydore, two at Palm Beach and two at Kirra) were documented. With the exception of Maroochydore, these structures are predominantly constructed from rock, with concrete cubes used on the Gold Coast Seaway training wall heads and the northern training wall of the Tweed River. Effective structure lengths were estimated using publicly available aerial photographs and readily available literature. Note that the effectiveness of each structure's function as a littoral drift barrier is more dependent on depth rather than length. Some of the structures are not perpendicular to the shoreline, however, orientation has not been included in this table. Crest and toe levels have also been included based on literature or estimates by WRL's coastal engineers. The available characteristics for each of the structures are tabulated in Table 9.10.

Table 9.10: Groynes and Training Walls in Southern Queensland and Northern NSW

Location	Year of Construct.	Av Sand Level at Head(1) (m AHD)	Approx. Length (m)	Crest Level (m AHD)	Construction Material
Noose River Training Wall (S)	1978	-1.0(2)	55	3.0(2)	Rock
Noosa Woods Groyne	1983	-2.0(3)	125	3.0(2)	Rock
Maroochydore Beach Groyne 4 (N)	2001-03	-1.0(2)	65	1.5(2)	Geo. Containers
Maroochydore Beach Groyne 3	2001-03	-1.0(2)	50	1.5(2)	Geo. Containers
Maroochydore Beach Groyne 2	2001-03	-1.0(2)	100	1.5(2)	Geo. Containers
Maroochydore Beach Groyne 1 (S)	2001-03	-1.0(2)	100	1.5(2)	Geo. Containers
Mooloolah River Training Wall (W)	Late 1960s	-2.0(4)	255	4.0(4)	Rock
Mooloolah River Training Wall (E)	Late 1960s	-3.0(4)	150	4.0(4)	Rock
Gold Coast Seaway Training Wall (N)	1986	-3.0(2)	210	4.0(2)	Rock, Conc. Cubes
Gold Coast Seaway Training Wall (S)	1986	-7.0(5)	450	4.0(2)	Rock, Conc. Cubes
Tallebudgera Creek Training Wall (S)	1978	-2.0(2)	190	3.5(2)	Rock
Palm Beach Groyne (N – 21st Ave)	1980	-1.0(6)	55	2.0(2)	Rock
Palm Beach Groyne (S – 11th Ave)	1980	-1.0(6)	75	2.0(2)	Rock
Currumbin Creek Training Wall (N)	1980	-2.0(2)	160	3.0(2)	Rock
Currumbin Creek Training Wall (S)	1973	n/a(7)	200	2.0(2)	Rock
Miles Street Groyne (North Kirra)	1974	+3.0(2)	120	3.0(2)	Rock
Kirra Point Groyne	1972	-3.0(8)	160	3.0(8)	Rock
Tweed River Training Wall (N)	1962-65	-5.0(2)	425	5.5-6.5(9)	Rock, Conc. Cubes
Tweed River Training Wall (S)	1962-65	-4.0(2)	200	6.0(9)	Rock
Cudgen Creek Training Wall (N)	1966	-1.0(10)	120	3.0(10)	Rock
Cudgen Creek Training Wall (S)	1966	-1.5(10)	120	3.0(10)	Rock
Mooball Creek Training Wall (N)	1966-67	-1.0(2)	75	2.2-2.5(9)	Rock
Mooball Creek Training Wall (S)	1966-67	-1.5(2)	100	2.0(9)	Rock
Kendall's Groyne (New Brighton)	1970s	+1.0(2)	25	2.5(2)	Rock
Brunswick River Training Wall (N)	1960-1962	-2.0(2)	275	4.0-3.5(9)	Rock
Brunswick River Training Wall (S)	1960-1962	-3.0(2)	200	4.5(9)	Rock
Jonson Street Spur Groyne	1975	-0.5(2)	40	5.0(11)	Rock

Notes:

(1) This is an average estimate but may vary by ±1.5 m due to accretion, erosion/recession, scour and beach nourishment.
(2) Estimated by WRL's experienced coastal engineers and requires confirmation by survey.
(3) Source: Cox and Carley, 2003.
(4) Source: Nittim, 1974.
(5) Source: Turner et al, 1998.
(6) Source: BMT WBM, 2013.
(7) An average sand level was not estimated at the head of this structure since this groyne connects the mainland to a rock platform offshore of the northern end of Currumbin Beach.
(8) Source: WorleyParsons, 2009. The Miles Street Groyne (North Kirra) and the Kirra Point Groyne were shortened by 30 m in 1996, with Kirra Point then lengthened in 2014. Table 9.10 includes the dimensions for both of these groynes 1996-2013.
(9) Source: MHL, 1994.
(10) Source: TSC, 2011.
(11) Source: WorleyParsons, 2013.

Of the eleven groynes, Miles Street Groyne at North Kirra, constructed in 1974, and Kendall's Groyne, constructed at New Brighton in the 1970s are now very short (extending to approximately +3 and +1 m AHD, respectively) and are no longer having any impact on the shoreline alignment (WorleyParsons, 2009 and WBM, 2000). The two groynes at Palm Beach constructed in 1980 (Splinter et al, 2011) and the Jonson Street Spur Groyne in Byron Bay can also be considered short, and were estimated to extend to approximately -1, -1 and -0.5 m AHD respectively. WRL is aware that consideration is presently being given to extending the Palm Beach Groynes to approximately -3 m AHD (BMT WBM, 2013). Note that the Jonson Street Spur Groyne was originally the second (central) of three spur groynes; however, the other two groynes at either end of the Jonson Street coastal protection works now have negligible action as littoral drift barriers and have been excluded from the inventory on this basis. The four groynes at Maroochydore Beach are composed of 2.5 m^3 sand-filled geotextile containers extending to approximately -1 m AHD and were constructed between 2001 and 2003. While these groynes are also considered relatively short, they have successfully stabilised Maroochydore Beach for over 10 years (Hornsey et al, 2011). Noosa Woods Groyne and Kirra Point Groyne are much longer, extending to approximately -2 and -3 m AHD respectively. Noosa Woods Groyne was completed in January 1983, and the construction was accompanied by 220,000 m^3 of nourishment sand (Coughlan, 1989). This sand was eroded and in 1988 another 140,000 m^3 was pumped onto the beach and recommendations made that further nourishment be used to maintain a useable beach. Since then, regular beach nourishment exercises have placed approximately 80,000 m^3 of sand on the beach every two years (Chamberlain and Tomlinson, 2006), with 40,000 to 60,000 m^3/year able to be backpassed with a "sandshifter" transport system (Slurry Systems Pty Ltd, 2014).

Kirra Point Groyne was originally constructed in 1972 extending seaward to -5 m AHD (Robinson and Patterson, 1975) with an approximate length of 180 m, but was then shortened by 30 m in 1996 (WorleyParsons, 2009) and re-extended in 2014. In 2009 the groyne extended to approximately -3 m AHD (WorleyParsons, 2009) and is generally considered to be fulfilling its function of protecting Coolangatta/Greenmount Beach. Miles Street Groyne, located approximately 500 m west of the Kirra Point Groyne, originally had a length of 120 m which was also shortened by 30 m in 1996 (WorleyParsons, 2009). Design parameters for the Kirra Point Groyne are reproduced in Table 9.11.

Table 9.11: Kirra Point Groyne Design Parameters (Source: WorleyParsons, 2009)

Design Parameter	Original Imperial Units	Converted Metric Units
Alignment	North-East	
Length	600 feet	183 m
Height	R.L. 10.0 feet (State Datum)	3.05 m AHD
Armour (trunk)	5 to 8 tons rock	5.1 to 8.1 tonnes rock
Armour (head)	10 to 15 tons rock	10.2 to 15.2 tonnes rock
Design Wave Conditions(2)	16 feet	4.9 m
Side slopes (natural)	1V:1.25H to 1V:1.25H	
Side slopes (design wave conditions)	1V:2.5H	
Crest width	12 feet	3.6 m

Notes:

(1) State Datum is roughly equivalent to AHD.

(2) WRL understands that this is the maximum expected depth limited wave height (H_{MAX}).

Information was located regarding the armour used on the Gold Coast Seaway training walls, constructed in 1986. The seaway walls are composed of rock and concrete cubes.

Approximately one million tonnes of rock was imported, with rock sizes up to 15 tonnes, and 4,500 concrete cubes between 20 and 25 tonnes were used to create the seaway training walls (Gold Coast City Council, date unknown). No information was found regarding armour units on any of the other training walls or groynes in Queensland.

The NSW Breakwaters - Asset Appraisal, conducted by Manly Hydraulics Laboratory in 1994, documented all breakwaters and training walls along the NSW coastline assessing three main areas:

- Structural stability of the breakwaters and training walls;
- Public use and related safety aspects of the breakwaters and training walls; and
- Maintenance of the breakwaters and training walls.

As part of this report, information about the rock size and condition of each breakwater and training wall, as well as the crest level of each breakwater was provided. Relevant information about NSW training walls has been included in Table 9.10.

At the southern end of Kingscliff Beach, training walls were constructed on Cudgen Creek. They were designed as part of a flood mitigation scheme to alleviate the flood problem in the Cudgen Lake and Cudgen Creek area, with construction completed in 1966 (MHL, 1994).

While it has not been constructed, it is noteworthy that a concept design for a groyne field north-west of the Jonson Street Groyne at Byron Bay was developed by the Gordon et al PWD (1978). The characteristics for a typical groyne were as follows:

- Length: extending seaward to the -3 m AHD contour;
- Crest Level: 5 m AHD (seaward end) and 7 m AHD (landward end);
- Armour (trunk): 10 t rock;
- Armour (head): 12-15 t rock; and
- Side slopes: 1V:1.5H.

9.8 Preliminary Groyne Design for Byron Bay

The Gordon et al. PWD (1978), WBM (2003) and Patterson Britton & Partners (2006) studies all suggested that the end control structure and/or groynes should extend to approximately -3 m AHD. This is consistent with the Kirra Point groyne.

Due to evidence of shorter groynes/training walls providing coastal stabilisation within the region (Table 9.10), and the considerable cost of constructing structures to -3 m AHD, for this study the groyne field designs have been extended to -2 m AHD, while the single groyne/end control structure has been extended to -3 m AHD. The groyne field groynes would have a crest length of the order of 100 to 140 m, while the single end control structure would have a crest length of the order of 150 to 200 m. This can be compared to structures in the surrounding area shown in Table 9.10.

Detailed modelling and/or field monitoring would be needed to confirm this, however, future extension of flexible rock structures is reasonable and feasible in accordance with adaptive management principles.

9.8.1 Multiple Groyne Field and Training Walls

For preliminary design of the groyne field option the following locations are suggested:

- Northern end or central portion of private land on North Beach;
- Southern bank of Belongil Creek;
- North of northernmost private property on Belongil spit;
- In the vicinity of the second jetty site.

For the multiple groyne field option, an initial trial groyne is recommended before completing the field. This would require monitoring and would be to ascertain the sand trapping performance and downdrift impacts for a given length of groyne. From the monitoring of the trial, it may be possible to shorten or lengthen the initial trial groyne and subsequent groynes. Subject to further design, it may be possible to consider alternative materials (to rock) for the trial groyne.

If groynes are used as training walls for Belongil Creek, they will alter the flood and ecological characteristics of Belongil Creek. This was considered within BMT WBM (2013b) as summarised in Section 19.14 of this WRL report.

The benefit of training walls on upstream flood levels was found to be greatest under conditions of large terrestrial floods, particularly without ocean storm tides. The BMT WBM (2013b) modelling found that for relatively frequent (5 and 10 year ARI) events, the storm tide effects caused minor increases (0.04 m) in the upstream flood levels compared with an untrained entrance. Under 100 year ARI flood conditions with a normal spring high tide (MHWS), upstream flood levels would reduce by 0.5 m with a trained entrance. Nevertheless, BMT WBM (2014) found that the economic benefit of entrance training walls was low from a flood reduction perspective.

Note that the modelling presented was for the peak of the event. Under storm tide conditions, the storm tide peak will persist for 1 to 2 hours, with ocean water levels then dropping due to the astronomical tide component. Due to diurnal inequality, during spring tides, there is only one large high tide per day in NSW, with the second high tide typically 0.5 m lower.

Note that more recent guidance (Toniato, McLuckie and Smith, 2014) indicates that a trained entrance may have a more beneficial effect on tailwater and flood levels than that allowed for in BMT WBM (2013b).

9.8.2 Single Groyne/End Control Structure

For the preliminary design of a single end control structure, the location options are similar to the groyne field, however, all will involve limitations, particularly without nourishment. Without nourishment, the single groyne will transfer erosion/recession from one area to another. Ideally, the resulting accretion would occur in an area with lower buffer and/or higher economic (or other) value, while the erosion/recession would occur in an area with greater buffer and/or lower economic (or other) value. The downdrift recession will generally stabilise when bypassing of the groyne eventuates.

Potential locations for a single groyne would include:

- Northern end or central portion of private land on North Beach – this would prevent recession of private land at North Beach, but would have negligible impact on the high use areas of Belongil and would cause recession at Tyagarah Beach.
- Southern bank of Belongil Creek - this would prevent recession of northern Belongil spit, but without nourishment would cause substantial recession of private land at North Beach, and would have negligible impact on the high use areas of Belongil.

- North of northernmost private property on Belongil spit - this would prevent recession of northernmost Belongil private properties, but without nourishment would cause substantial recession and breakthrough of northern Belongil spit and recession of private land at North Beach, and would have negligible impact on the more southern high use areas of Belongil. This location would also influence sand width at the mouth of Belongil Creek, however, the additional seaward translation of the berm is unlikely to substantially alter the hydraulic grade line of the creek under flood conditions. Additional sand width there could be managed in a similar manner to the existing entrance management plan.

Without nourishment, none of the three potential locations for a single groyne can fulfil the objective of accreting sand in areas of lower buffer/higher value while also limiting recession to areas of higher buffer/lower value.

9.8.3 Managed Adaptive Scheme

While the potential for staging is implicit in the options presented above, BSC and OEH requested that greater consideration be given to a staged adaptive management scheme.

Adaptive management is a flexible method of allowing development to be retained at acceptable probabilities of damage/failure (typically 100 year ARI) under a changing climate, through a series of interventions and monitoring, rather than undertaking large scale interventions which may be difficult to reverse. An example of adaptive management from DEFRA (2006) is shown in Figure 9.3.

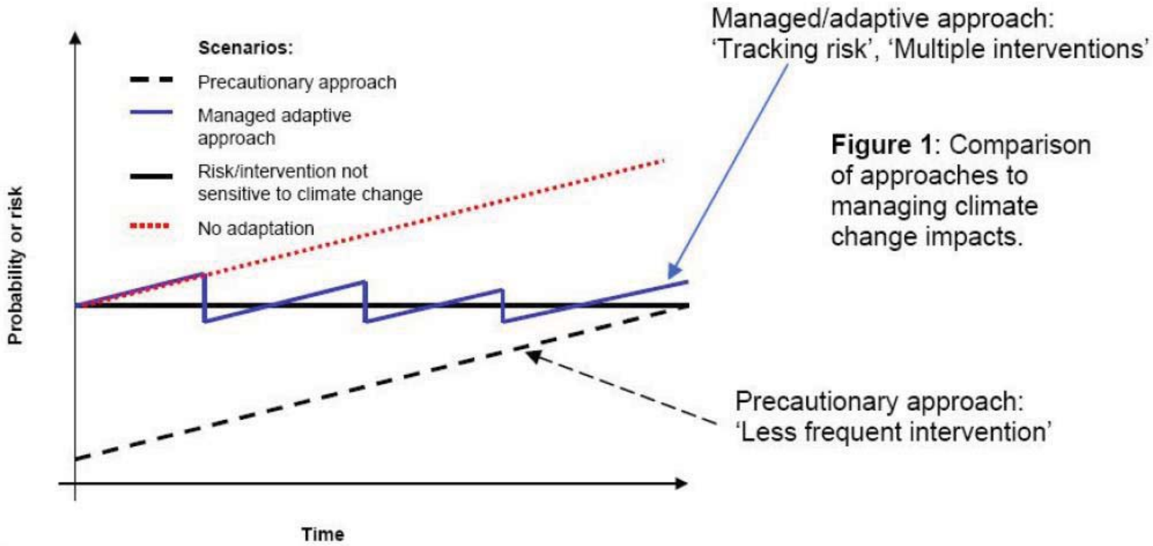


Figure 9.3: Managed Adaptive Approach (DEFRA, 2006)

A suggested sequence of adaptive stages for the Belongil section of the Byron Bay embayment is:

- 6.1 Seawalls (initially from Border Street to the northernmost private Belongil property);
- 6.2a. An initial trial groyne;
- 6.2b. Additional groynes;
- 6.3 A small scale sand transfer plant or nourishment.

Subject to monitoring, later stages in the sequence may not be required. If sea level rise continues and/or accelerates, there may be some point in the future when protective works are no longer economically viable, however, this is likely to be more than 100 years into the future.

There is some uncertainty as to whether to undertake sand transfer before or after constructing groyne(s). Due to the potential planning difficulties in accessing sand, and the potential for the groynes to be self-filling, groynes have been adopted earlier than sand transfer.

Towards the end of the initial design life (2050) additional extension of the Jonson Street seawall may be required beyond First Sun Caravan Park towards Border Street if protection of the railway corridor is warranted – this will be highly dependent on the future use of the railway corridor.

9.8.4 Planning Controls for Protection Options

For all the protection options listed above, some form of complementary planning controls would still be required. As a minimum it is recommended that an easement for future maintenance/repairs be created for the seawall. A suggested minimum width of 4 m (landward of the most landward portion of the crest) is suggested for this easement, noting that the Gold Coast requires a minimum of 8.1 m from the seaward extent of the crest (which is approximately 4.6 m from the most landward portion of the crest for its standard design.

If protection works are implemented, planning decisions would need to be made regarding any intensification of development in areas protected by the works. This decision should consider that the engineering design life of the works is approximately 50 years.

10. Management Recommendations for other Locations and Hazards in Byron Bay Embayment

Due to the substantial number of private properties potentially vulnerable to coastal erosion in Belongil, this has received the bulk of emphasis in this and previous management options studies.

Nevertheless, there are 19 identified cadastre parcels within the Immediate Hazard zone (for both Scenario 1 and 2) that lie in the Clarkes Beach and Main Beach sections. This is consistent between both Scenario 1 and Scenario 2. This figure increases to 20 (under both scenarios) when recession to 2050 is incorporated into the hazard assessment. The majority of these cadastre parcels are public land.

Suggested management options for other sites and hazards within the Byron Bay embayment are listed below.

10.1 Wategos

No hazard lines were presented for Wategos Beach in BMT WBM (2013) on account of the beach being underlain/backed by bedrock and a seawall.

The following actions are recommended:

- Accurately map the bedrock surface and seawall extent (this may be possible with ground penetrating radar);
- Check the stability of the existing seawall; and
- Consider rebuilding the seawall and/or partial retreat of Marine Parade which may involve conversion to one way traffic flow.

10.2 The Pass to Clarkes Beach

WBM (2013 Figure 4-41) noted that "the erosion hazard at The Pass extends to bedrock". The erosion hazard lines extend into the Captain Cook car park (slightly by 2050) and Lighthouse Road for 2100, however, bedrock levels there are uncertain. Due to the requirement for road access to Wategos, additional geotechnical works to retain Lighthouse Road may be required. Given the proximity to bedrock, these would not displace substantial portions of sandy beach and would not be required prior to 2050.

Options for the Captain Cook car park are minor retreat by 2050 or similar works to those suggested for Lighthouse Road. These would not be needed immediately.

The following actions or considerations are recommended:

- Accurately map bedrock surface to confirm hazard lines relative to structures; and
- The small number of structures potentially vulnerable to hazards may make retreat of these structures more justifiable than more intensely developed areas.

10.3 Main Beach

The following actions are recommended:

- Generally allow natural processes to prevail in conjunction with upgrading the Jonson Street structure (WorleyParsons, 2014).

10.4 Cavvanbah

Future changes to this beach will be affected by management options for Belongil. There are no structures within the erosion/recession hazard zone to 2050. The railway corridor is within the erosion/recession hazard zone in 2050 but not in the immediate hazard zone. If nourishment is undertaken for Belongil, Cavvanbah would be a potential placement site, however, protection of Cavvanbah with a seawall is unlikely to be economically justified to 2050. Reopening or alternative use of the railway line/corridor would necessitate a review of the need for protection in the future. There is substantial development within the erosion/recession hazard zone to 2100. If the projections for ongoing recession and sea level rise beyond 2050 to 2100 eventuate, management options would require reconsideration.

10.5 North Beach

Future changes to this beach will be affected by management options for Belongil, however, there are no structures within the hazard zones to 2050 or 2100. Impacts on North Beach need to be considered in the design of any structures for Belongil. Some existing or future developed areas may be vulnerable to coastal lake or watercourse entrance instability. This could be managed through monitoring and/or the groyne schemes proposed, and is presently partially managed through the existing entrance opening management procedures. If a groyne scheme is implemented for Belongil and/or training walls installed at Belongil Creek, it is recommended that one or more groynes be installed at North Beach to prevent downdrift impacts if shoreline modelling of the groyne impacts (not yet undertaken) indicates that such recession would cause unacceptable impacts.

10.6 Inundation Hazard

BMT WBM (2013) indicated that there was an inundation hazard for areas of Byron Bay, however, most dunes were sufficiently elevated to prevent overtopping. BMT WBM noted that potential dune overtopping could occur at the northern end of the Jonson Street protection works, Manfred Street and northern Belongil Spit (beyond the northernmost house). They noted that the dune heights at North Beach north of Belongil Creek were high and therefore not subject to overtopping. They also noted that the berm fronting the Belongil Creek mouth was low and therefore subject to overtopping, however, assessment did not extend into the Belongil Creek mouth and any assessment of inundation through wave propagation across the entrance to the dune on its landward side. The inundation hazard (excluding wave runup) within Belongil Creek was also addressed in the BMT WBM (2014) Belongil Creek Floodplain Risk Management Study Report. The mapping produced by BMT WBM (2013) indicates areas of potential inundation, however, substantial additional work and analysis would be required to extend this into a risk assessment. Such work would include mapping of the depth of inundation and an inventory of the floor levels of vulnerable structures.

If a protection management option is pursued, the potential breach at Manfred Street would be prevented with an appropriately designed seawall. Under a retreat scenario, dune strengthening with minor beach scraping (when the beach is accreted) may reduce the likelihood of a breach at Manfred Street. However, neither of these actions would prevent inundation from Belongil Creek, although it should be noted that creek inundation levels are well below wave runup levels. Inundation and flooding from Belongil Creek and its management is substantially covered in BMT WBM (2014).

The following additional actions or considerations are recommended:

- Consider the dynamic component of wave overtopping in locations such as Jonson St;
- Consider wave runup and overtopping for waves propagating across the entrance to Belongil Creek;
- Consider the inundation hazard in conjunction with the terrestrial flood hazard; and
- Potentially manage the inundation hazard with floor level controls, flood resistant materials and emergency management, including forecasting.

11. Costs of Shortlisted Options for Economic Assessment

This section presents engineering costs for shortlisted options, which apply predominantly for the Belongil precinct. These are then used as inputs in the cost component of the cost benefit assessment (Appendix N). Costs have generally been considered out to 2050. This is approximately the design life of many protection structures and they may require major reconstruction beyond this. The estimated shoreline impacts are based on WRL's broad experience only, and have not been modelled at this stage.

This planning period for economic assessment is because of:

- Higher uncertainty beyond 2050;
- NSW Treasury (2007) guidelines for project life;
- Discount rates of 4 to 10% reduce the net present value of long term future expenditure; and
- The design life for "normal" maritime structures is 50 years (AS4997-2005), which would extend to 2065.

11.1 Cost Sharing

For the options involving seawalls, the following approximate shoreline lengths have been used in developing speculative cost sharing proportions.

- Shoreline length from Border St to northernmost private Belongil property: 1060 m;
- Private property: 850 m (80%);
- Council assets (street ends): 135 m (12%);
- Assuming 50:50 funding split between Council and OEH on Council asset seawalls:
    - Council: 6%
    - OEH: 6%; and
- Crown Lands (second jetty site): 80 m (8%).

The approximate shoreline length for dune stabilisation (for options where a dune would form) would be up to approximately 2 km from First Sun Caravan Park to northern Belongil Spit.

Given that one beach access is on the second jetty site, it has been assumed that this would be funded by Crown Lands.

11.2 Cost Assumptions for Option 2 Retreat (Public-Private)

The following assumptions have been adopted for Retreat (Public-Private) over a planning period to 2050:

- All protective works (except Jonson St) are removed, with the material carted 20 km;
- Belongil Spit is breached at Manfred St in 5 year ARI and repaired (Appendix N);
- Dunes are rebuilt and revegetated for 2 km from First Sun Caravan Park to northern Belongil Spit;
- Four beach access works (timber steps and/or board and chain walkways) are provided at Border St, Don St, second jetty site and Manfred St;
- Based on the most recent audit available (Byron Shire Council Report No, 30 June 2011), there are approximately 14 properties (contiguous land parcels forming a single ratepaying landholding) on Belongil which were privately purchased prior to 1988 and

are located within the erosion/recession hazard zone to 2050 – seven are located within the immediate hazard zone (beachfront) and a further seven (generally "second row") are located within the 2050 hazard zone. Funding of retreat for these properties would be at the public expense – the public component of retreat. That is, approximately 25% of the 56 properties potentially subject to retreat by 2050 may be "publically" retreated. and

- Retreat of post 1988 privately purchased properties (the private component of retreat) has been valued in Appendix N.

Engineering costs and/or items for retreat are set out in Table 11.1, a speculative funding split percentage is shown in Table 11.2 and speculative funding amounts are shown in Table 11.3. Engineering costs do not include property losses which are considered in Appendix N. Benefits and losses are presented in Section 12 and Appendix N. Discounting is covered in Appendix N. If adopted, planned retreat would continue beyond 2050 in quantities beyond those costed in Table 11.1.

Table 11.1: Engineering Costs for Option 2 Retreat (Public-Private) excluding Property Losses

Item	Unit	Quantity	Rate	$ ex GST
Capital costs				
Removal of rock walls and cart	m	1,000	3,000	3,000,000
Demolition of buildings (up to)	No	50	25,000	1,250,000
Dune stabilisation and planting (a)	m	2,000	600	1,200,000
Construction of beach accesses	No	4	10,000	40,000
Removal of roads and restoration	m^2	9,500	60	570,000
Removal of rail corridor and restoration	m^2	25,000	60	1,500,000
Removal of services: Telstra, Water, Sewer, Electricity not costed (b)	Note			
Sub total				7,560,000
Contingency	Item		20%	1,512,000
Design and professional advice	Item		5%	378,500
Total capital costs				**9,450,000**
Episodic Costs				
Repair of breach of Belongil Spit	Item	1	1,000,000	1,000,000
Moving of relocatable houses	Item	1	10,000	10,000
Maintenance and recurrent costs				
Legal costs (c)	Note			
Maintenance of dunes	per year		5%	60,000
Maintenance of beach access	per year		10%	4,000
Monitoring	per year	1	20,000	20,000
Maintenance costs excl. legal and dune breach repair per year	per year			**84,000**

Notes

(a) These are commercial rates. In reality work may be assisted by volunteers or subsidised (e.g. work for the dole or green corps).

(b) Not quantified – services not needed after retreat, but removal costs would be incurred.

(c) Not quantified, but may be substantial for all options.

Table 11.2: Speculative Funding Split (%) of Engineering Costs for Option 2 Retreat (Public-Private) excluding Property Losses

Item	Land owners	Council	State Govt. Coastal	Utilities and State Govt. other	Federal Govt.
Capital costs					
Removal of rock walls and cartage	88%	6%	6%		
Demolition of buildings (up to) (d)	75%	12%	12%		
Dune stabilisation and planting (a)		48%	48%	4%	
Construction of beach accesses		38%	37%	25%	
Removal of roads and restoration		50%	50%		
Removal of rail corridor and restoration				100%	
Removal of services: Telstra, Water, Sewer, Electricity not costed (b)					
Sub total	50%	15%	15%	20%	
Contingency	50%	15%	15%	20%	
Design and professional advice		50%	50%		
Total capital costs	48%	16%	16%	20%	
Episodic Costs					
Repair of breach of Belongil Spit				50%	50%
Moving of relocatable houses	100%				
Maintenance and recurrent costs					
Legal costs (c)					
Maintenance of dunes		96%		4%	
Maintenance of beach access		75%		25%	
Monitoring		100%			
Maintenance costs excl. legal and dune breach repair per year	0%	96%	0%	4%	0%

Notes

(a) These are commercial rates. In reality work may be assisted by volunteers or subsidised (e.g. work for the dole or green corps).
(b) Not quantified – services not needed after retreat, but removal costs would be incurred.
(c) Not quantified, but may be substantial for all options.
(d) Based on proportions of BSC (2011) coastal audit for Planned Retreat (Public-Private).

Table 11.3: Speculative Funding Split ($) of Engineering Costs for Option 2 Retreat (Public-Private) excluding Property Losses

Item	Land owners	Council	State Govt. Coastal	Utilities and State Govt. other	Federal Govt.
Capital costs					
Removal of rock walls and cartage	2,640,000	180,000	180,000	-	-
Demolition of buildings (up to) (d)	937,500	150,000	150,000	-	
Dune stabilisation and planting (a)	-	576,000	576,000	48,000	-
Construction of beach accesses	-	15,200	14,800	10,000	-
Removal of roads and restoration	-	285,000	285,000	-	-
Removal of rail corridor and restoration	-	-	-	1,500,000	-
Removal of services: Telstra, Water, Sewer, Electricity not costed (b)	-	-	-	-	-
	-	-	-	-	-
Sub total	3,577,500	1,206,200	1,205,800	1,558,000	-
	-	-	-	-	-
Contingency	715,500	241,240	241,160	311,600	-
Design and professional advice	-	189,000	189,000	-	-
	-	-	-	-	-
Total capital costs	4,293,000	1,636,440	1,635,960	1,869,600	-
	-	-	-	-	-
Episodic Costs	-	-	-	-	-
Repair of breach of Belongil Spit	-	-	-	500,000	500,000
Moving of relocatable houses	10,000	-	-	-	-
	-	-	-	-	-
Maintenance and recurrent costs	-	-	-	-	-
Legal costs (c)	-	-	-	-	-
Maintenance of dunes	-	57,600	-	2,400	-
Maintenance of beach access	-	3,000	-	1,000	-
Monitoring	-	20,000	-	-	-
	-	-	-	-	-
Maintenance costs excl. legal and dune breach repair per year	-	80,600	-	3,400	-

Notes

(a) These are commercial rates. In reality work may be assisted by volunteers or subsidised (e.g. work for the dole or green corps).

(b) Not quantified – services not needed after retreat, but removal costs would be incurred.

(c) Not quantified, but may be substantial for all options.

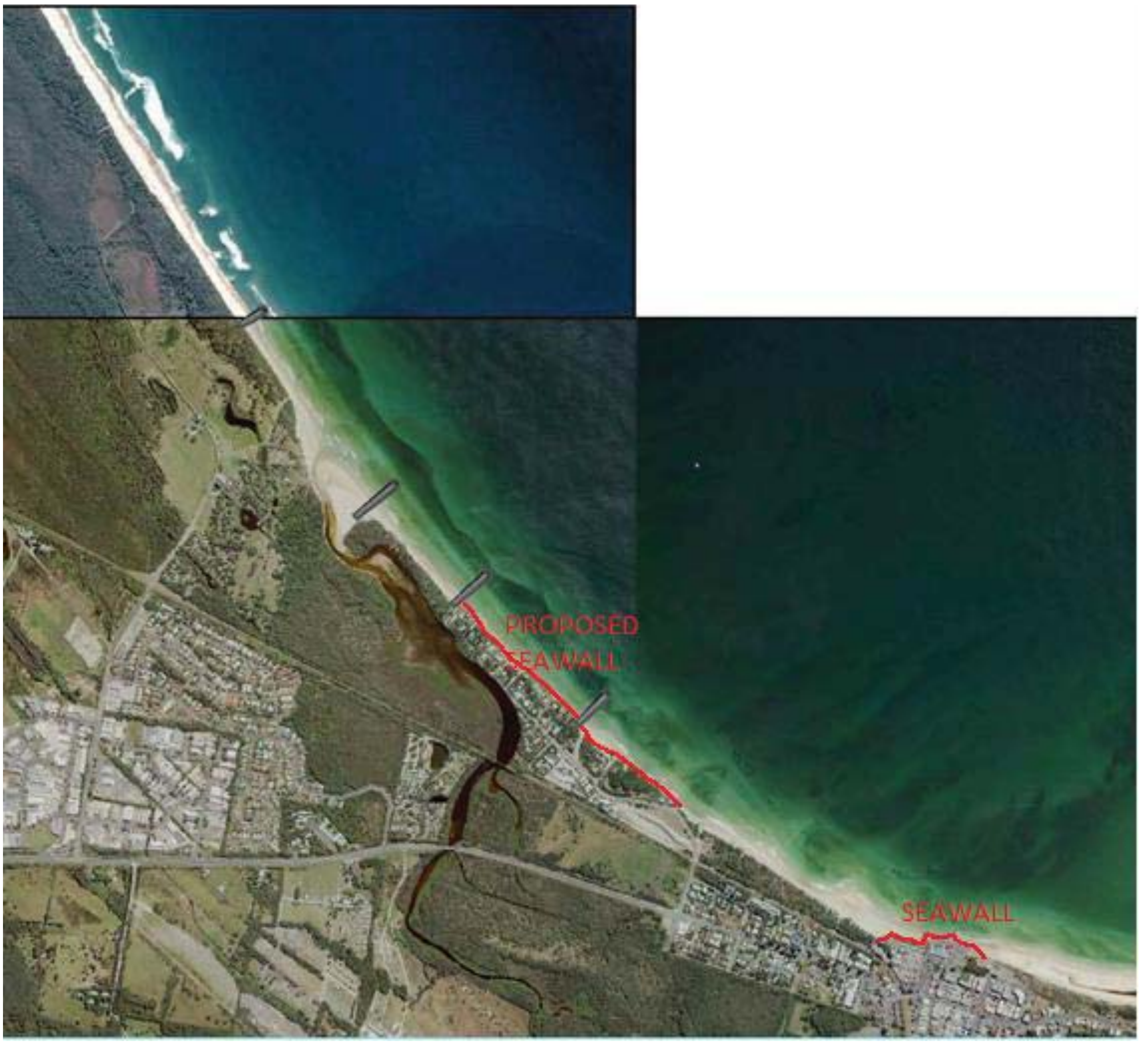
(d) Based on proportions of BSC (2011) coastal audit for Planned Retreat (Public-Private).

11.3 Cost Assumptions for Option 3 Groyne Field, Seawall and Nourishment

A schematic of a groyne field is shown in Figure 11.1. The following assumptions have been adopted for the groyne field, seawall and nourishment option:

- A 2050 life for costing purposes;
- Four groynes, located at second jetty, north Belongil, southern Belongil Creek and North Beach;
- Groynes initially constructed to -2 m AHD isobath;
- New/upgraded seawalls from Border Street to north Belongil (1,060 m);
- Walkway incorporated into seawall crest for alongshore pedestrian access;
- Structures designed for 50 year life, 100 year ARI design event;
- Sand nourishment quantities as per Section 8;
- Dunes are rebuilt and revegetated for 2 km from First Sun Caravan Park to northern Belongil Spit;
- Four beach access works (timber steps and/or board and chain walkways) are provided at Border St, Don St, second jetty site and Manfred St; and
- Access steps are provided over each groyne.

Costs and/or items for the groynes, seawall and nourishment option are set out in Table 11.4, a speculative funding split percentage is shown in Table 11.5 and speculative funding amounts are shown in Table 11.6.



Note: existing seawall is present in this image, but is relatively obscured by sand and vegetation

Figure 11.1: Schematic of Groyne Field

Table 11.4: Costs for Option 3 Groyne Field, Seawall and Nourishment

Item	Unit	Quantity	Rate	$ ex GST
Capital costs				
Initial design, investigations and approvals	Item	1	1,000,000	1,000,000
Construction of groynes	No	4	3,000,000	12,000,000
New/upgraded seawalls	m	1,060	12,000	12,720,000
Nourishment establishment	Item	1	5,000,000	5,000,000
Dredge and place	m^3	1,080,000	7	7,560,000
Dune stabilisation and planting (a)	m	2,000	600	1,200,000
Construction of beach accesses	No	4	10,000	40,000
Capital Sub total				39,520,000
Contingency	Item		20%	7,904,000
Detailed design and professional advice	Item		5%	1,976,000
Sand transfer establishment	Item	1	2,000,000	2,000,000
Capital total				**51,400,000**
Maintenance and recurrent costs				
Renourishment	m3/year	30000	10	300,000
Legal costs (b)				
Maintenance of groynes	per year		1%	120,000
Maintenance of seawalls	per year		1%	127,200
Maintenance of dunes (a)	per year		5%	60,000
Maintenance of beach access	per year		10%	4,000
Monitoring	per year	1	40,000	40,000
Maintenance and renourishment per year	per year			**651,200**

Notes

(a) These are commercial rates. In reality work may be assisted by volunteers or subsidised (e.g. work for the dole or green corps).

(b) Not quantified, but may be substantial for all options.

Table 11.5: Speculative Funding Split (%) for Option 3 Groyne Field, Seawall and Nourishment

Item	Land owners	Council	State Govt. Coastal	Utilities and State Govt. other	Federal Govt.
Capital costs					
Initial design, investigations and approvals	33%	33%	33%		
Construction of groynes	25%	38%	37%		
New/upgraded seawalls	80%	6%	6%	8%	
Nourishment establishment	33%	33%	33%		
Dredge and place	33%	33%	33%		
Dune stabilisation and planting (a)	40%	28%	28%	4%	
Construction of beach accesses		38%	37%	25%	
Capital Sub total					
Contingency	46%	26%	25%	3%	
Detailed design and professional advice	46%	26%	25%	3%	
Sand transfer establishment	33%	33%	33%		
Capital total	46%	26%	25%	3%	
Maintenance and recurrent costs					
Renourishment	50%	50%			
Legal costs (b)					
Maintenance of groynes	25%	75%			
Maintenance of seawalls	80%	12%		8%	
Maintenance of dunes (a)	40%	56%		4%	
Maintenance of beach access		75%		25%	
Monitoring		100%			
Maintenance and renourishment per year	47%	51%	0%	2%	0%

Notes

(a) These are commercial rates. In reality work may be assisted by volunteers or subsidised (e.g. work for the dole or green corps).

(b) Not quantified, but may be substantial for all options.

Table 11.6: Speculative Funding Split ($) for Option 3 Groyne Field, Seawall and Nourishment

Item	Land owners	Council	State Govt. Coastal	Utilities and State Govt. other	Federal Govt.
Capital costs					
Initial design, investigations and approvals	330,000	330,000	330,000	-	
Construction of groynes	3,000,000	4,560,000	4,440,000	-	
New/upgraded seawalls	10,176,000	763,200	763,200	1,017,600	
Nourishment establishment	1,650,000	1,650,000	1,650,000	-	
Dredge and place	2,494,800	2,494,800	2,494,800	-	
Dune stabilisation and planting (a)	480,000	336,000	336,000	48,000	
Construction of beach accesses	-	15,200	14,800	10,000	
	-	-	-	-	
Capital Sub total	18,130,800	10,149,200	10,028,800	1,075,600	
Contingency	3,626,160	2,029,840	2,005,760	215,120	
Detailed design and professional advice	906,540	507,460	501,440	53,780	
Sand transfer establishment	660,000	660,000	660,000	-	
	-	-	-	-	
Capital total	23,323,500	13,346,500	13,196,000	1,344,500	
	-	-	-	-	
Maintenance and recurrent costs	-	-	-	-	
Renourishment	150,000	150,000	-	-	-
Legal costs (b)	-	-	-	-	-
Maintenance of groynes	30,000	90,000	-	-	-
Maintenance of seawalls	101,760	15,264	-	10,176	-
Maintenance of dunes (a)	24,000	33,600	-	2,400	-
Maintenance of beach access	-	3,000	-	1,000	-
Monitoring	-	40,000	-	-	-
	-	-	-	-	-
Maintenance and renourishment per year	305,760	331,864	-	13,576	-

Notes

(a) These are commercial rates. In reality work may be assisted by volunteers or subsidised (e.g. work for the dole or green corps)

(b) Not quantified, but may be substantial for all options.

11.4 Cost Assumptions for Option 4 Single End Control Structure, Seawall and Nourishment

A schematic of a single end control structure in three potential locations is shown in Figure 11.2. The single end control structure would take the form of a groyne which would likely extend to the -3 m AHD isobath or deeper. A more substantial headland (such as Jonson St but extending to the -3 m AHD isobath) could be constructed, but would be more expensive.

Potentially feasible locations for a single end control structure would be:

- Northern or central part of North Beach private land;
- Belongil Creek mouth; or
- Northern end of Belongil private property.

It should be noted that there would be substantial recession on the northern side of the end control structure, however, provided that nourishment is undertaken, this recession would be reduced compared with the case of no nourishment. Depending on the length of the structure and subject to detailed modelling, the structure is likely to stabilise the coast for a distance of between 200 and 1000 m to the south. With regard to private property protection and Belongil beach amenity, a location just north of the northernmost private house on Belongil spit would be the most suitable, however, this would have substantial impacts further north. On this basis, the adopted preliminary location of the structure is at the northern end of private property at North Beach. This would be a valuable "proof of concept", but would likely require additional future groynes if this option was to be pursued.

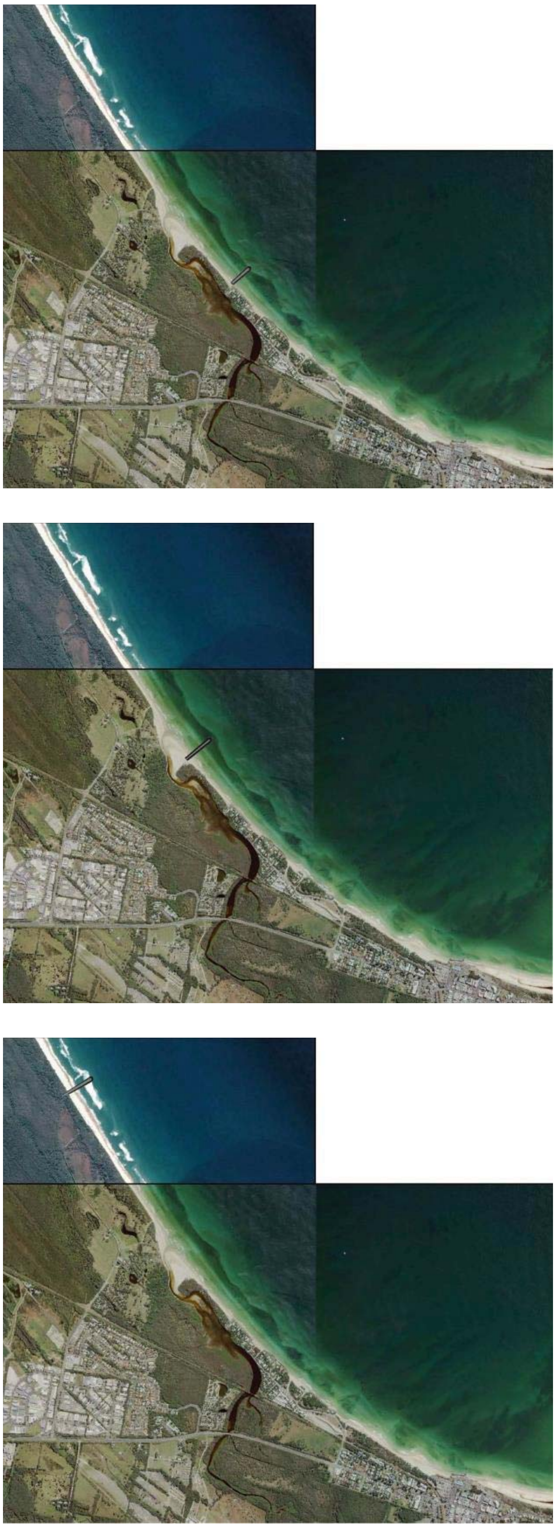
The following assumptions have been adopted for the single end control, seawall and nourishment option:

- A 2050 life for costing purposes;
- Single end control structure at North Beach at northern end of private property;
- Structure initially constructed to -3 m AHD;
- New/upgraded seawalls from Border Street to north Belongil (1,060 m);
- Walkway incorporated into seawall crest for alongshore pedestrian access;
- Structures designed for 50 year life (2065), 100 year ARI design event;
- Sand nourishment quantities as per Section 8;
- Dunes are rebuilt and revegetated for 1 km from First Sun Caravan Park to Border Street (seawalls partly exposed);
- Four beach access works (timber steps and/or board and chain walkways) are provided at Border St, Don St, second jetty site and Manfred St; and
- Access steps are provided over the groyne.

The northern location would also influence sand width at the mouth of Belongil Creek, however, the additional seaward translation of the berm is unlikely to substantially alter the hydraulic grade line of the creek under flood conditions. Additional sand width there could be managed in a similar manner to the existing entrance management plan.

The main disadvantages of this scheme over the multi groyne scheme are that there is less certainty that a usable beach width can be maintained in front of the 1 km of proposed seawall, and that the nourishment sand life would be lower. Therefore, if this option is pursued, additional groyne structures would likely be required in the future.

Costs and/or items for the single end control, seawall and nourishment option are set out in Table 11.7, a speculative funding split percentage is shown in Table 11.8 and speculative funding amounts are shown in Table 11.9.



Note: existing seawall is present in these images, but is relatively obscured by sand and vegetation. Bottom panel adopted for initial assessment.

Figure 11.2: Schematic of Single End Control Structure (Three Potential Locations)

Table 11.7: Costs for Option 4 Single End Control, Seawall and Nourishment

Item	Unit	Quantity	Rate	$ ex GST
Capital costs				
Initial design, investigations and approvals	Item	1	800,000	800,000
Construction of groyne	No	1	7,000,000	7,000,000
New/upgraded seawalls	m	1,060	12,000	12,720,000
Nourishment establishment	Item	1	5,000,000	5,000,000
Dredge and place	m^3	1,080,000	7	7,560,000
Dune stabilisation and planting (a)	m	1,000	600	600,000
Construction of beach accesses	No	4	10,000	40,000
Sub total				33,720,000
Contingency			20%	6,744,000
Detailed design and professional advice			5%	1,686,000
Sand transfer establishment	Item	1	2,000,000	2,000,000
Capital total				**44,150,000**
Maintenance and recurrent costs				
Renourishment	m^3/year	30,000	10	300,000
Legal costs (b)				0
Maintenance of groynes	per year		1%	70,000
Maintenance of seawalls	per year		1%	127,200
Maintenance of dunes (a)	per year		5%	30,000
Maintenance of beach access	per year		10%	4,000
Monitoring	per year	1	30,000	30,000
Maintenance/renourishment per year	per year			561,200

Notes

(a) These are commercial rates. In reality work may be assisted by volunteers or subsidised (e.g. work for the dole or green corps).

(b) Not quantified, but may be substantial for all options.

Table 11.8: Speculative Funding Split (%) for Option 4 Single End Control, Seawall and Nourishment

Item	Land owners	Council	State Govt. Coastal	Utilities and State Govt. other	Federal Govt.
Capital costs					
Initial design, investigations and approvals	33%	33%	33%		
Construction of groyne		50%	50%		
New/upgraded seawalls	80%	6%	6%	8%	
Nourishment establishment	33%	33%	33%		
Dredge and place	33%	33%	33%		
Dune stabilisation and planting (a)		50%	50%		
Construction of beach accesses		38%	37%	25%	
Sub total					
Contingency	43%	27%	27%	3%	
Detailed design and professional advice	43%	27%	27%	3%	
Sand transfer establishment	33%	33%	33%		
Capital total	43%	27%	27%	3%	
Maintenance and recurrent costs					
Renourishment	50%	50%			
Legal costs (b)					
Maintenance of groynes		100%			
Maintenance of seawalls	80%	12%		8%	
Maintenance of dunes (a)		100%			
Maintenance of beach access		75%		25%	
Monitoring		100%			
Maintenance/renourishment per year	45%	53%	0%	2%	0%

Notes

(a) These are commercial rates. In reality work may be assisted by volunteers or subsidised (e.g. work for the dole or green corps).

(b) Not quantified, but may be substantial for all options.

Table 11.9: Speculative Funding Split ($) for Option 4 Single End Control, Seawall and Nourishment

Item	Land owners	Council	State Govt. Coastal	Utilities and State Govt. other	Federal Govt.
Capital costs					
Initial design, investigations and approvals	264,000	264,000	264,000	-	
Construction of groyne	-	3,500,000	3,500,000	-	
New/upgraded seawalls	10,176,000	763,200	763,200	1,017,600	
Nourishment establishment	1,650,000	1,650,000	1,650,000	-	
Dredge and place	2,494,800	2,494,800	2,494,800	-	
Dune stabilisation and planting (a)	-	300,000	300,000	-	
Construction of beach accesses	-	15,200	14,800	10,000	
	-	-	-	-	
Sub total	14,584,800	8,987,200	8,986,800	1,027,600	
Contingency	2,916,960	1,797,440	1,797,360	205,520	
Detailed design and professional advice	729,240	449,360	449,340	51,380	
Sand transfer establishment	660,000	660,000	660,000	-	
	-	-	-	-	
Capital total	18,891,000	11,894,000	11,893,500	1,284,500	
	-	-	-	-	
Maintenance and recurrent costs	-	-	-	-	
Renourishment	150,000	150,000	-	-	-
Legal costs (b)	-	-	-	-	-
Maintenance of groynes	-	70,000	-	-	-
Maintenance of seawalls	101,760	15,264	-	10,176	-
Maintenance of dunes (a)	-	30,000	-	-	-
Maintenance of beach access	-	3,000	-	1,000	-
Monitoring	-	30,000	-	-	-
	-	-	-	-	-
Maintenance/renourishment per year	251,760	298,264	-	11,176	-

Notes

(a) These are commercial rates. In reality work may be assisted by volunteers or subsidised (e.g. work for the dole or green corps).

(b) Not quantified, but may be substantial for all options.

11.5 Cost Assumptions for Option 5 Single End Control and Seawall (without Nourishment)

A schematic of a single end control structure is shown in Figure 11.2. This option was proposed in the Councillor workshop on 13 March 2014 following discussion and consideration of factors such as feasibility and cost/reasonableness, and the potential legislative and planning difficulties in accessing suitable nourishment sand. This option could be undertaken (without nourishment) as the initial stage of more comprehensive options involving nourishment, with future nourishment and/or additional groynes incorporated at a later date.

The single end control structure would take the form of a groyne which would likely extend to -3 m AHD isobath. A more substantial headland (such as Jonson Street) could be constructed, but would be more expensive.

As per Section 11.4, potentially feasible locations for a single end control structure would be:

- Northern or central part of North Beach private land;
- Belongil Creek mouth; or
- Northern end of northernmost Belongil private property.

It should be noted that there would be substantial recession on the northern side of the end control structure, which would not be offset with nourishment. Depending on the length of the structure and subject to detailed modelling, the structure is likely to stabilise the coast for a distance of between 200 and 1000 m to the south. With regard to private property protection and Belongil beach amenity, a location just north of the northernmost private house on Belongil spit would be the most suitable, however, this would have substantial impacts further north. On this basis, the adopted preliminary location of the structure is at the northern end of private property at North Beach.

The following assumptions have been adopted for the single end control, seawall and nourishment option:

- A 2050 life for costing purposes;
- Single end control structure at North Beach;
- Structure initially constructed to -3 m AHD isobath;
- New/upgraded seawalls from Border Street to north Belongil (1,060 m);
- Walkway incorporated into seawall crest for alongshore pedestrian access;
- Structures designed for 50 year life (2065), 100 year ARI design event;
- No sand nourishment quantities;
- Dunes are rebuilt and revegetated for 1 km from First Sun Caravan Park to Border Street (seawalls partly exposed);
- Four beach access works (timber steps and/or board and chain walkways) are provided at Border St, Don St, second jetty site and Manfred St; and
- Access steps are provided over the groyne.

This main disadvantage of this scheme over the nourishment schemes is that there is less usable beach.

Costs and/or items for the single end control and seawall option are set out in Table 11.10. a speculative funding split percentage is shown in Table 11.11 and speculative funding amounts are shown in Table 11.12.

Table 11.10: Costs for Option 5 Single End Control, Seawall and NO Nourishment

Item	Unit	Quantity	Rate	$ ex GST
Capital costs				
Initial design, investigations and approvals	Item	1	400,000	400,000
Construction of groyne	No	1	7,000,000	7,000,000
New/upgraded seawalls	m	1,060	12,000	12,720,000
Dune stabilisation and planting (a)	m	1,000	600	600,000
Construction of beach accesses	No	4	10,000	40,000
Sub total				20,760,000
Contingency	Item		20%	4,152,000
Detailed design and professional advice	Item		5%	1,038,000
Capital total				25,950,000
Maintenance and recurrent costs				
Legal costs (b)				0
Maintenance of groynes	per year		1%	70,000
Maintenance of seawalls	per year		1%	127,200
Maintenance of dunes (a)	per year		5%	30,000
Maintenance of beach access	per year		10%	4,000
Monitoring	per year	1	30,000	30,000
Maintenance per year	per year			261,200

Notes

(a) These are commercial rates. In reality work may be assisted by volunteers or subsidised (e.g. work for the dole or green corps).

(b) Not quantified, but may be substantial for all options.

Table 11.11: Speculative Funding Split (%) for Option 5 Single End Control, Seawall and NO Nourishment

Item	Land owners	Council	State Govt. Coastal	Utilities and State Govt. other	Federal Govt.
Capital costs					
Initial design, investigations and approvals	33%	33%	33%		
Construction of groyne		50%	50%		
New/upgraded seawalls	80%	6%	6%	8%	
Dune stabilisation and planting (a)	33%	33%	33%		
Construction of beach accesses		38%	37%	25%	
Sub total	51%	22%	22%	5%	
Contingency	51%	22%	22%	5%	
Detailed design and professional advice	51%	22%	22%	5%	
Renourishment establishment					
Capital total	51%	22%	22%	5%	
Maintenance and recurrent costs					
Legal costs (b)					
Maintenance of groynes		100%			
Maintenance of seawalls	80%	12%			
Maintenance of dunes (a)	80%	12%			
Maintenance of beach access		75%		25%	
Monitoring		100%			
Maintenance per year	48%	47%	0%	0%	0%

Notes

(a) These are commercial rates. In reality work may be assisted by volunteers or subsidised (e.g. work for the dole or green corps).

(b) Not quantified, but may be substantial for all options.

Table 11.12: Speculative Funding Split ($) for Option 5 Single End Control, Seawall and NO Nourishment

Item	Land owners	Council	State Govt. Coastal	Utilities and State Govt. other	Federal Govt.
Capital costs					
Initial design, investigations and approvals	132,000	132,000	132,000	-	
Construction of groyne	-	3,500,000	3,500,000	-	
Reconstruction of seawalls	10,176,000	763,200	763,200	1,017,600	
	-	-	-	-	
	-	-	-	-	
Dune stabilisation and planting (a)	198,000	198,000	198,000	-	
Construction of beach accesses	-	15,200	14,800	10,000	
	-	-	-	-	
Sub total	10,506,000	4,608,400	4,608,000	1,027,600	
Contingency	2,101,200	921,680	921,600	205,520	
Detailed design and professional advice	525,300	230,420	230,400	51,380	
Renourishment establishment	-	-	-	-	
	-	-	-	-	
Capital total	13,132,500	5,760,500	5,760,000	1,284,500	
	-	-	-	-	
Maintenance and recurrent costs	-	-	-	-	
	-	-	-	-	-
Legal costs (b)	-	-	-	-	-
Maintenance of groynes	-	70,000	-	-	-
Maintenance of seawalls	101,760	15,264	-	-	-
Maintenance of dunes (a)	24,000	3,600	-	-	-
Maintenance of beach access	-	3,000	-	1,000	-
Monitoring	-	30,000	-	-	-
	-	-	-	-	-
Maintenance per year	125,760	121,864	-	1,000	-

Notes

(a) These are commercial rates. In reality work may be assisted by volunteers or subsidised (e.g. work for the dole or green corps).

(b) Not quantified, but may be substantial for all options.

11.6 Cost Assumptions for Option 6 Staged Adaptive Management

The following assumptions have been adopted for costing the managed adaptive option:

- Initial 2050 life for costing purposes;
- New/upgraded seawalls from Border Street to north Belongil (1,060 m);
- Walkway incorporated into seawall crest for alongshore pedestrian access;
- Structures designed for 50 year life (but costed to 2050), 100 year ARI design event;
- Four groynes, located at second jetty, north Belongil, southern Belongil Creek and North Beach;
- Groynes initially constructed to -2 m AHD isobath;
- Dunes are rebuilt and revegetated for 2 km from First Sun Caravan Park to northern Belongil Spit.;

- Four beach access works (timber steps and/or board and chain walkways) are provided at Border St, Don St, second jetty site and Manfred St;
- Access steps are provided over each groyne; and
- A sand transfer plant or small scale future nourishment.

Costs are shown in Table 11.13, however, it should be noted that the costs shown for later stages are discounted within the economic cost benefit assessment (Appendix N).

A speculative percentage funding split is shown in Table 11.14 and a speculative dollar funding split is shown in Table 11.15.

Table 11.13: Costs for Option 6 Adaptive Management

Item	Unit	Quantity	Rate	$
STAGE 1 Seawall only Capital costs				
Seawall Initial design, investigations and approvals	Item	1	200,000	200,000
New/upgraded seawalls	m	1,060	12,000	12,720,000
Dune stabilisation and planting (a)	m	0	600	0
Construction of beach accesses	No	4	10,000	40,000
Stage 1 Subtotal				12,960,000
Stage 1 Contingency	item		20%	2,592,000
STAGE 1 TOTAL				15,552,000
STAGE 2 Self filling groynes				
Groyne 1 Initial design, investigations and approvals	Item	1	150,000	150,000
Groyne 1 construction	Item	1	3,000,000	3,000,000
Groyne 2 Initial design, investigations and approvals	Item	1	50,000	50,000
Groyne 2 construction	Item	1	3,000,000	3,000,000
Groyne 3 Initial design, investigations and approvals	Item	1	50,000	50,000
Groyne 3 construction	Item	1	3,000,000	3,000,000
Groyne 4 Initial design, investigations and approvals	Item	1	50,000	50,000
Groyne 4 construction	Item	1	3,000,000	3,000,000
Dune stabilisation and planting (a)	m	2,000	600	1,200,000
Stage 2 Subtotal				13,500,000
Stage 2 Contingency	Item		20%	2,700,000
STAGE 2 TOTAL				16,200,000
STAGE 3 Sand transfer system				
Sand transfer Initial design, investigations and approvals	Item	1	200,000	200,000
Sand transfer construction	Item	1	2000000	2,000,000
Stage 3 Subtotal				2,200,000
Stage 3 Contingency	Item		20%	440,000
STAGE 3 TOTAL				2,640,000
CAPITAL TOTAL				34,392,000
Maintenance and recurrent costs				
Stage 1				
Maintenance of seawalls	per year		1%	155,520
Maintenance of beach access	per year		10%	4,000
Monitoring	per year	1	40,000	40,000
Legal costs (b)				
Stage 1 total	per year			199,520
Stage 2				
Maintenance of groynes	per year		1%	162,000
Monitoring	per year	1	40,000	40,000
Maintenance of dunes (a)	per year		5%	60,000

Stage 2 total				262,000
Stage 3				
Renourishment	m3/year	50000	10	500,000
Stage 3 total				500,000
Maintenance and renourishment total	per year			1,723,520

Table 11.14: Speculative Funding Split (%) for Option 6 Adaptive Management

Item	Landowners	Council	State Govt. Coastal	Utilities and State Govt. other	Federal Govt.
STAGE 1 Seawall only Capital costs					
Seawall Initial design, investigations and approvals	33%	33%	33%		
New/upgraded seawalls	80%	6%	6%	8%	
Dune stabilisation and planting (a)	0%	50%	50%		
Construction of beach accesses		38%	38%	25%	
Stage 1 Subtotal	79%	6%	6%	8%	
Stage 1 Contingency	79%	6%	6%	8%	
STAGE 1 TOTAL	79%	6%	6%	8%	
STAGE 2 Self filling groynes					
Groyne 1 Initial design, investigations and approvals	33%	33%	33%		
Groyne 1 construction	33%	33%	33%		
Groyne 2 Initial design, investigations and approvals	33%	33%	33%		
Groyne 2 construction	33%	33%	33%		
Groyne 3 Initial design, investigations and approvals	33%	33%	33%		
Groyne 3 construction	33%	33%	33%		
Groyne 4 Initial design, investigations and approvals	100%				
Groyne 4 construction	100%				
Dune stabilisation and planting (a)	40%	28%	28%	4%	
Stage 2 Subtotal	49%	25%	25%	0%	
Stage 2 Contingency	49%	25%	25%	0%	
STAGE 2 TOTAL	49%	25%	25%	0%	
STAGE 3 Sand transfer system					
Sand transfer Initial design, investigations and approvals	33%	33%	33%		
Sand transfer construction	33%	33%	33%		
Stage 3 Subtotal	33%	33%	33%	0%	
Stage 3 Contingency	33%	33%	33%	0%	
STAGE 3 TOTAL	33%	33%	33%	0%	
CAPITAL TOTAL	61%	17%	17%	4%	
Maintenance and recurrent costs					
Stage 1					
Maintenance of seawalls	80%	12%		8%	
Maintenance of beach access		75%		25%	
Monitoring	50%	50%			
Legal costs (b)					
Stage 1 total	62%	11%	0%	7%	

Stage 2					
Maintenance of groynes		100%			
Monitoring		100%			
Maintenance of dunes (a)	43%	54%		4%	
Stage 2 total	10%	89%	0%	1%	
Stage 3					
Renourishment	50%	50%			
Stage 3 total	50%	50%	0%	0%	
Maintenance and renourishment total	40%	59%	0%	1%	

Table 11.15: Speculative Funding Split ($) for Adaptive Management Option

Item	Landowners	Council	State Govt. Coastal	Utilities and State Govt. other	Federal Govt.
STAGE 1 Seawall only Capital costs					
Seawall Initial design, investigations and approvals	66,000	66,000	66,000	-	
New/upgraded seawalls	10,176,000	763,200	763,200	1,017,600	
Dune stabilisation and planting (a)	-	-	-	-	
Construction of beach accesses					
Stage 1 Subtotal	10,242,000	829,200	829,200	1,017,600	
Stage 1 Contingency	2,048,400	165,840	165,840	203,520	
STAGE 1 TOTAL	12,290,400	995,040	995,040	1,221,120	
	-	-	-	-	
STAGE 2 Self filling groynes	-	-	-	-	
Groyne 1 Initial design, investigations and approvals	49,500	49,500	49,500	-	
Groyne 1 construction	990,000	990,000	990,000	-	
Groyne 2 Initial design, investigations and approvals	16,500	16,500	16,500	-	
Groyne 2 construction	990,000	990,000	990,000	-	
Groyne 3 Initial design, investigations and approvals	16,500	16,500	16,500	-	
Groyne 3 construction	990,000	990,000	990,000	-	
Groyne 4 Initial design, investigations and approvals	50,000	-	-	-	
Groyne 4 construction	3,000,000	-	-	-	
Dune stabilisation and planting (a)	480,000	336,000	336,000	48,000	
Stage 2 Subtotal	6,582,500	3,388,500	3,388,500	48,000	
Stage 2 Contingency	1,316,500	677,700	677,700	9,600	
STAGE 2 TOTAL	7,899,000	4,066,200	4,066,200	57,600	
STAGE 3 Sand transfer system				-	
Sand transfer Initial design, investigations and approvals	66,000	66,000	66,000	-	
Sand transfer construction	660,000	660,000	660,000	-	
Stage 3 Subtotal	726,000	726,000	726,000	-	
Stage 3 Contingency	145,200	145,200	145,200	-	
STAGE 3 TOTAL	871,200	871,200	871,200	-	
CAPITAL TOTAL	21,060,600	5,932,440	5,932,440	1,278,720	
	-	-	-	-	
Maintenance and recurrent costs	-	-	-	-	
Stage 1					
Maintenance of seawalls	124,416	18,662	-	12,211	
Maintenance of beach access	-	3,000	-	1,000	
Monitoring	20,000	20,000	-	-	
Legal costs (b)	-	-	-	-	
Stage 1 total	144,416	41,662	-	13,211	

Stage 2					
Maintenance of groynes	-	162,000	-	-	
Monitoring	-	40,000	-	-	
Maintenance of dunes (a)	25,500	32,250	-	2,330	
Stage 2 total	25,500	234,250	-	2,330	
Stage 3					
Renourishment	250,000	250,000	-	-	
Stage 3 total	250,000	250,000	-	-	
	-	-	-	-	
Maintenance and renourishment total	695,416	1,010,162	-	17,871	

11.7 Summary of Speculative Funding Split

A summary of the preceding speculative funding split for capital amounts is shown in Table 11.16 and for maintenance amounts in Table 11.17. For Planned Retreat (Public-Private), Table 11.16 also includes property losses from Appendix N.

Table 11.16: Summary of Capital, Property Losses and One Off Costs Speculative Funding Split ($) for all Options

Option	Land owners	Council	State Govt. Coastal	Utilities and State Govt. other	Federal Govt.
2 Planned Retreat (Public-Private) property losses	37,299,315	6,216,552	6,216,552	**-**	**-**
2 Planned Retreat (Public-Private) works	4,293,000	1,636,440	1,635,960	1,869,600	500,000
3 Groynes, seawall, nourishment	23,323,500	13,346,500	13,196,000	1,344,500	-
4 End Control, seawall, nourishment	18,891,000	11,894,000	11,893,500	1,284,500	-
5 End Control, seawall, NO nourishment	13,132,500	5,760,500	5,760,000	1,284,500	-
6 Adaptive scheme Stage 1	12,290,400	995,040	995,040	1,221,120	-
6 Adaptive scheme Stage 2	7,899,000	4,066,200	4,066,200	57,600	-
6 Adaptive scheme Stage 3	871,200	871,200	871,200	-	-
6 Adaptive Scheme three Stage total	21,060,600	5,932,440	5,932,440	1,278,720	-

Table 11.17: Summary of Maintenance Costs Speculative Funding Split ($/year) for all Options

Option	Land owners	Council	State Govt. Coastal	Utilities and State Govt. other	Federal Govt.
2 Planned Retreat (Public-Private)	-	80,600	-	3,400	-
3 Groynes, seawall, nourishment	305,760	331,864	-	13,576	-
4 End Control, seawall, nourishment	251,760	298,264	-	11,176	-
5 End Control, seawall, NO nourishment	125,760	121,864	-	1,000	-
6 Adaptive scheme Stage 1	144,416	41,662	-	13,211	-
6 Adaptive scheme Stage 2	25,500	234,250	-	2,330	-
6 Adaptive scheme Stage 3	250,000	250,000	-	-	-
6 Adaptive Scheme total	419,916	525,912	-	15,541	

12. Economic Assessment of Shortlisted Options

The economic assessment of shortlisted options was undertaken by Dr Dave Anning of GCCM in accordance with NSW Government Guidelines for Economic Appraisal (CBA), (NSW Treasury, 2007). It was also undertaken in accordance with *"Using Cost-Benefit Analysis to assess coastal management options: Guidance for Councils", Consultation Draft, ISBN 978-1-76039-184-3, OEH 2015/0805"* (OEH, November 2015) and previous review comments provided by OEH.

The full economic assessment is contained in Appendix N.

The purpose of the economic assessment is to place a quantifiable economic value on the costs and benefits of each management option. Thus the economic assessment is focussed on:

- The tourism value of beaches;
- The resident recreational value of beaches;
- Land values; and
- Property values.

A range of sensitivity tests were undertaken. Two main scenarios cases are presented, with a range of parameters varied to test for sensitivity:

- The consultants' "best estimate", which includes parameters specified by OEH (November 2015);
- The BSC case, specified by Byron Shire Council in Resolution 16-028, 4 February 2016, and where factors were not specified by BSC, the consultants' 'best estimate' was used for the BSC case.

Acknowledged limitations of the economic assessment are:

- Environmental changes, legal costs and surfing amenity are not quantified in dollar terms; and
- Costs and benefits are determined on a society- or economy-wide basis, without consideration of who or which entity pays or benefits. Therefore the main assessment does not consider equity issues, however, separate speculative funding splits and a distribution analysis of the benefits are provided.

A summary of the CBA is provided in Table 12.1. A summary of the components is provided in Table 12.2 for the best estimate base case assumptions from the consultants and/or OEH. Projects with a benefit to cost ratio (BCR) of greater than one and/or a net present value (NPV) greater than zero are considered to be economically viable (NSW Treasury, 2007). Projects with a BCR of less than one and/or a NPV less than zero are not considered to be economically viable, but may be desirable on other (non-economic) criteria.

Option 6.1 (Adaptive scheme – with seawall only) has the highest NPV and BCR. Option 2 (Planned Retreat public private) has the lowest NPV and BCR. It is emphasised that the economic assessment should be considered in decision making, but is not usually the sole basis for a decision.

The NPV and BCR values are based on an economy-wide basis. In reality, the benefits for each option will accrue to different parties. Distribution analyses are shown in Table 12.3 and Table 12.4. OEH (November, 2015) excludes non-resident landowners from the CBA. Because of the likelihood that non-resident landowners would be required to contribute to funding, an additional column has been included for this group within the distribution analysis. The distribution analysis shows that tourists/tourism would benefit most from Planned Retreat, whereas affected landowners (both resident and non-resident) would benefit from protection options. Byron Shire Council would benefit from Planned Retreat and protection options through reduced maintenance.

A comparison of the proposed funding proportions with the beneficiaries is shown in Table 12.5 for the options of Planned Retreat (Public-Private) and the adaptive scheme. It can be seen that while funding models are presently speculative and would be subject to negotiation, the adaptive scheme has an approximate balance between funding sources and the beneficiaries, while Planned Retreat (Public-Private) has a substantial imbalance.

While council rates and land tax represent transfer payments and are not directly included in a conventional CBA, changes in these are of interest to Council and the state government. Changes in council rates and land tax are shown in Table 12.6.

Single page summaries for each option are shown in Table 12.7 to Table 12.14.

Table 12.1: Summary of Economic Assessment

		Net present value (NPV)* over planning period ($ million)		Benefit Cost Ratio (BCR)*	
Option	**Description**	**Best Estimate**	**BSC Base Case**	**Best Estimate**	**BSC Base Case**
2	Planned retreat	-28.26	-40.79	0.35	0.40
3	Groyne Seawall Nourishment	-23.13	11.62	0.56	1.22
4	End Control Seawall Nourishment	-16.45	15.88	0.63	1.36
5	End control Seawall no Nourishment	-2.10	25.15	0.92	1.91
6	Adaptive management - all components	-7.25	22.51	0.79	1.66
6.1	Adaptive management- seawall only	7.24	31.94	1.42	2.87
6.2	Adaptive management - Seawall + single groyne	5.19	31.86	1.26	2.59
6.3	Adaptive management - Seawall + groyne field	-3.76	24.42	0.87	1.82

Table 12.2: Summary of Components of Economic Assessment under Consultant and OEH Base Case Assumptions

	Description	Capital Cost ($M)	Maint PV at 7% to 2050 – incl nourish ($M)	Property damage ($M)	PV of total costs ($M)	Beach Benefits - above Status Quo ($M)	Avoided Losses and improved protection ($M)	Reduced Maint ($M)	Present value of benefits ($M)	NPV to 2050 ($ M)	Benefit Cost Ratio (BCR)
1	Status Quo	0.0	10.2	0.0	10.2	0.0	0.0	0.0	0.0	-10.2	N/A
2	Planned retreat	8.9	3.5	30.8	43.2	5.5	0.0	9.5	15.0	-28.26	0.35
3	Groyne Seawall Nourishment	30.7	21.5	0.0	52.1	4.7	14.9	9.5	29.0	-23.13	0.56
4	End Control Seawall Nourishment	23.9	20.5	0.0	44.3	3.5	14.9	9.5	27.9	-16.45	0.63
5	End control Seawall no Nourishment	24.3	3.4	0.0	27.6	1.3	14.9	9.5	25.5	-2.10	0.92
6	Adaptive management - all components	26.4	7.5	0.0	34.0	2.3	14.9	9.5	26.7	-7.25	0.79
6.1	Adaptive management-seawall only	14.5	2.6	0.0	17.1	0.0	14.9	9.5	24.4	7.24	1.42
6.2	Adaptive management - Seawall + single groyne	17.4	2.7	0.0	20.1	0.9	14.9	9.5	25.3	5.19	1.26
6.3	Adaptive management - Seawall + groyne field	25.2	4.6	0.0	29.7	1.6	14.9	9.5	26.0	-3.76	0.87

Table 12.3: Summary of Distribution of Benefits ($) under Consultant and OEH Base Case Assumptions (non-resident landowners added)

		Beneficiary						
		Byron residents - recreation	Tourists	Belongil residents	Belongil non-resident land owners	Council (a)	NSW Government (a)	Total
		Benefits in $						
1	Status Quo	0	0	0	0	0	0	0
2	Planned retreat	410,471	5,117,958	0	0	9,447,140	0	14,975,569
3	Groyne Seawall Nourishment	345,659	4,309,859	14,913,926	12,202,303	9,447,140	0	41,218,887
4	End Control Seawall Nourishment	262,419	3,271,976	14,913,926	12,202,303	9,447,140	0	40,097,764
5	End control Seawall no Nourishment	87,473	1,167,005	14,913,926	12,202,303	9,447,140	0	37,817,847
6	Adaptive management - all components	173,917	2,168,492	14,913,926	12,202,303	9,447,140	0	38,905,778
6.1	Adaptive management- seawall only	0	0	14,913,926	12,202,303	9,447,140	0	36,563,369
6.2	Adaptive management - Seawall + single groyne	67,660	843,620	14,913,926	12,202,303	9,447,140	0	37,474,649
6.3	Adaptive management - Seawall + groyne field	119,672	1,492,133	14,913,926	12,202,303	9,447,140	0	38,175,174

Notes: (a) All protection options are likely to result in an additional NPV of rates revenue and land tax revenue (see below).

Table 12.4: Summary of Distribution of Benefits (%) under Consultant and OEH Base Case Assumptions (non-resident landowners added)

		Byron residents - recreation	Tourists	Belongil residents	Belongil non-resident land owners	Council (a)	NSW Government (a)
		Benefits in %					
1	Status Quo	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2	Planned retreat	2.7%	34.2%	0.0%	0.0%	63.1%	0.0%
3	Groyne Seawall Nourishment	0.8%	10.5%	36.2%	29.6%	22.9%	0.0%
4	End Control Seawall Nourishment	0.7%	8.2%	37.2%	30.4%	23.6%	0.0%
5	End control Seawall no Nourishment	0.2%	3.1%	39.4%	32.3%	25.0%	0.0%
6	Adaptive management - all components	0.5%	5.6%	38.3%	31.4%	24.3%	0.0%
6.1	Adaptive management-seawall only	0.0%	0.0%	40.8%	33.4%	25.8%	0.0%
6.2	Adaptive management - Seawall + single groyne	0.2%	2.3%	39.8%	32.6%	25.2%	0.0%
6.3	Adaptive management - Seawall + groyne field	0.3%	3.9%	39.1%	32.0%	24.8%	0.0%

Notes: (a) All protection options are likely to result in an additional NPV of rates revenue and land tax revenue (see below).

Table 12.5: Comparison of Distribution of Funding and Benefits under Consultant and OEH Base Case Assumptions (non-resident landowners added)

		Beneficiary					
		Byron residents - recreation	**Tourists**	**Resident Belongil landowners**	**Belongil non-resident land owners**	**Council (a)**	**NSW Government (a)**
Planned Retreat (public-private)	Benefits	2.7%	34.2%	0.0%	0.00%	63.1%	0.0%
	Funding	0.0%	0.0%	69.0%		15.0%	16.0%
Adaptive Management	Benefits	0.4%	5.6%	38.3%	31.4%	24.3%	0.0%
	Funding	0.4%	0.0%	61.4%		17.2%	21.0%

Notes: (a) All protection options are likely to result in an additional NPV of rates revenue and land tax revenue (see below).

Table 12.6: Summary of Rates and Land Tax

	Land Tax		**Council Rates**		**Combined**
	$/year	**$ NPV**	**$/year**	**$ NPV**	**Total $ NPV**
Total properties affected by coastal hazards to 2050	$0.6 M to 2.4 M	+9.6 M to +40.6 M	+407,593	+6.99 M	+16.6M to +47.6 M
Change with retreat	Not calculated	Not calculated	NPV only	-1.73 M	Not calculated
Change with protection	NPV only	+1.4 M to +5.7M	NPV only	+0.9 M	+2.3 M to +6.6 M

Table 12.7: Summary of Costs and Benefits for Option 2 Planned Retreat (Public-Private) - Consultant and OEH Base Case Assumptions

Costs	**$M**	**$M not in CBA**	**Benefits**	**$M**
Engineering/Capital works	8.9		Improved recreational amenity through wider beaches	0.4
Property losses	30.8		Improved tourism amenity through wider beaches	5.1
NPV of maintenance	3.5		Avoided maintenance costs	9.5
Transfer payments (not included in CBA)				
Rates revenue decrease due to property loss		1.5		
Land tax decrease due to property loss		Potentially 9.6 to 40.6		
Total ($ millions - Present Value)	**43.2**	**11.1 to 42.1**		**15.0**

NPV = -$28.3M
BCR = 0.35

Table 12.8: Summary of Costs and Benefits for Option 3 Groynes, Seawall, Nourishment - Consultant and OEH Base Case Assumptions

Costs	$M	Benefits	$M
Engineering/Capital works	30.7	Improved recreational amenity through wider beaches	0.3
Property losses	0.0	Improved tourism amenity through wider beaches	4.3
NPV of maintenance	21.5	Avoided property damage	14.9
		Avoided maintenance costs	9.5
Total ($ millions - Present Value)	**52.1**		**29.0**

NPV = $-23.1M

BCR = 0.56

Table 12.9: Summary of Costs and Benefits for Option 4 End Control, Seawall, Nourishment - Consultant and OEH Base Case Assumptions

Costs	**$M**	**Benefits**	**$M**
Engineering/Capital works	23.9	Improved recreational amenity through wider beaches	0.3
Property losses	0.0	Improved tourism amenity through wider beaches	3.3
NPV of maintenance	20.5	Avoided property damage	14.9
		Avoided maintenance costs	9.5
Total ($ millions - Present Value)	**44.3**		**27.9**

NPV = -$16.5M
BCR =0.63

Table 12.10: Summary of Costs and Benefits for Option 5 End Control, Seawall, NO Nourishment - Consultant and OEH Base Case Assumptions

Costs	$M	Benefits	$M
Engineering/Capital works	24.3	Improved recreational amenity through wider beaches	0.1
Property losses	0.0	Improved tourism amenity through wider beaches	1.2
NPV of maintenance	3.4	Avoided property damage	14.9
		Avoided maintenance costs	9.5
Total ($ millions - Present Value)	**27.6**		**25.5**

NPV = $-2.1M
BCR = 0.92

Table 12.11: Summary of Costs and Benefits for Option 6 Adaptive Scheme - Consultant and OEH Base Case Assumptions

Costs	$M	Benefits	$M
Engineering/Capital works	26.4	Improved recreational amenity through wider beaches	0.3
Property losses	0.0	Improved tourism amenity through wider beaches	18.7
NPV of maintenance	7.5	Avoided property damage	14.9
		Avoided maintenance costs	9.5
Total ($ millions - Present Value)	**34.0**		**26.7**

NPV = -$7.25 M

BCR = 0.79

Table 12.12: Summary of Costs and Benefits for Option 6.1 – Seawall Only - Consultant and OEH Base Case Assumptions

Costs	**$M**	**Benefits**	**$M**
Engineering/Capital works	14.5	Improved recreational amenity through wider beaches	0
Property losses	0.0	Improved tourism amenity through wider beaches	0
NPV of maintenance	2.6	Avoided property damage	14.9
		Avoided maintenance costs	9.5
Total ($ millions - Present Value)	**17.1**		**24.4**

NPV = $7.24 M

BCR = 1.42

Table 12.13: Summary of Costs and Benefits for Option 6.2 – Seawall and Groyne - Consultant and OEH Base Case Assumptions

Costs	**$M**	**Benefits**	**$M**
Engineering/Capital works	17.4	Improved recreational amenity through wider beaches	0.1
Property losses	0.0	Improved tourism amenity through wider beaches	0.8
NPV of maintenance	2.7	Avoided property damage	14.9
		Avoided maintenance costs	9.5
Total ($ millions - Present Value)	**20.1**		**25.3**

NPV = $ 5.19M

BCR = 1.26

Table 12.14: Summary of Costs and Benefits for Option 6.3– Seawall and Groyne Field - Consultant and OEH Base Case Assumptions

Costs	$M	Benefits	$M
Engineering/Capital works	25.2	Improved recreational amenity through wider beaches	0.1
1.5Property losses	0.0	Improved tourism amenity through wider beaches	1.5
NPV of maintenance	4.6	Avoided property damage	14.9
		Avoided maintenance costs	9.5
Total ($ millions - Present Value)	**29.7**		**26.0**

NPV = $-3.8 M

BCR = 0.87

13. Preliminary Environmental Assessment of Components of Shortlisted Options

Detailed environmental assessment (such as a Statement of Environmental Effects, Review of Environmental Factors or an Environmental Impact Statement) under the Environmental Planning and Assessment Act 1979 (or its replacement) would be required for the adopted management option. Detailed assessment also needs to consider cultural, social and economic factors.

The following sets out broad environmental issues relevant to each option. For this overview, environmental effects have been classified as physical or ecological. There are existing analogues for all suggested coastal management options within Byron Shire or nearby.

13.1 Retreat

13.1.1 Precedent within Byron Shire

Brunswick North Beach/Sheltering Palms, parts of New Brighton and the former function centre at North Beach have undergone retreat in the past, with dune reconstruction undertaken at Brunswick North Beach/Sheltering Palms. Substantial strengthening of this dune was needed to prevent breakthrough of the river.

13.1.2 Physical Impacts

Removal of the existing seawalls along Belongil would reduce the "end effect" to the north, though there may be a breakthrough of northern Belongil Spit. Due to the resolution to retain the Jonson Street works and protect the town centre, the physical impacts of these works will still prevail. Assets such as the railway line and the railway crossing at Belongil Creek may be lost under retreat. Similarly, a breakthrough of Belongil Spit at Manfred Street is possible. This may remove road access to properties which would otherwise be able to continue to be occupied.

Demolition and cleanup is likely to uncover substantial domestic and industrial waste which would need to be disposed of correctly.

13.1.3 Ecological Impacts

Retreat offers the best potential opportunity to restore Belongil to its optimum ecological condition, however, it should be noted that unless people are excluded, the impacts of human visitation will persist.

Breakthrough of Belongil Spit will impact Belongil Creek and if not repaired, the impacts may migrate relatively quickly, with significant impact and ecological change.

13.2 Seawalls

13.2.1 Precedent within Byron Shire

There are existing seawalls along most of Belongil, plus at Jonson Street and Wategos Beach. There are also nearby seawalls at Lennox Head, Kingscliff and most of the Gold Coast.

13.2.2 Physical Impacts

Seawalls create "end effects" when the beach erodes or recedes. This is generally to the north of the structure on the Byron coast. The end effects to the north from the Belongil and Jonson Street structures would continue, but could be reduced with other management actions proposed.

Without the incorporation of promenades, seawalls may prevent alongshore access on the sand during times of eroded beaches, large waves and/or high tides. With ongoing recession this loss of access may become more frequent or permanent. However, in many locations such as the Gold Coast, Manly and Bondi, functional beaches coexist with seawalls, and natural beaches coexist with backing cliffs. It is noted that the seawalls proposed for this project provide provision for a public promenade.

The public use and appearance of the proposed new seawalls would be substantially improved over the existing ones.

13.2.3 Ecological Impacts

Seawalls alter the ecology compared with a sandy beach, however, sandy beaches and natural rock platforms, outcrops and reefs coexist in nature.

The presence of voids in a seawall (e.g. rock rubble as opposed to solid concrete) provides ecological habitat.

13.3 Groynes

13.3.1 Precedent within Byron Shire

A list of groynes in northern NSW and southern Queensland is provided in Section 9.7. There are approximately 70 breakwaters and/or river mouth training walls in NSW. These are similar to (but generally larger than) groynes, but have a similar effect to groynes in interrupting longshore sand transport.

In Byron Shire there are existing groynes at Jonson Street and medium sized river training walls at Brunswick Heads.

13.3.2 Physical Impacts

Groynes in northern NSW generally stabilise land to the south and recede land to their north, with this recession stabilising in time when sand bypassing re-establishes. While generally perceived as a negative, recession may uncover reef systems previously buried in sand. Similarly, accretion to the south of the groyne may bury existing reef systems or shipwrecks in sand.

13.3.3 Ecological Impacts

If groynes function as training walls for Belongil Creek, this may alter the water levels and consequent ecology in the creek. Note that the creek is presently artificially opened in accordance with triggers in the estuary management plan.

Groynes alter the ecological habitat of a site which is otherwise sandy. For rubble groynes, substantial new habitat is provided in the voids of the structure.

13.4 Large Scale Nourishment

13.4.1 Precedent within Byron Shire

Large scale nourishment has not been undertaken within NSW, but is regularly undertaken in Queensland, including on the Gold Coast.

13.4.2 Physical Impacts

If sand is extracted in an unfavourable configuration or water depth, incident waves reaching the beach may be altered and consequently change the shoreline. This can be avoided with appropriate project design studies.

There is usually increased turbidity at both the extraction and deposition sites, however, recent advances in dredging technology can reduce turbidity to acceptable levels.

13.4.3 Ecological Impacts

Organisms living in the extraction zone may be killed. Organisms living in the placement zone may be buried. While sandy foreshores are generally perceived positively, placed sand may bury nearshore reefs.

Careful project design can assist recolonisation in extraction and placement areas. The generally aggressive environment in the surf zone means that the placement of nourishment sand is often less ecologically disruptive than normal surf zone processes.

13.5 Sand Transfer

13.5.1 Precedent within Byron Shire

Sand transfer is not presently undertaken within Byron Shire. Beach scraping is undertaken annually at New Brighton. Sand bypassing at a much larger scale than proposed for Byron is undertaken at the Tweed River and Nerang River mouths. Sand transfer at a similar scale to that proposed for Byron is undertaken at Currumbin on the Gold Coast and Noosa on the Sunshine Coast.

13.5.2 Physical Impacts

Extraction below the water may cause local deepening. This may be dangerous for swimmers. It may alter the sand banks for surfing, however, there are insufficient cases and high uncertainty as to whether this would be positive or negative.

With appropriate environmental planning, sand bypassing from Tallow Beach may be able to be undertaken with low environmental impacts. Tallow Beach is generally fed with littoral drift sand from the south.

There is usually increased turbidity at deposition sites.

13.5.3 Ecological Impacts

As stated above, beach scraping has been undertaken regularly at New Brighton. Environmental monitoring of beach scraping has been reported in Smith et al (2011), who could find no negative ecological impacts. As with sand nourishment, it has been postulated that this is because of the aggressive environment present within the surf zone and the relatively small extraction and deposition zone.

14. Consideration of OEH (2013) Principles for Shortlisted Options

14.1 Principles from OEH Guidelines (2013)

Principles from NSW OEH Guidelines (2013) emanate from the Coastal Protection Act 1979 and the NSW Coastal Policy (1997). These principles were conveyed to stakeholders and Councillors during briefing sessions and workshops. The basic principles as outlined in the OEH Guidelines (2013) are:

Principle 1
Consider the objects of the Coastal Protection Act 1979 and the goals, objectives and principles of the NSW Coastal Policy 1997.

Principle 2
Optimise links between plans relating to the management of the coastal zone.

Principle 3
Involve the community in decision-making and make coastal information publicly available.

Principle 4
Base decisions on the best available information and reasonable practice; acknowledge the interrelationship between catchment, estuarine and coastal processes; adopt a continuous improvement management approach.

Principle 5
The priority for public expenditure is public benefit; public expenditure should cost-effectively achieve the best practical long-term outcomes.

Principle 6
Adopt a risk management approach to managing risks to public safety and assets; adopt a risk management hierarchy involving avoiding risks where feasible and mitigation where risks cannot be reasonably avoided; adopt interim actions to manage high risks while long-term options are implemented.

Principle 7
Adopt an adaptive risk management approach if risks are expected to increase over time, or to accommodate uncertainty in risk predictions.

Principle 8
Maintain the condition of high value coastal ecosystems; rehabilitate priority degraded coastal ecosystems.

Principle 9
Maintain and improve safe public access to beaches and headlands consistent with the goals of the NSW Coastal Policy.

Principle 10
Support recreational activities consistent with the goals of the NSW Coastal Policy.

14.2 Coastal Protection Act 1997

Objects of the Coastal Protection Act 1997 are contained in Section 3 of that Act:

> "3 Objects of this Act
> The objects of this Act are to provide for the protection of the coastal environment of the State for the benefit of both present and future generations and, in particular:
>
> (a) to protect, enhance, maintain and restore the environment of the coastal region, its associated ecosystems, ecological processes and biological diversity, and its water quality, and
> (b) to encourage, promote and secure the orderly and balanced utilisation and conservation of the coastal region and its natural and man-made resources, having regard to the principles of ecologically sustainable development, and
> (c) to recognise and foster the significant social and economic benefits to the State that result from a sustainable coastal environment, including:
> (i) benefits to the environment, and
> (ii) benefits to urban communities, fisheries, industry and recreation, and
> (iii) benefits to culture and heritage, and
> (iv) benefits to the Aboriginal people in relation to their spiritual, social, customary and economic use of land and water, and
> (d) to promote public pedestrian access to the coastal region and recognise the public's right to access, and
> (e) to provide for the acquisition of land in the coastal region to promote the protection, enhancement, maintenance and restoration of the environment of the coastal region, and
> (f) to recognise the role of the community, as a partner with government, in resolving issues relating to the protection of the coastal environment, and
> (g) to ensure co-ordination of the policies and activities of the Government and public authorities relating to the coastal region and to facilitate the proper integration of their management activities, and
> (h) to encourage and promote plans and strategies for adaptation in response to coastal climate change impacts, including projected sea level rise, and
> (i) to promote beach amenity."

14.3 NSW Coastal Policy (1997)

14.3.1 NSW Coastal Policy Principles

The NSW Coastal Policy (1997, page 14) is based on the four principles of Ecologically Sustainable Development (ESD) contained in the Intergovernmental Agreement on the Environment (IGAE) signed in 1992.

"These principles are:

- Conservation of biological diversity and ecological integrity. This refers to the need to conserve the variety of all life forms, especially the variety of species, and to ensure that the productivity, stability and resilience of ecosystems is maintained.
- Inter-generational equity. This requires that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations. Social equity considerations, in terms of equal access opportunities to resources, is inherent in the concept of inter-generational equity.

- Improved valuation, pricing and incentive mechanisms. This requires environmental factors, such as the value of ecosystems, polluter pays principles etc., to be incorporated into the valuation of assets and services and considered in decision making processes.
- The precautionary principle. Requires a risk averse approach to decision making. Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty is not to be used as a reason for postponing measures to prevent environmental degradation."

14.3.2 NSW Coastal Policy Goals

There are nine goals in the NSW Coastal Policy 1997 (Appendix B and page 20 of that document). The headings for these are:

- Natural Environment;
- Natural Processes;
- Aesthetic Qualities;
- Cultural Heritage;
- Ecologically Sustainable Development and use of Resources;
- Ecologically Sustainable Human Settlement;
- Public Access and Use;
- Information to Enable Effective Management; and
- Integrated Planning and Management.

14.3.3 NSW Coastal Policy Objectives

There are 29 objectives listed in Figure 3 of the NSW Coastal Policy (1997). For more details, the reader should refer to the original document.

14.3.4 Other NSW Coastal Policy Considerations

The NSW Coastal Policy (1997, page 15) also states:

"Equally, it is not possible to consider a future for the coast where development opportunities are totally curtailed. Such an approach would not be consistent with the social equity principles inherent in the ESD concept of inter-generational equity, as it would reduce access to living opportunities in the coastal zone and would inflate the value of existing developments by reducing supply."

Section 2.2 page 20 of the NSW Coastal Policy (1997) states that:

"Coastal lands with high conservation values will continue to be acquired and dedicated or reserved for a public purpose."

Section 2.4 page 23 of the NSW Coastal Policy (1997) states that the policy applies for 1 km landward of the open coast high water mark and for 1 km around coastal estuaries, coastal lakes and lagoons. Therefore, it applies to most of the developed area of Byron Bay.

Section 2.4 page 23 of the NSW Coastal Policy (1997) also notes that in urban areas, the policy only applies to new developments and publically owned land, and has no impact on existing use development rights.

Section 3.1 page 48 of the NSW Coastal Policy (1997) states that:

"Significant coastal lands with scenic qualities will continue to be acquired under the Coastal Lands Protection Scheme." To WRL's knowledge, there have been no acquisitions of property by the State in the Byron Bay embayment in the 17 years since the release of the NSW Coastal Policy (1997). Lipman and Stokes (2003) noted that for Collaroy Narrabeen in Sydney, voluntary purchase "… is unlikely to be implemented due to massive increases in real estate prices since the introduction of the scheme in 1997".

14.4 Compliance with Principles in OEH (2013)

WRL's opinion regarding compliance of coastal management options with the principles of OEH (2013) are listed in Table 14.1. Specialist legal and/or policy advice would be needed to confirm the preliminary assessment provided below. This opinion has not been extended to the 29 objectives listed in Figure 3 of the NSW Coastal Policy (2013).

In summary:

- Option 1 Status Quo complies with the least number of principles;
- Option 2 Planned Retreat Public-Private complies best with the most number of principles;
- Among the protection schemes, Option 6 Managed adaptive scheme complies with the most number of principles.

It should be noted though, that the quantity of principles complied with does not provide any weighting on their relative importance.

Table 14.1: Compliance with Policies

Principle from OEH (2013)	**Option 1 Status Quo**	**Option 2 Planned Retreat (Public-Private)**	**Option 3 Groynes Seawall Nourishment**	**Option 4 End Control, Seawall, Nourishment**	**Option 5 End Control, Seawall, NO Nourishment**	**Option 6 Adaptive Management**
OEH Principle 1						
NSW Coastal Protection Act (CPA) Objectives						
CPA Section 3 (a)	No	Complies best	Partly complies	Partly complies	Partly complies	Partly complies
CPA Section 3 (b)	No	No	Complies	Complies	Complies	Complies best
CPA Section 3 (c) i	No	Complies best	Partly complies	Partly complies	Partly complies	Partly complies
CPA Section 3 (c) ii	No	Partly complies	Partly complies	Partly complies	Partly complies	Complies best
CPA Section 3 (c) iii	Partly complies	Partly complies	Partly complies	Partly complies	Partly complies	Complies best
CPA Section 3 (c) iv	Involved in consultation process, but unknown					
CPA Section 3 (d)	Partly complies	Complies best	Complies	Complies	Complies	Complies
CPA Section 3 (e)	No	Partly complies	No	No	No	No
CPA Section 3 (f)	No	Complies	Complies	Complies	Complies	Complies
CPA Section 3 (g)	No	Complies	Complies	Complies	Complies	Complies
CPA Section 3 (h)	No	Complies	Complies best	Complies	Complies	Complies
CPA Section 3 (i)	No	Complies best	Complies	Complies	No	Complies
NSW Coastal Policy (CP) goals						
CP Goal 1	No	Complies best	Complies	Complies	No	Complies
CP Goal 2	No	Complies best	Complies	Complies	No	Complies
CP Goal 3	No	Complies best	Complies	Complies	Complies	Complies
CP Goal 4	Partly complies	No	Complies best	Complies	Complies	Complies
CP Goal 5	No	Complies best	Partly complies	Partly complies	Partly complies	Partly complies
CP Goal 6	No	No	Complies best	Complies	Complies	Complies
CP Goal 7	Partly complies	Complies best	Partly complies	Partly complies	Partly complies	Partly complies
CP Goal 8	Complies	Complies	Complies	Complies	Complies	Complies
CP Goal 9	No	Complies	Complies	Complies	Complies	Complies

OEH Principle 2	No	Complies best	Partly complies	Partly complies	Partly complies	Partly complies
OEH Principle 3	No	Complies	Complies	Complies	Complies	Complies
OEH Principle 4	No	Complies	Complies	Complies	Complies	Complies
OEH Principle 5	Partly complies	Partly complies	Partly complies	Partly complies	Partly complies	Partly complies
OEH Principle 6	No	Complies	Complies	Complies	Complies	Complies best
OEH Principle 7	No	Complies	Complies	Complies	Complies	Complies best
OEH Principle 8	Partly complies	Complies best	Complies	Complies	Complies	Complies
OEH Principle 9	Partly complies	Complies best	Complies	Complies	Complies	Complies
OEH Principle 10	Partly complies	Complies	Complies	Complies	Complies	Complies best
TOTALS						
Total criteria	29	29	29	29	29	29
No	20	3	1	1	4	1
Partly complies	8	4	8	8	8	6
Complies	1	10	17	20	17	16
Complies best	0	12	3	0	0	6
Percentages						
No	69%	10%	3%	3%	14%	3%
Partly complies	28%	14%	28%	28%	28%	21%
Complies	3%	34%	59%	69%	59%	55%
Complies best	0%	41%	10%	0%	0%	21%

15. Reasonableness of Shortlisted Options

15.1 OEH Consideration of Reasonableness

OEH (2013) provided the following notes on reasonableness:

"*Feasible options should then be assessed to identify if they are reasonable. In assessing whether an option is reasonable, the following should be considered:*

- *the Coastal Management Principles*
- *the social, environmental and economic impacts of the option, including its benefits and costs, and any impacts on the cultural values of the local area, and*
- *the views of the community and other stakeholders, including those provided during the exhibition of the draft CZMP. In some circumstances there will be conflicting community and stakeholder perspectives on how to manage an issue. The CZMP should seek to achieve a balanced approach after considering the community and stakeholder views in the context of potential environmental, social and economic costs, impacts and benefits."*

At the time of writing, the views of stakeholders have been considered in shortlisting options within the consultation program (Appendix M), but a draft CZMP has not been exhibited.

OEH (2013) also notes that: "*The scale of the management options proposed in the CZMP should be consistent with the amount of funding reasonably likely to be available over the CZMP's implementation period.*"

15.2 Multiple Objectives

All shortlisted options are somewhat staged and seek to address multiple objectives. Option 6 (Staged Managed Adaptive) involves the highest degree of staging of the protection options. Option 2 (Planned Retreat public-private) offers a staged implementation provided breaches to Manfred Street are repaired – if repairs were not undertaken, retreat of properties to the north of Manfred Street would be immediate following the trigger event.

15.3 Options Involving Large Scale Nourishment

Access to offshore sand for large scale nourishment is not presently feasible in NSW, and may remain off limits within the Cape Byron Marine Park. Notwithstanding this, nourishment options remain economically feasible, sand extraction for beach nourishment may be permitted under the Marine Parks Act 1997, and it may be staged. Substantial sand nourishment campaigns have been undertaken and are proposed in the future for the Gold Coast. If appropriately timed, nourishment for the Byron Bay embayment of other NSW locations may defray the substantial establishment costs for an international dredge. Nevertheless, planning approval for access to offshore sand is likely to be protracted, so the following options are therefore less likely to be able to be implemented in the short term due to access to offshore sand:

- Option 3 (Groynes Seawall Nourishment); and
- Option 4 (End Control, Seawall, Nourishment).

Note that a sand lobe beyond the boundary of the Cape Byron Marine Park is present offshore from New Brighton, but has not been investigated in detail.

15.4 Options Involving a Single End Control Structure

As detailed in the report, there is no ideal location for a single end control structure. That is, a single end control structure would either cause increased recession in other developed areas and/or increase beach width only in areas where it is not needed. Therefore, a single end control structure would be the initial stage of a multi groyne scheme. The following options have therefore been eliminated on the grounds that a single end control structure is not feasible:

- Option 5 (End Control, Seawall, NO Nourishment); and
- Option 4 (End Control, Seawall, Nourishment).

15.5 WRL Comments on Planned Retreat (Public-Private)

DCP no 1 was adopted by Byron Shire Council in 1988. Planned Retreat was the adopted option in the Draft CZMP (2010), but Planned Retreat has not been adopted within a finalised CZMP. Planned Retreat has received backing in some court rulings for new development with regard to setbacks and relocatable buildings. However, over this time, hard coastal protection works have proliferated and now protect all private Belongil properties, and are in effect the de facto present management.

Planned Retreat would offer the best opportunity to restore Belongil to a natural ecological state, however, human use is likely to remain medium to high, irrespective of the presence or absence of houses.

Planned Retreat most closely aligns with the NSW Coastal Policy 1997 and Coastal Protection Act 1979, however, page 14 of the NSW Coastal Policy states:

"*Equally, it is not possible to consider a future for the coast where development opportunities are totally curtailed. Such an approach would not be consistent with the social equity principles inherent in the ESD concept of inter-generational equity, as it would reduce access to living opportunities in the coastal zone and would inflate the value of existing developments by reducing supply.*"

The public-private model of Planned Retreat means that retreat would be primarily funded by private landowners who purchased their properties after the DCP of 1988, while the benefits (primarily more natural beaches) would be gained primarily by tourists and the broader community. Given the substantial potential losses incurred by landowners, that some landowners attribute their loss to coastal management of the Byron Bay town centre, and the imbalance between funding sources and beneficiaries, protracted resistance from affected landowners is also likely.

Full compensation to affected landowners would remove this imbalance between funding sources and beneficiaries, and much of the resistance, but this would then become a Planned Retreat (public) model, which was not shortlisted for this project. A Planned Retreat (public) model would result in far higher funding requirements from Council and/or the State.

The logistics of removing existing seawalls, some of which may have been approved, remains an unresolved foundation of Planned Retreat (Public-Private).

The requirement to compensate some landowners and the need to repair breaches of Manfred Street means that state government and Council funding would be higher for Planned Retreat (Public-Private) than some protection options.

If the funding, equity, logistical and resistance issues can be resolved, Planned Retreat would offer the best opportunity to restore Belongil to a natural ecological state.

15.6 Managed Adaptive Scheme

Option 6, the managed adaptive scheme offers the best economic performance. Stage 1 (seawall) of Option 6 offers a low financial outlay for Council and the state government.

The full scheme complies with fewer state government policy principles than Planned Retreat does. Subject to negotiation, it would require substantial financial contribution from landowners, but this contribution is comparable to the benefit they will receive, so the scheme would be perceived as more equitable.

As with all protection schemes, Council rates and land tax revenue would increase compared with the status quo and Planned Retreat.

While there are likely to be divergent community views, Stage 1 (seawall) would effectively be an engineered replacement for the status quo, albeit with enhanced alongshore public access via a promenade. The consequences of delaying or not undertaking the latter stages would be similar to the status quo with regard to beach impacts, however, maintenance costs and the likelihood of seawall failure and a breach at Manfred Street would be reduced to low levels. Stage 3 (sand transfer) is likely to involve a protracted planning and approvals process, with permission to proceed uncertain. A recommended contingency is to continue to investigate and pursue alternative sand nourishment sources and dredgers of opportunity, such as those servicing the Gold Coast.

16. Recommended Coastal Management Option for Belongil

16.1 Previous Studies

Three coastal management studies have been undertaken in the past.

The Gordon, Lord and Nolan (PWD 1978, 243 pages) study recommended:

- Groynes + nourishment.

The Geomarine (Lord and Nielsen, 1989, 65 pages) study recommended the following actions (the majority of which have since been undertaken):

1. Commitment by Council to protect/upgrade town centre.
2. Reassess hazard lines in town centre and Clarkes Beach.
3. Redefine erosion escarpment.
4. Adopt soft management for Clarkes Beach.
5. Train Belongil Creek.
6. Dune works and beach nourishment along Belongil.
7. Reassess hazard lines for Belongil.
8. Rock groynes between Belongil Creek and the town centre, at:
    a. Manfred St;
    b. The second jetty site;
    c. The town centre (possibly in conjunction with a tourist jetty.
9. Dune maintenance.

The WBM (Patterson and Witt, 2003, 433 pages) study recommended the following option for Belongil:

- Seawall + nourishment + end control structure.

WBM recommended Planned Retreat if sand nourishment was not found to be viable, but noted many impediments to its implementation, and therefore recommended further alternative protection options.

16.2 Economics of Options in this WRL Study

A cost benefit analysis (CBA) was undertaken in accordance with NSW Treasury guidelines and recent draft guidelines supporting a revised draft NSW Coastal Management Manual, for a planning horizon to 2050. A Benefit to Cost Ratio (BCR) greater than one and/or a Net Present Value (NPV) greater than zero means a project is economically viable. A summary of the CBA results is shown in Table 16.1. Within this table, the consultants' best estimate values are based on values for inputs determined by WRL and/or GCCM, together with interpretation and advice provided by OEH. Byron Shire Council (resolution 16-028) also directed WRL and GCCM to adopt certain values for variables within the CBA, with the results of these also shown in Table ES.2. Details of this are shown in Appendix N. It can be seen that the best economic option is 6.1, the adaptive scheme with engineered seawall only.

Table 16.1: Summary of CBA Results

		NPV ($ million)		BCR	
Option	**Description**	**Best Estimate**	**BSC Base Case**	**Best Estimate**	**BSC Base Case**
2	Planned retreat	-28.26	-40.79	0.35	0.40
3	Groyne Seawall Nourishment	-23.13	11.62	0.56	1.22
4	End Control Seawall Nourishment	-16.45	15.88	0.63	1.36
5	End control Seawall no Nourishment	-2.10	25.15	0.92	1.91
6	Adaptive management - all components	-7.25	22.51	0.79	1.66
6.1	Adaptive management-seawall only	7.24	31.94	1.42	2.87
6.2	Adaptive management - Seawall + single groyne	5.19	31.86	1.26	2.59
6.3	Adaptive management - Seawall + groyne field	-3.76	24.42	0.87	1.82

Transfer payments (e.g. Council rates or land tax) were not included in the CBA, however, this revenue stream is of interest to stakeholders.

Council rates revenue for properties in the Byron Bay embayment potentially affected by erosion/recession to 2050 is:

- Present rates revenue: $407,000 per annum
- NPV of present rates revenue to 2050: $7 million

The potential range of land tax revenue for properties in the Byron Bay embayment potentially affected by erosion/recession to 2050 is:

- Present land tax revenue: $0.6 to $2.4 million per annum
- NPV of present land tax revenue to 2050: $10 to $41 million

16.3 WRL Comments on Planned Retreat (Public-Private)

Planned Retreat most closely aligns with the NSW Coastal Policy 1997 and Coastal Protection Act 1979, however, this is not unequivocal. Planned Retreat was the preferred management option by Byron Shire Council in the draft 2010 CZMP and has appeared within development control plans since 1988, but it has not been adopted within an operational CZMP.

Planned Retreat has received backing in court rulings regarding setbacks for new development. However, during this time, coastal protection works (seawalls of varying coastal engineering standard) have proliferated. Seawalls now protect all private Belongil beachfront properties and are the status quo. Planned Retreat could only be implemented with the orderly removal of all seawalls on Belongil.

Planned Retreat (Public-Private) offers the main advantages of:

- Restoration of a more natural ecological environment (however, human use is likely to remain medium to high); and
- Improved alongshore pedestrian access and beach amenity.

Planned Retreat (Public-Private) also offers economic benefits due to increased beach availability, but this would be outweighed by property losses. The predominant economic benefits of Planned Retreat accrue to tourists/tourism and the general public in the form of enhanced natural beaches, but the Public-Private model involves this being funded predominantly by landowners.

The main disadvantages of Planned Retreat (Public-Private) are:

- Low economic viability:
    - NPV -$28 million and BCR = 0.35 (consultants'/OEH best estimates);
    - NPV -$41 million and BCR = 0.40 (BSC inputs)
- Funding inequity;
- Likely protracted resistance from affected landowners, including attribution of recession hazard to Jonson Street works and/or climate change; and
- High probability of a breakthrough of Belongil Spit at Manfred Street during a major storm.

Subject to funding agreements being reached, the predominant distribution of costs and benefits for Planned Retreat (Public-Private) relative to the status quo would be:

• Funding (costs):	Private Landowners:	69% ($31 M)
	Public sector	25% ($12 M)
• Beneficiaries:	Council	63% ($9.5 M)
	Tourists:	34% ($5.1 M)

That is, the Planned Retreat (Public-Private) option would require $12 million of public funding relative to the status quo. If a 20 m buffer (from the face of the erosion escarpment) is applied to Planned Retreat, private property losses would increase by approximately $30 million.

A range of useable public beaches, from urban to nature reserve wilderness will still be available within the 37 km of coastline in Byron Shire without Planned Retreat.

16.4 WRL Recommended Option for Belongil

WRL recommends that as a minimum, the status quo be improved with Stage 1 (engineered seawall) of Option 6, the adaptive scheme. This sub option as a standalone measure has the best economic performance. The full three stage adaptive management protection scheme has components of:

- Stage 1: Seawall with walkway;
- Stage 2a: An initial self-filling trial groyne;
- Stage 2b: Additional groynes; and
- Stage 3: Small scale sand nourishment.

Progress to later stages would be warranted if triggers within the adaptive scheme are reached. These could include the community, Council or the state government desiring or requiring wider beaches than the status quo. Economic modelling indicates that such increased beach width over a 1 km stretch of Belongil is not economically justified.

The adaptive management scheme is flexible and staged, without large scale nourishment, and aims to minimise the financial commitment of Council and the State, while providing engineered protection to the built environment and alongshore access to residents and visitors.

Stage 1 of Option 6 staged adaptive management protection scheme offers the main advantages of:

- Technical feasibility;
- Economic feasibility;
- Funding equity – beneficiaries are predominant funders;
- Low financial commitment from Byron Shire Council and the State;
- Improved alongshore pedestrian access; and
- An improvement on the status quo for all parties.

The approximate capital funding requirements for the adaptive scheme (subject to funding negotiations) are:

- Stage 1 (year 1): Seawall with walkway
  - Landowners: $12 M (80%)
  - Council: $1 M (7%)
  - State Government coastal program: $1 M
  - State Government other: $1 M

- Total (over approximately 10 years, if latter stages are undertaken):
  - Landowners: $21 M (62%)
  - Council: $6 M (18%)
  - State Government coastal program: $6 M
  - State Government other: $1 M

Provided that a funding model, public access and a wall alignment can be negotiated, the outlay from Council and the State for Stage 1 of Option 6 staged adaptive scheme is only about 15% of other options including Planned Retreat (public-private). The scheme offers benefits to all parties compared with the status quo.

Subject to the realisation of more extreme scenarios of projected global climate change and sea level rise, ongoing recession of the beach and ongoing monitoring, there may be a time in the future when protection options are no longer viable.

Retreat may then become a viable option, however, this may be more than 100 years into the future. Climate, environmental, economic, social, political, regulatory and technological change over this time means that accurate planning of coastal management on a century timescale may be unrealistically speculative.

17. Recommended Management Options for other Areas within Byron Bay Embayment

Suggested management options for other sites and hazards within the Byron Bay embayment are listed below.

17.1 Wategos

The following actions are recommended:

- Accurately map the bedrock surface and existing seawall extent;
- Check the stability of the existing seawall; and
- Consider rebuilding the seawall and/or partial retreat of Marine Parade which may involve conversion to one way traffic flow.

17.2 The Pass to Clarkes Beach

BMT WBM (2013 Figure 4-41) noted that "the erosion hazard at The Pass extends to bedrock". The erosion hazard lines extend into the Captain Cook car park (slightly by 2050) and Lighthouse Road for 2100, however, bedrock levels there are uncertain. Due to the requirement for road access to Wategos, additional geotechnical works to retain Lighthouse Road may be required. Given the proximity to bedrock, these would not displace substantial portions of sandy beach and would not be required prior to 2050.

Options for the Captain Cook car park are minor retreat by 2050 or similar works to those suggested for Lighthouse Road. These would not be needed immediately.

The following actions or considerations are recommended:

- Accurately map bedrock surface to confirm hazard lines relative to structures.
- The small number of structures potentially vulnerable to hazards may make retreat of these structures more justifiable than more intensely developed areas.

17.3 Main Beach

Generally continue dune management to allow natural processes to prevail, in conjunction with upgrading the Jonson Street seawall structure. Monitor beach change, particularly if modifications are undertaken to Jonson Street works.

17.4 Cavvanbah

Future changes to this beach will be affected by management options for Belongil. There are no buildings within the erosion/recession hazard zone to 2050. The railway corridor is within the erosion/recession hazard zone in 2050 but not in the immediate hazard zone. If nourishment is undertaken for Belongil, Cavvanbah would be a potential placement site. Based on present land use, there is no economic justification for protection of Cavvanbah with a seawall (north from First Sun towards Border Street) to 2050. However, reopening or alternative use of the railway line/corridor would necessitate a review of the need for protection in the future.

17.5 North Beach

Future changes to this beach will be affected by management options for Belongil, however, as of May 2013 there were no structures within the hazard zones to 2050 or 2100. BMT WBM (2013) did not map hazard zones at the Belongil Creek entrance, however, a zone of estuary entrance instability was noted. Impacts on North Beach need to be considered in the design of any structures for Belongil.

17.6 Inundation Hazard

BMT WBM (2013) indicated that there was an inundation hazard for areas of Byron Bay, however, most dunes were sufficiently elevated to prevent overtopping. BMT WBM noted that potential dune overtopping could occur at the northern end of the Jonson Street protection works, Manfred Street and northern Belongil Spit (beyond the northernmost house). They noted that the dune heights at North Beach north of Belongil Creek were high and therefore not subject to overtopping. They also noted that the berm fronting the Belongil Creek mouth was low and therefore subject to overtopping, however, assessment did not extend into the Belongil Creek mouth and any assessment of inundation through wave propagation across the entrance to the dune on its landward side. The inundation hazard (excluding wave runup) within Belongil Creek was also addressed in the BMT WBM (2014) Belongil Creek Floodplain Risk Management Study Report. The mapping produced by BMT WBM (2013) indicates areas of potential inundation, however, substantial additional work and analysis would be needed to extend this into a risk assessment. Such work would include mapping of the depth of inundation and an inventory of the floor levels of vulnerable structures.

If a protection management option is pursued, the potential breach at Manfred Street would be prevented with an appropriately designed seawall. Under a retreat scenario, dune strengthening with minor beach scraping (when the beach is accreted) may reduce the likelihood of a breach at Manfred Street. However, neither of these actions would prevent inundation from Belongil Creek, which is largely covered in the BMT WBM (2014) floodplain management study.

The following additional actions or considerations are recommended:

- Consider the dynamic component of wave overtopping in locations such as Jonson St;
- Consider the inundation hazard in conjunction with the terrestrial flood hazard; and
- Potentially manage the inundation hazard with floor level controls, flood resistant materials and emergency management, including forecasting.

17.7 Coastal Entrance or Watercourse Entrance Instability

BMT WBM (2013) did not map hazard zones at the Belongil Creek entrance, however, a zone of estuary entrance instability was noted. Detailed modelling of this has not been undertaken, however, the presence of the bridges on Ewingsdale Road and the disused railway line serve to reduce the spatial extent of the instability. Management options for the Byron Bay embayment involving groynes would most effectively manage the estuary entrance instability. The instability is presently somewhat managed within the existing opening procedures for the estuary, through the location of the initial channel cut.

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Coastal Hazard Management Study – Byron Bay Embayment Appendices

WRL Technical Report 2013/28
March 2016

By J T Carley, I R Coghlan, C D Drummond, P Dean-Jones and D Anning

19. Appendix A: Review of Previous Studies

Previous coastal studies pertaining to the Byron Bay embayment are laid out in chronological order. Following the coastal studies, a brief summary of coastal aspects of Belongil Creek flood studies is provided. Many of these studies have become the basis of Council resolutions, however, this report is not a repository for these resolutions.

19.1 Byron Bay – Hastings Point Erosion Study (Gordon et al, PWD, 1978)

This seminal work was the first comprehensive coastal hazard and management study undertaken by the state government of NSW. Due to the resources invested in the study over two (2) years, it arguably remains the most comprehensive coastal study undertaken in NSW.

Utilising photogrammetry, computer modelling, geology and data collection, the study found that the recession rate in the Byron Bay-Belongil region was approximately 1.5 m/year. This was primarily due to sediment budget imbalances resulting from:

- Differential littoral drift;
- Episodic sand bypassing of Cape Byron; and
- Offshore losses due to the interaction of the East Australian Current with Cape Byron.

Extrapolated recession lines for 50 and 100 year planning horizons were developed and were later adopted as the "Part J" coastal planning lines by Byron Shire Council. These incorporated a factor of safety of 2.

The study suggested a range of management options, namely:

1. No co-ordinated management plan;
2. A re-zoning of affected areas;
3. A policy of relocation;
4. An insurance scheme;
5. Engineering works.

Potential engineering works considered in the study were:

- Seawalls and rock revetments;
- Groynes;
- Submerged offshore breakwaters; and
- Sand nourishment.

A single Shire-wide management or engineering option was not recommended, however, "… *as it was felt that social and economic factors other than those considered in the investigation should be accounted for before such a plan is formalised.*"

For the Byron Bay township area (to just north of Belongil Creek mouth), the recommended management options were:

1. A groyne scheme;
2. Sand nourishment; and
3. An insurance scheme

19.2 Geomarine (1989)

The Geomarine (1989) report has not been considered in previous recent hazard and management studies for Byron Bay. It was only discovered/retrieved well into the course of this WRL study, and appears to be the first Byron Bay coastal engineering study to consider climate change/sea level rise over engineering planning horizons (50 to 100 years).

Geomarine (1989) considered the viability of coastal engineering management options between Clarkes Beach and Belongil Creek. It did not consider policy implications in depth, nor undertake extensive consultation. Nevertheless, it did note that "Byron Shire Development Control Plan No.1, Part J … permits the planned and orderly development of the Shire…. There are shortcomings in applying the D.C.P. to existing developed areas of the Shire …."

Geomarine noted that an ad-hoc revetment existed along most of Belongil. They noted that in isolation, a terminal revetment is unlikely to be a viable management option due to cost and impacts to the north.

They suggested ongoing nourishment of 65,000 m^3/year. This could be achieved from sand bypassing from Tallow to Clarkes Beach (method not stated), with other potentially viable sources being:

- The Cape Byron sand lobe;
- Nearshore dredging off Clarkes Beach;
- Importation of sand from outside the active coastal zone; and
- Beach scraping ("skimming").

They noted that available funding would be unlikely to be sufficient to continue ongoing nourishment, but that additional measures (most likely groynes) could enhance beach amenity.

The main elements of Geomarine's recommendations were:

1. Commitment by Council to protect/upgrade town centre.
2. Reassess hazard lines in town centre and Clarkes Beach.
3. Redefine erosion escarpment.
4. Adopt soft management for Clarkes Beach.
5. Train Belongil Creek.
6. Dune works and beach nourishment along Belongil.
7. Reassess hazard lines for Belongil.
8. Construct rock groynes between Belongil Creek and the town centre, which may be at:
    - Manfred St;
    - The second jetty site;
    - The town centre (possibly in conjunction with a tourist jetty.
9. Dune maintenance.

WRL notes that elements 1, 2, 3, 4 and 7 have been implemented. Element 9 has been implemented at some locations. Elements 5, 6 and 8 have not been implemented.

19.3 Coastal Engineering Advice to the Department of Planning (Moratti/PWD, 1990)

The Moratti/PWD (1990) report was entitled: "Coastal Engineering Advice to the Department of Planning in Relation to Lots 11 – 14, Section 3, D.P.1623, Childe Street, Byron Bay". It considered the impacts of the following factors on the subject properties:

- Long-term coastline recession;
- Short-term storm fluctuations;
- Greenhouse effect;
- Oceanic inundation/flooding.

The Moratti/PWD study quoted the analysis from Gordon et al (1978) which found average recession rates for Belongil from 1947 to 1977 of 1 m/year. While acknowledging the potential limitations and inaccuracies of historical surveys, a brief analysis was undertaken of historical surveys from 1885, 1914 and 1921, which found average recession rates of 0.5 m/year since 1885 or 0.7 m/year since 1921.

The Moratti/PWD study estimated a "design" storm erosion volume of 200 m^3/m.

It was one of the first coastal hazard studies to consider climate change/sea level rise over engineering planning horizons (50 to 100 years) and adopted a Bruun Factor of 50, utilising the following sea level rise scenarios:

- 50 year period:
    - Low scenario: 0.15 m;
    - Mid scenario: 0.26 m;
    - High scenario: 0.37 m.

- 100 year period:
    - Low scenario: 0.43 m;
    - Mid scenario: 0.84 m;
    - High scenario: 1.26 m.

Moratti/PWD noted that: "*A land survey was taken through the dune fronting Manfred Street on 8 February 1990 to align with a photogrammetric profile … dated 23 June 1987. Application of a short term storm demand figure of 200 m^3/m … shows that the entire dunal system could be removed during a severe storm event … Without a dunal buffer, oceanic inundation across Manfred Street is likely under combined conditions of severe wave attack and elevated ocean levels.*"

The relevant figure from Moratti/PWD is reproduced in Figure 19.1 below. Note that this part of Moratti's analysis did not include climate change and ongoing recession, but was "present day" for 1990.

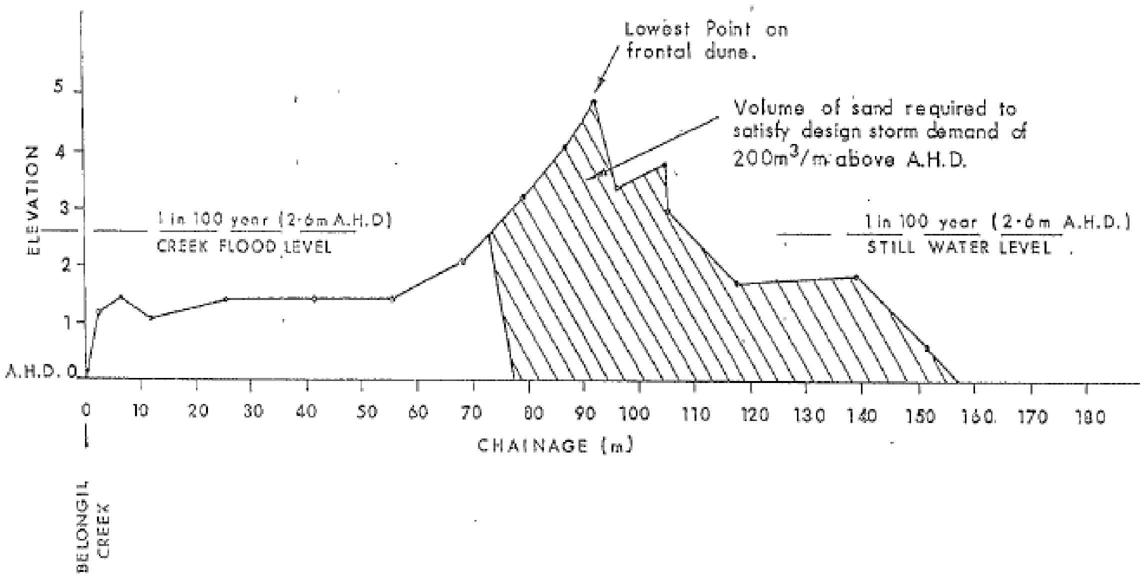


Figure 19.1: Storm Demand applied to Manfred Street (Figure 17 of Moratti/PWD, 1990)

19.4 Byron Shire Coastline Hazard Definition Study Final Report (WBM, 2000)

WBM (2000) provided the first revision of coastal hazards since the PWD (1978) study. It was undertaken within the guidelines of the NSW Government (1990) Coastline Management Manual and considered hazards for immediate, 2050 and 2100 planning horizons. The principal physical hazards and their quantification as derived by WBM are listed below:

- Storm erosion:
    - Cape Byron to The Pass: 100 m^3/m above AHD (50 m^3/m relative to 1990);
    - The Pass to Memorial Pool: 150 m^3/m above AHD (100 m^3/m relative to 1990);
    - Memorial Pool to Belongil Creek: 250 m^3/m above AHD (200 m^3/m relative to 1990).

- Ongoing recession:
    - The Pass to Memorial Pool: 0.10 m/year (range 0.05 to 0.20 m/year);
    - Memorial Pool to Border Street: 1.20 m/year (range 0.90 to 1.50 m/year);
    - Border Street to Belongil Creek: 0.80 m/year (range 0.60 to 1.00 m/year).

- Recession due to sea level rise (Bruun Factor) for Belongil Spit: 70 times the sea level rise.

- Sea level rise projections:
    - 2050: 0.2 m;
    - 2100: 0.5 m.

WBM's ongoing recession measurement involved more than 20 years of additional data compared with PWD (1978). WBM's best estimates of recession were lower than PWD (1978). This was rationalised as being due to stormier conditions prevailing in the 1960s and 1970s being tempered by milder conditions in the 1980s and 1990s.

The sea level rise projections used by WBM were (and are) consistent with "mid-range" emissions/sea level rise scenarios and were commonly adopted at the time of publication. Later planning guidance and policies adopted "high-range" emissions/sea level rise scenarios.

19.5 Byron Coastline Values Study (Byron Shire Council, 2000)

The Byron Coastline Values Study consisted of background information on the main ecological, social and economic values of the coastline in Byron Shire. It covered the intertidal zone, flora and fauna, cultural heritage, landscape, recreation, economic and residential values. The study area was limited to the immediate coastline and any parcels of land that adjoin the high water mark or the 2050 erosion hazard line.

It considered the following values:

- Ecological values:
  - Intertidal zone;
  - Flora and fauna.

- Social Values:
  - Cultural heritage;
  - Landscape;
  - Recreation.

- Economic values.

19.6 Scoping Study on the Feasibility to Access the Cape Byron Sand Lobe for Sand Extraction for Beach Nourishment (PBP, 2006)

Following the recommendation of WBM (2003), a scoping study was undertaken by Patterson Britton & Partners (2006). This study relied predominantly on existing information rather than collection of new data.

Patterson Britton & Partners (2006) found that accessing the Cape Byron sand lobe for beach nourishment was technically feasible, however, the depths of water within the "general use" zone of the Cape Byron Marine Park were beyond the reach of Australian-based dredges, necessitating an international vessel.

Patterson Britton & Partners (2006) found that the unit rates for sand extraction were less than those estimated in WBM (2003) but the volume needed may be 2.85 times the original estimate – with an increase from 1,000,000 m^3 to 2,850,000 m^3. This was primarily due to finer sediment indicated to be present in the sand lobe than within the active beach profile. However, both these volumes were predicated on providing a volume equivalent to 250 m^3/m above the water, plus the associated underwater component. This is notionally sufficient to offset a 100 year ARI erosion event.

Unit rates for sand dredging and placement on Belongil were found to be:

- Pump ashore: $5.80 per m^3;
- Rainbowing (jetting into the air): $4.00 per m^3; and
- Bottom dump: $2.80 per m^3.

This compared with an adopted rate of $8 per m^3 determined in WBM (2003).

Patterson Britton & Partners (2006) estimated costs for nourishment of Belongil were:

- Initial nourishment: $18.8 M
- End control structure (groyne): $ 4.1 M
- Seawall upgrading: $ 6.2 M

- Dune stabilisation: $ 0.5 M
- Contingencies: $ 5.9 M
- Detailed design and supervision: $ 2.2 M

- **Total initial cost: $37.9 M**

Future maintenance of the structures plus one episode of renourishment was estimated to cost:

- At 7% discount over 50 years: $ 3.0 M
- At 0% discount over 50 years: $14.0 M

The main gaps identified by Patterson Britton & Partners (2006) were:

- There is only limited data available regarding sediment characteristics in the borrow and deposition zones.
- The Patterson Britton & Partners (2006) study did not include ecological investigation, but included generic information from other sites.

Patterson Britton & Partners (2006) recommended that a scenario of nourishment without an end control structure be investigated.

Due to the potential difficulties in gaining access to sand within the Marine Park, PBP also noted that an alternative potentially suitable sand lobe was present offshore from New Brighton. Less information is available about this lobe, however, it is outside the Marine Park boundaries and limited samples indicate that it has coarser sand than the Cape Byron lobe.

19.7 Modelling Byron Bay Erosion and Effects of Seawalls (Patterson, 2010)

This study utilised computer modelling to estimate the coastal evolution of the Byron Bay embayment (with and without the presence of seawalls, including the Jonson Street seawall) due to the processes of sediment imbalance, alongshore impacts of structures and sea level rise. The study was primarily a research exercise based on the author's PhD (completed 2013) which considered coastal evolution in northern NSW and south-east Queensland.

The study found that the numerous seawalls (from Jonson Street to northern Belongil Spit) have acted as mini headlands, stabilising the coast to their south-east and exacerbating recession to their north-west, however, the overall recessionary trend (over the past 50 years) was an underlying one and was not the sole result of the seawalls.

The study found that the Jonson Street seawall alone had an incremental recessionary impact for approximately 4 km to its north-west for modelling taken out to 2050. Patterson noted: "*Correspondingly, the seawall at Jonson St has affected Belongil Spit erosion as an incremental increase in addition to what would have occurred naturally in its absence, but is thus not the whole contributor to the erosion that has occurred. This incremental effect has an unusual and* *unexpected longshore distribution, being of relatively modest extent (approx. 20m) extending over a long section of shoreline rather than a more extensive effect over a limited distance …"*

19.8 Peer Review of Report on Byron Bay Coastal Modelling by Dean Patterson (WRL, 2010)

WRL (2010) undertook a review of Patterson/WBM (2010). WRL commended the commissioning and undertaking of such a modelling exercise, as it allows greater insight into the coastal processes of Byron Bay.

The review noted that the Patterson/WBM (2010) work contained sophisticated enhancements of the modelling of some physical processes compared with several commercially available models. The complexity and difficulty of the processes being modelled was noted by WRL. Due to lack of field data, there is considerable uncertainty regarding the magnitude of cross embayment transport.

Due to the in-house and experimental nature of the model, WRL cautioned against an overreliance on the model for future planning.

19.9 Draft Coastal Zone Management Plan for Byron Shire Coastline (BSC, 2010)

The extensive Draft Coastal Zone Management Plan (CZMP) for Byron Shire Coastline (BSC, 2010) covered the entire Shire and coordinated the previous studies.

The Draft CZMP (2010) enshrined planned retreat as the preferred management option, with the exception of the Byron Bay town centre, where protection through the Jonson Street protection works was to be retained and upgraded into the future.

Many of the actions detailed in the Draft CZMP (2010) have since been undertaken or commenced. Examples include:

- Beach scraping design and trials at New Brighton;
- Modelling of the impacts of the Jonson Street works and other seawalls on erosion/recession;
- Risk assessment of coastal structures on Belongil; and
- Design for upgrade of Jonson Street works.

The Draft CZMP was adopted by Council and submitted to the Minister for certification under the Coastal Protection Act 1979. Council subsequently withdrew the Draft CZMP from the Minister and resolved instead to prepare a new draft CZMP in accordance with the new statutory guidelines and amended Coastal Protection Act (BSC resolution 11-276).

19.10 Byron Shire Coastal Audit Conducted May 2010 to May 2011, Ordinary Meeting 30 June 2011, Report No.12.19

As a result of Council Resolution 04-1059, BSC conducted an audit of properties which may be impacted by coastal hazards. The coastal audit was focussed on New Brighton and Belongil.

The project involved (/will involve) eight stages (Stages 1 to 4 and 6 partially or substantially completed as at 30 June 2011, Stages 5, 7 and 8 still to be completed as at 30 June 2011), namely:

- Stage 1: Ownership, restrictions on title and zoning certificates;
- Stage 2: Planning instrument review;
- Stage 3: Review of consents and certificates;
- Stage 4: Audit of erosion protection works;
- Stage 5: Road Reserve ownership and gazettal;
- Stage 6: Ground truthing;
- Stage 7: Legal interpretation; and
- Stage 8: Financial analysis.

The following information was relied upon:

- All development applications and planning certificates;
- Conveyancing Act 1919, Section 88E title restrictions;
- Director-General Concurrence (where applicable);
- NSW Land and Environment Court decisions;
- Site plans;
- File notes;
- Media publications; and
- Distances to the erosion escarpment (where ground-truthed).

An erosion escarpment was surveyed on 10 May 2011 by Cantys Surveyors in response to Council Resolution 09-407. Ground truthing for Belongil was undertaken in May 2011.

It was found that "the coastal audit has suffered some difficulties due to the poor or incomplete condition of historical property files. Issues encountered include: poor image quality, absence of site plans, absence of planning documents that validate the legality of structures (DA, 15 BA, building permits, construction certificates, occupation certificates, Ministerial concurrence etc.), and incomplete documentation such as files not dated or signed."

A total of 483 individual properties were identified as being located within the immediate and 50 year coastal erosion zones (precincts 1 and 2 of DCP 2010 Part J). New Brighton and Belongil were not separated in these numbers, however, they could be separately tabulated from the source documents.

There were 16 properties located at Belongil Beach and New Brighton Beach where the buildings were in close proximity to the erosion escarpment and did not have development restrictions relating to the proximity of the whole dwelling to the erosion escarpment and did not have post 1988 purchases/transfers.

There were 33 properties within Belongil Beach and New Brighton Beach where the buildings were in close proximity to the erosion escarpment that had development consent conditions that supported the removal or relocation of residences in relation to the proximity of development to the erosion escarpment.

The ground-truth survey of Belongil Beach immediate beachfront development indicated that there were five (5) dwellings that may have triggered development consent conditions, requiring the removal or re-location of structures due to proximity to the erosion escarpment. Three (3) lapsed development consents were also found for restricting the use of parts of dwellings as opposed to restricting use on the whole dwelling.

The coastal audit identified 41 properties (that is, contiguous land parcels under private ownership) located along the immediate beachfront at Belongil, and a further 15 "second row" properties there seaward of Childe Street. That is, there were 56 Belongil properties potentially subject to retreat at Belongil. It found that 11 of the beachfront Belongil properties were purchased prior to 1988 and a further three "second row" properties, that is there were 14 properties purchased pre-1988. WRL notes that under a retreat management option, many "second row" properties may become "beachfront" in the future.

19.11 Investigating the Re-design of the Jonson Street Protection Works (WorleyParsons, Revision 6 11/02/2014)

The WorleyParsons report presented the modelling and evaluation of preliminary design options to upgrade the Jonson Street Protection Works.

Wave modelling of the 1 year, 10 year and 100 year ARI wave and water level conditions was undertaken to determine appropriate design parameters for the existing structure, as well as assess the existing risks associated with the structure (including wave overtopping and associated safety of the public), ability to withstand storm events of a particular magnitude and the future effects of climate change.

A range of potential management options for the upgrade of the Jonson Street Protection Works was canvassed. The following options may be appropriate:

- Rigid near-vertical and stepped gravity structures;
- Sloping pattern-placed unit revetments with a wave return wall;
- Flexible near-vertical rock gravity structures; and
- Flexible sloping rock rubble revetments.

In addition to the various types of structures available, various structure alignments were considered for the upgrade of the works, including:

- Maintaining the existing structure alignment;
- Removing the spur groynes from in front of the structure; and
- Moving the structure landward to restore as closely as possible the natural beach alignment and natural longshore sediment transport regime.

Modelling (using contemporary modelling techniques) and data analysis was undertaken to examine the potential impact of the various options for structure alignment. It was found that removal of the spur groynes would help restore some of the natural longshore sediment transport, but that the structure would continue to interrupt sediment transport into the future unless it is moved landward.

Initial assessment by Council and State agency stakeholders using multiple criteria assessment ranked the rock rubble revetment as the highest scoring option. This was followed by the near-vertical rock gravity structure ranked second. Then the stepped seawall option and sloping pattern placed unit revetment was ranked equal third. The near-vertical seawall option was ranked last out of the five options. A hybrid option was also presented comprising a stepped concrete seawall with access ramps in front of the surf club and reserve to the north, and a rebuilt rock revetment fronting the car park, memorial pool and First Sun caravan park. The same assessment process ranked "removing the spur groynes from in front of the structure" as the most favoured alignment.

WorleyParsons recommended that the highest priority area for upgrading was the section fronting the car park, due to its status as an iconic coastal location, the potential for public injury as a result of wave overtopping and the ability of the present seawall in this area to withstand storm events.

Council made resolutions regarding this document, however, such resolutions do not form part of the document being reviewed.

19.12 Byron Bay Erosion Protection Structures – Risk Assessment (WorleyParsons, 2013)

WorleyParsons (2013) undertook a risk assessment of coastal structures located between Byron Bay SLSC and the northernmost private property on Belongil Spit. Seventeen separately identifiable structures were considered.

These structures were variously constructed of:

- Sand filled geotextile containers;
- Rock rubble; and
- Concrete cubes and demolition concrete.

The study utilised contemporary coastal and geotechnical engineering techniques.

Risk (likelihood times consequence) was assessed with regard to:

- Structure resilience;
- Coastal processes;
- Coastal ecology; and
- Public safety and amenity.

Of the 10 rock structures considered, WorleyParsons (2013) estimated that during eroded beach conditions:

- Eight would fail in less than 1 year ARI conditions;
- Two would fail in approximately 10 year ARI conditions.

19.13 Design of Interim Beach Access Stabilisation Works – Belongil, Byron Bay (WRL, 2013)

WRL (2013) produced a design for interim beach access stabilisation works at Manfred Street, Don Street and Border Street on Belongil.

These works are proposed to replace existing sandbag structures which have been in place since approximately 2001. The sandbag structures have been damaged on numerous occasions due to overtopping and/or container displacement. Council resolved to investigate replacing these sandbag structures with rock and/or hard materials.

The WRL works were designed to contemporary engineering standards and comprised 3 tonne primary armour, with a crest at 6 m AHD and a toe founded at -2 m AHD. A Review of Environmental Factors (REF) was undertaken by Umwelt as part of the design process.

19.14 Coastal Aspects of Belongil Creek Flood Studies

Only aspects of Belongil Creek flood study documents relevant to coastal management at Belongil are detailed below.

19.14.1 SMEC (2009) Belongil Creek Flood Study

SMEC (2009) used the following wave setup values for a closed and open entrance respectively, with the value for an open entrance adopted for the flood study:

- 5 year ARI: 0.52 m closed; 0.32 m open;
- 10 year ARI: 0.55 m closed; 0.35 m open;
- 20 year ARI: 0.57 m closed; 0.37 m open;
- 50 year ARI: 0.62 m closed; 0.44 m open;
- 100 year ARI: 0.65 m closed; 0.45 m open.

Table 10 of SMEC (2009) presented the following values for various tailwater components for 100 year ARI conditions:

- Spring tide: 0.87 m;
- Barometric setup: 0.60 m;
- Wind setup: 0.40 m;
- Wave setup: 0.55 m;
- Ongoing sea level rise: 0.12 m;
- Additional SLR: 0.18 m;
- Accelerated ice melt: 0.10 m;
- Total: 2.82 m AHD

The total sea level rise component for the 100 year ARI tailwater level used was 0.4 m which is consistent with the previous NSW government benchmark for 2050.

For present day conditions, the SMEC (2009) 100 year ARI ocean tailwater condition is therefore 2.42 m AHD.

19.14.2 BMT WBM (2013b) Belongil Creek Floodplain Risk Management Study and Plan Discussion Paper 4: Flood Modification Measures Assessment April 2013 Revision 2

This document fed into the BMT WBM (2014) Belongil Creek Floodplain Risk Management Study Summary (August 2014 Revision 4). The 2014 document does not cover additional coastal material, so is not discussed in this WRL report.

With regard to entrance management, BMT WBM noted: *"Since 2001, Council has operated under a licence condition (granted as an interim licence) which allows the Council to open the creek entrance when water levels reach 1.0 m AHD at the Ewingsdale Bridge (WBM, 2007). These works are undertaken to reduce flood levels under Council's duty of care responsibility to the community. The current sand extraction licence is valid until 11th September 2019."*

They investigated the training of Belongil Creek and noted:
"The impacts of training the Belongil Creek entrance on the catchment flood behaviour are complex and varied. These impacts have been assessed using the Belongil Creek catchment flood model, updated to represent the following two catchment states.

1. *Closed Creek Entrance Scenario (Beach berm = 1.6 m AHD); and*
2. *Open Creek Entrance Scenario (Trained creek entrance combined with a scoured channel depth to -2 m AHD)."*

Table 3-1 from BMT WBM is reproduced in Figure 19.2 below, and shows the potential impacts of Belongil Creek training walls on flood levels. This shows minor increases in flood levels for low (frequent) ARI (which are storm tide dominated) and minor to moderate reductions in larger (infrequent) ARI events where the flooding is catchment runoff dominated. The improvement would be more substantial away from the peak of the tide, noting that even under storm tide conditions, the astronomical component means that the peak ocean level will only persist for approximately 1 to 2 hours before dropping. During times of spring tides, the diurnal inequality means that there is only one large high tide per day.

Table 3-2 from BMT WBM indicates that under PMF (probable maximum flood) conditions, with training walls the number of flood affected properties would:

- Reduce by 78 residential properties (from 626 to 584);
- Reduce by 16 commercial properties (from 131 to 115).

The monetary benefit of this reduction was low relative to the cost of training walls, so from a flood management economic perspective, BMT WBM found that the cost of training walls was not justified. BMT WBM did note: "*Construction of a trained entrance to Belongil Creek may act to stabilise the beach orientation, mitigating the persistent longshore sediment transport erosion …*"

WRL notes that more recent guidelines (described below) regarding the incorporation of wave setup into tailwater levels may provide additional flood reduction from a trained entrance.

Table 3-1 Flood Impact Summary: Ewingsdale Road Bridge - Measure 1

Design Flood Event (ARI)	*Peak Flood Level (mAHD)*		*Change in Flood Level (m)* *(Entrance Open minus Entrance Closed)*	*Comment*
	Entrance Closed	*Entrance Open (Trained)*		
5	1.9	1.9	+0.04	Storm Tide Dominated
10	2.0	2.0	+0.04	Storm Tide Dominated
20	2.1	2.1	-0.01	Storm Tide and Catchment Runoff Influence
100	2.3	2.3	-0.03	Catchment Runnoff Dominated
PMF	3.3	3.1	-0.20	Catchment Runoff Dominated
Sensitivity Testing				
100 year ARI 2100 climate change	3.1	3.1	+0.02	Storm Tide Dominated
100 year ARI Storm Tide (no catchment flooding)	1.8	2.1	+0.30	Storm Tide Dominated
100 year ARI Catchment Runoff MHWS Tide (no storm tide)	2.1	1.6	-0.52	Catchment Runoff Dominated

Figure 19.2: Flood Impact of Training Wall Option (Table 3-1 from BMT WBM, 2013b)

19.14.3 OEH Tailwater Guidelines

Recent OEH (Toniato, McLuckie and Smith, 2014) guidance for estuaries north of Crowdy Head suggests the following present day peak tailwater levels be used for flood modelling:

- Untrained ICOLL (Intermittently closed or open lake or lagoon; Type C):
  - 20 year ARI: 2.45 m AHD;
  - 100 year ARI: 2.65 m AHD.

- Trained open estuary (Type B; small, non-navigable):
  - 20 year ARI: 2.00 m AHD;
  - 100 year ARI: 2.10 m AHD.

That is, (subject to detailed modelling) under 100 year ARI conditions, the tailwater level may be reduced by 0.45 to 0.55 m for a trained entrance. The reduced tailwater level for the trained entrance is due to reduced wave setup.

20. Appendix B: Literature Review of Seawalls

20.1 What is a Seawall?

Seawalls can sometimes be referred to as revetments in technical literature. In common usage, a revetment is usually considered to be sloping and flexible, while a seawall may be either vertical or sloping, and either rigid or flexible. In this report the term seawall has been used to include revetments.

The following definitions are presented from standard coastal engineering references.

Seawall:

"*Seawalls are onshore structures with the principal function of preventing or alleviating overtopping and flooding of the land and the structures behind due to storm surges and waves. Seawalls are built parallel to the shoreline as a reinforcement of a part of the coastal profile.*" (USACE, 2003, p VI-2-1)

"*A structure separating land and water areas, primarily designed to prevent erosion and other damage due to wave action*" (SPM, 1984, p A-30).

Revetment:

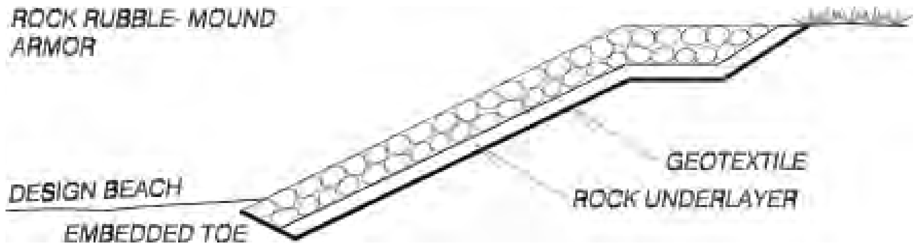
"*Revetments are onshore structures with the principal function of protecting the shoreline from erosion. Revetment structures typically consist of a cladding of stone, concrete, or asphalt to armour sloping natural shoreline profiles.*" (USACE, 2003, p VI-2-1).

"*A facing of stone, concrete etc., built to protect a scarp, embankment, or shore structure against erosion by wave action or currents*" (SPM, 1984, p A-28).

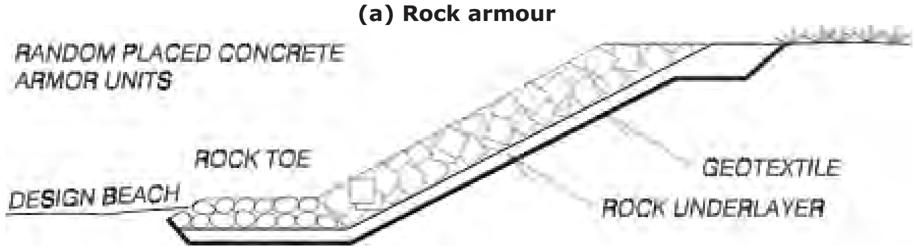
"*Protective structure normally placed on an embankment or profiled fill material, normally to form a seawall*" (CIRIA, 2007, p 9).

20.2 Main Types of Seawalls

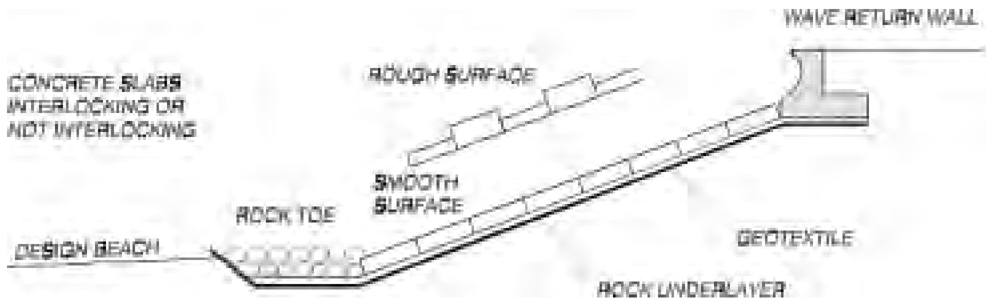
Seawalls (and revetments) are generally parallel to the shore and can be classified as sloping-front or vertical-front structures. Sloping-front structures can be constructed as flexible rubble-mound structures which are able to adjust to some toe and crest erosion or as rigid structures which have a fixed form and position. Sloping-front seawalls are typically built from randomly placed armour (rock or concrete units), pattern-placed concrete armour units (see Figure 20.1), reinforced concrete, geotextile containers, or gabion baskets, though numerous other less successful materials have been used in the past.



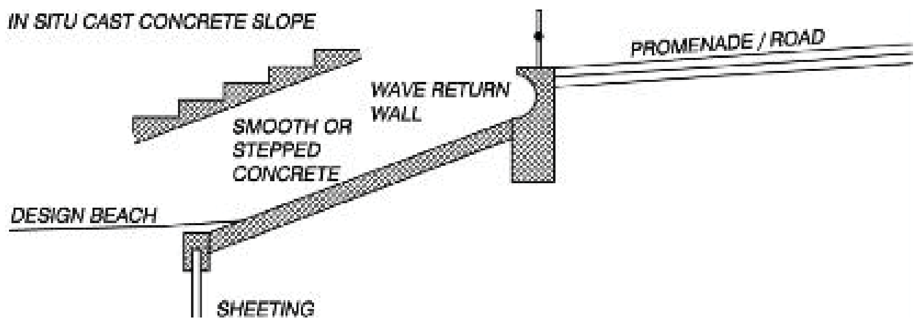
(a) Rock armour



(b) Random placed concrete armour units



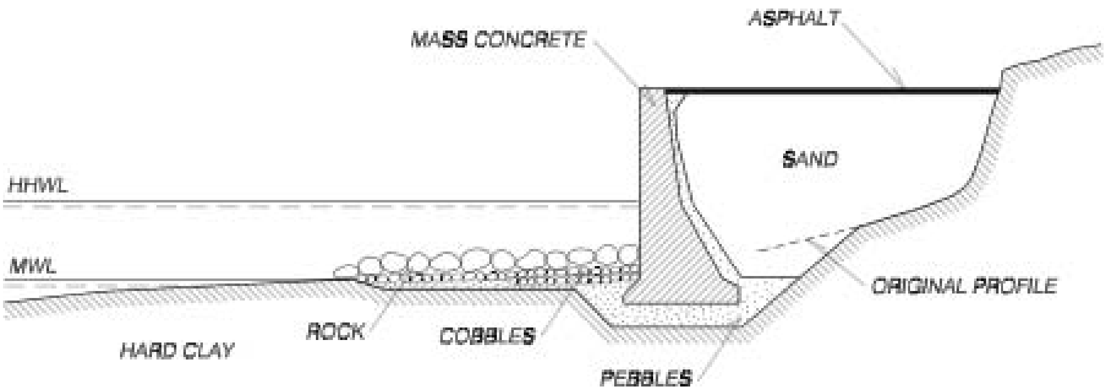
(c) Concrete slabs or pattern placed concrete armour units



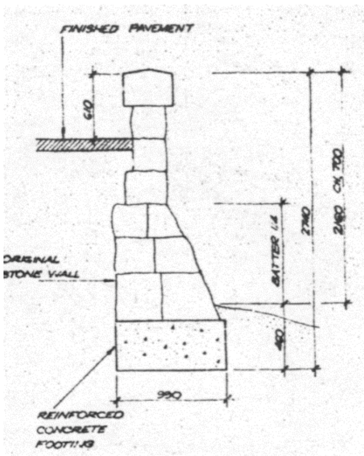
(d) Solid concrete

Figure 20.1: Examples of Sloping Front Seawall Structures [Source: USACE (2003)]

Vertical-front seawalls are usually composed of stone or concrete blocks, reinforced concrete, mass concrete, or steel sheet piles. Such vertical structures can either be built as tied-in, gravity or cantilever walls (see Figure 20.2). Vertical seawalls typically also act as retaining walls to material located behind.



(a) Vertical concrete gravity wall [Source: USACE (2008)]



(b) Vertical stone gravity wall [Source: Bray & Tatham (1992)]

Figure 20.2: Examples of Vertical Seawall Structures

There is a wide range of seawall types, either sloping-front or vertical-front, located within the local government areas of NSW as can be observed on the examples given in Figure 20.3.

(a) Solid Concrete (Mosman Council)

(b) Seabee concrete units (Sutherland Council)

(c) Vertical Sandstone (Pittwater Council)

(d) Concrete stepped face (Manly Council)

Figure 20.3: Examples of Seawall Types

These structures typically have a horizontal surface (or cap) at the crest. In some cases the seawall cap can be wide enough to contain a promenade on top of the structure or provide access to the shore. Many structures involve a combination of materials, e.g. a concrete crest wall on a rock structure, or a vertical seawall with a rock toe.

20.3 Wave/Seawall Interactions

As described in USACE (2003), the main forcing parameters on a seawall can be separated into the hydraulic responses of the waves, and the structural response of the seawall.

20.3.1 Hydraulic Responses

There are three main hydraulic responses which need to be considered for the design of a seawall.

The first is the *wave runup* level, as it determines the design crest level of the seawall in cases where no, or only marginal overtopping is acceptable.

The second is the *wave overtopping*. Wave overtopping occurs when the structure crest height is below the runup level. Overtopping discharge is a particularly important design parameter as it determines the geometric design of the crest level, the structural design of the seawall and the safety of infrastructure, vehicles and people located on/behind the crest.

Finally, *wave reflection* occurs to varying degrees in front of seawalls, depending on the slope and armouring of the seawall. Wave reflection can induce steep waves and create problems for navigation and berthing of boats. This issue is of particular importance for harbour seawalls. Strong wave reflection also increases the sea bed erosion potential in front of protective structures and may contribute to erosion at the seawall toe and of adjacent beaches.

20.3.2 Structure Loading and Structural Responses

When designing a seawall, it is important to accurately assess the various loads and the related stresses, deformations and stability conditions of the different structural parts of the seawall.

For rubble-mound structures, the main loads and structural responses to determine can be summarised as:

- Stability of the armour layer;
- Structural integrity of the individual concrete armour units;
- Toe stability and protection; and
- Design of the cross section.

Due to the complex nature of the flow of waves impacting the armour layer, it is uncommon to calculate wave forces acting on the armour of rubble-mound structures. The common approach is to treat the actual forces as a "black box" transfer function and derive the response of the armour units in terms of movements related directly to parameters of the incident waves.

For vertical-front structures, the main loads and structural responses to determine can be summarised as:

- Wave forces on the vertical wall;
- Wave forces on the concrete cap;
- Stability of the vertical wall and concrete cap against sliding and overturning;
- Uplift forces;
- Settlement of the seawall;
- Pore pressure behind the wall and drainage; and
- Geotechnical stability of the soil profile.

For vertical-front structures, it is possible either from theory or experiments to estimate the wave loadings and subsequently determine stresses, deformations, and stability.

Finally, it is of great importance to assess the foundation loads of seawalls to ensure stability. The main geotechnical aspects to verify when designing a seawall are the assurance of safety against soil failure (slip circle failure) as well as assurance of limited settlement in the foundation soils.

20.4 Failure Modes of Seawalls

The US Corps of Engineers (USACE, 2003), defines the failure of a coastal structure as:

"*Damage that results in structure performance and functionality below the minimum anticipated by design."*

The most common reasons for the failure of a coastal defence structure are (USACE, 2003; CIRIA, 2007):

- Design failure: this occurs when either the structure as a whole, including its foundation, or individual structure components cannot withstand load conditions within the design criteria;
- Load exceedance failure: this results from an underestimation of the design conditions;
- Construction failure: this can be caused by unsuitable construction techniques or poorly suited construction materials; and
- Deterioration failure: this failure is the result of structure deterioration and lack of project maintenance.

In the particular case of rigid seawall structures, the main failure modes can be detailed as:

- Undermining, in which the sand or rubble toe level drops below the footing of the wall, causing the wall to subside and collapse in the hole;
- Sliding, in which the wall topples away from the retained profile;
- Overturning, in which the wall topples over;
- Slip circle failure, in which the entire embankment fails;
- Loss of structural integrity, due to wave impact; and
- Erosion of the backfill, caused by wave overtopping, high water table levels, or leaching through the seawall.

In the case of flexible sloping-front structures, failures are typically the result of wave action or geotechnical factors, such as slope failure, foundation failure, and internal erosion. Toe erosion, slope failure, internal erosion, hydraulic damage and severe overtopping, which can cause erosion of the crest and lee-side damage, are key causes of major damages (CIRIA, 2007).

Following work completed in the UK in the late 1980's and early 1990's, it is documented in CIRIA (1991) that *"around 34% of seawall failures arise directly from erosion of beach or foundation material, and that scour is at least partially responsible for a further 14%".*

Figure 20.4 shows some past examples of seawall failures which were the result from excessive toe erosion ((a) and (b)) or erosion of the backfill material (c).

(a) Damaged gabions, Cronulla seawall, 1986

(b) Dee Why collapsed seawall, 1998

(c) North Steyne collapsed seawall, 1950

Figure 20.4: Examples of Past Seawall Failures

20.5 Coastal Hazards Responsible for Seawall Failures

The failures modes described in the previous section are mainly caused by three types of coastal hazards:

- Erosion of sand in front of the seawall during storm events;
- Wave overtopping (inundation) of the seawall due to elevated water levels and storm wave conditions; and
- Wave impact due to elevated water levels and large wave conditions.

20.5.1 Erosion Hazard

(a) Loss of promenade at Manly, 1950

(b) Beach erosion at Narrabeen, 2011

Figure 20.5: Example of Erosion at Beaches [Source: WRL]

The erosion of sand during storm events can cause the reduction of beach levels fronting the seawall and consequently undermine the foundations of the seawall (see Figure 20.5). This can potentially cause failure of the seawall by exposing the toe of the structure to direct wave impact, or by reducing foundation support. For each seawall section, the likelihood of seawall undermining can be related to the following factors:

- Seawall toe design and toe levels as determined by previous geotechnical investigations or from design drawings (when available);
- Average and minimum levels against the seawall, as determined through analysis of historical profile variations (photogrammetry analysis);
- Storm demand or estimated volume of sand eroded (above mean sea level) during the design extreme erosion event;
- Typical pre-storm volume of sand above mean sea level as determined through analysis of historical profile variations (photogrammetry analysis); and
- Wave conditions and exposure.

20.5.2 Wave Impacts, Overtopping and Inundation Hazard

Wave overtopping of seawalls is caused by direct (and often violent) impact of waves on the structure. Wave impacts can cause damage to the structure, in particular to freestanding parapets and concrete caps. More importantly, the water discharged above the seawall crest constitutes a hazard to not only the structure crest and promenade, but also to people and infrastructure located directly behind the seawall (see Figure 20.6). Overtopping can also cause saturation of the soil profile, increasing pore water pressure and the chance of failure from sliding, overturning, or removal of retained soil.

Overtopping is commonly quantified in terms of volume of water being discharged past the seawall crest and expressed in *L/s* per metre length of crest.

Figure 20.6: (Top) Wave overtopping the Manly to Shelly Beach seawall; (Bottom) Wave runup at Manly LSC boat ramp and Manly beach stairs (Victoria Pde). (Photos: James Carley WRL)

The estimated overtopping rates refer to the zone immediately behind the structure crest and can be related to the published tolerable rates (CEM, 2003; EurOtop, 2007) in regards to structural and people safety. Limits of mean tolerable overtopping rates for seawalls are presented in Table 20.1 (EurOtop, 2007).

Table 20.1: Limits for Tolerable Mean Wave Overtopping Discharges (EurOtop, 2007)

Hazard Type	Mean Overtopping Discharge (L/s per m)
Unaware pedestrian, no clear view of the approaching waves, not prepared to get wet, poor/uneven ground surfaces	0.03
Aware pedestrian, clear view of the sea, able to tolerate getting wet	0.1
Trained staff, well shod and protected, expecting to get wet	1-10
Damage to paved promenade behind seawall	200
Damage to grassed promenade behind seawall	50
Structural damage to seawall crest	200
Structural damage to building	(1) 1

Notes: (1) This limit relates to the effective overtopping defined at the building.

20.6 Potential Impacts of Seawalls

20.6.1 Physical Impacts

Potential physical impacts of seawalls/revetments include:

- Altered erosion and accretion seaward of the wall;
- Altered erosion and accretion either side (alongshore) from the wall;
- Altered longer term recession and progradation alongshore from the wall;
- Propensity to form rips;
- Changes to wave runup; and
- Changes to surfing amenity.

20.6.2 Socio-Economic Impacts

Seawalls/revetments may also have socio-economic impacts.

Positive impacts may include:

- Provision of additional, improved or more secure public recreational space;
- Improved security to landowners; and
- Changes to property values.

Negative impacts may include:

- Loss of recreational beach amenity;
- Erosion and/or recession due to off site (alongshore) impacts of structures; and
- Increased wave runup and overtopping due to smooth/hard structures.

20.7 Physical Impacts of Seawalls

Seawalls (including revetments) are shore parallel structures and have been used extensively within Australia and worldwide to "*prevent landward retreat of the shoreline and inundation or* *loss of the upland by flooding and wave action"* (Kraus and McDougal, 1996). While these structures, if well designed and built, are highly successful in achieving their intended purpose of protecting land from erosion (Pilkey and Dixon, 1996), their effect on other parts of the beach system including the fronting and adjacent beaches is more variable with adverse effects often reported.

The fundamental difference between a seawall and the beach itself is that the latter is mobile and dynamic while the former is static and designed to be unyielding. The interaction between these static and dynamic entities has been the subject of much debate in the engineering, geomorphology and management communities (Pilkey and Wright, 1988; Dean, 1986; Basco, 2004, 2006). While a substantial amount of research has been undertaken investigating the structure-beach interaction and documenting cases of beach response (summarised in Kraus, 1988; Kraus and McDougal, 1996), robust and widely-accepted methods for predicting the magnitude and extents of beach response are not available. This is due in part to the great number of variables which affect such a relationship. These were summarised by (Weggel, 1988; Griggs 1990) and include structural parameters (seawall placement, geometry, length and material), sediment properties (material, supply and rates of transport), hydrodynamic regimes (tidal range, mean, seasonal and extreme wave climate) and antecedent morphology (background rates of long-term and cyclical shoreline change).

Kraus and McDougal (1996) attributed much of the controversy about the potential adverse effects of seawalls on beaches to lack of differentiation between 'passive erosion' and 'active erosion' (Pilkey and Wright, 1988; Griggs et al. 1991, 1994). Passive erosion is defined as being caused by "*tendencies which existed before the wall was in place*" and active erosion as being "*due to the interaction of the wall with local coastal processes*". Of passive erosion, Griggs et al*.* (1994) stated that whenever a seawall is built along a shoreline undergoing long-term net erosion (recession), the shoreline will eventually migrate landward behind the structure resulting in the gradual loss of beach in front of the seawall as the water deepens and the shore face profile migrates landward.

Dean (1986) presented a list of nine possible and often suggested effects of seawalls on adjacent shorelines and beaches (Figure 20.7). He then critically examined these postulations and concluded (Basco, 2004, 2006) the following (bracketed numbers are potential effect from Figure 20.7):

Dean found that armouring of a beach does NOT cause:

- Profile steepening (6);
- Delayed beach recovery after storms (5);
- Increased longshore transport (8);
- Sand transport further offshore (9); and
- Increase in long-term average erosion rate (3).

Dean found that armouring of the beach CAN contribute to:

- Frontal effects (toe scour, depth increases, 1a);
- End-of-wall effects (flanking; 1b);
- Blockage of littoral drift when projecting into surf zone (groyne effect; 4); and
- Reduced beach width fronting armouring (2).

Pilkey and Wright (1988) refuted the conclusion that armouring does not cause an increase in the long-term average erosion (recession) rate (3) and does not delay beach recovery after storms (5) on the grounds that seawalls intensify surf zone processes including rip currents, longshore currents and wave reflection.

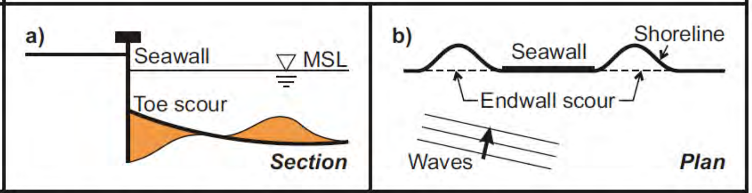
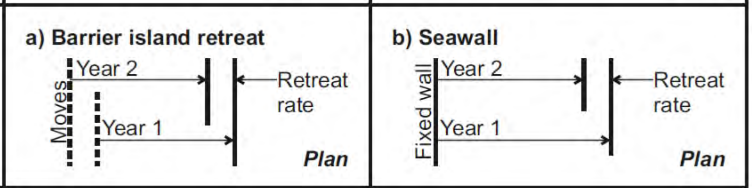
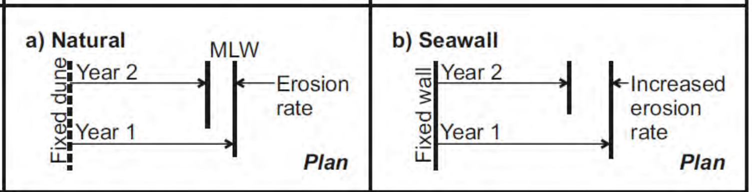
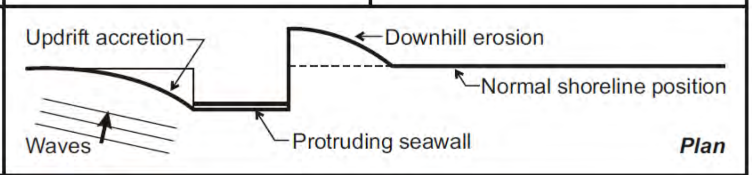
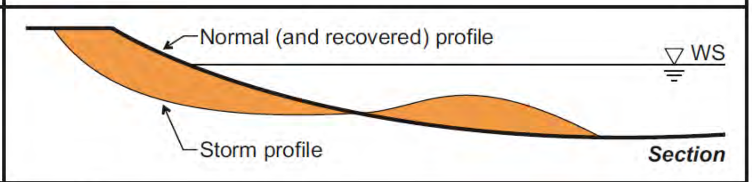
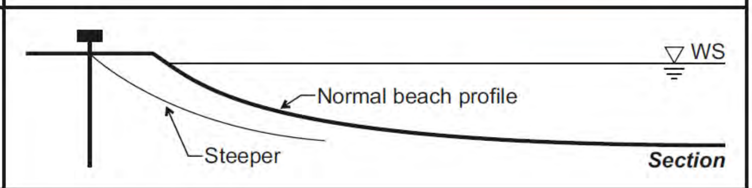
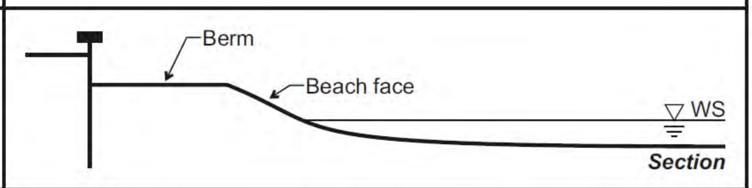
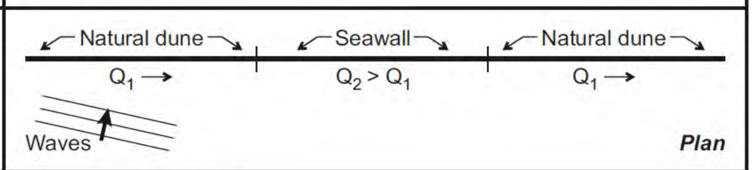
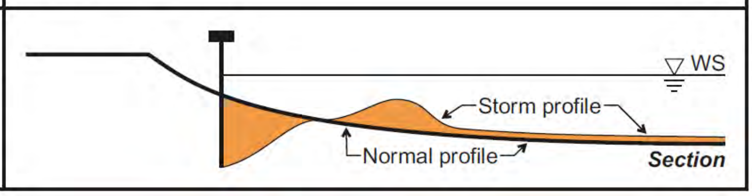
No.	Possible Effect	Sketch
1	Causes local scour a) Toe of seawall b) Endwall effects	
2	Causes beach fronting seawall to diminish in width	
3	Causes acceleration of beach erosion rate	
4	Causes downdrift erosion	
5	Causes delay in post-storm beach recovery	
6	Causes beach profile to steepen	
7	Serves no purpose if located well back on stable beach	
8	Causes increase in longshore sediment transport rate	
9	Causes sand transport substantial distance offshore	

Figure 20.7: Commonly Stated Effects of Seawalls on Adjacent Shorelines and Beaches [Basco, 2004 based on Dean, 1986]

20.8 Mechanisms for Beach Response

Despite the widespread use of seawalls, their interaction with dynamic beach systems are not fully understood and their impacts on fronting and adjacent beaches remain disputed. Several possible mechanisms for beach response have been proposed in the literature (Dean, 1986; Kraus, 1988; Tait and Griggs, 1990; Kraus and McDougal, 1996; Basco, 2004, 2006; CEM, 2006). Such mechanisms either control the sediment supply or influence the hydrodynamic system.

20.8.1 Sand Trapping (impoundment)

Landward entrapment (truncation of active beach)

After seawall construction, sand trapped behind the wall is not available for mobilisation and transport offshore and to adjacent beaches during and after storm events (Basco et al. 1997). This results in excess erosional stress along the front of the structure and on unprotected adjacent beaches (CEM 2006). Dean (1986) proposed the "*approximate principle*" relating the volume of toe scour at a wall to the volume that might be potentially scoured in the absence of that wall. This principle appears to be supported by a number of physical model tests (Barnett and Wang, 1998; Hughes and Fowler, 1990; Miselis, 1994). It should be noted, however, that restrictions in the preservation of similitude between sediment and wave parameters in small to medium-scale physical model tests is difficult and results should be primarily considered qualitative (Kraus and McDougal, 1996) due to scale effects. Basco (2000) and Ozger (1999) proposed that the amount of sediment impounded behind the seawall as a function of the total active cross-shore volume during a storm event (the *wall trap ratio*, WTR) better describes the possible impact of a seawall in terms of changes to the cross-shore sediment budget.

End entrapment (groyne effect)

Where a seawall protrudes seaward of the shoreline, updrift impoundment of wave-driven littoral sediment can result in a deficit (and hence erosion) on the downdrift beach. This was found by Griggs and Tait (1988) on beaches adjacent to seawalls in California and by Toue and Wang (1990) in laboratory studies. This is the classical process response to a groyne, and hence is referred to as the 'groyne effect'. This mechanism is particularly associated with coasts having a net littoral drift regime. However, all coasts are subject to gross littoral drift, which may induce groyne effects to some extent, even on coasts without net littoral drift.

20.8.2 Hydrodynamic Effects

Wave reflection and turbulence at structure ends

The most obvious mechanism for localised end erosion consists of waves reflecting off the ends of a seawall and the associated turbulence eroding the adjacent coast (Tait and Griggs, 1990). Wave refraction and diffraction enhance this process by increasing the amount of energy reaching the structure's end/flank once the localised erosion begins to form an embayment alongshore away from the structure's end.

Rip currents at structure ends

Rip currents have been observed at wall ends along the USA west coast (Plant, 1990; Plant and Griggs, 1992) and in laboratory experiments (McDougal et al. 1987). In general, upper beach erosion is commonly observed landward of such rips resulting in 'rip embayments'. The rip currents associated with seawalls are more likely to be driven by hydrodynamic gradients rather than the topographically/bathymetrically constricted flow (channels) which occur naturally on many oceanic beaches near headlands and reefs (and which have been included in the high energy storm erosion statistics presented by Gordon (1987).

Oblique wave reflection off front of structure
Waves reflecting obliquely off the front of a seawall interact with incident waves to produce localised areas of concentrated wave energy ("*caustics*") which result in adjacent down coast erosion (Silvester and Hsu 1993). Such an effect was captured on video by Shand (2010) at Kapiti Beach on the West Coast of New Zealand where obliquely aligned waves were generated by reflection from a seawall and propagated down the coast.

20.9 Structural Considerations

Structural parameters such as the material, geometry, location and length are variable in each design and can influence beach response. More complete descriptions of seawalls are provided within Thomas and Hall (1992) and USACE (1995; 2003), but are summarised in brief below.

20.9.1 Structure Geometry

The slope of seawalls generally range from vertical to gently sloped at 1V:10H to 20H, although flatter structures are generally avoided due to the larger material volumes required and higher cost. The majority of sloping seawalls constructed worldwide have slopes between 1V:1.5H and 1V:2.5H. The slope of a structure may directly influence energy absorption and reflection with flatter sloped structures generally reflecting less energy. Structures may be of a constant slope, stepped or include recurved upper portions intended to redirect wave energy offshore (Thomas and Hall, 1992).

20.9.2 Materials

Seawalls may be constructed of materials including loose rock or loose concrete armour units, interlocking blocks or units, massive concrete, timber, steel sheet pile, gabion baskets or geotextile containers (USACE, 1995; 2003). Flatter revetments generally use more porous, loose rock or armour units, while steeper seawalls tend to be constructed of less porous concrete, timber or steel units. The porosity of the structure affects the way in which it absorbs or reflects wave energy with less porous structures generally reflecting more wave energy. While conventional paradigms suggest that less reflective structures should induce less erosion of fronting beaches, Griggs et al*.* (1991) found little difference when analysing vertical and sloping, permeable structures in Monterey Bay, California.

20.9.3 Location

The location of the seawall on the beach system influences the extent to which the structure interacts with the active beach system (Weggel, 1988) and its ability to intensify surf zone processes (Pilkey and Wright, 1988). Structures located high up the beach interact with wave and sediment transport processes infrequently and impound a smaller percentage of the total cross-shore sediment budget. In contrast, structures within the everyday active beach zone interact frequently with hydrodynamic and sediment transport processes and impound large volumes of sediment which are thereafter unavailable for normal cross- or long-shore processes. Weggel (1988) presented six classifications of seawall dependent on their location within the active beach system (Figure 20.8, Table 20.1). The intersection of the structure and beach profile may, however, change over time as beach level and position change. This is particularly relevant on long-term receding beaches where a seawall, originally built as a back-stop wall may, in time, move relatively further into the active beach zone, impound relatively more sediment and induce greater beach response.

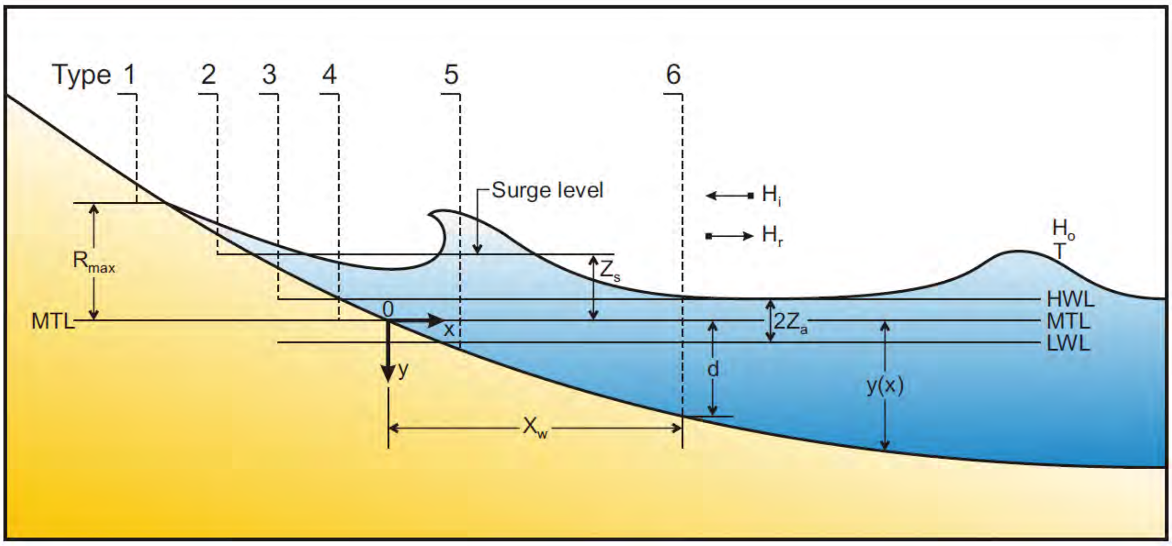


Figure 20.8: Seawall location according to Weggel classification [Source: Weggel (1988)]

Table 20.2: Weggel Seawall Classification [Source: Weggel (1988)]

Type	Location of Seawall
1	Landward of maximum level of run-up during storms. The wall does not affect either hydraulic or sedimentation processes under any wave or water level conditions, although may affect aeolian processes.
2	Above still water level of maximum storm surge and below the level of maximum run-up. Exposed only to the runup of waves during storm events.
3	Above normal high water and below the still water level of storm surge. Base will be submerged during storms and during exceptionally high astronomical tides but will normally be above water.
4	Within the normal tide range; base is submerged at high water.
5	Seaward of mean low water; base is always submerged; subjected to breaking and broken waves.
6	So far seaward that incident waves do not break on or seaward [of the wall].

20.9.4 Structure Length

The alongshore extent of structure affects the total volume of sand impounded, although this is sensitive to the cross-shore location of the seawall as described above. Relationships between the total seawall length and the magnitude and extent of adjacent beach response (end erosion) have been reported within the field by Chiu (1977) and laboratory by McDougal et al. (1987) and Toue and Wang (1990), however, the precise mechanisms of the relationship are still not well understood. Hydrodynamic processes (reflection, refraction and turbulence) are unlikely to be markedly affected by seawall length with effects typically limited to 50 to 150 m from the structure ends (Griggs and Tait, 1989; Griggs et al., 1991; Plant and Griggs, 1992; Dean, 1996; Griggs, 2005). This leaves sediment supply processes as the key parameter relating wall length to end effect distance. Griggs and Tait (1988), and Toue and Wang (1990) found end entrapment could cause a sediment deficit and erosion on downdrift beaches, however, this is dependent on the wall being located seaward of the adjacent coast and acting as a groyne. Brown (2008) suggests that landward entrapment of sediment also causes a reduced sediment input downdrift resulting in additional erosion, however, quantitative studies (Basco, 2000; Ozger, 1999) have focused on the relationship between cross-shore sediment impoundment and scour in front of the wall rather than adjacent.

It is also possible that the relationship between seawall length and end effect distance is associative rather than causative, with longer seawalls likely to be constructed on coastlines experiencing more extensive erosion/recession. Any passive erosion occurring adjacent to such longer seawalls would be similarly expected to be more extensive.

20.10 Field Observations

Griggs (1990); and Griggs et al. (1991; 1994) presented results of seven years of bi-weekly and monthly data from Monterey Bay in California where a number of vertical and sloping seawalls are located. While significant seasonal changes between summer and winter profiles were evident, the beach was found to be in long-term equilibrium, negating passive erosion and enabling the study to focus on the active erosion associated with the seawalls only. The study found that, during an erosion cycle, the berm in front of the seawalls was typically cut back sooner relative to the adjacent control beaches and was lost quickest in front of seawalls located closer to the shoreline. However, no significant difference was noted in front of vertical seawalls and sloping structures of higher permeability. Once this berm was eroded, the authors found no notable difference in the profile fronting the seawall and that of the adjacent beach. Griggs and Tate (1989) found that on the updrift side of seawalls, accretion tended to outweigh any tendency to scour. The authors reported no significant long-term effects or impacts shown from seven years of data. They did report significant flanking effects at one seawall site for an alongshore downdrift distance of 150 m adjacent to a 300 m long seawall, that is 50% of the seawall length.

In contrast to the long-term stable beach at Monterey Bay, Basco (1990) analysed 120 years of field data from Sandbridge, Virginia which was found to be receding at a long-term average rate of 1.1 to 2.9 m/year. Basco (1990) compared recession rates before seawall construction with rates following construction of seawalls over 50 years ago and found that seawalls had not increased the average rate of recession of adjacent beaches. Basco et al. (1992) statistically analysed changes in profile volumes along protected and non-protected shorelines for four years of monitoring data and found that although sediment loss seaward of the wall was higher on walled beaches than non-walled, loss of sediment landward of the wall was, naturally, lower. The total loss on the walled beaches was less than on the non-walled and thus the claim that seawalls have caused higher shoreline recession rates was rejected.

Pilkey and Wright (1988) and Hall and Pilkey (1991) assessed dry beach width (distance between the high water line and onset of stabilisation, dunes or vegetation) along the developed shoreline of New Jersey, North Carolina and South Carolina. They found that beaches with stabilisation structures were statistically narrower than beaches without such structures and that dry beach width decreases with density of stabilisation structure placement. However, details on whether this narrowing is due to passive, ongoing erosion (i.e. the seawall *moves* relatively seaward with adjacent shoreline recession) or due to active erosion induced by the seawall were not presented.

Mossa and Nakashima (1989) compared the shoreline and beach morphology changes and responses to storms from 1985 to 1988 along sections of a rapidly eroding coast at Fourchon, Louisiana USA including monitoring of the effects of Hurricane Gilbert. The study found greater volumetric losses and greater recovery at the seawalled beach than the natural beaches.

Jayappa et al. (2003) used 30 profile lines along eight beaches in Southern Karnataka, India to assess beach response to a variety of coastal structures including groynes, training walls and seawalls. While the authors reported significant shoreline accretion and erosion adjacent to large scale shore-normal breakwaters (groynes), quantifying the effect of adjacent seawalls on beach response is nearly impossible due to the presence of large scale shore-normal structures (groynes), natural rocky outcrops, high rates of net longshore sediment transport and significant (illegal) sand mining. While the authors concluded that seawalls either intensify beach erosion or shift the erosional sites towards adjacent areas, contamination of the data by these numerous other contributing factors renders the statement unsubstantiated.

20.11 Predictive Formula for Beach Response

20.11.1 Frontal Erosion

Dean (1986) proposed the "*approximate principle*" which related the volume of toe scour at a wall to the volume that might be potentially scoured in the absence of that wall. This principle was verified in small and mid-scale physical model testing by Barnett and Wang (1988), Hughes and Fowler (1990) and Miselis (1994) but was not observed in field studies by Griggs *et al.* (1994). Kraus and McDougal (1996) suggested that the approximate principle will not necessarily apply in cases where the profile is in near equilibrium and no demand is made for sand to move out of the profile. Kraus (1988) suggested a general rule that limiting scour depth is a function of the deep water wave height. More recent studies by Sutherland et al. (2007) have combined existing datasets of scour in front of vertical or sloping seawalls (Hughes and Fowler, 1990; Kraus and Smith, 1994; Xie, 1981) with new laboratory experiments (Figure 20.9) to derive equations representing scour depth at the structure toe and maximum across-profile scour depth. Scour depths were found to vary as a function of relative water depth with a maximum toe scour depth on sandy beaches predicted not to exceed a function of the deep water significant wave height in agreement with Kraus (1988). Equations. (20.1) and (20.2) present the derived best fit equation for maximum scour depth as a function of deep water wave height (these are Equations 10 and 11 from Sutherland *et al.* 2007).

$$\frac{S_{max}}{H_s} = \left(35\frac{h_t^*}{L_m+0.40}\right)^2 \qquad \text{(for } h_t^*/L_m \leq 0.016\text{)} \qquad (20.1)$$

$$\frac{S_{max}}{H_s} = \frac{0.036}{\sinh(h_t^*/L_m)^{0.8}} \qquad \text{(for } h_t^*/L_m > 0.016\text{)} \qquad (20.2)$$

Where

S_{max} is the maximum scour depth following laboratory testing of 3000 waves
H_s is the deep water significant wave height
h_t^* is the toe depth including wave setup (prior to any scour)
L_m is the deep water mean wavelength.

It should be noted these expressions are based on values derived in small to medium scale laboratory tests following single storm events from an assumed initial profile and are likely to be subject to scale effects.

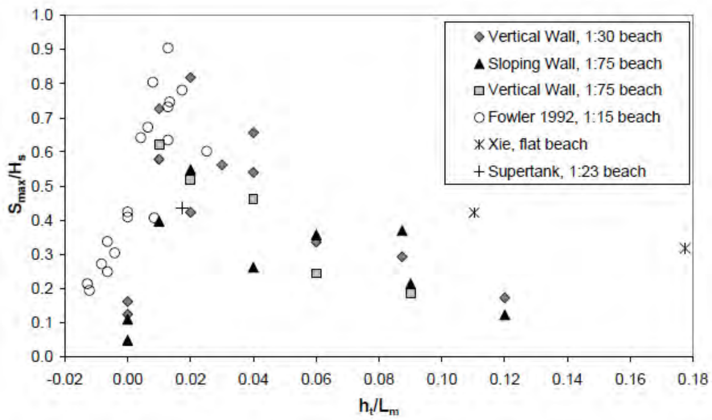


Figure 20.9: Laboratory Measurements of Relative Maximum Scour Depth (Source: Sutherland et al, 2007)

20.11.2 End Erosion

The general concept of end erosion is shown in Figure 20.10 together with a field example Figure 20.11 from the Gold Coast, Queensland after cyclones in 1967. The shape of the observed embayment due to end effects often resembled the *zeta* curve or parabolic bay shape (Silvester et al., 1980).

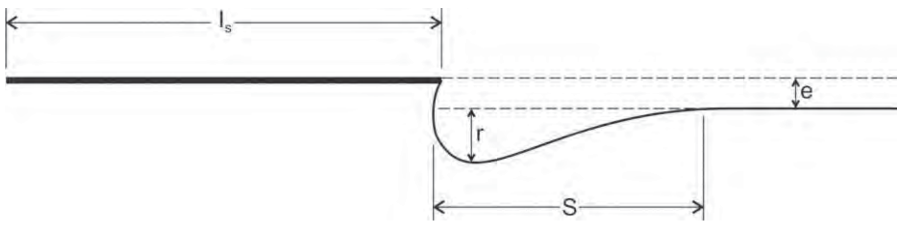


Figure 20.10: Schematic Diagram of Excess Seawall End Erosion, Depth and Length (Source: McDougal et al., 1987)

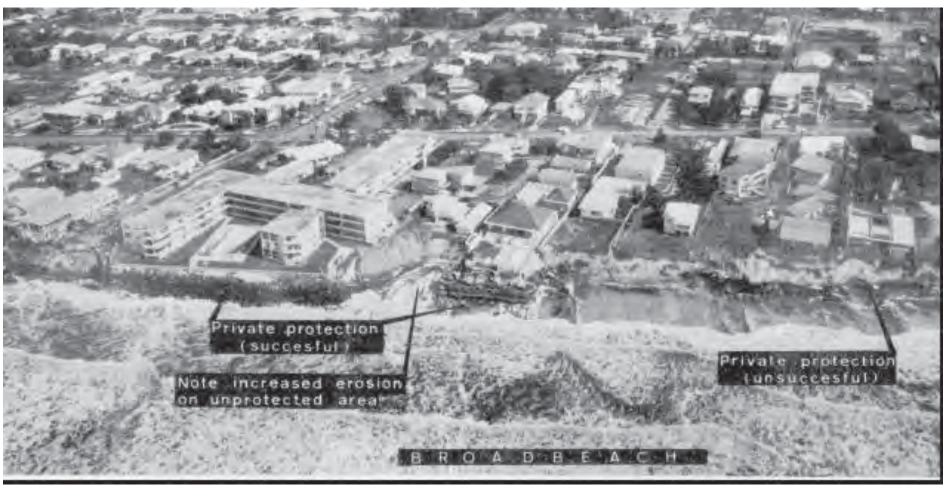


Figure 20.11: Example of Excess Seawall End Erosion – Gold Coast, 1967 (Source: Delft, 1970)

Chiu (1977) presented field data obtained from Walton and Sensabaugh (1978) of the depth of (seawall associated) excess recession observed adjacent to several seawalls on the Gulf Coast of the United States following Hurricane Eloise in 1975. Their values are presented within Figure 20.12 and show that while significant scatter is evident, there is a general relationship of increased localised landward depth of erosion adjacent to the seawall end with increased seawall length. Furthermore, the data tends to asymptote towards a limiting erosion depth indicating that as the length of seawall increases, erosion depth does not also linearly increase. The scatter present in the data was attributed by McDougal et al. (1987) to the multitude of site specific variables including pre-storm beach configuration, elevation of the structure toe, size and source of sediment and the intensity, direction and duration of the storm.

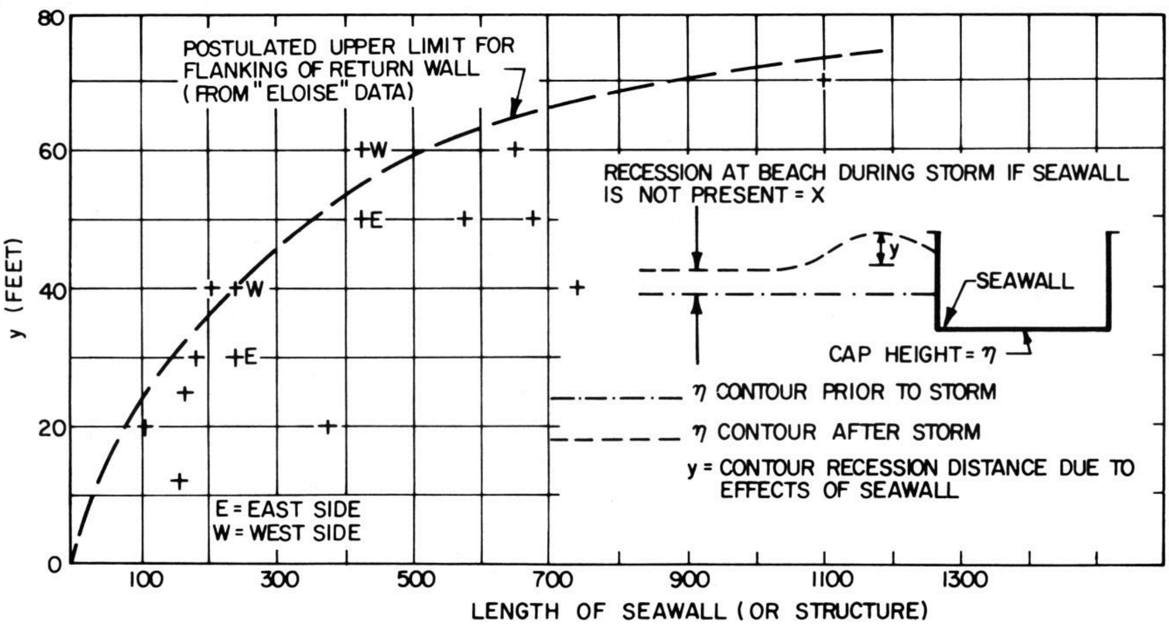


Figure 20.12: Additional Bluff Recession Due to Seawalls Following Hurricane Eloise (Source: Chiu, 1977)

McDougal et al. (1987) undertook subsequent laboratory experimentation in a small scale wave basin facility and observed similar excess erosion at the ends of a seawall placed at or above the still water level. A best fit linear trend line was found to give a correlation coefficient of R = 0.84 (which, for a sample size of 6 is statistically significant to the 95th percentile using a Pearson correlation test) and from this derived the expression,

$$r = 0.101\ L_s \tag{20.3}$$

where r is the excess depth of flanking erosion and L_s is the length of structure. The maximum length of flanking erosion, s was similarly related to seawall length with a best fit linear trend line found giving a correlation coefficient of R = 0.94 and the expression,

$$s = 0.689\ L_s \tag{20.4}$$

From this relationship, depth of erosion, r, can be related to length of erosion, s, as.

$$s = 6.82\ r \tag{20.5}$$

However, as Basco (2004, 2006) pointed out, these relations should be considered qualitatively correct only due to the disparity between the Froude and Reynolds number scales for sand particles in small scale laboratory testing. McDougal et al. (1987) then compared their results with the field results of Chiu (1977), plotting both datasets on the same plot and overlying Equation (5.3). While the line appears in good agreement with all points, the logarithmic axes and clustering of the two datasets essentially provides two points without taking into account the scatter and more non-linear trends observed in the field data particularly. Of note, applying a linear best-fit line to the field data gives a non-statistically significant correlation coefficient of only R = 0.68. McDougal et al. (1987) suggested that instead, the relation derived from the laboratory data should be used, with the field data used for verification. From these expressions and figures, the often-cited 70% rule for the ratio of end effect length to seawall length has arisen and is frequently used in design, planning and litigation. However, this rule fails to adequately account for the asymptotic trends evident in the original field data (Chiu, 1977).

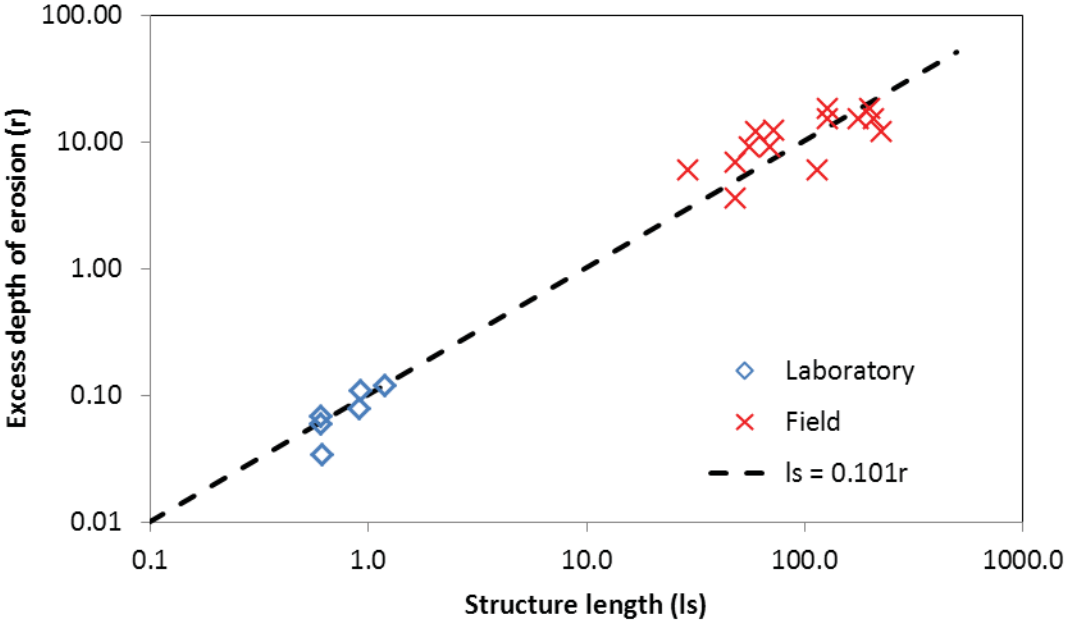


Figure 20.13: Excess Depth of Erosion as a Function of Seawall Length [Source: Basco (2004); Field; Chiu (1977); Laboratory: McDougal et al (1987)]

Shand (2010) quantified seawall end effects for several examples in New Zealand by fitting parabolic curves to embayment plan shape. End effects for a 380 m long structure at Buffalo Beach, Whitianga were found to extend for 150 m. At South Raumati on the Kapiti Coast, a 3 km and a 150 m long seawall were found to exhibit end effects for 200 m and 100 m respectively. End effects adjacent to a 440 m long structure at Marine Parade on the Kapiti Coast were observed to 100 – 150 m, however contamination by factors such as emergency beach replenishment and ad-hoc seawalls resulted in the point being excluded from further assessment.

Shand (2010) reanalysed the field data of Walton and Sensahaugh (1978) and found a non-linear function as originally depicted in Chiu (1977) provided an improved fit. Using the ratio of end embayment depth to length found by McDougal et al. (1987), a revised non-linear model was proposed:

$$s = 6.1 L_s^{0.54} \quad (20.6)$$

Where s is the alongshore length of end erosion embayment and L_s is the length of structure. This result indicates that as seawall length increases, the end-embayment dimensions do not necessarily increase linearly. This revised model was tested against data from the nearby Arawa Street Seawall and against data from Monterey Bay, California (Griggs and Tait, 1989). These comparisons are presented within Table 20.3 and indicate that the model may slightly under-predict the alongshore length of end erosion, particularly for shorter structures but may provide an improved estimate for longer structures where the expression of McDougal *et al.* (1987) clearly over-predicts effects. For very long seawalls such as the 3 km long South Raumati seawall, the revised (non-linear) equation still over-predicted erosion, although not to the same extent as the linear equation.

Table 20.3: Comparison of Observed and Predicted Erosion at Three Seawalls

Source	**Location**	**Length of seawall (m)**	**Erosion length observed (m)**	**Erosion predicted by linear eqn. (5.4) (m)**	**Erosion predicted by non-linear eqn. (5.6) (m)**
Griggs and Tait (1989)	Monterey Bay CA USA	300	150	207 (+38%)	129 (-14%)
Shand (2010)	Buffalo Beach, NZ	380	150	262 (+75%)	151 (+0%)
	South Raumati, Kapiti NZ	3000	200	2067 (+934%)	460 (+130%)
	Arawa Street, Kapiti NZ	150	100	103 (+3%)	89 (-11%)

20.12 Summary of Beach Response to Seawalls

The effect of seawalls on fronting and adjacent beaches remains somewhat unresolved. While a substantial body of research including laboratory studies and intensive field monitoring programs were undertaken in the late 1980s and early 1990s, consensus was not obtained as to whether seawalls actively promote greater erosion than would otherwise occur without the seawall in place. Much of the controversy is attributed to lack of distinguishing between 'sand entrapment', 'passive erosion' and 'active erosion' (Pilkey and Wright, 1988; Griggs et al. 1991, 1994).

- Sand entrapment truncates that portion of the active beach behind (or beside) the seawall, denying that volume to the lower (or adjacent) beach but preserving that part entrapped. A corresponding lowering of the fronting beach in times of storm demand is predicted by Dean's 1986 *approximate principle*.
- Passive erosion is defined as being caused by "tendencies which existed before the wall was in place" and again, a relative seaward movement of the seawall and resultant narrowing of the fronting beach should be expected (Griggs et al., 1994; Pilkey and Wright, 1988). It is analogous to recession as defined in this report.
- Active erosion is defined as being "due to the interaction of the wall with local coastal processes" and is the most controversial. Arguments for active erosion of fronting beaches include '*telescoping*' of surf zone processes and inhibition of storm recovery (Pilkey and Wright, 1988). Field studies on both long-term stable beaches (Griggs et al., 1990; 1991; 1994) and on actively eroding coasts (Basco et al., 1992; 1993) found that while beach

profiles were typically lowered faster in front of seawalls during storm conditions, there were no substantial long-term differences between walled and non-walled beaches which could not be explained by entrapment and passive erosion. Seawall end effects are well recognised due to turbulence and oblique wave reflection (Tait and Griggs, 1990; McDougal et al. 1987; and others).

Exact and universally-accepted methods for predicting the magnitude and extents of beach response are not yet available. Reasons for this include:

- Wide variation in types and placement of structures;
- The paucity of sites where comprehensive monitoring has been undertaken;
- Variation in antecedent beach morphology which precludes deriving predictive expressions which are applicable over all conditions;
- Difficulty in separating erosion (short term) and recession (long term); and
- High noise, natural variability and three dimensional effects in coastal processes.

The '*approximate principle*' of Dean (1986) suggests that the scour fronting the seawall should be equivalent to the amount of sand entrapped behind the structure and Kraus (1988) and Sutherland et al. (2007) suggest that the maximum scour depth is related to the offshore wave height. Laboratory studies of seawall end effects by McDougal et al. (1987) proposed a linear relation between seawall length and the distance and depth of excess end erosion which could be expected following a storm event. These relationships were shown to somewhat over predict the landward extent of erosion and alongshore length caused by longer seawalls in field studies (Griggs et al. 1994; Shand, 2010) and a modification, asymptoting at longer seawall lengths was proposed by Shand (2010).

Seawalls which protrude substantially seaward into the active beach may induce erosion and recession further downdrift, similar to a groyne, headland or river mouth training wall. For most seawalls, where there is not a high rate of passive erosion (recession) on the updrift side, this groyne effect will eventually equilibrate, since sand buildup on the updrift side will bypass the structure.

21. Appendix C: Literature Review of Groynes

21.1 Preamble

WRL undertook a literature review considering two different types of groynes, impermeable and permeable, for potential use within the Byron Bay Embayment. While the use of impermeable groynes in Australia is relatively common, the use of permeable groynes in an Australian context is limited, as is knowledge and understanding of their suitability and performance. During this study, WRL contacted a representative of the NSW Coastal Panel who indicated that in addition to other literature, the Journal of Coastal Research Special Issue No. 33 (2004) should be included in the review. This journal issue, entitled "Functioning and design of coastal groins [sic]: the interaction of groins [sic] and the beach - process and planning", contains 22 articles of relevance to the use of groynes in an international context. Additional literature included in the review was obtained through library literature searches and through citations in the aforementioned journal publication.

21.2 Overview

Groynes are one of the oldest and most regularly used structures for beach stabilisation (Aminti et al, 2004). They are found along coastlines worldwide as both engineered and non-engineered, ad-hoc, structures. The objective of groynes, often deployed in series (field), is to stabilise a beach where a net longshore loss of sand causes erosion/recession (Galgano, 2004). In modern coastal engineering practice groynes are regularly combined with sand nourishment (Kraus and Rankin, 2004), reducing the downdrift impacts of the sand entrapment. Groynes are most effective where the longshore transport has a predominant direction (Kraus et al, 1994 and Galgano, 2004).

It is important to note that groynes essentially offer no reduction in wave energy from large, shore-normal waves experienced during storms. Consequently, cross-shore sediment transport processes during storms are essentially the same regardless of the presence of groynes (Basco and Pope, 2004). Groynes do not directly protect the beach, but provide assistance to developing a stable shoreline and sand buffer. Due to this, it is likely that there is more sand within the system of the groyne field than prior to groyne construction and thus protection is provided in the form of this sand buffer.

It has been reported (Elsayed and Mahmoud, 2007) that a fisherman made the first known discovery of the influence of groynes in the 1600s where after discovering sediment accumulation at his jetty, he built groynes at nearby locations to retain additional sediment. A further example of observations of the "groyne like" entrapment of littoral material is the temporary reprieve of the lighthouse at Cape Henlopen, Delaware, USA. In 1883, the lighthouse was in imminent danger of collapsing into the ocean. In March of that year, a large storm caused a sailing ship to run aground just north of the lighthouse (Bascom, 1980). The wreck trapped sand, extending the life of the lighthouse into the early part of the next century. The lighthouse remained in place until 1926. Recognition of interactions such as these has been linked to the evolution of the modern day groyne (Galgano, 2004).

Kraus et al (1994) defined groynes as *"shore-perpendicular structures emplaced for the purpose of either (1) maintaining the beach behind them, or (2) controlling the amount of sand moving alongshore".* The Coastal Engineering Manual (USACE, 2006) outlined that groynes "*are built to stabilize [sic] a stretch of natural or artificially nourished beach against erosion that is due primarily to a net longshore loss of beach material*". Previous definitions of the purpose of groynes have included accumulating or trapping sand (SPM, 1984), implying the removal of sand from the littoral system by entrapment. However, modern coastal engineering practice requires a regional perspective. Subsequently it is necessary to consider the stability of the beaches adjacent to the groynes and the coastal zone as a whole. A successful groyne system will have a sediment budget in which the rate of natural sand supply, plus any beach fill, less the rate of sand loss from the project area, equals the erosion of sand. Thus, a stable shoreline position will be maintained (USACE, 2006). The combination of beach nourishment and groynes allows sand to immediately begin to bypass the groyne field system.

The functioning of groynes depends on a variety of hydraulic, morphodynamic and morphological factors. The nearshore processes at groynes are subject to not only highly complex temporal and spatial changes, but also the processes and groynes are interdependent. Trampenau et al (2004) suggested that groynes are among the most difficult research topics in coastal engineering and that in 2004 the state of knowledge was still not sufficient to provide a full description of the functioning of groynes and of the associated processes. *"While most of the nearshore processes at sandy coasts are qualitatively well understood, their interaction with groynes is still very controversial"* (Trampenau et al, 2004).

Groynes exist in a range of shapes and sizes, with varying levels of functional success. They differ due to many factors, including the materials with which they have been built, orientation to the shoreline, "type" of groyne and factors such as length, width and height. This being said, groynes can generally be classified into two main types: traditional, impermeable groynes and permeable groynes.

Traditional impermeable groynes tend to block the nearshore current, interrupting the longshore sediment transport over the entire groyne length (Trampenau et al, 2004). Traditional rock groynes are classed as impermeable, although they are permeable to some extent. This permeability tends to be because of leakage rather than intention. Rubble mound (rock) groynes are likely to become less permeable through time as sand and silt block the voids in the groynes (Raudkivi, 1996), although in other cases, a previously impermeable core can leach (wash out) increasing permeability. Permeable groynes are groynes that have been created with purposeful and continued permeability. Permeable groynes act differently to traditional groynes as they do not directly catch and trap sand. Instead, permeable groynes work by slowing the longshore current and decreasing the capacity of the current to transport sand (Poff et al, 2004). If the wave energy and longshore transport is great enough, erosional trends are likely to persist over the effects of the groyne field (Poff et al, 2004). Permeable groynes come in many different forms, with the most common being permeable pile groynes.

There are numerous examples of groynes that have fulfilled their purpose and many others which have not been successful. Indeed, some have intensified the problems they were intended to solve (Balsillie and Berg, 1972). Problems associated with traditional groyne design, (generally over performance and downdrift affects), have led to shortening, lowering or notching of existing groynes to allow for sediment bypass (Aminti et al, 2004). Groyne notching, the purposeful lowering of a portion of the structure to promote controlled movement of sand alongshore, has been implemented at locations in the United States, for example, along the New Jersey coast (Wang and Kraus, 2004). Notching increases the permeability of the structure, subsequently increasing longshore sand transport through the structure, while maintaining some of the sand retention properties of the groynes. It is typically more economical than shortening existing structures (Wang and Kraus, 2004). Details regarding notched groynes are not included in Section 14.4 as this is used to retro-fit and improve poorly performing systems and generally would not be considered an option for the creation of new groynes. Aspects relating to groyne implementation and management, including monitoring, are discussed in Section 14.5.

21.3 Impermeable Groyne Design

21.3.1 General

Traditionally, groynes were straight, impermeable structures, built perpendicular to the shoreline. Groyne design has now evolved and there are a range of different groyne orientations used (USACE, 2006) and different levels of permeability. Furthermore, a variety of different groyne construction methods and materials exist.

Groynes around the world's coastline have been developed to varying standards. Some have progressed through a detailed engineering design process while others have been simply placed as "ad-hoc", un-engineered structures. A well-designed groyne system, with associated beach nourishment, will allow sand bypassing at nearly pre-groyne conditions, thus reducing downdrift erosion/recession (Galgano, 2004). Nonetheless, groyne projects have experienced varied success. Trampenau et al (2004) suggested that a fundamental deficiency of groyne design practice existed in the early to mid-20th century with subsequent groyne failures. During that time, the design process included the belief that groynes provided a universal solution for coastal protection, which could be applied with similar success to any coastline.

In the past, groyne design has somewhat resembled trial and error, with varying levels of success. Advances in numerical computer simulation, such as the development of the shoreline evolution model GENESIS (Hanson and Kraus, 1989) in recent years, can be used to approximate performance and shoreline behaviour in response to discrete groyne design characteristics. Comprehensive explanations of groyne design were provided by SPM (1984), Fleming (1990), USACE (1992), Kraus et al (1994), USACE (2006) and CIRIA (2007), in addition to the many groyne design articles included in the aforementioned Journal of Coastal Research, Special Issue No. 33 (2004).

Balsillie and Berg (1972) highlighted three basic categories forming the basis for groyne design:

1. Littoral processes (e.g. wind and wave data, beach slope, sediment type);
2. Functional design (e.g. length, height, spacing); and
3. Structural design (e.g. material types, construction procedures).

The key considerations of the groyne design process, pertinent to impermeable groynes, are discussed in the following sections with these three categories each forming a sub-section.

21.3.2 Littoral Processes

The successful design of a groyne, or series of groynes, requires an understanding of the local sediment budget and longshore transport conditions (Galgano, 2004). Groyne fields change the sediment budget of a beach. These changes are temporary or permanent depending on the design of the system, and the physical characteristics of the project site (USACE, 2006). Clearly, an important prerequisite to the effective functional design of any shoreline protection structure is an understanding of the littoral processes at work. Figure 21.1 provides a summary of the environmental factors controlling littoral processes and beach configuration.

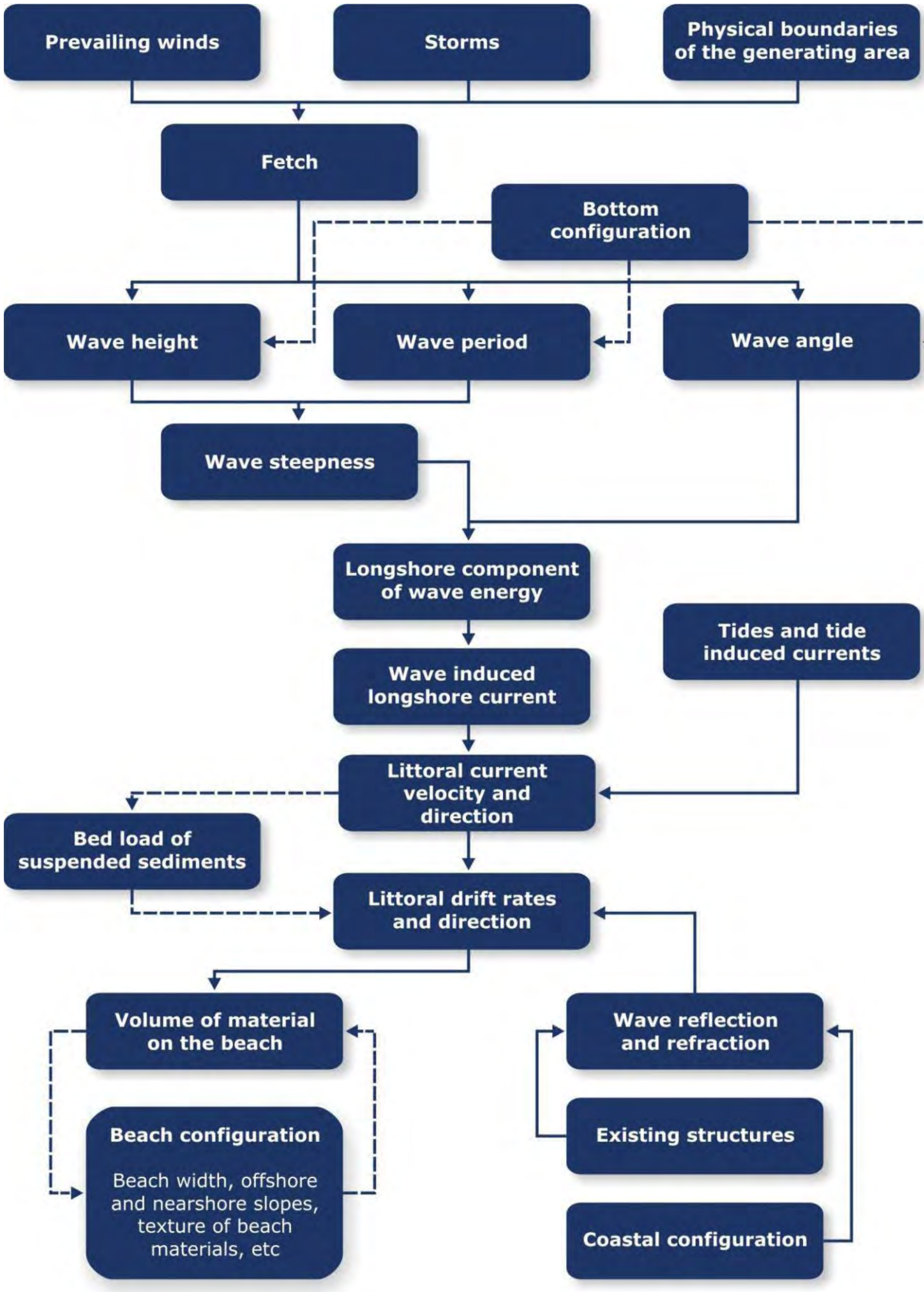


Figure 21.1: Environmental Factors which Affect Shorelines (after Balsillie and Berg, 1972)

Balsillie and Berg (1972) highlighted that these littoral processes must be comprehensively understood when undertaking the functional design of groynes. It is suggested that too often such knowledge is deficient, or totally lacking, and the effectiveness of the resulting groyne(s) is a matter of chance (Balsillie and Berg, 1972).

Furthermore, coastal engineers and managers must realise that all beaches are different and have unique combinations of processes. No standard design solutions exist; what works well on one beach can potentially lead to a catastrophe on another (Balsillie and Berg, 1972). As previously mentioned, a successful groyne system design will have a sediment budget in which the rate of natural sand supply, plus any beach fill, less the rate of sand loss from the project area, equals the erosion of sand, subsequently maintaining a stable shoreline position (USACE, 2006). When considering the littoral processes and designing the groyne system it is also important to design the beach nourishment required. Two key design parameters required to forecast the plan area and length of a groyne-retained beach are:

1. The distance the shoreline will advance adjacent to the structure (fillet width), and
2. The orientation of the structure-retained shoreline with respect to the pre-project shoreline (fillet angle) (Everts and Eldon, 2004).

Everts and Eldon (2004) provided a detailed method with which to calculate fillet width and angle.

21.3.3 Functional Groyne Design

As highlighted in Section 14.3.2, each location presents the coastal engineer with a unique set of physical characteristics to be understood. Processes such as tides, wave characteristics, and longshore currents (Figure 21.1) make successful functional design of a groyne system a difficult task.

Functional design refers to determining whether groynes can provide an acceptable solution to a beach erosion control problem (USACE, 1992). While groynes can be described simply, functional design characteristics are often complicated and can be significant because the effect of groynes can extend a considerable distance both up and down coast (Galgano, 2004).

Kraus et al (1994) outlined a range of functional properties attributed to groynes, providing a critical evaluation outlined in Table 21.1. These properties should be acknowledged and understood prior to groyne design.

Table 21.1: Functional Properties Attributed to Groynes and Critical Evaluation (after Kraus et al, 1994)

Property	Comment
1. Wave angle and wave height are leading parameters (longshore transport).	Accepted. For fixed groyne length, these parameters determine bypassing and the net and gross longshore transport rates.
2. Groyne length is a leading parameter for single groynes (length controls depth at tip of groyne).	Accepted, with groyne length defined relative to surfzone width.
3. Groyne length to spacing ratio is a leading parameter for groyne fields.	Accepted. See previous item.
4. Groynes should be permeable.	Accepted. Permeable groynes allow water and sand to move alongshore, and reduce rip current formation and cell circulation.
5. Groynes function best on beaches with a pre-dominant longshore transport direction.	Accepted. Groynes act as rectifiers of transport. As the ratio of gross to net transport increases, the retention functioning decreases.
6. The updrift shoreline at a groyne seldom reaches the seaward end of the groyne.	Accepted. Because of sand bypassing, groyne permeability, and reversals in transport, the updrift shoreline cannot reach the end of a groyne by longshore transport processes alone. Onshore transport is required for the shoreline to reach a groyne tip, for a groyne to be buried, or for a groyne compartment to fill naturally.
7. Groyne fields should be nourished (and/or feeder beaches emplaced on the downdrift side).	Accepted. Nourishment promotes bypassing and mitigates downdrift erosion.
8. Groyne fields should be tapered if located adjacent to an unprotected beach.	Accepted. Tapering decreases the impoundment and acts as a transition from regions of erosion to regions of stability.
9. Groyne fields should be built from the downdrift to updrift direction.	Accepted, but with the caution that the construction schedule should be coordinated with expected changes in seasonal drift direction.
10. Groynes cause impoundment to the farthest point of the updrift beach and erosion to the farthest point of the downdrift beach.	Accepted. Nourishing a groyne field does not guarantee 100% sand bypassing. Sand will be impounded along the entire updrift reach, causing erosion downdrift of the groyne(s).
11. Groynes erode the offshore profile.	Questionable and doubtful. No clear physical mechanism has been proposed.
12. Groynes erode the beach by rip-current jetting of sand far offshore.(1)	Questionable. Short groynes cannot jet material far offshore, and permeable groynes reduce the rip-current effect. However, long impermeable jetties might produce large rips and jet material beyond the average surfzone width.
13. For beaches with a large predominant wave direction, groynes should be oriented perpendicular to the breaking wave crests.	Tentatively accepted. Oblique orientation may reduce rip current generation.

Notes:

(1) In WRL's experience, the groyne's action as a littoral drift barrier exceeds the ability of rips to transport sediment seaward.

Basco and Pope (2004) summarised ten modern rules for groyne design (Table 21.2), including rule "0", to emphasise groynes are only useful where longshore sediment transport processes dominate. Furthermore, groynes are more likely to be successful if:

1. Agreement on the minimum, dry beach width, Y_{min} is reached;
2. Numerical beach simulation models such as GENESIS and SBEACH are employed to study their design; and
3. A field monitoring effort is established to measure performance and adjacent beach impacts (Basco and Pope, 2004).

Table 21.2: Basic Rules for Functional Design of Groynes (after Basco and Pope, 2004)

Rule	Description
0	If cross-shore sediment transport processes are dominant, consider nearshore breakwater systems first.
1	Conservation of mass for transport of sediment alongshore and cross-shore means groynes neither create nor destroy sediment.
2	To avoid erosion of adjacent beaches, always include a beach fill in the design.
3	Agree on the minimum, dry beach width, Y_{min}, for upland protection during storm events as a measure to judge success.
4	Begin with X_g/Y_g = 2-3, where X_g is the long shore spacing and Y_g is the effective length of the groyne from its seaward tip to the design shoreline for beach fill at time of construction.
5	Use a modern, numerical simulation model (e.g. GENESIS) to estimate shoreline change around single groynes and groyne fields.
6	Use a cross-shore, sediment transport model (e.g. SBEACH) to estimate the minimum, dry beach width, Y_{min} during storm events.
7	Bypassing, structure permeability and the balance between net and gross longshore transport rates are the three key factors in the functional design. Use the model simulation to iterate a final design to meet the, Y_{min} criterion.
8	Consider tapered ends, alternate planforms, and cross-sections to minimize impacts on adjacent beaches.
9	Establish a field monitoring effort to determine if the project is successful and to identify adjacent beach impacts.
10	Establish a "trigger" mechanism for decisions to provide modification (or removal) if adjacent beach impacts found not acceptable.

Seven criteria regularly considered for functional groyne design are: length, height, spacing, permeability, orientation, siting and sediment budget. Of these, groyne length, height, and permeability often appear in the literature as the most important parameters affecting groyne design, and subsequent beach configuration (Galgano, 2004). Balsillie and Berg (1972) tabulated studies that considered these three important parameters, as well as groyne orientation, to provide an overview of the published findings and recommendations regarding groyne length, height, permeability and orientation to date. It is generally accepted that no two beaches are the same, and consequently, there does not exist a single design criteria that is universally applicable to groyne design (Dong, 2004).

The following sub-sections discuss the key groyne design characteristics, as displayed in Figure 21.2 and Figure 21.3, to consider when designing groyne fields.

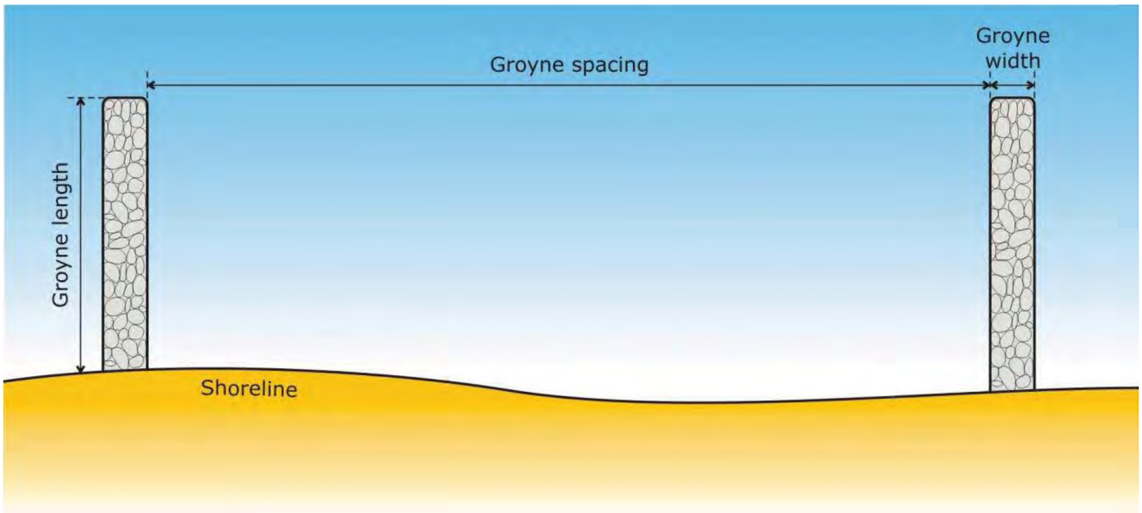


Figure 21.2: Functional Groyne Design – Plan View

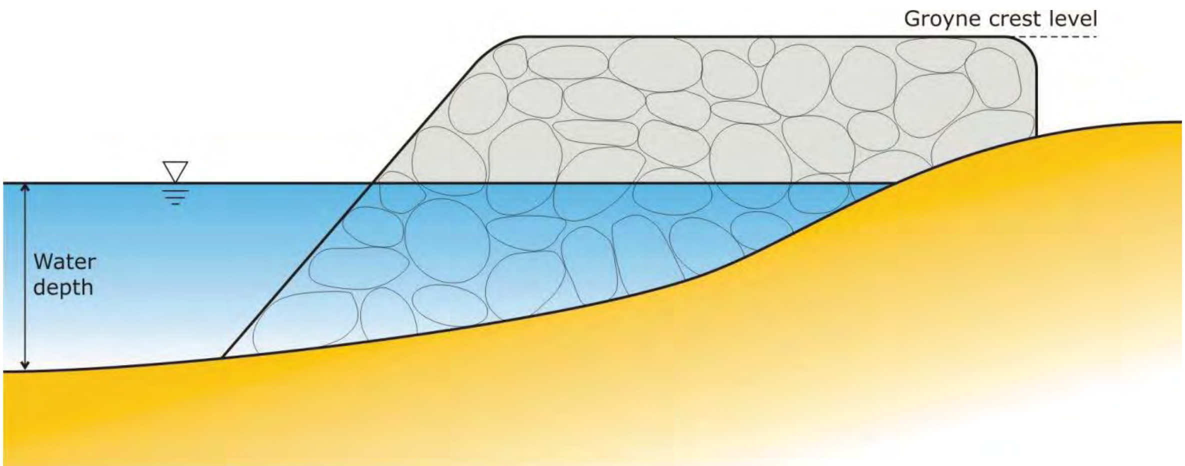


Figure 21.3: Functional Groyne Design – Side View

Effective Groyne Length (Y_g)

Regularly groynes are categorised according to their length: long or short. The definition of the length of a groyne is a relative term, typically linked to the width of the surf zone. The effective groyne length is taken from the seaward tip of the groyne to the design shoreline for beach nourishment at the time of construction. Most groynes are designed to act as short structures during severe sea states and as long structures under normal conditions (USACE, 2006).

Generally the literature has not clearly identified between long and short groyne types (Balsillie and Berg, 1972). The shoreward position of the groyne is defined by beach contours and is often taken as the high water mark (CIRIA, 2007). It is important to consider if the beach is to be extended using artificial beach nourishment and that subsequently, the shoreline position might change.

As expected, long groynes extend further into the littoral zone, generally impounding larger volumes of sand than short groynes. The literature includes several attempts to define the difference between long and short groynes, mostly concentrating on classifying the minimum length of a “long” groyne. Balsillie and Berg (1972) correlated long groynes with the distance from the shoreline to the average break point of storm and fair weather waves, whereas Omholt (1974) defined long groynes in terms of littoral drift. Using Omholt’s definition, a long groyne is one that impounds 80% or more of the littoral drift. The Coastal Engineering Manual (USACE, 2006) defined a long groyne to be one traversing the entire surf zone. However, variations in wave energy and sediment supply at various locations make these limited definitions at best. Long groynes are not recommended unless it is necessary to prevent the downdrift movement of sand, such as the last groyne updrift of a sediment sink (USACE, 1992 and SPM, 1984). Short groynes are said to be best in conditions where it is necessary to maintain the downdrift sand supply (SPM, 1984 and (Galgano, 2004).

The length of each groyne is governed by:

- The volume of littoral drift estimated to bypass the groyne head; and
- The post-nourishment cross-shore bathymetry profile below mean sea level.

The consideration of littoral drift bypassing involves a trade-off between the construction cost of extra groyne length and the maintenance requirements of period renourishment. The frequently cited design principle recommendation (originally from Nagai, 1956 and, Nagai and Kubo, 1958) that groynes should extend 40% to 60% into the predominant plunger line, is based on the goal of prevention of scour downdrift of the groynes through extensive littoral drift bypassing. However, if groynes are too short there is an increased risk of catastrophic (or apparent) failure of the nourished beach under storm conditions due to the combination of storm cut and bypassing.

Groyne Spacing (X_g)

Groyne spacing refers to the distance between the groynes in a groyne field. Spacing is generally defined as a ratio of groyne length to the distance apart (Galgano, 2004). Kraus et al (1994) suggested that groynes on sandy beaches perform best if their spacing is two to four times the groyne length. Fleming (1993) cited the results of a survey of groyne installations in the UK. The ratio of groyne spacing to length was found to vary between 0.8 and 2.7, though it should be noted that (wave reflecting) timber groynes were the favoured construction method in the UK in 1993. These criteria have been developed for groynes which allow bypassing of littoral drift. These spacing rules are, thus, engineering “rules of thumb”.

The Shore Protection Manual (1984) recommended a spacing ratio of between two and three, while the Coastal Engineering Manual (USACE, 2006) endorsed a groyne spacing to length ratio of two to four.

Silvester (1992) presented a graphical procedure for estimating the ratio of groyne spacing to length. The ratio is a function of the incident wave angle and varies from two to fourteen. However, no field or laboratory data was cited to support this method.

Literature regarding permeable groynes suggests a closer spacing would be better for these groyne systems.

Groyne Height (G_h)

Groynes can be also classified as “high” or “low”. This measurement usually depends on the height of the groyne crest relative to the normal beach berm level (USACE, 1992). High groynes generally have crest elevations above the high-tide level and the normal wave run-up on the beach. These groynes trap more sand than lower groynes, as little wave energy and sediment is transported over the groyne. Subsequently, high groynes are generally linked to cases of accelerated downdrift erosion/recession (Galgano, 2004). Low groynes, with crest elevations below the high-tide level, permit some littoral materials to pass over at high tide, reducing downdrift erosion/recession. Galgano (2004) suggested that high groynes are generally not recommended unless it is necessary to prevent the continued supply of sand downdrift. However, as with long groynes, they may be desirable at the end of a groyne field in some circumstances.

21.3.4 Structural Design Considerations

Impermeable groynes can be built with a range of materials. Rubble mound groynes are the most common at exposed sites because of a rubble mound structure's ability to withstand severe wave loads and to decrease wave reflection (USACE, 2006). Other materials for construction of groynes include concrete, steel pilings, timber and rubble (SPM, 1984). Galgano (2004) alluded that less conventional materials, such as tyres and scrap metal, have also been used. The Coastal Engineering Manual stated that additional construction materials and methods used for impermeable groynes in the United States include; sheet-pile construction with timber, timber-steel, prestressed-concrete or cellular-steel (filled) sheets (USACE, 2006). The Coastal Engineering Manual (USACE, 2006) suggested that timber groynes are used for smaller and less exposed applications, whereas rubble mound groynes can be used for all conditions. It is highlighted that on very exposed coastlines, the armour required is often concrete armour units.

Furthermore, in recent years the use of sand-filled geotextile containers for coastal engineering construction, including groynes, has increased. Carley et al (2011) reported on geotextile container groyne stability for both physical model testing and during Tropical Cyclone Yasi in northern Queensland in 2011. In practice, structural design of groynes and construction material selection, are dictated by two factors; wave energy and cost (SPM, 1984).

Structural design of a groyne is somewhat easier than the functional design processes, as the variables are better defined. The engineer is generally in more familiar territory for structural groyne design, as structural and fluid mechanics dictate the design process (Nordstrom et al, 1979). This being said, many groynes still fail as they cannot withstand the wave energy and currents onsite (Dick and Dalrymple, 1983). The structural design of a typical groyne must account for wave and current forces, as well as forces exerted by both sediment loading and wave-carried debris (USACE, 1992).

Waves can generally be considered the key factor of groyne stability design. It is important that the coastal engineer quantifies the potential magnitude of wave energy at the site in question, as part of the wave energy is exerted against the structure itself. Unless the groyne is strong enough to resist successive breaking waves in both normal and storm conditions, it is unlikely that it will survive for its entire design life without costly reconstruction (Balsillie and Berg, 1972 and Dick and Dalrymple, 1983). CIRIA (2007) provided information about the stability of rock for both breakwaters and groynes. Rubble mound groynes may be considered the "simplest" to design due to prior experience with the material. Kana et al (2004) suggested that the stability of rubble mound groynes can be improved by grouting the voids without greatly increasing the section volumes, especially for existing structures that contain inadequate rock sizes. However, this will decrease the permeability of the structure.

Gómez-Pina (2004) highlighted that during the structural design phase special care should be paid to aesthetic aspects of groyne design. In Spain, many beach nourishment projects have incorporated the re-designing of the existing coastal groynes in order to enhance the aesthetic of the whole project (Gómez-Pina, 2004). This had an immediate positive appreciation by local beach users and summer visitors, increasing the social and economic value associated with the beach restoration project. Coastal groyne projects fulfilling the usual functional design aspects may not be successful within the community if the aesthetics are not well integrated in the whole project.

For aesthetics, coastal groynes should have the minimum visual intrusion on the beach landscape when considering crest width and height. Gómez-Pina (2004) recommended that crest heights be in the range of 0.5 to 1.0 metre above the subaerial part of the nourished profile. Coastal groyne crest widths should be kept at the minimum dimensions compatible with constructive processes. Gómez-Pina (2004) highlighted that minimising crest dimensions is not always an easy constructive task. However, the effort in enhancing the aesthetic values in the design of the particular groynes in Spain has been intangibly rewarded by social acceptance.

21.4 Permeable Groynes

21.4.1 General

As mentioned previously, permeable groynes are those that have been designed specifically to be permeable, allowing water and sediment to pass through them. Permeable groynes slow the longshore current in their vicinity, decreasing the capacity of the current to transport sediment. Subsequently, previously suspended sediment is deposited in the vicinity of each groyne, shifting the shoreline seaward. Permeable groynes may provide stabilisation to the beach in the adjacent areas, resulting in a more uniform shoreline when compared with the typical saw-tooth pattern associated with impermeable groynes. They may also reduce or eliminate the downdrift erosion/recession associated with traditional groyne design. It has been shown that with careful design, permeable groynes can have many beneficial qualities for protecting shorelines in certain conditions (Poff et al, 2004).

A range of styles and operational modes of permeable groynes exist. Some permeable groynes consist of piles or metal sheeting driven into the sand at spaced intervals while others have more complicated designs with interior holes providing their permeability (Poff et al, 2004). Two types observed by Poff et al (2004) include pile cluster groynes and slotted groynes. A pile cluster groyne traditionally consists of high-relief single or multiple pile rows driven into the seabed. A slotted timber groyne consists of low-relief wood piles and/or planks driven into the seabed connected by beams (Poff et al, 2004). Permeable groynes are typically of wooden composition. Balsillie and Berg (1972) highlighted that permeable groynes should not be used as individual units isolated along the beach but combined in a system (field).

For permeable groynes, particularly pile groynes, it is important to note that the permeability is often not constant along the entire length of the groyne. Depending on the spacing between individual piles, which may be varied along the row, the groyne is either permeable, impermeable or a combination of the two (Trampenau et al, 2004).

The basic mechanism is that pile groynes act as a roughness (resistance) to shore-parallel flow, but do not block it as impermeable groynes do. Consequently, the seaward shift of the current profile is reduced and the increase of velocities past the groyne field is smaller than with impermeable groynes (Raudkivi, 1996).

Galgano (2004) suggested that there are no quantitative guidelines for determining permeability based on a given design geometry and wave regime (Omholt, 1974; Everts, 1979; SPM, 1984 and USACE, 1992) and did not discuss permeable pile groynes. It is suggested there have been numerous structural problems preventing the successful operation of permeable groynes and many designs have rapidly succumbed to high wave energy during storms (SPM, 1984). CERC (1981) suggested that low, impermeable groynes are preferable (over permeable groynes) when controlled bypassing is desired, due to these problems.

The major benefits of permeable groynes are; low construction and maintenance costs, reduction in both tidal and wave induced currents, decrease in longshore sediment transport, a more uniform shoreline, decreased intensity of seaward currents along the updrift side of the structure, and a reduction in erosion/recession on the downdrift side of the groyne (Bakker et al, 1984 and Raudkivi, 1996). In particularly, permeable pile groynes are also a very flexible design, especially when compared with rock groynes. Piles can be added, lifted or removed, and in the case of very heavy erosion, there is the potential to add stone berms at a later stage (Bakker et al, 1984).

It has been suggested in the literature that permeable pile groynes are much cheaper than impermeable, rubble mound groynes (e.g. Bakker et al, 1984 and Trampenau et al, 2004). However, it is important to consider if a structure is suitable for implementation on site. If the structure cannot be designed to be stable for a large storm event, or series of events, then savings in initial costs are irrelevant if the structure is destroyed.

Trampenau et al (2004) suggested considerable advantages to permeable pile groynes:

1. Because of the permeability of the groynes, a considerable portion of the longshore current, and thereby the longshore littoral transport, is allowed to pass. The balance between the distribution of suspended sediment concentration and the eroding forces downdrift of the groynes can be greatly improved.
2. As a result of the longshore current in the groyne field, circulation cells and rip currents may be substantially diminished.
3. Water level differences, and thereby gravity currents, will possibly be reduced.
4. The increase of the current velocity seaward of the head of the groynes is expected to be much lower than in the case of impermeable pile groynes.
5. Scour development along the trunk and at the head of the groynes can be considerably diminished.
6. Reflection and diffraction effects at permeable groynes can be greatly reduced.
7. As a result of the more favourable flow patterns, the underwater profile may be built up causing waves to break further seaward. Due to of the earlier breaking, the maximum of energy dissipation is shifted further seaward.
8. A typical linear shape of the shoreline is generally expected to occur for permeable groynes while unfavourable large-scale downdrift erosion is commonly associated with the use of impermeable groynes.
9. Permeable pile groynes are considerably less expensive to construct than their impermeable counterparts.

The literature on permeable groynes is somewhat limited. Subsequently, assumptions cannot be made regarding the “typical” structural and environmental characteristics of permeable pile groynes. However, the trend shows that permeable groynes are more likely to be used, and successful, in lower wave energy environments. Pile groynes are also used for river training and bank stabilisation purposes (e.g. Anlanger, 2008). Three regions in which the use of permeable groynes have been documented are Naples (Florida, USA), The Netherlands and the Baltic Sea (Germany and Poland). Crossman and Simm (2004) suggest that permeable groynes constructed from sawn timbers have been used at a number of locations around the British coast, but anecdotal evidence suggested that their effectiveness and durability is poor compared to conventional impermeable structures. Hyder (2011) reviewed the condition of nine permeable timber groynes on the exposed western coast of Victoria (Australia) and more than 20 permeable timber groynes on the relatively low energy foreshore of Lake Victoria (Gippsland Lakes, Victoria). While the performance of these groynes was not discussed in detail, the permeable groynes located on the open coast were providing no benefit to the beach and were recommended to be removed as they represented a safety hazard to recreational beach users. Typical problems included rotting and splitting of timber members, dilapidated connections (bolts and nails) and vandalism. While these problems also existed with the permeable groynes located on the lower energy lake foreshore, anecdotal evidence suggested that the groynes were more successful in retaining sand in that environment.

Poff et al (2004) discussed the permeable, wooden groyne field at Naples Beach, Florida. The groynes were constructed in the 1950s, designed to stabilise the beach and reduce sediment losses from the beach into the inlet (Gordon Pass) at the end of the littoral cell. By the late 1990s the permeable groynes had become weathered, dilapidated, and no longer functioned as originally intended. One pile cluster groyne was restored as a trial, monitored for four years and determined to be successfully reducing the beach fill erosion rate within its zone of influence (Coastal Engineering Consultants, 2000). To determine the potential permeable groyne impacts to the coastal system, a study was initiated with the University of Florida. Wave tank experiments were conducted and a numerical model developed to establish design criteria, address stakeholder concerns, and analyse groyne impacts on the adjacent beaches. The study's conclusions supported the field monitoring observations and described the positive benefits of the permeable groyne field on Naples Beach (Poff et al, 2004).

Bakker et al (1984) reported on model experiments and up to 20 years of practice in nature with permeable groyne systems on the Dutch coast. Permeable pile groynes (or “screens”) have been constructed on this stretch of coast since 1965 as an alternative to the more massive, and commonly used, rubble mound groynes. The pile groynes consist of wooden piles driven into the beach, with mutual distances of about one pile-diameter, so that permeable pile screens were formed (Bakker et al, 1984). The pile screens were initially constructed as an experiment, and different geometric variations (length, height, spacing, single or double rows, etc.) were included.

At some sites the groynes were successful and at others they were not. At the sites that failed, failure of the screens (i.e. swept away/dislodged) occurred. On the NW coast of Walcheren, heavy damage occurred to the groynes during a storm, with some 12 m long piles being washed out (Bakker et al, 1984). In another section of the coast, four double pile screens were developed, extending to 3 m below mean sea level, with three short groynes in between. These 0.3 m diameter piles were spaced 0.3 m apart. In order to determine the pile length, a seasonal depth variation of 1 m was allowed for. After being in place for about two and a half years, two of the longer groynes lost about 30% of their piles in a large storm. Bakker et al (1984) states that at this site the project was discontinued.

Bakker et al (1984) highlight the importance of determining the stable pile length. The engineer might face situations in which even the maximum practical pile length will not be enough to guarantee constructional stability and subsequently the project may be discontinued. Furthermore, one of the reasons that the projects mentioned failed was that the severe erosion experienced at each location was not predicted and subsequently the piles were not long enough. Bakker et al (1984) also highlight that regular maintenance is required with permeable groynes to remove marine growth (e.g. mussels) from the piles.

Raudkivi (1996), Dette et al (2004) and Trampenau et al (2004) detailed the many groynes built along the coastline of the Baltic Sea. Almost 2,000 permeable pile groynes have been built along the Baltic Sea coastline of Germany and Poland (Weiss, 1991). These groynes are quite different to those that would be required in an open coast environment because the wave climate has quite a low energy and the Baltic Sea is tideless. Water level variations due to the wind are usually within ± 50 cm (Raudkivi, 1996). As such, it has been possible for the groynes to be constructed with heights of between 0.1 m and 0.6 m above mean sea level, with a typical height of 0.5 m above mean sea level (Raudkivi, 1996). It appears that the groynes, as a whole, have been functioning suitably along the coastline, with those in Germany constructed onwards from 1843 (Raudkivi, 1996).

21.4.2 Littoral Processes

The littoral processes associated with the design of permeable groyne systems are the same as those considered in Section 14.3.2. However, a slotted wall, or pile groyne, acts as a resistance to the longshore current, not stopping it completely as is the case for some impermeable groynes. Field observations and model studies suggest that the pile groynes approximately halve the velocity of the littoral current through the groyne field, compared to the same, groyneless conditions (Raudkivi, 1996).

21.4.3 Functional Groyne Design

Due to the small number of successful permeable groyne projects around the world, there is limited information about functional groyne design. In their discussion of permeable pile groynes in the Baltic Sea, Dette et al (2004) highlighted that there is little in the literature about this type of groyne, and how to design them. Furthermore, the functional design parameters for permeable groynes have been determined from a few field, laboratory and numerical modelling experiments. Subsequently, not enough data is available to enable the establishment of quantitative design rules for permeable pile groynes (Dette et al, 2004).

Numerical models such as GENESIS (Hanson and Kraus, 1989) can be used for prediction of shoreline response to groynes. The permeability of the study groyne is included in the GENESIS model, however no examples were found in the literature of the successful use of the GENESIS model, or other numerical models, for successful and accurate prediction of shoreline response due to the installation of permeable pile groynes.

Trampenau et al (2004) highlighted that a variety of permeable groyne parameters have been seemingly successfully examined in laboratory experiments, such as those of Bakker et al (1984), with fundamental qualitative relations established between groyne design aspects. These aspects include groyne length, spacing, orientation to the shoreline, permeability, beach slope and flow conditions in the groyne fields. It was noted that laboratory experiments regularly suffer from a lack of verification data. Trampenau et al (2004) conducted their laboratory experiment in conjunction with a series of field observations, verifying their data. Comparison of the flow patterns within the immediate area of the groynes in the laboratory and in the field provides qualitative evidence that the model and field conditions are in agreement.

The key groyne design properties; length, height and spacing, are discussed in the following sub-sections, as well as the very important aspect of permeability for permeable groynes.

Groyne Permeability (P)

Several key studies refer to the permeability of pile groynes. Firstly, it is important to note that many investigations recommend a variation of the permeability along the groyne. Field data indicates pile groynes should not be closely rammed at the shoreward end (Kolp, 1970). A certain amount of permeability allows shore-parallel movement in the swash zone and reduces the tendency for the development of rip currents. However, other studies have recommendations contradicting this. Raudkivi (1996) highlighted that too low a permeability will lead to conditions as with impervious groynes, while too high a permeability will lead to decreased velocity reduction.

Dette et al (2004) stated that the permeabilities of pile groynes along the German coast vary from 8% to 44%, with a mean of 25%. In most cases the inshore end of the groyne is tight. They continued to recommend quantitatively that the permeability be varied along the groyne, from tightly driven piles at the landward end to about 40% at the seaward end. An example of this recommendation is a transition from 0% permeability at the landward end, to 30% at 0.2 times the groyne length, constant permeability of 30% from 0.2 to 0.8 times the groyne length, increasing from there on to about 40% at the seaward end of the groyne (Dette et al, 2004).

Trampenau et al (2004) established through laboratory experiments that groynes with a permeability of less than 35% perform satisfactorily, creating long-term beach profile growth, while groynes with a permeability of 35% do not significantly change the near-shore underwater profile. Results indicated that for a groyne permeability of 30%, the longshore current is decreased over the entire groyne length up to 40% of the initial velocity, in the case of a single groyne, while two groynes cause a velocity reduction of around 80%. Trampenau et al (2004) recommended a four-groyne system with an average permeability between 20 and 30% for conditions such as those tested. The authors followed this by highlighting that in order to avoid the generation of an eddy path at the head of the first groyne, 35% permeability was recommended for the groyne segment near the head. Dette et al (2004) confirmed the value suggested by Trampenau et al (2004) with both laboratory and field data, indicating that a mean permeability of approximately 30% leads to the optimal flow conditions in the groyne fields.

Poff et al (2004) also recommended that groyne permeability should be increased seaward, to inhibit formation of strong updrift offshore flows. However, they highlighted a very important point; that groyne permeability is site specific, with a recommendation of 50 to 80%.

Bakker et al (1984) referred to permeable pile groynes in the field being spaced at mutual distances of about one pile diameter. However, it was determined in preliminary calculations for laboratory work that velocity reductions of 30% would result for screens with a permeability of 50 to 75%, 200 m long and 400 m apart, with further reductions requiring progressively more piles per unit beach length (decreased permeability).

From these findings, it would appear that the majority of researchers recommended increasing permeability seaward. It is evident that the ideal permeabilities vary a great deal from site to site; subsequently it is recommended that detailed investigations be conducted for each specific site to determine the ideal permeability.

Groyne Length (Y_g)

Raudkivi (1996), Poff et al (2004) and Trampenau et al (2004) suggested tentative recommendations for the design length of permeable groynes. Raudkivi (1996) suggested that pile groynes should extend only to the trough of the first shore-parallel bar in barred systems. Poff et al (2004), following laboratory experiments based on the western coast of Florida suggested that permeable pile groynes should extend seaward through the average surf zone and extend landward well above the mean high water level.

Trampenau et al (2004), after their work on the tideless coast of the Baltic Sea and associated laboratory experiments, suggested tentative recommendations for the design of permeable pile groynes on tideless coasts. Trampenau et al (2004) determined the highest hydraulic performance of permeable groynes, under the conditions tested, was obtained for a groyne length (Y_g) in order of the width of the surf zone (B_z), and a groyne spacing (X_g) in order of the groyne length (as shown in Equation 21.1).

$$\frac{Y_g}{B_z} \approx \frac{X_g}{Y_g} \approx 1 \qquad (21.1)$$

Groyne Spacing (X_g)

Raudkivi (1996) stated that the spacing of pile groynes on the southern coast of the Baltic Sea is one to two times the length of the groynes. Dette et al (2004) and Poff et al (2004) highlighted that the spacing of groynes depends on wave directions and heights, and has to be optimised to local conditions. However, there are no known methods for calculation of the distance over which waves will re-establish the incident velocity of the longshore current in the groyne field. The spacing should limit the velocity at the next groyne to approximately 80% of the incident velocity. It was also suggested that a double-width pile groyne is more effective than two single groynes spaced far apart (Poff et al, 2004).

As mentioned when discussing groyne length, Trampenau et al (2004) determined that under the conditions tested, the optimum hydraulic performance of the permeable pile groynes was observed when the spacing was in order of the groyne length.

It would appear that permeable pile groynes work more efficiently when deployed closer together than the spacing recommended for impermeable groynes. Subsequently, the installation of a permeable pile groyne field would result in more groynes per section of beach.

Groyne Height (G_h)

In the context of permeable groynes, groyne height still refers to the height of the groyne crest relative to the normal beach berm level. However, for permeable pile groynes, groyne height is also linked to the overall length of the pile. Poff et al (2004) highlighted that piles should be driven to a sufficient depth to provide stability for the life of the structure, recommending that 60% of the pile length should be driven below the lowest expected bed elevation.

Trampenau et al (2004) concluded that a groyne height of about 0.5 m above mean sea level is efficient in the tideless Baltic Sea, and that wooden pile groynes can be rammed without any difficulties in water depths of up to about 3 m. Raudkivi (1996) suggested a large tidal range will lead to long-exposed lengths of piles and significant structural problems. Evidently, to overcome this on tidal coasts, the groyne would have to slope down seaward, in order to keep the pile length acceptable (Dette et al, 2004).

Dette et al (2004) suggested that the performance of pile groynes, as judged from existing information, is only marginally affected by the height of the groynes, and it appears that their height could be limited to less than 1.5 m above the seabed. However, this means that the seaward ends of the groynes would become submerged. It is stated that no field installations of permeable pile groynes with submerged seaward ends are known, although it is quite common with impermeable groynes. This observation suggests that the permeable pile groynes discussed by Bakker et al (1984) are no longer functioning.

21.4.4 Structural Design Considerations

When considering permeable pile groynes, the key structural consideration is the length (and associated height) of the pile. Accurate calculation of the lowest expected bed elevation is important. The Coastal Engineering Manual (USACE, 2006) provides detailed information to calculate wave forces on vertical piles and scour around piles.

Bakker et al (1984) discussed the failure of some of the pile groynes in The Netherlands as the erosion and scour at the location was worse than ever anticipated. When considering permeable pile groynes for tidal locations and/or having submerged piles, further investigations will need to be conducted regarding structural design considerations.

Dette et al (2004) suggested that the lack of piles on marine coastlines may be due in part to the damage done to wooden piles by the marine borer, which is less widespread in the Baltic Sea. They suggest that these would not affect concrete piles, which could be used on sandy, marine coastlines. However, no evidence was found of long-lasting permeable pile structures, made from wood or concrete, on marine coastlines as part of this investigation. The groynes discussed in Florida (albeit on a more sheltered coastline of the state) had fallen into a state of disrepair after 40 years and some of the groynes discussed by Bakker et al (1984) did not even last three years before being destroyed by stormy conditions.

21.5 Groyne Implementation and Management

While it is very important to get the groyne design process correct whether the selected groyne type is impermeable or permeable, it is also important to conduct continued monitoring of the groyne site to ensure that is it performing to the best of its ability. It may be necessary to undertake periodic renourishment depending on the wave, and storm conditions at the beach. The establishment of "trigger" or "threshold" mechanisms for decision making to perform maintenance via renourishment, or to modify (or remove) groynes (if adjacent beach impacts are found unacceptable), is recommended (Basco and Pope, 2004). Such management practices will help overcome the negative perceptions of groynes and groynes fields and promote the appropriate use of these structures for shore stabilisation (Basco and Pope, 2004). Kana et al (2004) suggested that detailed beach surveys should be an integral part of any groyne management plan such that downdrift erosion/recession may be quantified and addressed via periodic nourishment before other properties are threatened.

For impermeable groynes, and the associated beach nourishment, during the construction phase it is generally recommended that groynes be constructed from downdrift to updrift, and cells nourished to capacity. A “rule of thumb” for nourishment quantity is one half the difference between the groyne profile and average beach profile in the updrift cell applied over the length of the cell (Kana et al, 2004).

22. Appendix D: Literature Review of Offshore Breakwaters (Emergent)

22.1 Overall Design

Numerous offshore breakwaters have been constructed around the world. Rosati (1990) reported that over 4,000 had been constructed in Japan and several hundred in the Mediterranean. Very few offshore breakwaters have been constructed in the USA, UK and Netherlands. It is these countries from which the bulk of English language publications relating to coastal engineering are sourced, and therefore there is less readily accessible published design guidance on offshore breakwaters than for most other types of coastal structures, particularly with regard to the effects of variable wave transmission.

The following publications offer overall design guidance. Discussion of publications relating to specific design aspects and case studies is given in subsequent sections.

- Shore Protection Manual (1984);
- Dally and Pope (1986), "Detached Breakwaters for Shoreline Protection";
- Rosati (1990), "Functional Design of Breakwaters for Shore Protection: Empirical Methods";
- Rosati and Truitt (1990), "An Alternative Approach for Detached Breakwater Projects";
- Chasten et al (1993), "Engineering Design Guidance for Detached Breakwaters as Shoreline Stabilization Devices"; and
- Pilarczyk and Ziedler (1996), "Offshore Breakwaters and Shore Evolution Control".

All of the above publications provide useful information on the design of single and multiple offshore breakwaters, however, none provide methods for quantifying the shoreline effects due to different degrees of wave transmission over or through structures which may be overtopped.

22.2 Wave Transmission

22.2.1 Definition and Relevance

Salient formation on the shoreline is sensitive to wave transmission over (and through) offshore breakwaters. Transmission through a structure will occur for permeable rock structures, particularly if constructed without a core, however wave transmission through sand filled geotextile container structures would be negligible.

Wave transmission is conventionally measured in terms of the wave height transmission coefficient (Kt), which is the ratio of wave height landward of a structure to the wave height seaward of it:

$$Kt = \frac{H_t}{H_i} \qquad (22.1)$$

Where: H_t is transmitted (landward side) wave height
H_i is incident (seaward side) wave height

That is, for a structure which transmits no waves Kt = 0 and for a structure which causes no reduction in wave height Kt = 1.0.

22.2.2 Calculation of Wave Transmission

Three methods for calculating wave transmission were initially examined, namely:

- CIRIA/CUR (1991)
- Ahrens (1987)
- Van der Meer (1991)

Each of the above methods has some limitations which are discussed below. Other methods for calculating wave transmission exist, some of which involve graphical solutions which cannot be applied economically to time series data without developing lookup tables.

WRL has previously utilised the surf zone model of Dally, Dean and Dalrymple (1984) to examine wave transmission effects, however this can only be utilised with structures submerged at least 0.3 to 0.5 m.

Most methods use the concept of freeboard (F) or relative crest level (R_c) shown in Figure 22.1, Where:

$$Rc = F = h_c - d_s \qquad (22.2)$$

Where: h_c is the crest height of the structure above the bed
d_s is the local water depth at the structure

From equation 22.2, for an emergent structure F is positive, and for a submerged structure F is negative.

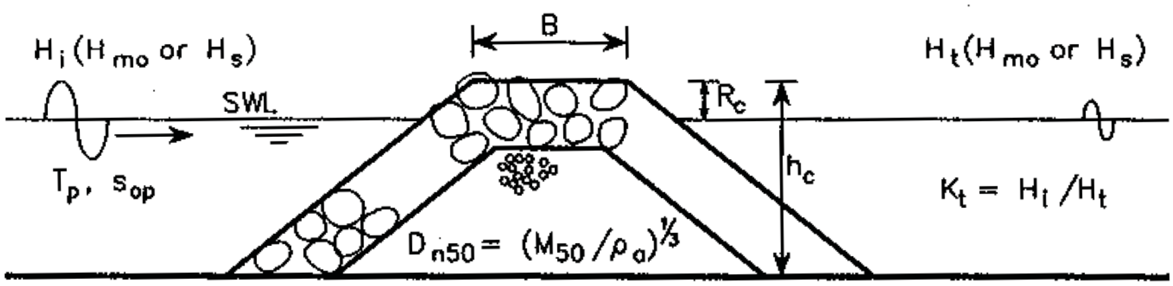


Figure 22.1: Definition Sketch for Freeboard (Source: Van Der Meer, 1996)

Method of CIRIA/CUR (1991)

CIRIA/CUR (1991) presented a simple wave transmission formula applicable to rock armour structures for initial approximations:

Kt = 0.80	for $-2.00 < F/H_i \le -1.13$	(22.3a)
Kt = 0.46 – 0.30 F/H_i	for $-1.13 < F/H_i \le 1.20$	(22.3b)
Kt = 0.10	for $1.20 < F/H_i \le 2.00$	(22.3c)

As this method also allowed for some transmission through (as well as over) a structure, which is less likely for a geotextile container structure than a rock structure, the following extrapolations can be made to allow Kt values of less than 0.10 and more than 0.80:

$$Kt = 1.00 \quad \text{for } F/H_i \leq -2.00 \tag{22.3d}$$

$$Kt = 0.00 \quad \text{for } 2.00 < F/H_i \tag{22.3e}$$

The advantages of this method are its simplicity, that no armour size is needed for input, and that there are no wave steepness (or other) terms which can "blow up" the equations if values outside the expected range are encountered. The disadvantages of this method are that the effect of crest width cannot be modelled, and the effects of other physical parameters may have been omitted.

Method of Ahrens (1987)

Ahrens (1987) undertook 205 separate physical model tests and derived the following formula for wave transmission (Kt) over a structure where F/Hs < 1.0. Other equations were presented for higher positive freeboards and for transmission through porous reef structures.

$$Kt = \frac{1.0}{1.0 + \left(\frac{h_c}{d_s}\right)^{C1} \left(\frac{A_t}{d_s L_p}\right)^{C2} \exp\left[C3\left(\frac{F}{H_i}\right) + C4\left(\frac{A_t^{3/2}}{d_{50}^2 L_p}\right)\right]} \tag{22.4}$$

Where : h_c , d_s and F are as above
A_t is the cross sectional area of the structure
L_p is the spectral peak wavelength in water depth d_s (at the structure) which can be approximated to 0.01% with a Padé approximation (Hunt, 1979)
Hi is incident wave height at the structure
d_{50} is median armour size of the structure
C1, C2, C3, C4 are coefficients with best fit values
C1 = 1.188
C2 = 0.261
C3 = 0.529
C4 = 0.00551

Wave steepness, Hs/L_{op}, (where L_{op} is offshore spectral peak wavelength) tested by Ahrens was in the range 0.0012 to 0.035. The crest width can be accounted for in the A_t term and the sensitivity to armour size d_{50} is minor for realistic values.

Method of Van der Meer (1991)

Van der Meer (1991) presented a method which incorporated the data of Ahrens (1987) and others. Van der Meer's equation (with suggested upper and lower limits of 0.75 and 0.075) is

$$Kt = a\frac{F}{d_{50}} + b \tag{22.5}$$

Where: $$a = 0.031\frac{H_i}{d_{50}} - 0.24 \quad (22.6)$$

and for conventional (with low permeability core) breakwaters:

$$b = 5.42\,S_{op} + 0.0323\frac{H_i}{d_{50}} - 0.00017\left(\frac{B}{d_{50}}\right)^{1.84} + 0.51 \quad (22.7)$$

Where: S_{op} is deepwater wave steepness (H_s/L_{op})
B is crest width

The restrictions placed on equations 22.5 to 22.7 by Van der Meer are that it is accurate for values of (H_i/d_{50}) between 1 and 6, and for wave steepness (S_{op}) 0.01 to 0.05.

This method results in less scatter than previous equations, particularly when the freeboard of the structure crest is zero. The disadvantages are that the restrictions on (H/d_{50}) make it more applicable to extreme rather than median/average conditions, and that it is sensitive to the rock armour size d_{50} which cannot necessarily be transformed to an equivalent geotextile container size.

22.2.3 Effect of Wave Transmission on Shoreline Response

Qualitatively, the higher the Kt value the less would be the shoreline effect of an offshore structure, however, there is little quantitative design guidance regarding the effect of Kt on shoreline response. Determining representative Kt values for a site is further complicated by the tidal/storm surge variation. That is, identical wave conditions could have a Kt of 0.0 and 1.0 at different phases in the tide cycle.

Hanson and Kraus (1989) presented results of GENESIS modelling of an offshore structure for Kt values of 0.0, 0.2, 0.4, 0.8, with the results reproduced in Figure 22.2. It is noted that Hanson and Kraus (1989) used a fixed duration for the simulation for each Kt case (180 hours) rather than asymptotic shorelines. Research previously undertaken by WRL indicated that Kt values of up to 0.5 still affect the shoreline, but as Kt increases, slower transition towards the asymptotic shape occurs.

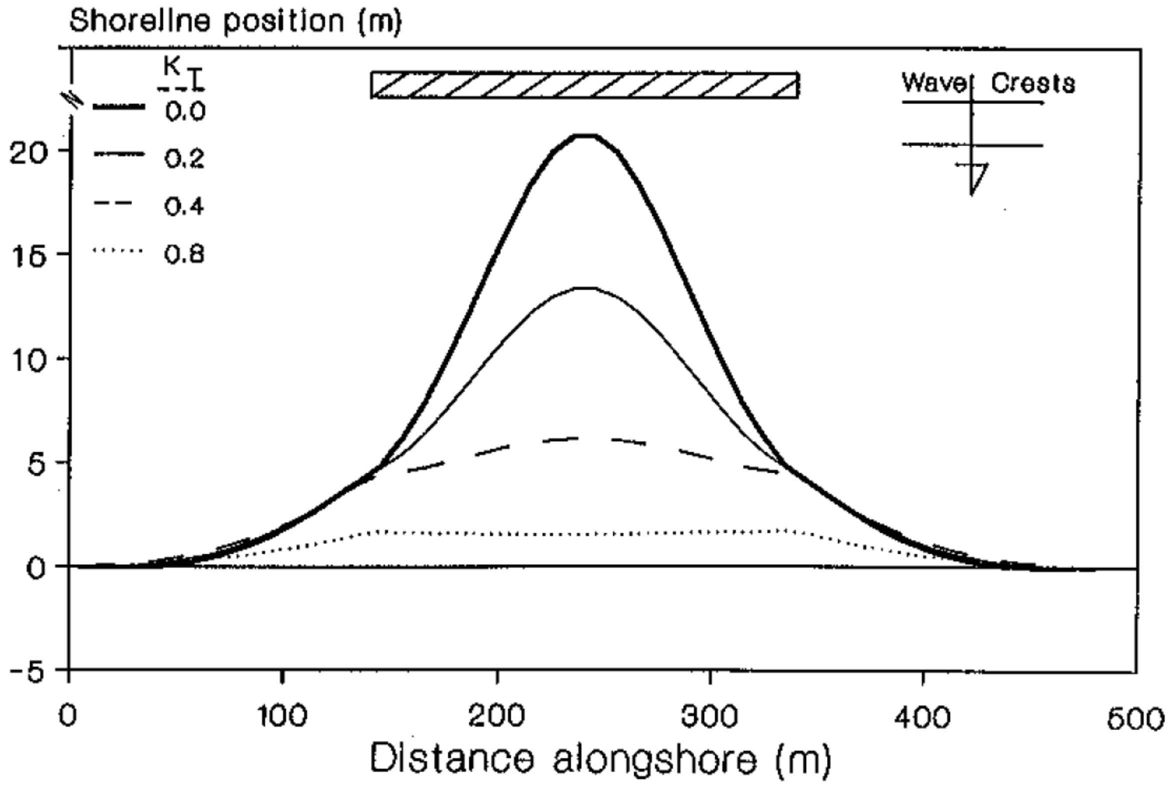


Figure 22.2: Effect of Wave Transmission Coefficient (Source: Hanson and Kraus, 1989)

Hamer et al (1998) and Fleming and Hamer (2000) reported on the Happisburgh to Winterton offshore breakwater project in England. The entire proposed scheme comprises 16 offshore breakwaters, designated number 1 at the updrift end and number 16 at the downdrift end. The tide range is stated as 3 m, the storm surge stated as exceeding 2 m and the mean Hs stated as 2 m. To date, breakwaters 5 to 8 were constructed as stage 1, followed by breakwaters 9 to 13 as stage 2. Stage 1 breakwaters have crest lengths (B) of 220 to 230 m, are separated by gaps of 280 m, and are located 200 m offshore (S) from the original shoreline in a mean water depth indicated to be 2 m. That is, the B/S ratio was 1.15 for stage 1. The four stage 1 breakwaters were constructed with crest levels 1.3 m above mean high water springs (MHWS) and were found to broadly perform as designed with salients predicted to be about 20 to 80 m from the original shore at mid tide level, though during storms the most exposed sections of beach opposite the gaps eroded back to the seawall. Physical modelling (for stage 1 breakwaters) established typical Kt values of 0.46 at mean high water springs (= 1.3 m emergence) and 0.6 during extreme storms. The average Kt value was not stated but was less than 0.3 based on statements for the lower crest of stage 2 breakwaters.

Following this successful trial for stage 1, a further four breakwaters (stage 2) were constructed to a generally less conservative design, with a similar distance offshore but with a 1.8 m lower (than stage 1) crest level of -0.5 m relative to MHWS. The stage 2 breakwaters had a crest length (B) of 160 m, giving a B/S ratio of 0.8. The gaps between the stage 2 breakwaters were reduced to 160 m to reduce storm erosion of the most exposed portion of beach opposite the gaps as occurred in stage 1. A mean sea level (MSL) average Kt value of 0.3 was reported for the stage 2 breakwaters. These lower crested stage 2 structures are also reported to be performing as designed. Of further interest is that the proposed four most updrift breakwaters (numbers 1 to 4) are now considered to be unnecessary due to littoral drift accumulation updrift of breakwater 5 for up to 1 km.

Sorenson and Weggel (1992) reported on an installation in New Jersey, USA of a system of two offshore breakwaters with crest lengths of 48 and 52 m separated by a gap of 33.5 m and located 112 m from the original shoreline. The two breakwaters consisted of 27 and 29 "Beachsaver" precast concrete reef units. The reported spring tide range is approximately 1.5 m and the 1 year ARI significant wave height 2.8 m. The structure was initially constructed in a MSL water depth of 1 m with a crest level up to 1.2 m above MSL or 0.5 m above the spring high tide level. Physical model tests were cited which found Kt values of 0.8 when the freeboard was zero and approximately 1.0 when the freeboard divided by the incident wave height (F/H_i) approached –0.1. No reports were made for Kt at the initially installed relative crest freeboard of +1.2 at MSL, but on the basis of the physical model results Kt would have been less than 0.8 even at high tide. Monitoring found that salients did initially form in the lee of the breakwaters, however, the concrete units settled markedly into the sand bed, with the crests dropping to approximately the mean high tide level. On the basis of the reported physical model results, this would result in a Kt of approximately 0.8 at mean high tide. With their location in only 1 m water depth relative to MSL, at low tide virtually all littoral drift bypassed the structures. The initial salients subsequently disappeared, as the settlement of the structures resulted in increased wave transmission.

Smith et al (1998) also reported on field monitoring of a proprietary precast concrete submerged reef system (PEP reef system) installed in Florida USA. In contrast to the other case studies reported above, this structure was approximately 915 m long and located between 68 and 80 m offshore with only limited gaps between segments, so is not directly comparable. The design average Kt was 0.9, however, with settlement of the structure this was measured to increase to 1.0. Monitoring found that the installation increased beach erosion in its lee, which was postulated to be caused by currents due to overtopping waves and setup which could only escape beyond the 915 m length of the structure.

22.3 Salient Extent and Shape

22.3.1 Seaward Extent of Salient or Tombolo

For offshore breakwaters there are numerous studies relating structure length (B) and distance offshore from the original shoreline (S) to the seaward extent of the salient/tombolo (X) – a definition sketch is shown in Figure 22.3. Hsu and Silvester (1990), Chasten et al (1993) and Dally and Pope (1986) summarised large amounts of previous studies. The criteria from Chasten et al (1993) are shown below in Table 22.1. Figure 22.4 shows Hsu and Silvester's (1990) summary of relevant studies.

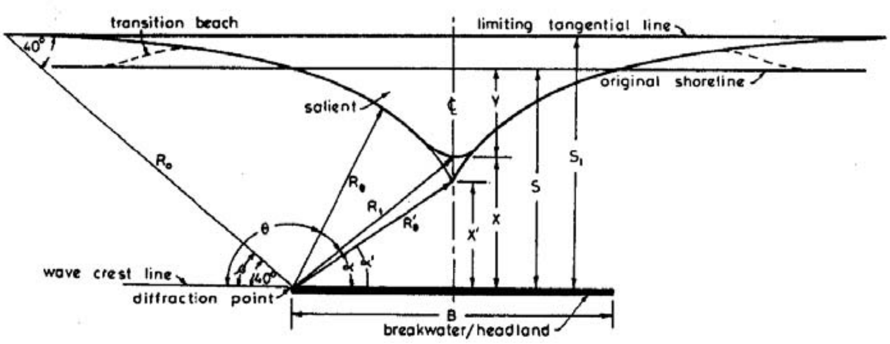


Figure 22.3: Definition Sketch for Salient (Source: Hsu and Silvester, 1990)

Table 22.1: Criteria for Salient/Tombolo Formation for Single Breakwater

B/S ratio	Comments	Reference
Conditions for tombolo formation		
> 2.0	Formation of tombolo	SPM (1984)
> 2.0	Double tombolo	Gourlay (1981)
0.67 to 1.0	Shallow water tombolo	Gourlay (1981)
2.5	Periodic tombolo	Ahrens and Cox (1990)
1.5 to 2.0	Tombolo	Dally and Pope (1986)
> 1.0	Tombolo	Suh and Dalrymple (1987)
Conditions for salient formation		
< 1.0	No tombolo	SPM (1984)
< 0.4 to 0.5	Salient	Gourlay (1981)
0.5 to 0.67	Salient	Dally and Pope (1986)
< 1.0	No tombolo	Suh and Dalrymple (1987)
< 1.5	Well developed salient	Ahrens and Cox (1990)
< 0.8 to 1.5	Subdued salient	Ahrens and Cox (1990)
Conditions for minimal shoreline response		
≤ 0.17 to 0.33	No response	Inman and Frautschy (1966)
≤ 0.27	No sinuosity	Ahrens and Cox (1990)
≤ 0.5	No deposition	Nir (1982)
≤ 0.125	Uniform protection	Dally and Pope (1986)
≤ 0.17	Minimal impact	Noble (1978)

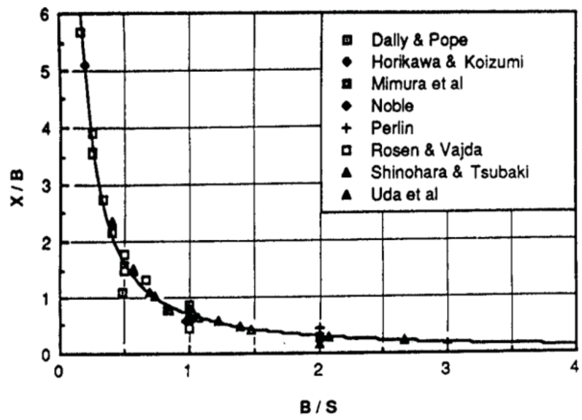


Figure 22.4: Salient and Tombolo Data (Source: Hsu and Silvester, 1990)

In summary, from Table 22.1 a B/S ratio of 1.0 is very likely to form a salient, with some possibility of tombolo formation and very little possibility of no shoreline effect, providing wave transmission is not excessive. A salient is generally seen as preferable as a tombolo is likely to cause greater downdrift erosion.

22.3.2 Planform of Salient/Tombolo

While a large number of studies have been undertaken on the seaward extent of salients/tombolos (albeit mostly from physical models), limited information exists on their planform. Hsu and Silvester (1990) presented a procedure for calculating salient planform behind a single offshore breakwater based on physical model studies. Silvester (1981) and Silvester and Hsu (1997) have published widely on the planform of logarithmic spiral or zeta curve bays due to artificial headland control. This method can account for net littoral drift, however its application is limited to tombolos being present.

Andrews (1997) and, Black and Andrews (2000) digitised aerial photos of 60 natural salients in Australia and New Zealand. It should be noted that these were all on the open coast. The best 14 of these, which were free from the influence of nearby headlands and multiple offshore obstacles, were analysed for shape. They then applied curve fitting techniques to parameterise the shoreline shape, and presented separate equations to describe salients due to emerged islands and submerged reefs. They found that the salients were larger than those observed in other studies such as Hsu and Silvester (1990) and attributed this to the limitations of physical modelling used by Hsu and Silvester for most of their data points. Possible limitations with the work of Black and Andrews are:

- It is not known whether their data was corrected for the tide level prevailing at the time of the aerial photo;
- Many of their examples were taken from coastlines with small net littoral drift relative to the prevailing wave heights;
- Consequently, their equations are for symmetrical salients; and
- The depth of offshore reefs cannot be judged from aerial photos, and light refraction effects may cause the underwater extent to be underestimated from an aerial photo.

For emerged islands Black and Andrews' best fit curve is:

$$y' = a + \frac{b}{\left[1 + \exp\left[\frac{x' - d\ln\left(2^{1/d} - 1\right) - c}{d}\right]\right]^{d}} \tag{22.8}$$

the salient amplitude from the baseline is:

$$y_{off} = S - 0.40\,B\left(\frac{B}{S}\right)^{-1.52} \tag{22.9}$$

and the basal width of the salient is:

$$D_{tot} = 8\,y_{off} \tag{22.10}$$

Where : $y' = y/y_{off}$

y_{off} = maximum amplitude from baseline of salient at apex

y = local distance from baseline to waterline (alongshore)

D_{tot} = the total basal width of the salient (assumed to be symmetrical)

$x' = x/y_{off}$

x = distance from extreme edge of salient (y = 0) with maximum at centreline of salient

B = offshore breakwater/island crest/longshore length

S = breakwater/island distance offshore from baseline/original shore

a, b, c, d are curve fitting coefficients with best fit values

a = -0.052

b = 1.187

c = 2.649

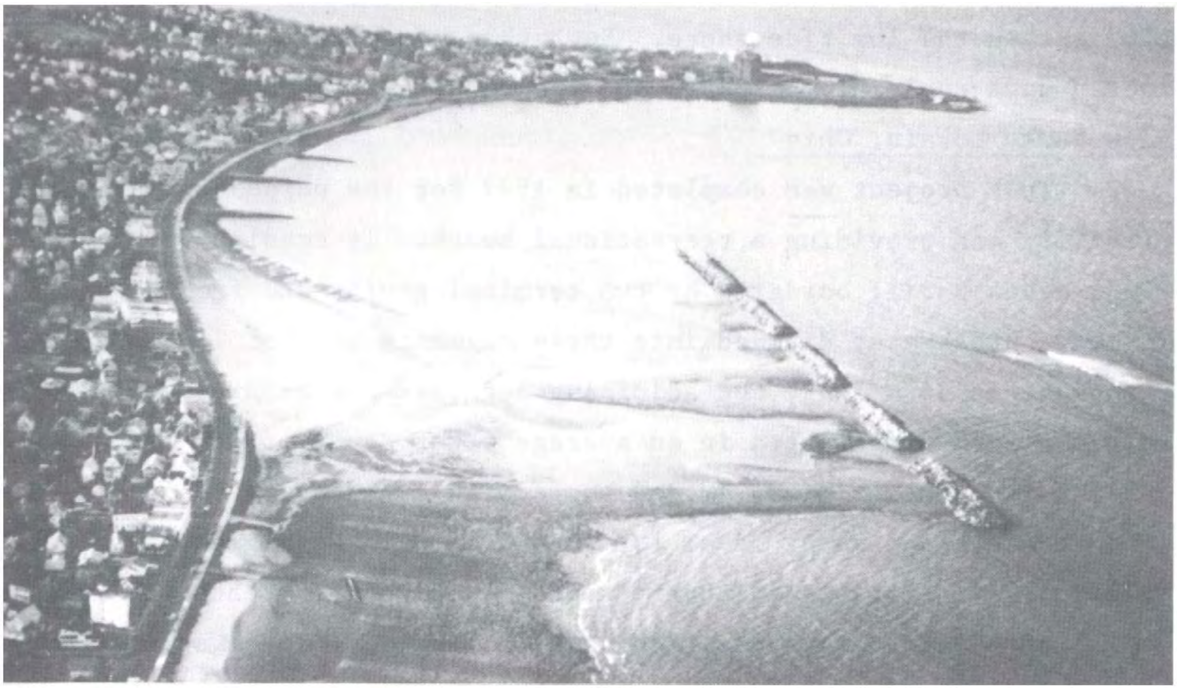
d = 0.606

For an offshore breakwater located (S) 200 m from the original shore and having a crest length B of 200 m, equation 3.9 above (Black and Andrews, 2000) predicts a salient amplitude of 120 m, whereas Hsu and Silvester (1990) predicts one of 64 m.

The use of numerical models such as GENESIS are a useful tool for predicting salient planform, particularly where net littoral drift exists. A limitation of GENESIS-95 is that it is unable to continue running when a tombolo forms. In fact, what occurs is that the model stops ("crashes" with an appropriate warning message) when a tombolo forms. The effects of a tombolo can then be partially modelled by re-running the model with a tee-head groyne.

22.4 Salient Cross-Shore Profile

There are reported cases (e.g. Dally and Pope, 1986) of changes to the cross-shore profile in the lee of offshore breakwaters. Figure 22.5 illustrates this phenomenon, with a distinct flattening of the profile. No quantitative methods exist for the prediction of this phenomenon. Such changes may alter the accretion volumes predicted by one line models such as GENESIS.



(a) Low Tide

(B) High Tide

Figure 22.5: Example of Cross-Shore Profile of Salient (Source: Dally and Pope, 1986)

Similar observations were reported by Hamer et al (1998) and Fleming and Hamer (2000) for the Happisburgh to Winterton offshore breakwater project in England, where near flat beaches (only visible at low tide) attached to the landward toe of the offshore breakwaters. These profiles could not be predicted by the one-line model used for design of the project.

22.5 Wave-Driven Currents

Offshore breakwaters reduce the wave driven longshore current in their lee. Localised scour in their lee has been reported for structures subject to overtopping such as the PEP reef case cited above (Smith et al, 1998).

For a field of (relatively impermeable) multiple breakwaters, water from overtopping waves will return to sea through the gaps between the breakwaters. This has been postulated as a mechanism for loss of sediment from the inshore littoral system, and presents a hazard for swimmers. Seelig and Walton (1980) suggested that this velocity be limited to 0.15 m/s (to limit sediment loss) and provided a method for its estimation. Given that a reasonably strong swimmer can sustain speeds of approximately 1 m/s, this 0.15 m/s criterion would present a relatively low hazard to swimmers. Such currents are not applicable to a single offshore breakwater.

Gourlay (1981) presented a conceptual model for currents generated due to the interaction with waves for both submerged and emergent single offshore breakwaters (Figure 22.4). Gourlay also presented a limited method for estimating the maximum current velocity in the lee of a single breakwater when wave diffraction effects dominate, that is, when wave transmission is minimal:

$$v = C_5 \, g^{0.5} \, H_b^{0.5} \qquad (22.11)$$

Where: v is velocity

C_5 is a function of breaker type which requires Gourlay's (1978) PhD thesis to be referred to

g is gravitational acceleration = 9.81 m/s^2

H_b is the breaking wave height away from the influence of the structure.

22.6 Summary of Offshore Breakwater Design

The following points summarise offshore breakwater design:

- There are several methods for calculating wave transmission (Kt) for offshore breakwaters. However, greater certainty could only be obtained through physical modelling or prototype monitoring.

- There is limited quantitative information on the effects of Kt on shoreline response. GENESIS can account for Kt, but only a single annual average value can be input, whereas with a moderate tide range, Kt would vary substantially at different tide levels.

- Based on reports from a series of projects, it is recommended that the average Kt value be less than 0.4 and the maximum during storms be less than 0.6.

- Precast concrete offshore breakwaters placed directly on the bed are prone to settlement and consequent increased wave transmission and reduced shoreline effect. Such units cannot have their crests topped up to counteract this, whereas this can be done relatively easily for sand-filled geotextile container and/or rock structures.

- The formation of a salient rather than tombolo is preferable to reduce downdrift erosion effects.

- From the work of numerous researchers, with crest length (B) and distance offshore (S), a B/S ratio of 1.0 is very likely to form a salient, very unlikely to have no shoreline effect, and has a small possibility of forming a tombolo.

- Numerous researchers have presented relationships for salient amplitude, symmetrical salient shape and the shape of headland/tombolo controlled bays, however, only numerical models such as GENESIS can predict the planform of asymmetric salients on net littoral drift coasts.

23. Appendix E: Literature Review of Offshore Breakwaters (Submerged Reef)

23.1 Overview

This appendix presents a comprehensive review of the use of submerged constructed reefs (SCRs) for coastal protection in NSW (Blacka et al, 2013). SCRs are often proposed as a 'softer' protection option due to their simulation of natural processes and negligible visual intrusion. Conclusive information regarding SCRs is less well documented within the literature compared with more conventional coastal structures. While the review has primarily focused on the use of SCRs for providing coastal protection, and in particular the applicability of SCRs for the NSW coast, a broader range of aspects have also been considered. The review considered in excess of one hundred and fifty (150) international references.

23.2 Design and Analysis Methods

The stability of rock armouring on submerged breakwaters has been studied in numerous detailed investigations and reasonable empirical design guidance is available. In contrast, the understanding of the behaviour of large sand-filled geotextile containers under wave attack is not yet well developed. A small number of studies looking at the stability of geotextile containers and tubes have been undertaken with varying approaches and results. However, there is no single publication presenting stability design curves or equations for geotextile tube submerged reef structures. While it is generally stated that the geotextile mega containers used in reef construction are so large that they are inherently stable, experience from existing reefs has shown that the tubes are able to be dislodged, re-worked, and damaged by wave attack.

There has been considerable improvement in the understanding of the mechanisms driving shoreline response to submerged reef/breakwater structures over the past decade, nevertheless all completed studies have significant limitations. No single study has comprehensively tested the effects of primary structural and environmental variables on quantitative shoreline response and the shoreline response equations published are based on either approximate field measurements of a limited number of parameters, or un-calibrated and un-validated modelling (both physical and numerical). This suggests that the available empirical techniques for assessing shoreline response are suitable only for preliminary engineering calculation and not detailed design. Structures that are designed using these methods should be considered as trial or experimental only and shoreline response to these designs will inherently contain higher uncertainty than many other beach control structures.

Numerical models are well suited to assessing wave, hydrodynamic, and morphological aspects of reef structures, with the degree of certainty in model predictions proportional to the level of model calibration. Physical models should be used preferentially for assessing reef armour stability, wave and hydrodynamic processes, and can also be applied to gain valuable qualitative and semi-quantitative insight into morphological response, but scaling limitations mean that they do not provide a complete answer. It is recommended that detailed design of any SCR structure adopt a hybrid modelling approach, whereby the individual strengths of both numerical and physical models are utilised to arrive at the final reef design. Furthermore, it is recommended that modelling of any structure with environmental, social, or economic significance be underpinned by site specific data collection programs for wave transformation, water levels, and sediment transport.

23.3 Existing Reef Projects

A review of existing SCR structures around the world was undertaken with key engineering, environmental and cost information summarised for each structure. Based on this review, the key findings were:

- Of the thirty-two (32) SCR structures reviewed, twenty-nine (29) were intended to provide coastal protection as a primary or secondary objective;
- Approximately half of the "protection" structures had no significant accretionary impact on shoreline alignment compared to the predicted morphological response;
- 55% of submerged breakwaters were successful at providing increased coastal protection, though not all to the degree initially predicted;
- One of five multi-purpose reef (MPR) structures may be providing a reasonable level of coastal protection but this structure has only been monitored for two to three years. Three other MPRs provide only minor or negligible coastal protection compared to design, and the performance of the newest MPR (Borth) is yet to be determined;
- Eight artificial reefs were constructed with the objective of improving surfability and approximately half of these were considered at least partially successful;
- The resulting shoreline morphology behind reef structures often differed significantly from the design predictions, even when the best available design methods were applied;
- Most structures settled and/or suffered from localised scour which resulted in an actual crest level which differed from that specified by design and subsequently led to further maintenance and top up costs or under performance; and
- Approximate construction costs (in 2013) per linear metre of coastline protected were in the order of $1,500 to $5,500 for submerged breakwater structures and $7,000 to $10,000 for MPR structures, compared with $5,000 to $10,000 for a high quality engineered rock seawall on the open NSW coast. The relatively high wave climate of the NSW coast is likely to further increase the construction costs of the offshore structures relative to the precedent structures located in milder wave climates.

23.4 Application of Submerged Constructed Reefs in NSW

In recent years SCRs and in particular MPRs have been proffered as a coastal protection option for some NSW communities, due to the perception of the benefits outweighing the limitations. However, within NSW the use of MPRs that combine surfing and protection objectives are likely to be limited in success by a number of factors including:

- NSW has a tidal range of approximately 1.5 m and a multi-directional wave climate with a wide wave height and period distribution. To accommodate surfing as a design objective the cross-shore dimension of a MPR has to be large enough to allow proper wave pre-conditioning under a range of wave and tidal conditions. This makes the structures relatively cost-inefficient at protecting any significant stretch of coast, unless used in series (which is expensive compared to other protection options);

- Most sections of the NSW coast are relatively rich in high quality natural surf breaks, resulting in high community expectations if surfing is a primary design objective; and

- Safety concerns for the various reef users results in reef designs that are not optimum for coastal protection or surfing.

As with all coastal protection structures being considered within the NSW coastal management framework, it is important that feasibility assessments of SCR structures give consideration to several key points:

- The existing hazards need to be well defined before a reef can be assessed for feasibility, if coastal protection is an objective;

- A range of alternative solutions should be considered at the feasibility stage to allow selection of the best option to achieve the management objectives;

- The reduction in hazard that can be achieved by the reef needs to be predicted through technical assessments and quantified in terms of present and future hazard/risk reduction; and

- The predicted reduction in hazard should be considered in terms of its environmental, financial, and social costs and benefits.

23.5 Future Applications of Submerged Constructed Reefs

On a relatively simple, straight coastline, it is likely that an emergent offshore breakwater designed in accordance with published methods would form a locally widened beach, provided there is sufficient available sand. The uncertainty in beach response increases as the crest elevation is lowered and the structure becomes submerged. This appears to stem from the complexity of processes leeward of the reef hampering understanding of the morphological response to reef structures in a naturally variable environment. As a result there is inherently a larger uncertainty associated with these structures. This uncertainty needs to be considered in any feasibility analysis, as it presents a significantly higher risk in comparison with other forms of coastal protection.

Consideration of SCRs built to date shows a relatively large number of structures underperforming in coastal protection objectives, even for cases where significant effort was put into very technical designs. This cannot be ignored when considering the current ability to be able to successfully predict the processes surrounding a SCR with required accuracy. Furthermore, many failures have been as a result of structural problems due to complexities of building a structure in an active surf zone on loose unconsolidated materials. This highlights the considerable improvements that are still needed in the design and construction of submerged reef structures.

Regardless of these current limitations, the potential benefits of SCRs mean that they should continue to be considered as an option for hard coastal protection, so long as the design and expectations take into consideration the lower level of certainty in performance. Future construction and monitoring of SCRs will result in an improved understanding of the processes and refined methods for predicting shoreline response to these structures. Throughout this period of ongoing improvement, consideration should be given to trial and experimental structures to reduce uncertainty and to create structures which meet the desired objectives.

The difficulty in attempting to meet multiple objectives is that the success in meeting one objective may be diluted by the attempts to meet the others. While some community groups may continue to favour multi-purpose structures due to their perceived benefits, there is little doubt that focussing the objective of coastal protection structures on coastal protection rather than multiple objectives will achieve improved results with more reliability and increased efficacy.

24. Appendix F: Literature Review of Beach Nourishment

24.1 Preamble

Beach nourishment involves the placement of large quantities of good quality sand on a beach to advance it seaward. Beach nourishment projects are usually conducted along beaches where erosional trends exist and the beach has eroded to a degree that homes and/or infrastructure may be jeopardised by major storms (Dean, 2002).

Section 24.2 provides a background for beach nourishment and the calculation methods. Section 24.3 discusses potential sand sources and the effect of borrow sand grain size on required nourishment volumes. Section 24.4 discusses implementation aspects and Section 24.5 discusses potential social and environmental implications of beach nourishment.

24.2 Beach Nourishment Theory

Beach nourishment volumes are initially estimated based on the existing sand characteristics for the beach (native sand). If available sand (borrow sand) does not exactly match the characteristics of the native beach sand, the nourishment volume required has to be adjusted. Borrow sand volumes are then estimated based on their 'compatibility' to the native sand characteristics.

There are two commonly used methods to estimate the volume of borrow sand required for nourishment. These are:

- The Equilibrium Beach Profile Method; and
- The Overfill Factor Method.

Each method assumes the beach profile is in equilibrium with the wave climate. The Coastal Engineering Manual (CEM, 2002) recommends use of the Equilibrium Beach Profile Method and subsequently this method has been adopted for volume calculations for this project. Both the Overfill Factor and Equilibrium Beach Profile concepts indicate that sediment compatibility is sensitive to the native composite median grain diameter. As such, the compatibility range varies depending on the characteristics of the native beach material, with coarse material being less sensitive to small variations between the native and borrow sediments than fine material. CEM (2002) recommends, as a rule of thumb, for native beach material with a composite median grain diameter exceeding 0.2 mm, borrow material with a composite median diameter within plus or minus 0.02 mm of the native median grain diameter.

24.2.1 Equilibrium Beach Profile Method

Most beach profiles exhibit broad similarities:

- They are generally concave upwards;
- Beaches composed of coarser sand tend to be steeper than those of fine sand; and
- Storm waves tend to transport sand seaward, cause beach recession and subsequently a reduction in the profile slope (Dean, 2002).

Bruun (1954) proposed beaches reach an equilibrium state (Equation 24.1) following an examination of beach profiles from Denmark and California. This was later confirmed theoretically by Dean (1977).

$$h = Ay^{2/3} \quad (24.1)$$

Where:
h = water depth
A = sediment scale factor
y = distance offshore

The Equilibrium Beach Profile Method can be used to make preliminary estimates of required fill volumes when the native and fill sediments have different composite median grain sizes. The dependence of the sediment scale factor, *A*, has interesting consequences regarding beach nourishment. When a volume of fill sand per unit length is added to the native beach profile, it is assumed that it will equilibrate eventually to the form provided in Equation 24.1. Depending on the fill and native sediment scale parameters (A_F and A_N) and the volume added, the nourished beach profile can be intersecting, non-intersecting or submerged, as presented in Figure 24.1.

Whether a profile is intersecting or nonintersecting is determined by Equation 24.2 (Dean, 1991):

$$W\left(\frac{A_N}{D_C}\right)^{3/2} + \left(\frac{A_N}{A_F}\right)^{3/2} \quad \begin{matrix} < 1, \text{Intersecting Profile} \\ > 1, \text{Nonintersecting Profile} \end{matrix} \quad (24.2)$$

Where:
W = desired additional beach width
A_N = native sand scale factor
A_F = fill sand scale factor
D_C = depth of closure

If the fill sediment size is smaller than the native sediment size, a nonintersecting profile will always be formed. When this is the case a submerged profile will be reached at equilibrium unless additional sand is added. Equation 24.3 estimates the volume of submerged sand required prior to establishment of any dry beach at equilibrium, while Equation 24.4 estimates the volume required to produce a dry beach of width W at equilibrium (CEM, 2002).

$$V = \frac{3}{5}\left(\frac{D_C}{A_F}\right)^{5/2}(A_N - A_F) \quad (24.3)$$

$$V = \frac{3}{5}\left(\frac{D_C}{A_F}\right)^{5/2}\left(A_N\left[1 + W\left(\frac{A_F}{D_C}\right)^{3/2}\right]^{5/3} - A_F\right) \quad (24.4)$$

Where:
V = required volume
W = desired dry beach width
A_N = native sand scale factor
A_F = fill sand scale factor
D_C = depth of closure

For intersecting beaches (Equation 24.2 > 1) the volume per unit length of beach required to advance a beach following equilibrium is estimated by Equation 24.5.

$$V = WB + \frac{\frac{3}{5}W^{5/3}A_N A_F}{\left(A_F{}^{3/2} - A_N{}^{3/2}\right)^{2/3}} \tag{25.5}$$

Where:
V = required volume
W = desired dry beach width
A_N = native sand scale factor
A_F = fill sand scale factor
D_C = depth of closure

It is important to note that equilibrium profile methods do not account for a sediment deficit in the pre-project profile. Subsequently if a beach has a sediment deficit, as determined by the comparison of offshore profiles and equilibrium/design profiles, additional sand may be required.

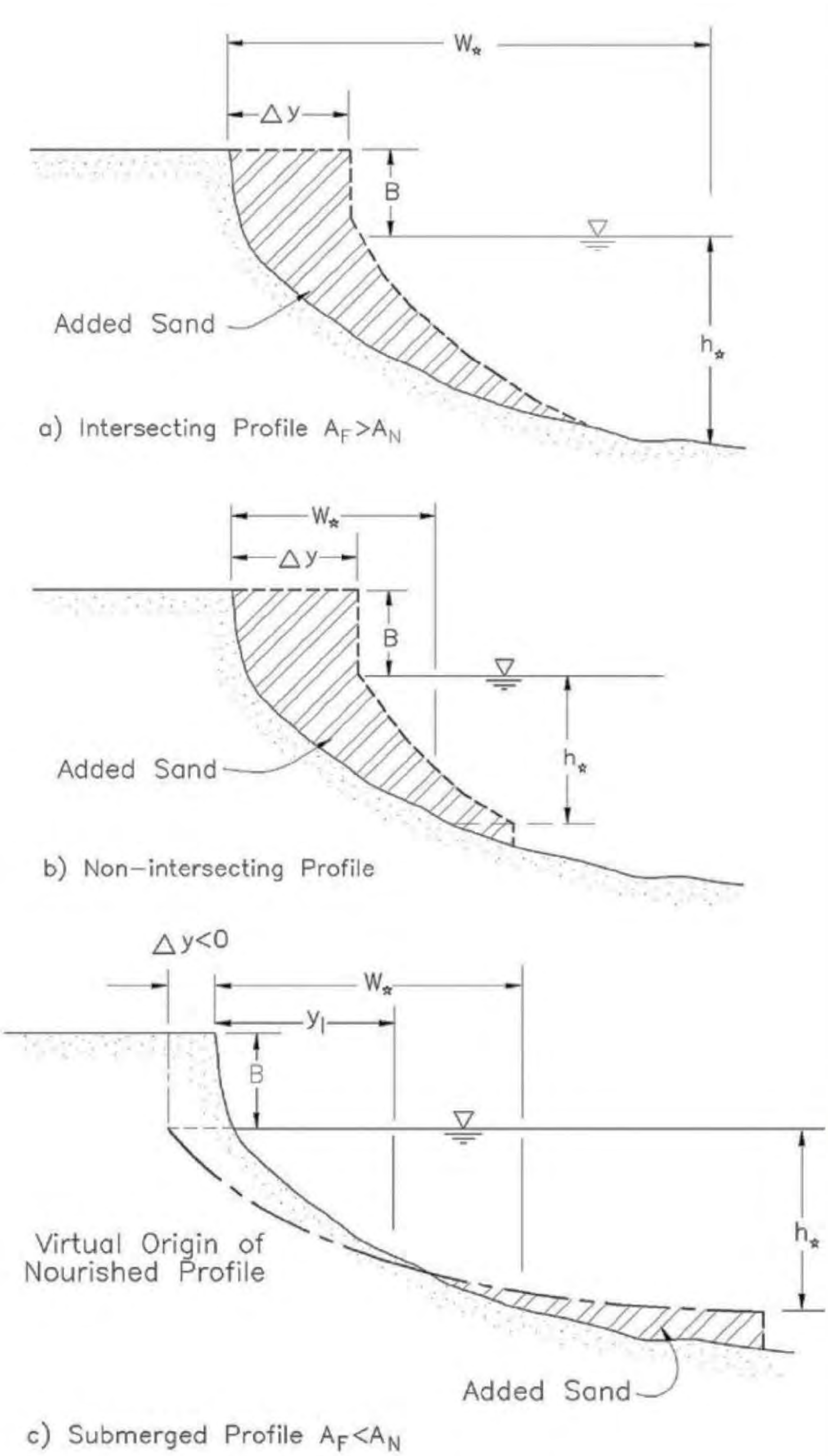


Figure 24.1: Three Generic Types of Nourished profiles

(a) intersecting, b) non-intersecting, c) submerged profile (CEM 2002)

24.2.2 The Overfill Factor Method

The Overfill Factor method is an alternative method for establishing the required volume of borrow sand for different levels of compatibility with native sand. The overfill factor (R_A) is the ratio of fill material required for a given borrow site compared to that required using the existing beach sediments. CEM (2002) suggests a beach nourishment project should use fill material with a composite median grain diameter equal to that of the native beach material, and with an Overfill Factor within the range of 1.00 to 1.05. However, obtaining this level of compatibility is not always possible due to limitations of available borrow sites.

The overfill factor takes into consideration the mean grain size and distribution of the borrow and native materials and provides an indication of the loss of material that will occur as a result of the differing sediment distributions.

Figure 24.2 shows isolines of the adjusted overfill factor. All sediment sizes are in phi units ($\varphi = -log_2(d)$) and the subscripts *b* and *n* refer to borrow and native sand respectively. The following values are included:

M_φ = the mean φ sediment size
σ_φ = standard deviation of φ

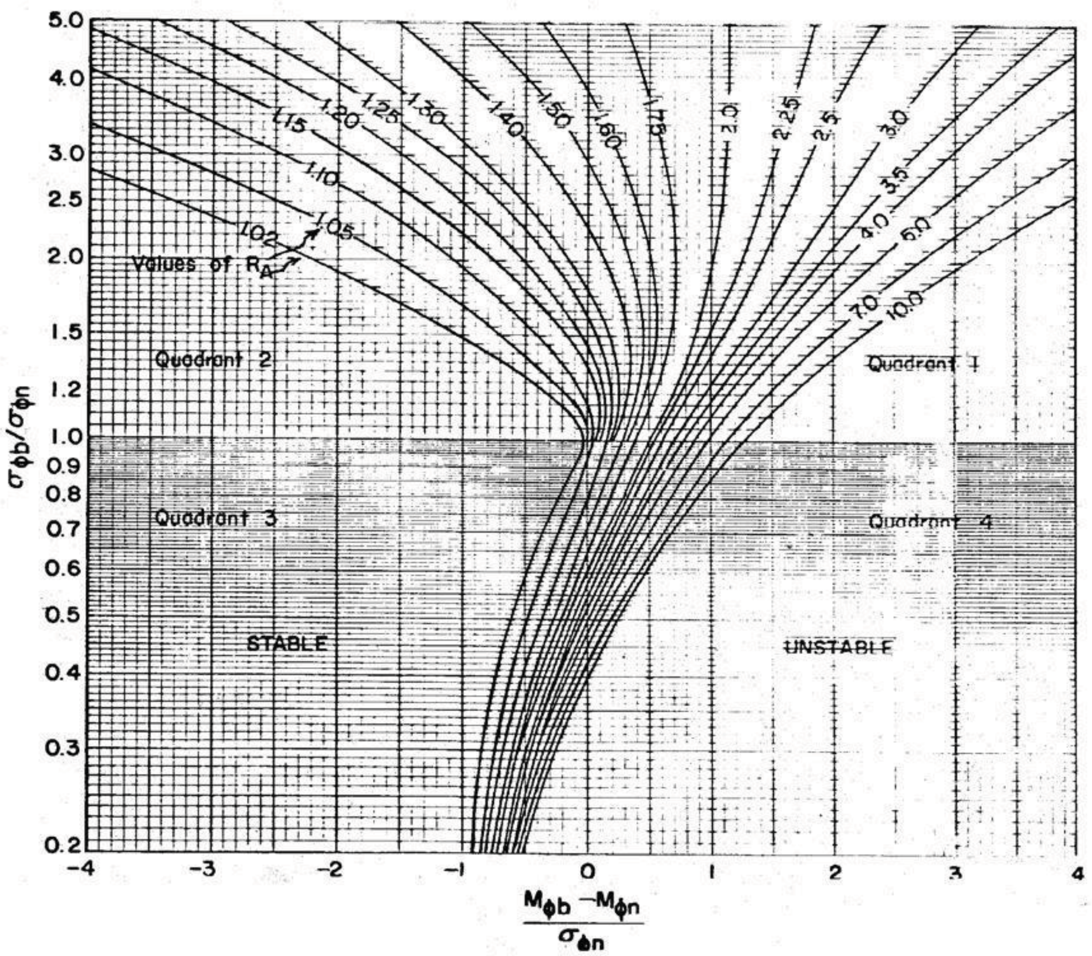


Figure 24.2: Isolines of Overfill Factor (Rijkswaterstaat and Delft Hydraulics, 1987)

24.2.3 Dune and Beach Design

The volumes of sand required for nourishment will vary along sections of a beach, however, for practicality the design nourished beach profile should be maintained relatively consistent over longer stretches of beach.

The NSW Dune Management Manual recommends the target dune face slope of dunes used for coastal defence should be between 1V:3H and 1V:5H.

Note that a substantial volume of sand is generally required under the water to meet the widening of the beach above the water.

24.3 Sediment Sources

24.3.1 Effect of Borrow Sand Grain Size on Required Nourishment Volumes

Typically, borrow material will not exactly match the native beach grain size. Ideally, it should be similar in grain size (or slightly coarser), composition, angularity and colour. An assessment is required of compatibility of the borrow material with the native beach, as the grain size distribution of the borrow material has a significant effect on the cross-shore shape of the nourished beach profile, sand loss rates and how the beach will respond to storms (as discussed in Section 24.2). The borrow sand compatibility is critical to the success of the nourishment campaign and the volume of nourishment sand required. Figure 24.3 demonstrates the effect of different fill grain sizes on the equilibrium beach profile. If finer borrow sand is placed on a beach, then the equilibrium profile will be flatter than the natural profile and significantly more borrow sand is required to meet target nourishment volumes above sea level (compared to the requirements for nourishment with matching borrow and native sand).

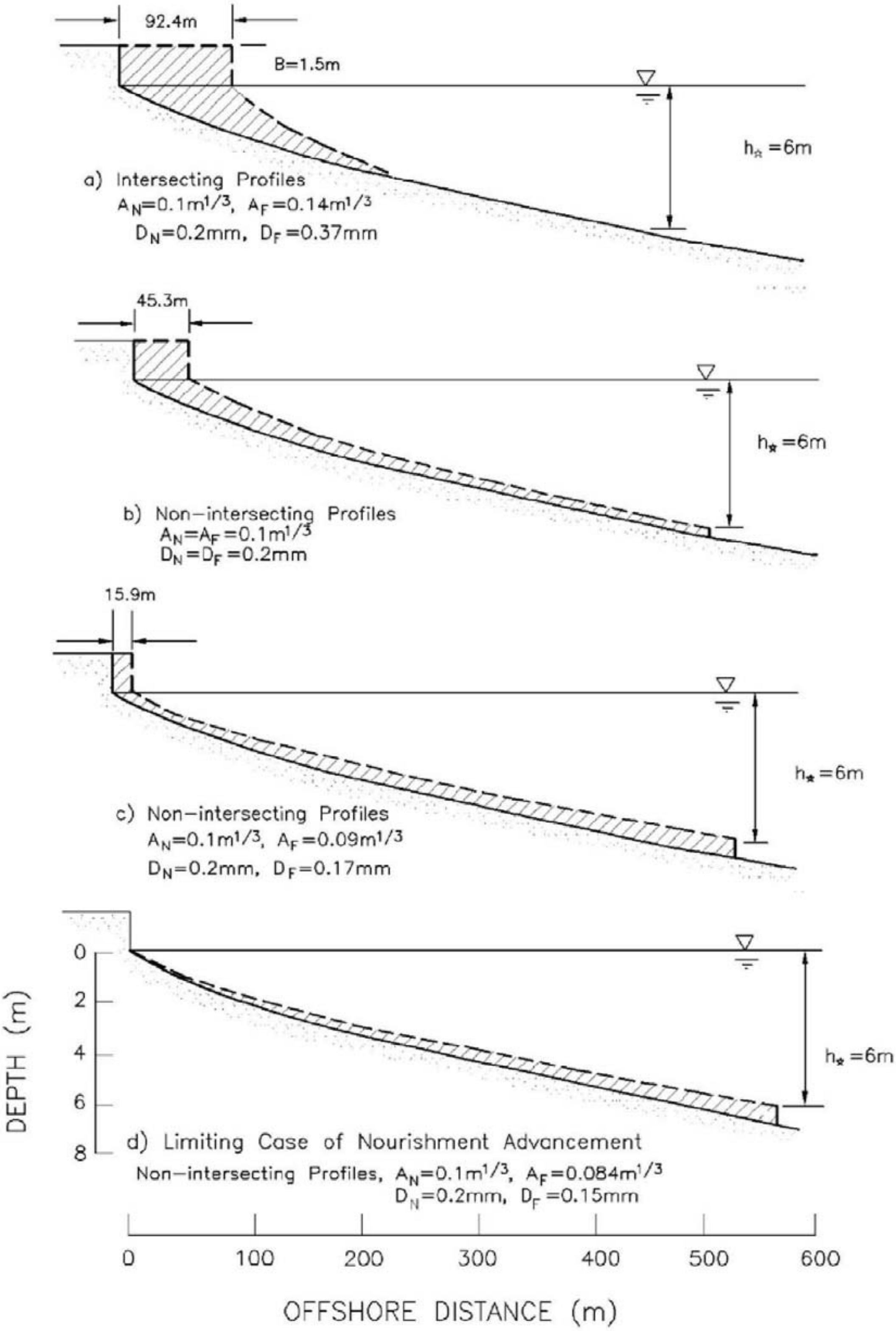


Figure 24.3: Effect of Nourishment Grain Size on Width of Dry Beach and Equilibrium Profile (CEM, 2002)

24.3.2 Available Nourishment Sand Supplies

Generally, two potential sand supplies sources for nourishment are:

- Offshore sand deposits; and
- Terrestrial sand quarries.

24.4 Implementation of Nourishment Works

24.4.1 Dredging of Offshore Sand

Dean (2002) suggests that more than 95% of all sand volumes placed in beach nourishment projects are through offshore dredging. Dredging may be reasonably non-disruptive to the community along a shoreline and, due to the efficiencies that can be achieved through large scale dredging operations, the unit costs are generally lower than by other approaches (Dean, 2002).

Within offshore dredging there are two different placement methods; pipeline dredges and hopper dredges. Pipeline dredging consists of a dredge moving systematically within the borrow area and excavating a bank. The dredge consists of a floating barge and a 'ladder' which is mounted at the bow of the barge. The ladder supports the intake pipe and is articulated vertically so that it can move up and down thereby accessing the borrow area. The sand/water mixture (slurry) is carried up to the barge where the main pump creates enough pressure to move the slurry mixture through a pipeline to the nourishment location. Additionally, pipeline dredges can be classified as 'cutter head' or 'suction head' dredges. Suction head dredges are the most effective for very mobile, fine sediments. Cutter head dredges include a rotating feature called a 'cutter head' at the lower end of the intake pipe. This is equipped with steel teeth or blades which mobilise the sediments, enhancing the flow of sediments into the pipe (Dean, 2002).

Hopper dredges are basically vessels equipped with dredge pumps and 'drag' arms that extend over one or both sides of the vessel, down to the sea floor. These arms remove material from the sea floor and pump the slurry up through the arms, into the ship hull. This process is carried out while the ship is moving at approximately 2 to 3 knots. Once the ship hopper is filled to capacity the ship moves near the beach nourishment area where there are several options for discharging. It can either drop the material to the sea floor through hopper doors, pump the material out through a pipeline up onto the beach or by using the 'rainbow' method, discharging the slurry by a jet with the bow of the hopper dredge brought as close to the shore as is practicable (Dean 2002).

If sand is pumped from an offshore dredge, the sand can be directly pumped into the nearshore surf zone for distribution over the active profile by waves, or alternatively it can be pumped to spill piles on the beach for distribution by bulldozer.

24.4.2 Truck Placement

While the majority of beach nourishment projects are carried out through dredging from offshore borrow areas a small percentage are carried out by placement via truck from land sources. These projects are usually relatively small due to the size of the possible supply as well as the relative inefficiency of land based haulage and social disruption from many truck movements. Material placed on-site by trucks may be tipped into stockpiles on the beach for spreading by bulldozer. Placement of sand over the submerged active profile is generally restricted to the zone between low and mid tide. It is assumed that the complete volume of sand required to nourish the submerged profile would be placed into this intertidal zone and allowed to be dispersed by the tide and waves.

24.4.3 Spreading of Sand Over Beach

Sand placed from either dredge or trucks requires spreading from spill piles across the beach. For dredge placed sand this will be the volume of sand required to be placed above mean sea level, however, for truck placed sand this will also include the sand required to nourish the remainder of the submerged profile (as discussed above).

A range of mechanical plant including front-end loaders, bulldozers, or truck and excavator combinations may be used for beach scraping. The machinery selected for a particular project varies, however, depending on a number of factors:

- The type of dune shaping required;
- Mechanical plant available to selected contractor; and
- Local commercial factors such as hire cost, supply, demand and transportation distance.

Mechanical plant which use tracks or skids are advantageous on beaches as the larger surface area of tracks means they apply less pressure to the beach surface than wheels. This means they are less likely to become bogged in soft or wet sand and may place less stress on local ecosystems. However, wheeled machinery may be driven on roads and thus may prove easier to transport from beach access points to designated setdown areas overnight.

24.4.4 Operating Constraints

Beach nourishment projects are subject to several operating constraints. These include things such as the weather, specific operating constraints of the selected fill placement method and closure of the beach for placement of the fill material.

Adverse weather conditions have the potential to have an impact on production rates for beach nourishment, dredging in particular. Large swell conditions have the potential to halt dredging and spreading of material on the beach. AECOM (2010) state medium to large trailing suction hopper dredges are able to operate in wave conditions of up to 3 m. Smaller vessels would have a lower operating threshold. Another potential limitation is the depth at the borrow site; if water depths are shallow the draught of the dredge and other work vessels is an important consideration.

Between construction periods (i.e. poor weather, large seas or overnight), mechanical plant should be removed from the beach via designated beach access points and stored in designated plant set-down areas. A number of such access points may be required to minimise long travel distances along the beach. These access ways will likely need to be shaped prior to, and maintained throughout the construction phase using beach sand and revegetated following construction. These issues should be addressed prior to project commencement.

24.4.5 Post-Nourishment Works

Vegetation on the coastal foredune assists in dune building and accretion of the upper beach and reduces aeolian sediment losses from the littoral budget. Dune vegetation is also widely recognised as contributing to maintaining healthy and diverse ecological systems including providing food and shelter to a variety of fauna (NSW Coastal Dune Management Manual, 2001).

Thus revegetation of formed dune areas should be undertaken immediately following beach nourishment to retain sand in the littoral system, promote further dune building and upper beach accretion and to restore ecological systems which may have been damaged during nourishment. It is anticipated that some continued management of the vegetated areas will be required for 2 to 3 years following works. This management may include re-fertilisation, watering and weed removal.

Planting should be undertaken using appropriate plant species (preferably locally indigenous) and correct timing and planning techniques. Selection of appropriate plants and planting techniques should be undertaken with assistance from local coastcare groups and ecologists.

Planting can be either from seed or from nursery raised seedlings. Seedlings are typically better planted in wetter, winter months. Plant density affects the speed and ability of plants to begin to trap sand. The Queensland Beach Protection Authority *Management Guidelines for Dune Use* (2003) recommends planting of dune binding grasses such as Spinifex at around 1 m centres and the application of 6-8 grams of high-nitrogen, slow-release fertiliser with each seedling. Planted seedlings should be staggered row to row to maximise wind disturbance and trapped sand. It is recommended that revegetation be restricted to the newly formed dune crest. This should ensure adequate trapping of wind-blown sand while avoiding smothering of vegetation during natural reshaping of the nourishment material. Additionally, if high energy events remove a portion of the newly formed dune-toe, loss of newly established vegetation will be minimised.

The closure of any existing unofficial access ways through the dunes and development of signed and fenced access ways is recommended. It is also recommended that vegetated areas be fenced to reduce impact of people using these areas and promote vegetation establishment.

24.5 Environmental Impacts of Beach Nourishment and Dredging

A wide range of environmental impacts are associated with beach nourishment, particularly when the material has been sourced by dredging. These include physical impacts, predominantly from extraction of the fill material, and ecological impacts, occurring at both the borrow and fill sites.

24.5.1 Physical Impacts

Studies of sand extraction and dredging show there is a possibility of some resultant impact on adjacent beaches. The extent of these effects depends upon the depth of extraction below the natural sea bed, and the water depth at which extraction occurs (AECOM, 2010).

Extraction of offshore sand has the potential to affect the coastline in several ways, including:

- If sand is extracted too close to the shore it may create a depression in which beach sediment is transported offshore into the extracted area;
- An offshore bank of sand may protect the coastline by absorbing or scattering some of the incoming wave energy. The removal of a barrier like this may result in additional erosion;

- Locally increased depths may alter the angle of incident waves and distribution of wave energy approaching the adjacent beaches, resulting in erosion and accretion; and
- The removal of offshore sediment may deprive the coast of a natural sediment source (AECOM, 2010).

If nourishment sand is to be sourced by dredging offshore of a beach, it is recommended that the dredging pattern be designed to minimise wave refraction effects. This would require numerical SWAN wave modelling, or at least alignment of post dredging contours with the dominant wave crest alignment at the site.

Quarrying and haulage of significant quantities of terrestrial sand would also have potential physical impacts, including but not limited to:

- Interruptions to traffic and damage to public roads from haul trucks;
- Carbon dioxide emissions (minimal local scale effect but contribution to global scale which is exacerbating local erosion problems);
- Clearing of land for quarry and associated stormwater runoff and siltation management issues; and
- Noise.

24.5.2 Ecological Impacts

Beach nourishment operations can disrupt existing biological communities both above and below the waterline. Placement of large quantities of sediment within the near shore zone, as is the case with beach nourishment, can have substantial effects on the biota residing in this area. Additionally, dredging of material for fill placement will also have ecological impacts. However, the active beach zone is dynamic, with the seasonal relocation of large quantities of sand from portions of the subaerial beach and near shore zone. Subsequently the animals residing in this region tend to be well-adapted to highly dynamic conditions (Dean, 2002).

Dean (2002) suggests ecological impacts can be divided into short-term and long-term impacts. Short-term impacts may include:

- Direct burial of the creatures that reside in the area;
- Lethal or damaging doses of turbidity; and
- Direct effects of equipment used in the beach nourishment process.

Long-term impacts may include:

- Beaches that are altered in their natural state;
- A long-term source of turbidity affecting light penetration; and
- Altered sediment compositions which may affect the types of biota of the area.

There are three (3) specific beach sections that are likely to be impacted by a beach nourishment project involving dredging: the subaerial beach, the sub-tidal beach, and the borrow source areas (Committee on Beach Nourishment and Protection, 1995). Likely impacts differ in each of the three (3) zones and are outlined in the following paragraphs.

Subaerial Beach
The subaerial beach comprises two (2) components: the supralittoral (dry) portion of the beach and the intertidal zone. As the primary purpose of beach nourishment is to increase the volume

of sand in this area substantial amounts of nourishment sand is added to these sections of the beach. Obvious positives of a beach nourishment program on the subaerial beach include protection of coastal property and infrastructure and improvement of the beach for recreational purposes. Possible negative ecological impacts include:

- Disturbance of the indigenous biota inhabiting the subaerial zones, in turn possibly affecting the foraging patterns of the species that feed on those organisms; and
- Disruption to species that use subaerial beach habitats or adjacent areas for nesting, nursing and breeding areas (Committee on Beach Nourishment and Protection, 1995).

Several studies have shown that even when beach-compatible materials are used, the nourished beach may be physically altered when compared to unnourished beaches with respect to sand compaction, shear resistance, moisture content, grain size and shape, and other factors (Committee on Beach Nourishment and Protection, 1995).

Sub-tidal Beach
Aquatic habitats adjacent to the subaerial beach, in the near shore zone, are affected by beach nourishment projects through nourishment of the active profile. These areas often support a diverse array of biota. Ecological consequences of beach nourishment projects can include:

- Burial of habitats in the surf zone as the beach is widened;
- Increased sedimentation in areas seaward of the surf zone as the fill material redistributes to a more stable profile;
- Changes in the near shore bathymetry and associated changes in wave action; and
- Elevated turbidity levels, particularly in the vicinity of pipeline effluent (Committee on Beach Nourishment and Protection, 1995).

Movement of sediment away from the designated nourishment area can have both beneficial and detrimental effects. Littoral drift may benefit beaches adjacent to the nourishment area by providing additional sand material. However, it may also have adverse effects on neighbouring vulnerable communities.

Biological effects resulting from alteration of the near shore zone have not been well documented (Committee on Beach Nourishment and Protection, 1995). However, mobile invertebrates and fishes found in this region should be able to avoid the major direct effects of beach nourishment. Surveys of fish populations off a nourished beach in Florida showed no evidence of adverse effects to the fish (Committee on Beach Nourishment and Protection, 1995). It has been suggested that hard-bottom reef habitats or seagrass beds, may be the most adversely affected by elevated turbidity surrounding beach nourishment. High turbidity and silt loads in these environments can smother organisms, inhibit filter-feeding processes and/or significantly decrease photosynthetic activity, potentially resulting in long-term damage to these resources (Courtenay *et al*., 1974; 1980; Goldberg, 1989).

Borrow Source Area
The primary biological effect of dredging to obtain beach nourishment material is removing benthic vegetation and creatures present on the sediments. Dredging can also increase turbidity in the borrow area. There is the potential for deep holes to alter water quality, potentially decreasing dissolved oxygen levels or increasing hydrogen sulphide levels. However, this is more likely to occur in sheltered regions. Dredging operations have also been known to damage reef habitats in areas adjacent to the borrow area when buffer zones have been inadequate

(Grober, 1992). However, with adequate buffer zones and the use of accurate positioning systems this can be avoided.

There is potential for contamination of sediment from heavy metals or other contaminants when sand is sourced from the seabed or contamination from weeds when sourced terrestrially. Test samples from the borrow source area are be required to confirm the presence (or absence) of heavy metals and other contaminants.

Introduction of weeds is a likely problem when using terrestrial sand sources, though the use of more expensive screened sand will help to minimise these effects. Regular monitoring of the beach and removal of any weeds following completion of the nourishment program will reduce this ecological impact.

25. Appendix G: Unfeasible Options for Areas with Existing Development Under Threat Prior to 2050

Table 25.1: Unfeasible or Marginally Feasible Coastal Hazard Management Options for Areas with Existing Development Under Threat Prior to 2050

Option Category	Option	Sub-Option	Basis for Unfeasibility
Changing the Likelihood	Coastal or flood protection works (short or long term)	Henkelriff System (interlocking concrete units placed on the bed of the ocean)	There is no available design guidance and no known applications on the open coast.
	Coastal or flood protection works (short or long term)	Foil System (aerofoil shaped structures constructed offshore)	There is no available design guidance and no known applications on the open coast.
	Coastal or flood protection works (short or long term)	Permeable Groynes	There are no long-lasting permeable groynes on marine coastlines in Australia or worldwide. Furthermore, there are problems associated with damage to these structures from wave impacts (Coghlan et al, 2013).
	Coastal or flood protection works (short or long term)	Permeable Offshore Breakwaters (i.e. floating breakwaters, skirt breakwaters, wavescreen breakwaters)	Only suitable for low wave energy environments; they are susceptible to storm damage and their performance is tuned to a narrow range of wave periods.
	Coastal or flood protection works (short or long term) Nourishment	Nourishment Seawall	Marginally feasible. Imported sand would be "lost" without an end control groyne or groyne field.
	Coastal or flood protection works (short or long term) Nourishment	Nourishment Offshore Breakwaters (Emergent)	Marginally feasible. Imported sand would be "lost" without an end control groyne or groyne field.
	Coastal or flood protection works (short or long term) Nourishment	Nourishment Offshore Breakwaters (Submerged Reef)	Marginally feasible. Imported sand would be "lost" without an end control groyne or groyne field.
	Nourishment	Nourishment Alone	Marginally feasible. Imported sand would be "lost" without an end control groyne or groyne field.

Table 25.1: Unfeasible or Marginally Feasible Coastal Hazard Management Options for Areas with Existing Development Under Threat Prior to 2050 (cont.)

Option Category	Option	Sub-Option	Basis for Unfeasibility
Changing the Likelihood (cont.)	Beach Scraping	N/A	Insufficient sand available. Most suited for isolated low points.
	Beach Dewatering	N/A	Beach dewatering systems are only suitable for low wave energy environments (if ever). They are susceptible to storm damage and they do not provide adequate protection from storm erosion (Mariani, 2012).
	Re-vegetation programs (e.g. dunes)	Dune Re-vegetation Alone	Insufficient sand to be standalone measure.
	Re-vegetation programs (e.g. dunes)	Planting of coastal vegetation (i.e. seagrasses, salt marshes and mangroves)	Insufficient sand to be standalone measure. This option is only suitable for low wave energy environments such as estuaries and deep embayments and would provide little beach erosion/recession protection on the open coast (Mariani, 2012).
	Compliance action relating to illegal works on beaches	N/A	This option is a necessary part of BBE foreshore management for safety reasons but it is not relevant to mitigating long term coastal hazards.
	Cliff and slope stabilisation works	N/A	Only suitable for mitigating the hazard of coastal cliffs instability.
Changing the Consequence	Catch walls	N/A	This option is unfeasible as does not mitigate the hazard of beach erosion/recession.
	Access control	N/A	This option is only suitable for mitigating the hazard of coastal cliffs instability, or as interim management of erosion or inundation.
	Public education	N/A	This option is a necessary part of BBE foreshore management but it is not relevant to mitigating long term coastal hazards.
Sharing the Risk with Another Party	Insurance	N/A	Insurance against the primary coastal hazards within the BBE (beach erosion/recession and coastal inundation) is not generally available in Australia.
Retaining the Risk by Informed Decision	Emergency management (including monitoring and warning)	N/A	This option is a necessary part of BBE foreshore management for safety reasons but it is not relevant to mitigating long term coastal hazards.

26. Appendix H: Overview of Assets Potentially Affected by Coastal Hazards

26.1 Overview

26.1.1 Erosion/Recession Hazard

Coastal hazards for the Byron Bay Embayment were assessed in BMT WBM (2013). BMT WBM produced hazard lines for the combined hazards of beach erosion, shoreline recession and (the sea level rise component of) climate change for three (3) planning horizons, namely:

- Immediate;
- 2050; and
- 2100.

Detailed mapping of other coastal hazards was not undertaken in BMT WBM (2013), so is not considered in this Appendix. For the shoreline recession hazard, BMT WBM (2013) produced three (3) estimates, namely low, "best estimate" and high. In order to reduce the permutations, WRL with the concurrence of BSC and OEH, undertook a count of assets potentially affected by coastal hazards for BMT WBM's "best estimate" of the shoreline recession hazard.

BMT WBM's (2013) hazard lines also considered two (2) scenarios, namely:

- Scenario 1: Keep/maintain/upgrade all existing coastal protection structures; and
- Scenario 2: Remove all existing coastal protection structures except Jonson Street (which would need to be maintained/upgraded.

Therefore, six (6) hazard lines were considered by WRL for counting assets potentially vulnerable to coastal hazards. Due to the presence of rock outcrops, headlands and existing coastal protection structures, the WBM hazard lines were not continuous for the Byron Bay embayment. In order to count assets situated near the ends of hazard lines, a line intersecting the endpoints of the 2100 and the immediate hazard lines was drawn and extended to an arbitrary point offshore, as shown in Figure 26.1. Future upgrades to protection structures and minor inaccuracies in hazard line plotting may alter the count of affected assets near the ends of the hazard lines.

Figure 26.1: Example of End of Hazard Lines - Shirley Street

Three asset types were assessed by WRL, namely:

- Properties (rateable addresses containing single or multiple cadastre parcels);
- Structures (buildings); and
- Significant infrastructure.

26.1.2 Other Coastal Hazards

Discussion regarding other coastal hazards is provided in Sections 2.6, 2.7 and 2.8.

26.2 Methodology

26.2.1 Property Count

A property was considered potentially affected by erosion/recession/climate change if a cadastre parcel was located seaward of or was intersected by a hazard line.

26.2.2 Structure Count

An aerial image provided to WRL by BSC ("byron_embayment_may_2013_20cm.jp2") of the area taken on May 2013 was inspected to identify structures potentially vulnerable for each hazard scenario. The following notable cases occurred in the property count:

- Single cadastre parcels containing multiple structures;
- Single structure located on multiple cadastre parcels; and
- Cadastre parcels with no structures present.

A structure located on multiple cadastre parcels was only counted once and attributed to the one cadastre parcel closest to the centre of the structure (generally its rateable address).

26.2.3 Significant Infrastructure

Water, stormwater and sewer infrastructure services were considered potentially affected by erosion if located seaward of or intersected by a hazard line.

Other public assets, considered potentially affected by erosion including streets, footpaths, amenities blocks, car parks, playgrounds and picnic areas, were identified based on desktop analysis.

26.3 Illustrated Examples

The following examples illustrate the application of the methodology used to prepare estimates of assets affected by erosion for present day and future scenarios.

26.3.1 Border Street, Byron Bay (Properties)

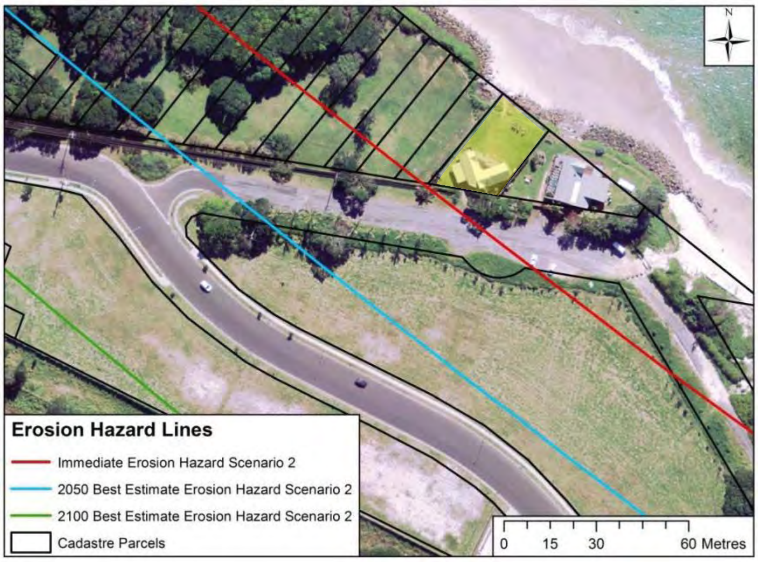


Figure 26.2: Example Border Street, Byron Bay Scenario 2

The highlighted property in Figure 26.2 (Border Street) is seaward of each of the three hazard lines and on this basis it potentially may be impacted by erosion for the immediate, 2050 and 2100 planning horizons (for Scenario 2, removal of protection structures).

26.3.2 Byron Bay Surf Life Saving Club (Structures)

The location of the hazard lines with regard to the Byron Bay Surf Club (BBSLSC) structure is shown in Figure 26.3 for Scenario 1 and 2. Based on the combination of hazard lines and their extrapolation seaward, the BBSLSC structure was marginally impacted by the hazard lines for the following best estimate planning horizons:

- 2050 (Scenario 1 only); and

- 2100 (Scenarios 1 and 2).

However, the impacts on BBSLSC are largely an artefact of the assumed eastward limit of the Jonson Street protection works. Given Council's resolve to retain and upgrade these works (resolution 14-66), it is likely that any upgrade will protect BBSLSC, but this must be considered in design and future maintenance.

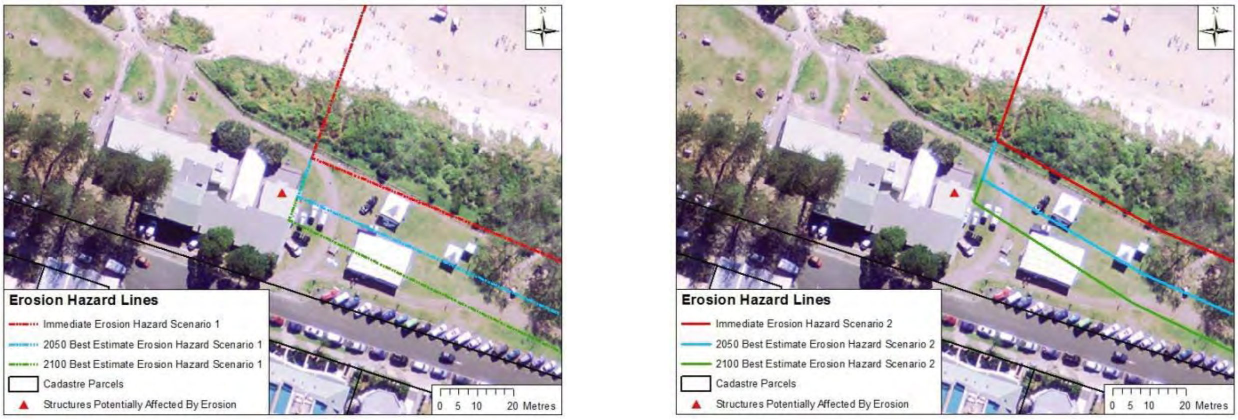


Figure 26.3: Example Byron Bay SLSC and hazard lines for Scenario 1 (left) and Scenario 2 (right)

26.3.3 Clarkes Beach Holiday Park (Structures)

Structures in the Clarkes Beach Holiday Park were considered in the risk assessment if described as a "cabin" in the park map, available on the North Coast Holiday Park website (North Coast Holiday Park, 2011). A total of 32 structures in the park are potentially vulnerable to erosion for the 2100 planning horizon shown in Figure 26.4.

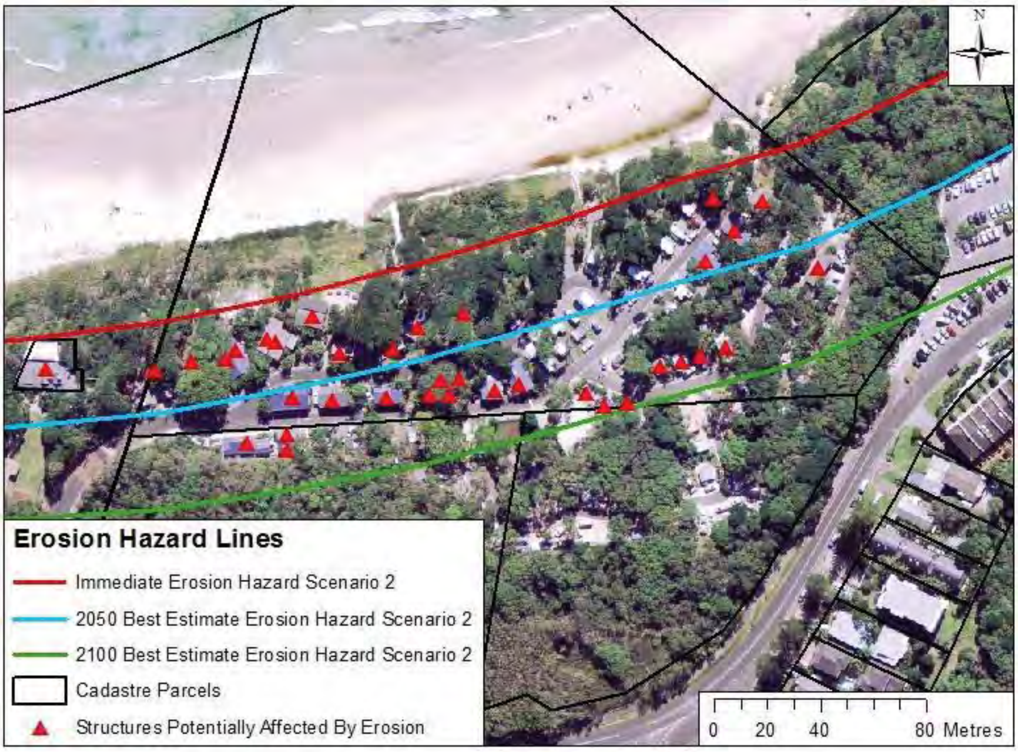


Figure 26.4: Example Clarkes Beach Holiday Park

26.3.4 Cavvanbah Street (Structures)

An example of one cadastre parcel at Cavvanbah Street containing multiple structures is shown in Figure 26.5. For Scenario 2 for the 2100 planning horizon, the two structures in the highlighted cadastre parcel (plus numerous others) are potentially vulnerable to erosion.

Figure 26.5: Example Cavvanbah Street

26.3.5 Don Street (Structures)

An example is illustrated Figure 26.6 of a single structure located on multiple cadastral parcels. Note that these multiple cadastre parcels have only one owner. For all planning horizons for erosion hazard scenario 2, one structure is counted for cadastre parcel ID 111210.

Figure 26.6: Example Don Street

26.3.6 Sewer Gravity Mains (Significant Infrastructure)

Figure 26.7 illustrates the sewer gravity mains located near Manfred Street. Services were counted if any part of the service was located seaward of or intersected by a hazard line. Using this methodology, the sewer gravity mains potentially affected by erosion for all planning horizons are highlighted in Figure 26.7 and include: ID 1156, ID 1162, ID 1170, ID 4229 and ID 4228. It should be noted, however, that if Scenario 2 is followed (removal of structures), the sewer services would not be needed, since the houses which they service are seaward of the sewer mains, and would therefore be lost to erosion prior to the sewer.

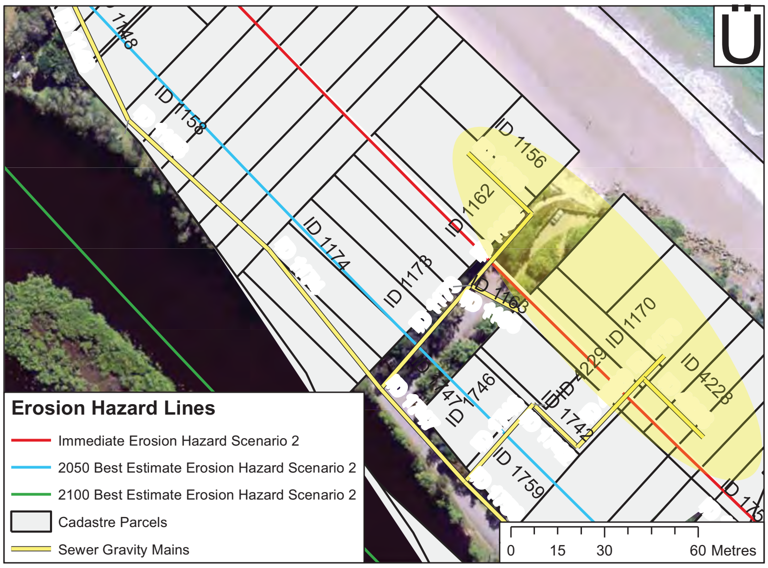


Figure 26.7: Example Sewer Gravity Mains

26.3.7 Massinger Street Public Assets (Significant Infrastructure)

Examples of public assets at Massinger Street potentially vulnerable to erosion for the 2100 planning horizon for Scenario 2 are shown in Figure 26.8.

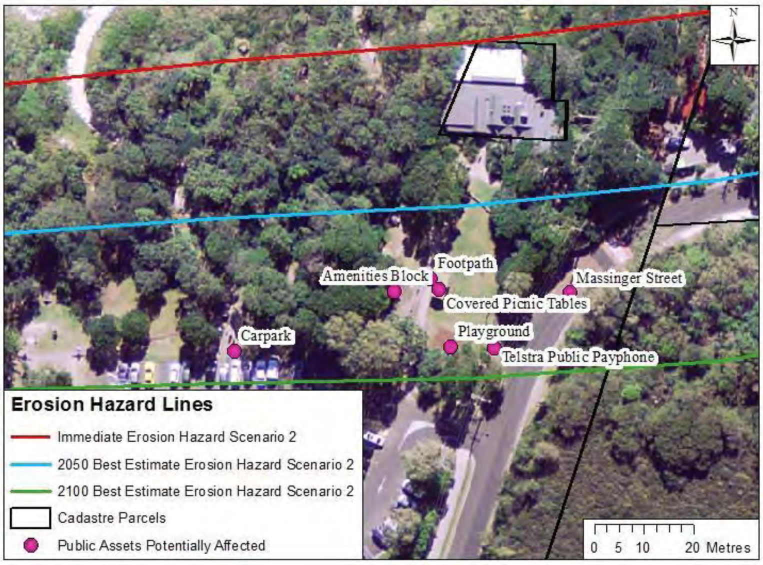


Figure 26.8: Example Massinger Street Public Assets

26.4 List of Assets Potentially Vulnerable to Erosion

A detailed database of assets potentially vulnerable to erosion was provided electronically to BSC. This Section summarises vulnerable assets, with additional details provided in Appendix I for each scenario.

The properties potentially at risk from erosion are summarised in Table 26.1.

Table 26.1: Properties Potentially at Risk from Erosion

Planning Horizon	Erosion Hazard	Scenario	Total Number of Cadastre Parcels at Risk
Immediate	Best estimate	1 (retain structures)	54
Immediate	Best estimate	2 (remove structures)*	134
2050	Best estimate	1 (retain structures)	58
2050	Best estimate	2 (remove structures)*	166
2100	Best estimate	1 (retain structures)	84
2100	Best estimate	2 (remove structures)*	230

Note: *Retain Jonson St works only.

The structures potentially vulnerable from erosion are summarised in Table 26.2.

Table 26.2: Structures Potentially Vulnerable from Erosion

Planning Horizon	Erosion Hazard	Scenario	Number of Structures at Risk
Immediate	Best estimate	1	2
Immediate	Best estimate	2	36
2050	Best estimate	1	22
2050	Best estimate	2	78
2100	Best estimate	1	60
2100	Best estimate	2	161

Other significant infrastructure potentially at risk from erosion is summarised in Table 26.3. Note that no sewer vacuum mains or water mains are potentially affected by erosion.

Table 26.3: Other Significant Infrastructure Potentially at Risk from Erosion

			Number Of Assets At Risk							
Planning Horizon	Recession Hazard	Scenario	Sewer Gravity Mains	Sewer Pressure Mains	Sewer Rising Mains	Stormwater Drains	Stormwater Mains	Sewer Vacuum Mains	Water Mains	Other (Public Assets)
Immediate	Best estimate	1	0	0	1	0	1	0	0	2
Immediate	Best estimate	2	12	0	1	0	1	0	0	5
2050	Best estimate	1	3	0	1	0	4	0	0	3
2050	Best estimate	2	28	1	1	0	6	0	0	6
2100	Best estimate	1	12	2	1	0	10	0	0	19
2100	Best estimate	2	64	36	1	3	19	0	0	34

27. Appendix I: Details of Assets Potentially Vulnerable to Erosion

27.1 Allotments Potentially Vulnerable to Erosion Hazard

Table 27.1: Immediate Erosion Hazard Scenario 1 (retain seawalls) - Properties

CADASTRE_I	LOT	SECTION_	DP	STRATA	HOUSE_NUM	STREET_NAM	STREET_TYP
90810	39	3	1623			The Esplanade	
90820	42	3	1623			The Esplanade	
90830	45	3	1623			The Esplanade	
90840	47	3	1623			The Esplanade	
90850	50	3	1623			The Esplanade	
90860	51	3	1623			The Esplanade	
123480	61	3	1623			The Esplanade	
123490	62	3	1623			The Esplanade	
123500	63	3	1623			The Esplanade	
123510	64	3	1623			The Esplanade	
123520	65	3	1623			The Esplanade	
123530	66	3	1623			The Esplanade	
162190	40	3	1623			The Esplanade	
162210	41	3	1623			The Esplanade	
162240	43	3	1623			The Esplanade	
162250	44	3	1623			The Esplanade	
165270	52	3	1623			The Esplanade	
165280	53	3	1623			The Esplanade	
165290	54	3	1623			The Esplanade	
165300	55	3	1623			The Esplanade	
165310	56	3	1623			The Esplanade	
165320	57	3	1623			The Esplanade	
165330	58	3	1623			The Esplanade	
165340	59	3	1623			The Esplanade	
165350	60	3	1623			The Esplanade	
167230	49	3	1623			The Esplanade	
167260	46	3	1623			The Esplanade	
167270	48	3	1623			The Esplanade	
182860	408		729057			The Esplanade	
184330	214		755695			Bay	Street
184340	323		755695			Bay	Street
184360	342		755695			Bay	Street
184450	329		755695			Bay	Street
184460	327		755695			Bay	Street
184470	328		755695			Bay	Street
184480	326		755695			Bay	Street

184490	338		755695			Bay	Street
184510	337		755695			Bay	Street
238789	9		1049827			Lawson	Street
239654	7013		1087016			The Esplanade	
168070	413		729062			Lighthouse	Road
168080	412		729062			Lighthouse	Road
168090	411		729062			Lighthouse	Road
241547	12		1164217			Lighthouse	Road
187230	5		827049			Lawson	Street
187240	6		827049			Lawson	Street
238790	10		1049827			Bay	Street
123540	67	3	1623			The Esplanade	
123550	68	3	1623			The Esplanade	
123560	69	3	1623			The Esplanade	
134390	11		243218		144	Bayshore	Drive
168100	410		729062			Lawson	Street
182800	5		729063			Childe	Street
184230	407		729057			Bayshore	Drive

Table 27.2: Immediate Erosion Hazard Scenario 2 (remove seawalls) - Properties

CADASTRE_I	LOT	SECTION_	DP	STRATA	HOUSE_NUM	STREET_NAM	STREET_TYP
90810	39	3	1623			The Esplanade	
90820	42	3	1623			The Esplanade	
90830	45	3	1623			The Esplanade	
90840	47	3	1623			The Esplanade	
90850	50	3	1623			The Esplanade	
90860	51	3	1623			The Esplanade	
123480	61	3	1623			The Esplanade	
123490	62	3	1623			The Esplanade	
123500	63	3	1623			The Esplanade	
123510	64	3	1623			The Esplanade	
123520	65	3	1623			The Esplanade	
123530	66	3	1623			The Esplanade	
162190	40	3	1623			The Esplanade	
162210	41	3	1623			The Esplanade	
162240	43	3	1623			The Esplanade	
162250	44	3	1623			The Esplanade	
165270	52	3	1623			The Esplanade	
165280	53	3	1623			The Esplanade	
165290	54	3	1623			The Esplanade	
165300	55	3	1623			The Esplanade	
165310	56	3	1623			The Esplanade	
165320	57	3	1623			The Esplanade	
165330	58	3	1623			The Esplanade	
165340	59	3	1623			The Esplanade	
165350	60	3	1623			The Esplanade	
167230	49	3	1623			The Esplanade	
167260	46	3	1623			The Esplanade	
167270	48	3	1623			The Esplanade	
182860	408		729057			The Esplanade	
184330	214		755695			Bay	Street
184340	323		755695			Bay	Street
184360	342		755695			Bay	Street
184450	329		755695			Bay	Street
184460	327		755695			Bay	Street
184470	328		755695			Bay	Street
184480	326		755695			Bay	Street
184490	338		755695			Bay	Street
184510	337		755695			Bay	Street
238357	7019		1113435			The Esplanade	
238789	9		1049827			Lawson	Street

239654	7013		1087016			The Esplanade	
168070	413		729062			Lighthouse	Road
168080	412		729062			Lighthouse	Road
168090	411		729062			Lighthouse	Road
241547	12		1164217			Lighthouse	Road
1070	1	1	1623		2	Border	Street
19660	1		808937		3	Don	Street
49580	38	2	1623		4	Manfred	Street
90560	28	2	1623		34	Childe	Street
90590	33	2	1623			Childe	Street
90600	35	2	1623		28A	Childe	Street
90610	36	2	1623		28A	Childe	Street
90620	37	2	1623		2	The Esplanade	
90630	2		521030			The Esplanade	
90640	1		521030			Manfred	Street
90660	15	3	1623		20	Childe	Street
90700	19	3	1623		16	The Esplanade	
90710	21	3	1623			The Esplanade	
90720	25	3	1623			The Esplanade	
90730	27	3	1623		10	The Esplanade	
90740	29	3	1623		8	The Esplanade	
90750	32	3	1623		6	The Esplanade	
90760	35	3	1623		4	The Esplanade	
90770	37		1623			The Esplanade	
111050	3	1	1623			Border	Street
111060	4	1	1623			Border	Street
111070	5	1	1623			Border	Street
111080	6	1	1623			Border	Street
111090	7	1	1623			Border	Street
111100	8	1	1623			Border	Street
111110	9	1	1623			Border	Street
111120	10	1	1623			Border	Street
111130	11	1	1623			Border	Street
111140	12	1	1623			Border	Street
111150	13	1	1623			Border	Street
111160	14	1	1623			Border	Street
111170	15	1	1623			Border	Street
111180	16	1	1623			Border	Street
111190	17	1	1623			Border	Street
111200	18	1	1623			Border	Street
111210	19	1	1623			Border	Street
111220	20	1	1623			Border	Street
111230	21	1	1623			Border	Street
111240	22	1	1623			Border	Street

123410	18	2	1623		48	Childe	Street
123420	19	2	1623		48	Childe	Street
123430	20	2	1623		48	Childe	Street
123460	21	2	1623		44	Childe	Street
123470	27	2	1623		38	Childe	Street
127040	1		778102			The Esplanade	
127200	2		778102			The Esplanade	
143750	39	2	1623		4	Manfred	Street
143830	34	2	1623		28A	Childe	Street
143860	7	3	1623		3-Jul	Manfred	Street
143890	B		371044		3-Jul	Manfred	Street
144080	32	2	1623			Childe	Street
144110	29	2	1623		34	Childe	Street
144200	26	2	1623		38	Childe	Street
144270	22	2	1623		44	Childe	Street
144430	2	2	1623			The Esplanade	
161820	2	1	1623		2A	Border	Street
161910	16	3	1623		20	Childe	Street
161970	20	3	1623		16	The Esplanade	
162000	22	3	1623			The Esplanade	
162030	23	3	1623		14	The Esplanade	
162040	24	3	1623		14	The Esplanade	
162070	26	3	1623			The Esplanade	
162100	28	3	1623		10	The Esplanade	
162130	30	3	1623		8	The Esplanade	
162160	31	3	1623		8	The Esplanade	
176660	23	2	1623		44	Childe	Street
176680	33	3	1623		6	The Esplanade	
176690	34	3	1623		6A	Childe	Street
176710	36	3	1623		4	The Esplanade	
178280	13	3	1623		22	The Esplanade	
178290	14	3	1623		22	The Esplanade	
187230	5		827049			Lawson	Street
187240	6		827049			Lawson	Street
210510	2		862599		40	Childe	Street
235070				65430	1	Don	Street
238356			1779 3050			Childe	Street
238395	18		1040635		18	The Esplanade	
241453				83141	1	Border	Street
90650	11	3	1623		22	The Esplanade	
161880	12	3	1623		22	The Esplanade	
238790	10		1049827			Bay	Street
90780	38	3	1623			The Esplanade	
123540	67	3	1623			The Esplanade	

123550	68	3	1623			The Esplanade	
123560	69	3	1623			The Esplanade	
134390	11		243218		144	Bayshore	Drive
168100	410		729062			Lawson	Street
182800	5		729063			Childe	Street
184230	407		729057			Bayshore	Drive

Table 27.3: 2050 Erosion Hazard Scenario 1 (retain seawalls) - Properties

CADASTRE_I	LOT	SECTION_	DP	STRATA	HOUSE_NUM	STREET_NAM	STREET_TYP
90810	39	3	1623			The Esplanade	
90820	42	3	1623			The Esplanade	
90830	45	3	1623			The Esplanade	
90840	47	3	1623			The Esplanade	
90850	50	3	1623			The Esplanade	
90860	51	3	1623			The Esplanade	
94780	1	7	1623			Bayshore	Drive
123480	61	3	1623			The Esplanade	
123490	62	3	1623			The Esplanade	
123500	63	3	1623			The Esplanade	
123510	64	3	1623			The Esplanade	
123520	65	3	1623			The Esplanade	
123530	66	3	1623			The Esplanade	
162190	40	3	1623			The Esplanade	
162210	41	3	1623			The Esplanade	
162240	43	3	1623			The Esplanade	
162250	44	3	1623			The Esplanade	
165270	52	3	1623			The Esplanade	
165280	53	3	1623			The Esplanade	
165290	54	3	1623			The Esplanade	
165300	55	3	1623			The Esplanade	
165310	56	3	1623			The Esplanade	
165320	57	3	1623			The Esplanade	
165330	58	3	1623			The Esplanade	
165340	59	3	1623			The Esplanade	
165350	60	3	1623			The Esplanade	
167230	49	3	1623			The Esplanade	
167260	46	3	1623			The Esplanade	
167270	48	3	1623			The Esplanade	
182860	408		729057			The Esplanade	
184330	214		755695			Bay	Street
184340	323		755695			Bay	Street
184350	341		755695			Bay	Street
184360	342		755695			Bay	Street
184450	329		755695			Bay	Street
184460	327		755695			Bay	Street
184470	328		755695			Bay	Street
184480	326		755695			Bay	Street
184490	338		755695			Bay	Street
184510	337		755695			Bay	Street

238789	9		1049827			Lawson	Street
239654	7013		1087016			The Esplanade	
168070	413		729062			Lighthouse	Road
168080	412		729062			Lighthouse	Road
168090	411		729062			Lighthouse	Road
241547	12		1164217			Lighthouse	Road
187230	5		827049			Lawson	Street
187240	6		827049			Lawson	Street
241453				83141	1	Border	Street
238790	10		1049827			Bay	Street
123540	67	3	1623			The Esplanade	
123550	68	3	1623			The Esplanade	
123560	69	3	1623			The Esplanade	
134390	11		243218		144	Bayshore	Drive
134410	12		243218			Bayshore	Drive
168100	410		729062			Lawson	Street
182800	5		729063			Childe	Street
184230	407		729057			Bayshore	Drive

Table 27.4: 2050 Erosion Hazard Scenario 2 (remove seawalls) - Properties

CADASTRE_I	LOT	SECTION_	DP	STRATA	HOUSE_NUM	STREET_NAM	STREET_TYP
90810	39	3	1623			The Esplanade	
90820	42	3	1623			The Esplanade	
90830	45	3	1623			The Esplanade	
90840	47	3	1623			The Esplanade	
90850	50	3	1623			The Esplanade	
90860	51	3	1623			The Esplanade	
94780	1	7	1623			Bayshore	Drive
123480	61	3	1623			The Esplanade	
123490	62	3	1623			The Esplanade	
123500	63	3	1623			The Esplanade	
123510	64	3	1623			The Esplanade	
123520	65	3	1623			The Esplanade	
123530	66	3	1623			The Esplanade	
162190	40	3	1623			The Esplanade	
162210	41	3	1623			The Esplanade	
162240	43	3	1623			The Esplanade	
162250	44	3	1623			The Esplanade	
165270	52	3	1623			The Esplanade	
165280	53	3	1623			The Esplanade	
165290	54	3	1623			The Esplanade	
165300	55	3	1623			The Esplanade	
165310	56	3	1623			The Esplanade	
165320	57	3	1623			The Esplanade	
165330	58	3	1623			The Esplanade	
165340	59	3	1623			The Esplanade	
165350	60	3	1623			The Esplanade	
167230	49	3	1623			The Esplanade	
167260	46	3	1623			The Esplanade	
167270	48	3	1623			The Esplanade	
182860	408		729057			The Esplanade	
184330	214		755695			Bay	Street
184340	323		755695			Bay	Street
184350	341		755695			Bay	Street
184360	342		755695			Bay	Street
184450	329		755695			Bay	Street
184460	327		755695			Bay	Street
184470	328		755695			Bay	Street
184480	326		755695			Bay	Street
184490	338		755695			Bay	Street
184510	337		755695			Bay	Street

238357	7019		1113435			The Esplanade	
238789	9		1049827			Lawson	Street
239654	7013		1087016			The Esplanade	
168070	413		729062			Lighthouse	Road
168080	412		729062			Lighthouse	Road
168090	411		729062			Lighthouse	Road
241547	12		1164217			Lighthouse	Road
1070	1	1	1623		2	Border	Street
10930	1		781460		24	Childe	Street
10940	1		781461		26	Childe	Street
10960	46	2	1623		30	Childe	Street
10980	52	2	1623		36	Childe	Street
11020	56	2	1623		42	Childe	Street
11040	58	2	1623		46	Childe	Street
19660	1		808937		3	Don	Street
49580	38	2	1623		4	Manfred	Street
49610	5	3	1623		1	Manfred	Street
49620	6	3	1623		3-Jul	Manfred	Street
90560	28	2	1623		34	Childe	Street
90590	33	2	1623			Childe	Street
90600	35	2	1623		28A	Childe	Street
90610	36	2	1623		28A	Childe	Street
90620	37	2	1623		2	The Esplanade	
90630	2		521030			The Esplanade	
90640	1		521030			Manfred	Street
90660	15	3	1623		20	Childe	Street
90700	19	3	1623		16	The Esplanade	
90710	21	3	1623			The Esplanade	
90720	25	3	1623			The Esplanade	
90730	27	3	1623		10	The Esplanade	
90740	29	3	1623		8	The Esplanade	
90750	32	3	1623		6	The Esplanade	
90760	35	3	1623		4	The Esplanade	
90770	37		1623			The Esplanade	
111050	3	1	1623			Border	Street
111060	4	1	1623			Border	Street
111070	5	1	1623			Border	Street
111080	6	1	1623			Border	Street
111090	7	1	1623			Border	Street
111100	8	1	1623			Border	Street
111110	9	1	1623			Border	Street
111120	10	1	1623			Border	Street
111130	11	1	1623			Border	Street
111140	12	1	1623			Border	Street

111150	13	1	1623			Border	Street
111160	14	1	1623			Border	Street
111170	15	1	1623			Border	Street
111180	16	1	1623			Border	Street
111190	17	1	1623			Border	Street
111200	18	1	1623			Border	Street
111210	19	1	1623			Border	Street
111220	20	1	1623			Border	Street
111230	21	1	1623			Border	Street
111240	22	1	1623			Border	Street
111250	23	1	1623			Border	Street
111260	24	1	1623			Border	Street
111270	25	1	1623			Border	Street
112740	48	2	1623		32	Childe	Street
112750	49	2	1623		32	Childe	Street
112760	1		775946		5	Childe	Street
123410	18	2	1623		48	Childe	Street
123420	19	2	1623		48	Childe	Street
123430	20	2	1623		48	Childe	Street
123440	60	2	1623			Childe	Street
123450	61	2	1623		48	Childe	Street
123460	21	2	1623		44	Childe	Street
123470	27	2	1623		38	Childe	Street
127040	1		778102			The Esplanade	
127200	2		778102			The Esplanade	
143750	39	2	1623		4	Manfred	Street
143830	34	2	1623		28A	Childe	Street
143860	7	3	1623		3-Jul	Manfred	Street
143890	B		371044		3-Jul	Manfred	Street
143910	4	3	1623		1	Manfred	Street
143940	3	3	1623		1	Manfred	Street
144050	47	2	1623		30	Childe	Street
144080	32	2	1623			Childe	Street
144110	29	2	1623		34	Childe	Street
144140	50	2	1623		34	Childe	Street
144170	51	2	1623		34	Childe	Street
144200	26	2	1623		38	Childe	Street
144240	53	2	1623		38	Childe	Street
144270	22	2	1623		44	Childe	Street
144300	57	2	1623		44	Childe	Street
144330	59	2	1623		48	Childe	Street
144430	2	2	1623			The Esplanade	
161820	2	1	1623		2A	Border	Street
161910	16	3	1623		20	Childe	Street

161970	20	3	1623		16	The Esplanade	
162000	22	3	1623			The Esplanade	
162030	23	3	1623		14	The Esplanade	
162040	24	3	1623		14	The Esplanade	
162070	26	3	1623			The Esplanade	
162100	28	3	1623		10	The Esplanade	
162130	30	3	1623		8	The Esplanade	
162160	31	3	1623		8	The Esplanade	
176660	23	2	1623		44	Childe	Street
176680	33	3	1623		6	The Esplanade	
176690	34	3	1623		6A	Childe	Street
176710	36	3	1623		4	The Esplanade	
178280	13	3	1623		22	The Esplanade	
178290	14	3	1623		22	The Esplanade	
187230	5		827049			Lawson	Street
187240	6		827049			Lawson	Street
198650	1		845990		2A	Manfred	Street
198660	2		845990		2B	Manfred	Street
210500	1		862599		40A	Childe	Street
210510	2		862599		40	Childe	Street
225630	100		1002051		28	Childe	Street
235070				65430	1	Don	Street
238356			1779 3050			Childe	Street
238394	17		1040635		18A	The Esplanade	
238395	18		1040635		18	The Esplanade	
241453				83141	1	Border	Street
90650	11	3	1623		22	The Esplanade	
161880	12	3	1623		22	The Esplanade	
238790	10		1049827			Bay	Street
90780	38	3	1623			The Esplanade	
123540	67	3	1623			The Esplanade	
123550	68	3	1623			The Esplanade	
123560	69	3	1623			The Esplanade	
134390	11		243218		144	Bayshore	Drive
134410	12		243218			Bayshore	Drive
168100	410		729062			Lawson	Street
182800	5		729063			Childe	Street
184230	407		729057			Bayshore	Drive

Table 27.5: 2100 Erosion Hazard Scenario 1 (retain seawalls) - Properties

CADASTRE_I	LOT	SECTION_	DP	STRATA	HOUSE_NUM	STREET_NAM	STREET_TYP
90810	39	3	1623			The Esplanade	
90820	42	3	1623			The Esplanade	
90830	45	3	1623			The Esplanade	
90840	47	3	1623			The Esplanade	
90850	50	3	1623			The Esplanade	
90860	51	3	1623			The Esplanade	
94780	1	7	1623			Bayshore	Drive
109930	2	7	1623			Bayshore	Drive
109940	3	7	1623			Bayshore	Drive
109950	4	7	1623			Bayshore	Drive
109960	5	7	1623			Bayshore	Drive
109970	6	7	1623			Bayshore	Drive
109980	7	7	1623			Bayshore	Drive
109990	8	7	1623			Bayshore	Drive
123480	61	3	1623			The Esplanade	
123490	62	3	1623			The Esplanade	
123500	63	3	1623			The Esplanade	
123510	64	3	1623			The Esplanade	
123520	65	3	1623			The Esplanade	
123530	66	3	1623			The Esplanade	
162190	40	3	1623			The Esplanade	
162210	41	3	1623			The Esplanade	
162240	43	3	1623			The Esplanade	
162250	44	3	1623			The Esplanade	
162400	48	7	1623			Bayshore	Drive
165270	52	3	1623			The Esplanade	
165280	53	3	1623			The Esplanade	
165290	54	3	1623			The Esplanade	
165300	55	3	1623			The Esplanade	
165310	56	3	1623			The Esplanade	
165320	57	3	1623			The Esplanade	
165330	58	3	1623			The Esplanade	
165340	59	3	1623			The Esplanade	
165350	60	3	1623			The Esplanade	
167230	49	3	1623			The Esplanade	
167260	46	3	1623			The Esplanade	
167270	48	3	1623			The Esplanade	
182860	408		729057			The Esplanade	
184330	214		755695			Bay	Street
184340	323		755695			Bay	Street

184350	341		755695			Bay	Street
184360	342		755695			Bay	Street
184450	329		755695			Bay	Street
184460	327		755695			Bay	Street
184470	328		755695			Bay	Street
184480	326		755695			Bay	Street
184490	338		755695			Bay	Street
184510	337		755695			Bay	Street
238789	9		1049827			Lawson	Street
239654	7013		1087016			The Esplanade	
168070	413		729062			Lighthouse	Road
168080	412		729062			Lighthouse	Road
168090	411		729062			Lighthouse	Road
241547	12		1164217			Lighthouse	Road
240007	18		1103954		148	Lighthouse	Road
9490	1		780935		2	Milton	Street
9510	1		741161		3	Cavvanbah	Street
9520	1		745951		5	Cavvanbah	Street
187230	5		827049			Lawson	Street
187240	6		827049			Lawson	Street
221610	7		841611		29	Shirley	Street
221630	9		841611		2	Milton	Street
240486				80835	Jul-21	Cavvanbah	Street
240701	11		1138310			Cavvanbah	Street
240702	12		1138310		29	Shirley	Street
241120	10		1153734		1	Cavvanbah	Street
241453				83141	1	Border	Street
238790	10		1049827			Bay	Street
123540	67	3	1623			The Esplanade	
123550	68	3	1623			The Esplanade	
123560	69	3	1623			The Esplanade	
134390	11		243218		144	Bayshore	Drive
134410	12		243218			Bayshore	Drive
134430	13		243218			Bayshore	Drive
168100	410		729062			Lawson	Street
179310	449		812102			Bayshore	Drive
182800	5		729063			Childe	Street
184230	407		729057			Bayshore	Drive
184580	159		755695			Massinger	Street
204800				50789	Sep-13	Shirley	Street
238645				68939	23-25	Shirley	Street
238888	2		1046489			Lawson	Street
239746	1		1090966		27	Shirley	Street
239941	1		1098133		19-21	Shirley	Street

Table 27.6: 2100 Erosion Hazard Scenario 2 (remove seawalls) - Properties

CADASTRE_I	LOT	SECTION_	DP	STRATA	HOUSE_NUM	STREET_NAM	STREET_TYP
90810	39	3	1623			The Esplanade	
90820	42	3	1623			The Esplanade	
90830	45	3	1623			The Esplanade	
90840	47	3	1623			The Esplanade	
90850	50	3	1623			The Esplanade	
90860	51	3	1623			The Esplanade	
94780	1	7	1623			Bayshore	Drive
109930	2	7	1623			Bayshore	Drive
109940	3	7	1623			Bayshore	Drive
123480	61	3	1623			The Esplanade	
123490	62	3	1623			The Esplanade	
123500	63	3	1623			The Esplanade	
123510	64	3	1623			The Esplanade	
123520	65	3	1623			The Esplanade	
123530	66	3	1623			The Esplanade	
162190	40	3	1623			The Esplanade	
162210	41	3	1623			The Esplanade	
162240	43	3	1623			The Esplanade	
162250	44	3	1623			The Esplanade	
162400	48	7	1623			Bayshore	Drive
165270	52	3	1623			The Esplanade	
165280	53	3	1623			The Esplanade	
165290	54	3	1623			The Esplanade	
165300	55	3	1623			The Esplanade	
165310	56	3	1623			The Esplanade	
165320	57	3	1623			The Esplanade	
165330	58	3	1623			The Esplanade	
165340	59	3	1623			The Esplanade	
165350	60	3	1623			The Esplanade	
167230	49	3	1623			The Esplanade	
167260	46	3	1623			The Esplanade	
167270	48	3	1623			The Esplanade	
182860	408		729057			The Esplanade	
184330	214		755695			Bay	Street
184340	323		755695			Bay	Street
184350	341		755695			Bay	Street
184360	342		755695			Bay	Street
184450	329		755695			Bay	Street
184460	327		755695			Bay	Street
184470	328		755695			Bay	Street

184480	326		755695			Bay	Street
184490	338		755695			Bay	Street
184510	337		755695			Bay	Street
238357	7019		1113435			The Esplanade	
238789	9		1049827			Lawson	Street
239654	7013		1087016			The Esplanade	
168070	413		729062			Lighthouse	Road
168080	412		729062			Lighthouse	Road
168090	411		729062			Lighthouse	Road
241547	12		1164217			Lighthouse	Road
9640	11	53	758207		2	Cavvanbah	Street
52830	1		582819		4	Milton	Street
83140	8	52	758207		29	Shirley	Street
83150	9	52	758207		29	Shirley	Street
83160	2		582819		29	Shirley	Street
83250	8	53	758207		51	Shirley	Street
122220	3	52	758207		17	Shirley	Street
197800				48681	41-43	Shirley	Street
213230				54115	45	Shirley	Street
231480				61675	53	Shirley	Street
238817				69811	47-49	Shirley	Street
239167				72428	35-39	Shirley	Street
240007	18		1103954		148	Lighthouse	Road
1070	1	1	1623		2	Border	Street
1080	1		781462			Border	Street
9490	1		780935		2	Milton	Street
9510	1		741161		3	Cavvanbah	Street
9520	1		745951		5	Cavvanbah	Street
10810	13	4	1623		23	Childe	Street
10820	14	4	1623		21	Childe	Street
10830	15	4	1623		19	Childe	Street
10840	16	4	1623		17	Childe	Street
10850	17	4	1623		15	Childe	Street
10860	18	4	1623		13	Childe	Street
10890	1	4	714899		7-Sep	Childe	Street
10930	1		781460		24	Childe	Street
10940	1		781461		26	Childe	Street
10960	46	2	1623		30	Childe	Street
10980	52	2	1623		36	Childe	Street
11020	56	2	1623		42	Childe	Street
11040	58	2	1623		46	Childe	Street
19660	1		808937		3	Don	Street
49580	38	2	1623		4	Manfred	Street
49610	5	3	1623		1	Manfred	Street

49620	6	3	1623		3-Jul	Manfred	Street
90560	28	2	1623		34	Childe	Street
90590	33	2	1623			Childe	Street
90600	35	2	1623		28A	Childe	Street
90610	36	2	1623		28A	Childe	Street
90620	37	2	1623		2	The Esplanade	
90630	2		521030			The Esplanade	
90640	1		521030			Manfred	Street
90660	15	3	1623		20	Childe	Street
90700	19	3	1623		16	The Esplanade	
90710	21	3	1623			The Esplanade	
90720	25	3	1623			The Esplanade	
90730	27	3	1623		10	The Esplanade	
90740	29	3	1623		8	The Esplanade	
90750	32	3	1623		6	The Esplanade	
90760	35	3	1623		4	The Esplanade	
90770	37		1623			The Esplanade	
111050	3	1	1623			Border	Street
111060	4	1	1623			Border	Street
111070	5	1	1623			Border	Street
111080	6	1	1623			Border	Street
111090	7	1	1623			Border	Street
111100	8	1	1623			Border	Street
111110	9	1	1623			Border	Street
111120	10	1	1623			Border	Street
111130	11	1	1623			Border	Street
111140	12	1	1623			Border	Street
111150	13	1	1623			Border	Street
111160	14	1	1623			Border	Street
111170	15	1	1623			Border	Street
111180	16	1	1623			Border	Street
111190	17	1	1623			Border	Street
111200	18	1	1623			Border	Street
111210	19	1	1623			Border	Street
111220	20	1	1623			Border	Street
111230	21	1	1623			Border	Street
111240	22	1	1623			Border	Street
111250	23	1	1623			Border	Street
111260	24	1	1623			Border	Street
111270	25	1	1623			Border	Street
111280	26	1	1623			Border	Street
111290	27	1	1623			Border	Street
112730	2		714899		11	Childe	Street
112740	48	2	1623		32	Childe	Street

112750	49	2	1623		32	Childe	Street
112760	1		775946		5	Childe	Street
123410	18	2	1623		48	Childe	Street
123420	19	2	1623		48	Childe	Street
123430	20	2	1623		48	Childe	Street
123440	60	2	1623			Childe	Street
123450	61	2	1623		48	Childe	Street
123460	21	2	1623		44	Childe	Street
123470	27	2	1623		38	Childe	Street
127040	1		778102			The Esplanade	
127200	2		778102			The Esplanade	
143750	39	2	1623		4	Manfred	Street
143830	34	2	1623		28A	Childe	Street
143860	7	3	1623		3-Jul	Manfred	Street
143890	B		371044		3-Jul	Manfred	Street
143910	4	3	1623		1	Manfred	Street
143940	3	3	1623		1	Manfred	Street
144050	47	2	1623		30	Childe	Street
144080	32	2	1623			Childe	Street
144110	29	2	1623		34	Childe	Street
144140	50	2	1623		34	Childe	Street
144170	51	2	1623		34	Childe	Street
144200	26	2	1623		38	Childe	Street
144240	53	2	1623		38	Childe	Street
144270	22	2	1623		44	Childe	Street
144300	57	2	1623		44	Childe	Street
144330	59	2	1623		48	Childe	Street
144430	2	2	1623			The Esplanade	
144460	22	42	1623		7-Sep	Childe	Street
152140	3		815981		43	Childe	Street
152160	5		815981		47	Childe	Street
161820	2	1	1623		2A	Border	Street
161910	16	3	1623		20	Childe	Street
161970	20	3	1623		16	The Esplanade	
162000	22	3	1623			The Esplanade	
162030	23	3	1623		14	The Esplanade	
162040	24	3	1623		14	The Esplanade	
162070	26	3	1623			The Esplanade	
162100	28	3	1623		10	The Esplanade	
162130	30	3	1623		8	The Esplanade	
162160	31	3	1623		8	The Esplanade	
170570	2		781462			Border	Street
176660	23	2	1623		44	Childe	Street
176680	33	3	1623		6	The Esplanade	

176690	34	3	1623		6A	Childe	Street
176710	36	3	1623		4	The Esplanade	
178280	13	3	1623		22	The Esplanade	
178290	14	3	1623		22	The Esplanade	
184250	1		729064			Childe	Street
187230	5		827049			Lawson	Street
187240	6		827049			Lawson	Street
198650	1		845990		2A	Manfred	Street
198660	2		845990		2B	Manfred	Street
206970				51491	45	Childe	Street
207980	1		857336		5	Childe	Street
207990	2		857336		5A	Childe	Street
208310	1		854069		25	Childe	Street
209750				52556	37	Childe	Street
210500	1		862599		40A	Childe	Street
210510	2		862599		40	Childe	Street
211500				53341	41	Childe	Street
221610	7		841611		29	Shirley	Street
221620	8		841611		2	Milton	Street
221630	9		841611		2	Milton	Street
223540				58754	39	Childe	Street
225630	100		1002051		28	Childe	Street
232750				63960	25	Cavvanbah	Street
235070				65430	1	Don	Street
238356			1779 3050			Childe	Street
238394	17		1040635		18A	The Esplanade	
238395	18		1040635		18	The Esplanade	
239879				76830	33-35	Childe	Street
240486				80835	Jul-21	Cavvanbah	Street
240701	11		1138310			Cavvanbah	Street
240702	12		1138310		29	Shirley	Street
241120	10		1153734		1	Cavvanbah	Street
204660				50656	49	Childe	Street
241551				85426	51	Border	Street
241453				83141	1	Border	Street
90650	11	3	1623		22	The Esplanade	
161880	12	3	1623		22	The Esplanade	
238790	10		1049827			Bay	Street
10920	25	4	1623		1	Childe	Street
49600	2	3	1623			Manfred	Street
90780	38	3	1623			The Esplanade	
123540	67	3	1623			The Esplanade	
123550	68	3	1623			The Esplanade	
123560	69	3	1623			The Esplanade	

134390	11		243218		144	Bayshore	Drive
134410	12		243218			Bayshore	Drive
134430	13		243218			Bayshore	Drive
143970	1	3	1623			Manfred	Street
168100	410		729062			Lawson	Street
179310	449		812102			Bayshore	Drive
182800	5		729063			Childe	Street
184230	407		729057			Bayshore	Drive
184580	159		755695			Massinger	Street
204800				50789	Sep-13	Shirley	Street
238645				68939	23-25	Shirley	Street
238888	2		1046489			Lawson	Street
239746	1		1090966		27	Shirley	Street
239941	1		1098133		19-21	Shirley	Street

27.2 Structures Potentially Vulnerable to Erosion Hazard

Table 27.7: Immediate Erosion Hazard Scenario 1 (retain seawalls) - Structures

CADASTRE_I	LOT	SECTION_	DP	STRATA	HOUSE_NUM	STREET_NAM	STREET_TYP	No. Structures at Risk
241547	12		1164217			Lighthouse	Road	1
187230	5		827049			Lawson	Street	1

Table 27.8: Immediate Erosion Hazard Scenario 2 (remove seawalls) - Structures

CADASTRE_I	LOT	SECTION_	DP	STRATA	HOUSE_NUM	STREET_NAM	STREET_TYP	No. Structures at Risk
1070	1	1	1623		2	Border	Street	1
19660	1		808937		3	Don	Street	2
90560	28	2	1623		34	Childe	Street	1
90620	37	2	1623		2	The Esplanade		1
90700	19	3	1623		16	The Esplanade		1
90710	21	3	1623			The Esplanade		1
90720	25	3	1623			The Esplanade		1
90730	27	3	1623		10	The Esplanade		1
90740	29	3	1623		8	The Esplanade		1
90760	35	3	1623		4	The Esplanade		1
111200	18	1	1623			Border	Street	1
123410	18	2	1623		48	Childe	Street	1
123430	20	2	1623		48	Childe	Street	1
123460	21	2	1623		44	Childe	Street	1
127040	1		778102			The Esplanade		1
127200	2		778102			The Esplanade		1
143750	39	2	1623		4	Manfred	Street	1
143830	34	2	1623		28A	Childe	Street	1
144080	32	2	1623			Childe	Street	1
144430	2	2	1623			The Esplanade		1
161820	2	1	1623		2A	Border	Street	1
162030	23	3	1623		14	The Esplanade		1
162040	24	3	1623		14	The Esplanade		1
162070	26	3	1623			The Esplanade		2
162130	30	3	1623		8	The Esplanade		1
176680	33	3	1623		6	The Esplanade		1
176690	34	3	1623		6A	Childe	Street	1
178280	13	3	1623		22	The Esplanade		1
187230	5		827049			Lawson	Street	1
210510	2		862599		40	Childe	Street	1
235070				65430	1	Don	Street	1
238395	18		1040635		18	The Esplanade		1
90750	32	3	1623		6	The Esplanade		1
241547	12		1164217			Lighthouse	Road	1

Table 27.9: 2050 Erosion Hazard Scenario 1 (retain seawalls) - Structures

CADASTRE_I	LOT	SECTION_	DP	STRATA	HOUSE_NUM	STREET_NAM	STREET_TYP	No. Structures at Risk
238789	9		1049827			Lawson	Street	1
241547	12		1164217			Lighthouse	Road	4
187230	5		827049			Lawson	Street	1
238790	10		1049827			Bay	Street	1
168100	410		729062			Lawson	Street	15

Table 27.10: 2050 Erosion Hazard Scenario 2 (remove seawalls) - Structures

CADASTRE_I	LOT	SECTION_	DP	STRATA	HOUSE_NUM	STREET_NAM	STREET_TYP	No. Structures at Risk
238789	9		1049827			Lawson	Street	1
241547	12		1164217			Lighthouse	Road	4
1070	1	1	1623		2	Border	Street	1
10930	1		781460		24	Childe	Street	1
10940	1		781461		26	Childe	Street	1
10960	46	2	1623		30	Childe	Street	1
10980	52	2	1623		36	Childe	Street	1
11020	56	2	1623		42	Childe	Street	1
11040	58	2	1623		46	Childe	Street	1
19660	1		808937		3	Don	Street	2
49610	5	3	1623		1	Manfred	Street	1
90560	28	2	1623		34	Childe	Street	1
90620	37	2	1623		2	The Esplanade		1
90660	15	3	1623		20	Childe	Street	1
90700	19	3	1623		16	The Esplanade		2
90710	21	3	1623			The Esplanade		2
90720	25	3	1623			The Esplanade		1
90730	27	3	1623		10	The Esplanade		1
90740	29	3	1623		8	The Esplanade		2
90760	35	3	1623		4	The Esplanade		1
111200	18	1	1623			Border	Street	1
112740	48	2	1623		32	Childe	Street	1
112750	49	2	1623		32	Childe	Street	1
123410	18	2	1623		48	Childe	Street	1
123430	20	2	1623		48	Childe	Street	1
123460	21	2	1623		44	Childe	Street	1
127040	1		778102			The Esplanade		1
127200	2		778102			The Esplanade		1
143750	39	2	1623		4	Manfred	Street	1
143830	34	2	1623		28A	Childe	Street	1
144050	47	2	1623		30	Childe	Street	1

144080	32	2	1623			Childe	Street	1
144170	51	2	1623		34	Childe	Street	1
144240	53	2	1623		38	Childe	Street	1
144430	2	2	1623			The Esplanade		1
161820	2	1	1623		2A	Border	Street	1
162030	23	3	1623		14	The Esplanade		1
162040	24	3	1623		14	The Esplanade		1
162070	26	3	1623			The Esplanade		2
162130	30	3	1623		8	The Esplanade		1
162160	31	3	1623		8	The Esplanade		1
176680	33	3	1623		6	The Esplanade		1
176690	34	3	1623		6A	Childe	Street	1
176710	36	3	1623		4	The Esplanade		1
178280	13	3	1623		22	The Esplanade		1
187230	5		827049			Lawson	Street	1
198650	1		845990		2A	Manfred	Street	1
198660	2		845990		2B	Manfred	Street	1
210500	1		862599		40A	Childe	Street	1
210510	2		862599		40	Childe	Street	1
225630	100		1002051		28	Childe	Street	1
235070				65430	1	Don	Street	1
238394	17		1040635		18A	The Esplanade		1
238395	18		1040635		18	The Esplanade		1
168100	410		729062			Lawson	Street	15
90750	32	3	1623		6	The Esplanade		1

Table 27.11: 2100 Erosion Hazard Scenario 1 (retain seawalls) - Structures

CADASTRE_I	LOT	SECTION_	DP	STRATA	HOUSE_NUM	STREET_NAM	STREET_TYP	No. Structures at Risk
238789	9		1049827			Lawson	Street	1
241547	12		1164217			Lighthouse	Road	4
122220	3	52	758207		17	Shirley	Street	1
213230				54115	45	Shirley	Street	1
238817				69811	47-49	Shirley	Street	3
9490	1		780935		2	Milton	Street	1
9510	1		741161		3	Cavvanbah	Street	2
9520	1		745951		5	Cavvanbah	Street	1
187230	5		827049			Lawson	Street	1
240486				80835	44378	Cavvanbah	Street	1
241120	10		1153734		1	Cavvanbah	Street	3
238790	10		1049827			Bay	Street	1
168100	410		729062			Lawson	Street	32
184580	159		755695			Massinger	Street	3
204800				50789	41518	Shirley	Street	2
238645				68939	23-25	Shirley	Street	1
239941	1		1098133		19-21	Shirley	Street	2

Table 27.12: 2100 Erosion Hazard Scenario 2 (remove seawalls) - Structures

CADASTRE_I	LOT	SECTION_	DP	STRATA	HOUSE_NUM	STREET_NAM	STREET_TYP	No. Structures at Risk
238789	9		1049827			Lawson	Street	1
241547	12		1164217			Lighthouse	Road	4
52830	1		582819		4	Milton	Street	1
83150	9	52	758207		29	Shirley	Street	1
122220	3	52	758207		17	Shirley	Street	3
197800				48681	41-43	Shirley	Street	1
213230				54115	45	Shirley	Street	1
238817				69811	47-49	Shirley	Street	3
239167				72428	35-39	Shirley	Street	1
1070	1	1	1623		2	Border	Street	1
9490	1		780935		2	Milton	Street	1
9510	1		741161		3	Cavvanbah	Street	2
9520	1		745951		5	Cavvanbah	Street	1
10810	13	4	1623		23	Childe	Street	1
10820	14	4	1623		21	Childe	Street	1
10830	15	4	1623		19	Childe	Street	1
10840	16	4	1623		17	Childe	Street	1
10850	17	4	1623		15	Childe	Street	1
10860	18	4	1623		13	Childe	Street	1

10890	1	4	714899		7-Sep	Childe	Street	1
10930	1		781460		24	Childe	Street	1
10940	1		781461		26	Childe	Street	1
10960	46	2	1623		30	Childe	Street	1
10980	52	2	1623		36	Childe	Street	1
11020	56	2	1623		42	Childe	Street	1
11040	58	2	1623		46	Childe	Street	1
19660	1		808937		3	Don	Street	2
49610	5	3	1623		1	Manfred	Street	1
90560	28	2	1623		34	Childe	Street	1
90620	37	2	1623		2	The Esplanade		1
90660	15	3	1623		20	Childe	Street	1
90700	19	3	1623		16	The Esplanade		2
90710	21	3	1623			The Esplanade		2
90720	25	3	1623			The Esplanade		1
90730	27	3	1623		10	The Esplanade		1
90740	29	3	1623		8	The Esplanade		2
90760	35	3	1623		4	The Esplanade		1
111200	18	1	1623			Border	Street	1
112730	2		714899		11	Childe	Street	2
112740	48	2	1623		32	Childe	Street	1
112750	49	2	1623		32	Childe	Street	1
112760	1		775946		5	Childe	Street	1
123410	18	2	1623		48	Childe	Street	1
123430	20	2	1623		48	Childe	Street	1
123460	21	2	1623		44	Childe	Street	1
127040	1		778102			The Esplanade		1
127200	2		778102			The Esplanade		1
143750	39	2	1623		4	Manfred	Street	1
143830	34	2	1623		28A	Childe	Street	1
144050	47	2	1623		30	Childe	Street	1
144080	32	2	1623			Childe	Street	1
144170	51	2	1623		34	Childe	Street	1
144240	53	2	1623		38	Childe	Street	1
144430	2	2	1623			The Esplanade		1
144460	22	42	1623		41889	Childe	Street	1
152140	3		815981		12-Feb	Childe	Street	1
161820	2	1	1623		2A	Border	Street	1
162030	23	3	1623		14	The Esplanade		1
162040	24	3	1623		14	The Esplanade		1
162070	26	3	1623			The Esplanade		2
162130	30	3	1623		8	The Esplanade		1
162160	31	3	1623		8	The Esplanade		1
176680	33	3	1623		6	The Esplanade		1

176690	34	3	1623		6A	Childe	Street	1
176710	36	3	1623		4	The Esplanade		1
178280	13	3	1623		22	The Esplanade		1
187230	5		827049			Lawson	Street	1
198650	1		845990		2A	Manfred	Street	1
198660	2		845990		2B	Manfred	Street	1
206970				51491	14-Feb	Childe	Street	1
207980	1		857336		5	Childe	Street	1
207990	2		857336		5A	Childe	Street	1
208310	1		854069		25	Childe	Street	2
210500	1		862599		40A	Childe	Street	1
210510	2		862599		40	Childe	Street	1
211500				53341	41	Childe	Street	1
223540				58754	39	Childe	Street	1
225630	100		1002051		28	Childe	Street	1
232750				63960	25	Cavvanbah	Street	3
235070				65430	1	Don	Street	1
238394	17		1040635		18A	The Esplanade		1
238395	18		1040635		18	The Esplanade		1
239879				76830	33-35	Childe	Street	3
240486				80835	44378	Cavvanbah	Street	6
241120	10		1153734		1	Cavvanbah	Street	4
241551				85426	51	Border	Street	1
241453				83141	1	Border	Street	1
90650	11	3	1623		22	The Esplanade		1
238790	10		1049827			Bay	Street	1
168100	410		729062			Lawson	Street	32
184580	159		755695			Massinger	Street	3
204800				50789	41518	Shirley	Street	4
238645				68939	23-25	Shirley	Street	1
239746	1		1090966		27	Shirley	Street	1
239941	1		1098133		19-21	Shirley	Street	3
90750	32	3	1623		6	The Esplanade		1

27.3 Other Significant Infrastructure Potentially Vulnerable to Erosion Hazard

Table 27.13: Immediate Erosion Hazard Scenario 2 (remove seawalls) - Sewer Gravity Mains

LINENUM	COMPNTID	DEPTH_1	DIAMETER	ASSET_ID	MATERIAL	CONST_YEAR
Line DP	DP01-DE	1	150	S-3005-GMN-1156	VC	1973
Line DP	DN01-DP01	0.9	150	S-3005-GMN-1162	VC	1973
Line DM	DM02-DEA	1.2	150	S-3005-GMN-1170	VC	1973
Line DK	DK06C-DK07	2	150	S-3005-GMN-1179	UPVC	1997
Line DPA	DPA03-DPA04	0	63	S-3005-GMN-1203	UPVC	2004
Line DL	DL01-DE	1.2	150	S-3005-GMN-1761	VC	1973
Line DM	DM02-DEB	1.5	150	S-3005-GMN-4229	VC	1973
Line DM	DM01A-DM02	1.5	150	S-3005-GMN-4230	VC	1973
Line DK	DK04-DK05	2.1	150	S-3005-GMN-4263	VC	1973
Line DK	DK05-DK06A	2.7	150	S-3005-GMN-4267	UPVC	1997
Line DK	DK06A-DK06B	2.1	150	S-3005-GMN-4268	UPVC	1997
Line DK	DK06B-DK06C	2.2	150	S-3005-GMN-4272	UPVC	1997

Table 27.14: 2050 Erosion Hazard Scenario 1 (retain seawalls) - Sewer Gravity Mains

LINENUM	COMPNTID	DEPTH_1	DIAMETER	ASSET_ID	MATERIAL	CONST_YEAR
Line DZ	DZ04-DZ05	0.8	150	S-3002-GMN-1272	VC	1973
Line DH	DH01-DE	0.8	150	S-3004-GMN-1768	UPVC	1973
Line DZ	DZ03-DZ04	1.2	150	S-3002-GMN-1827	VC	1973

Table 27.15: 2050 Erosion Hazard Scenario 2 (remove seawalls) - Sewer Gravity Mains

LINENUM	COMPNTID	DEPTH_1	DIAMETER	ASSET_ID	MATERIAL	CONST_YEAR
Line DJ	DJ08-DJ09	2	150	S-3005-GMN-1136	VC	1973
Line DJ	DJ07-DJ08	2.2	150	S-3005-GMN-1142	VC	1973
Line DJ	DJ06-DJ07	2.2	150	S-3005-GMN-1148	VC	1973
Line DP	DP01-DE	1	150	S-3005-GMN-1156	VC	1973
Line DP	DN01-DP01	0.9	150	S-3005-GMN-1162	VC	1973
Line DN	DN01-DE	1.1	150	S-3005-GMN-1163	VC	1973
Line DM	DM02-DEA	1.2	150	S-3005-GMN-1170	VC	1973
Line DN	DJ01-DN01	1.3	150	S-3005-GMN-1173	VC	1983
Line DK	DK06C-DK07	2	150	S-3005-GMN-1179	UPVC	1997
Line DPA	DPA03-DPA04	0	63	S-3005-GMN-1203	UPVC	2004
Line DZ	DZ04-DZ05	0.8	150	S-3002-GMN-1272	VC	1973
Line DM	DM01-DM01A	2.2	150	S-3005-GMN-1742	VC	1973
Line DM	DJ03-DM01	3	150	S-3005-GMN-1746	VC	1983
Line DL	DL02-DE	1.2	150	S-3005-GMN-1751	UPVC	1973
Line DL	DL01-DL02	1.3	150	S-3005-GMN-1760	UPVC	1973
Line DL	DL01-DE	1.2	150	S-3005-GMN-1761	VC	1973
Line DH	DH01-DE	0.8	150	S-3004-GMN-1768	UPVC	1973
Line DZ	DZ03-DZ04	1.2	150	S-3002-GMN-1827	VC	1973
Line DM	DM02-DEB	1.5	150	S-3005-GMN-4229	VC	1973
Line DM	DM01A-DM02	1.5	150	S-3005-GMN-4230	VC	1973
Line DL	DL00-DL01	1.2	150	S-3005-GMN-4231	UPVC	1973
Line DK	DK03-DK04	1.8	150	S-3005-GMN-4260	VC	1973
Line DK	DK04-DK05	2.1	150	S-3005-GMN-4263	VC	1973
LIne DK	DK02-DK03	2.4	150	S-3005-GMN-4264	VC	1973
Line DK	DK05-DK06A	2.7	150	S-3005-GMN-4267	UPVC	1997
Line DK	DK06A-DK06B	2.1	150	S-3005-GMN-4268	UPVC	1997
Line DK	DK06B-DK06C	2.2	150	S-3005-GMN-4272	UPVC	1997
Line DH	CX13-DH01	1	150	S-3004-GMN-1764	UPVC	1973

Table 27.16: 2100 Erosion Hazard Scenario 1 (retain seawalls) - Sewer Gravity Mains

LINENUM	COMPNTID	DEPTH_1	DIAMETER	ASSET_ID	MATERIAL	CONST_YEAR
Line CY	CY08-CY09	0.6	150	S-3004-GMN-1227	UPVC	1973
Line CY	CY07-CY08	1.2	150	S-3004-GMN-1238	UPVC	1973
Line DZ	DZ06-DE	1	150	S-3002-GMN-1270	VC	1973
Line DZ	DZ05-DZ06	1.2	150	S-3002-GMN-1271	VC	1973
Line DZ	DZ04-DZ05	0.8	150	S-3002-GMN-1272	VC	1973
Line DH	DH01-DE	0.8	150	S-3004-GMN-1768	UPVC	1973
Line CY	CY06-CY07	1.7	150	S-3004-GMN-1790	UPVC	1973
Line AM	AM28-AM29	0.7	150	S-3002-GMN-1815	VC	1973
Line DZ	DZ03-DZ04	1.2	150	S-3002-GMN-1827	VC	1973
Line DH	CX13-DH01	1	150	S-3004-GMN-1764	UPVC	1973
Line CX	CX12-CX13	0.7	150	S-3004-GMN-1772	UPVC	1973
Line CX	CX13-CX14	0.7	150	S-3004-GMN-1021	UPVC	1973

Table 27.17: 2100 Erosion Hazard Scenario 2 (remove seawalls) - Sewer Gravity Mains

LINENUM	COMPNTID	DEPTH_1	DIAMETER	ASSET_ID	MATERIAL	CONST_YEAR
Line DJ	DJ08-DJ09	2	150	S-3005-GMN-1136	VC	1973
Line DJ	DJ07-DJ08	2.2	150	S-3005-GMN-1142	VC	1973
Line DJ	DJ06-DJ07	2.2	150	S-3005-GMN-1148	VC	1973
Line DP	DP01-DE	1	150	S-3005-GMN-1156	VC	1973
Line DJ	DJ05-DJ06	2.6	150	S-3005-GMN-1158	VC	1973
Line DP	DN01-DP01	0.9	150	S-3005-GMN-1162	VC	1973
Line DN	DN01-DE	1.1	150	S-3005-GMN-1163	VC	1973
Line DM	DM02-DEA	1.2	150	S-3005-GMN-1170	VC	1973
Line DN	DJ01-DN01	1.3	150	S-3005-GMN-1173	VC	1983
Line DJ	DJ04-DJ05	2.8	150	S-3005-GMN-1174	VC	1973
Line DK	DK06C-DK07	2	150	S-3005-GMN-1179	UPVC	1997
Line DK	DK02-DPA01	1.5	150	S-3005-GMN-1184	VC	1973
Line DSA	DPA01-DSA01	0	40	S-3005-GMN-1185	UPVC	2004
Line DSA	DSA01-DE	0	63	S-3005-GMN-1186	UPVC	2004
Line DSA	DSA01-DSA02	0	90	S-3005-GMN-1191	UPVC	2004
Line DPA	DPA01-DPA02	1.5	150	S-3005-GMN-1194	VC	1973
Line DSA	DSA02-DE	0	63	S-3005-GMN-1198	UPVC	2004
Line DPA	DPA02-DPA03	0	40	S-3005-GMN-1199	UPVC	2004
Line DPA	DPA03-DPA04	0	63	S-3005-GMN-1203	UPVC	2004
Line CY	CY08-CY09	0.6	150	S-3004-GMN-1227	UPVC	1973
Line CY	CY09-CY10	1.2	150	S-3004-GMN-1228	UPVC	1973
Line CY	CY07-CY08	1.2	150	S-3004-GMN-1238	UPVC	1973
Line DZ	DZ06-DE	1	150	S-3002-GMN-1270	VC	1973
Line DZ	DZ05-DZ06	1.2	150	S-3002-GMN-1271	VC	1973

Line DZ	DZ04-DZ05	0.8	150	S-3002-GMN-1272	VC	1973
Line DM	DM01-DM01A	2.2	150	S-3005-GMN-1742	VC	1973
Line DM	DJ03-DM01	3	150	S-3005-GMN-1746	VC	1983
Line DJ	DJ03-DJ04	3	150	S-3005-GMN-1747	VC	1973
Line DL	DL02-DE	1.2	150	S-3005-GMN-1751	UPVC	1973
Line DJ	DJ02-DJ03	3	150	S-3005-GMN-1759	VC	1973
Line DL	DL01-DL02	1.3	150	S-3005-GMN-1760	UPVC	1973
Line DL	DL01-DE	1.2	150	S-3005-GMN-1761	VC	1973
Line DH	DH01-DE	0.8	150	S-3004-GMN-1768	UPVC	1973
Line CX	CX11-CX12	1.2	150	S-3004-GMN-1780	UPVC	1973
Line CY	CY06-CY07	1.7	150	S-3004-GMN-1790	UPVC	1973
Line CY	CY05-CY06	1.2	150	S-3004-GMN-1797	UPVC	1973
Line CY	CY04-CY05	0.7	150	S-3004-GMN-1804	UPVC	1973
Line DA	CY03-DA01	1.4	150	S-3004-GMN-1809	UPVC	1973
Line DA	DA01-DA02	1.5	150	S-3004-GMN-1813	UPVC	1973
Line AM	AM28-AM29	0.7	150	S-3002-GMN-1815	VC	1973
Line DZ	DZ03-DZ04	1.2	150	S-3002-GMN-1827	VC	1973
Line DM	DM02-DEB	1.5	150	S-3005-GMN-4229	VC	1973
Line DM	DM01A-DM02	1.5	150	S-3005-GMN-4230	VC	1973
Line DL	DL00-DL01	1.2	150	S-3005-GMN-4231	UPVC	1973
Line DL	DJ01-DL00	3.6	150	S-3005-GMN-4232	UPVC	1973
Line DJ	DJ01-DJ02	3.1	150	S-3005-GMN-4233	VC	1973
Line DJ	SPS3005-DJ01	3.4	150	S-3005-GMN-4237	VC	1973
Line DJA	DJ01-DJA01	4	150	S-3005-GMN-4244	VC	1973
Line DJB	DJA01-DEA	1.6	150	S-3005-GMN-4245	UPVC	1973
Line DJA	DJA01-DEB	1.1	150	S-3005-GMN-4250	VC	1973
Line DJ	DJ01-DK01	2.2	150	S-3005-GMN-4254	VC	1973
Line DK	DK01-DKA01	2.7	150	S-3005-GMN-4255	VC	1983
Line DK	DKA01-DE	1.6	150	S-3005-GMN-4256	VC	1983
Line DK	DK03-DK04	1.8	150	S-3005-GMN-4260	VC	1973
Line DK	DKA01-DKA02	1.6	150	S-3005-GMN-4262	VC	1983
Line DK	DK04-DK05	2.1	150	S-3005-GMN-4263	VC	1973
Line DK	DK02-DK03	2.4	150	S-3005-GMN-4264	VC	1973
Line DK	DK01-DK02	2.1	150	S-3005-GMN-4265	VC	1973
Line DK	DK05-DK06A	2.7	150	S-3005-GMN-4267	UPVC	1997
Line DK	DK06A-DK06B	2.1	150	S-3005-GMN-4268	UPVC	1997
Line DK	DK06B-DK06C	2.2	150	S-3005-GMN-4272	UPVC	1997
Line DH	CX13-DH01	1	150	S-3004-GMN-1764	UPVC	1973
Line CX	CX12-CX13	0.7	150	S-3004-GMN-1772	UPVC	1973
Line CX	CX13-CX14	0.7	150	S-3004-GMN-1021	UPVC	1973

Table 27.18: 2050 Erosion Hazard Scenario 2 (remove seawalls) - Sewer Pressure Mains

DESCRIPT	MATERIAL	ASSET_ID	CONST_YEAR	DIAMETER	ITEM_ID
Pressure Sewer Main	HDPE	S-3004-PSM-510	2009	90	510

Table 27.19: 2100 Erosion Hazard Scenario 1 (retain seawalls) - Sewer Pressure Mains

DESCRIPT	MATERIAL	ASSET_ID	CONST_YEAR	DIAMETER	ITEM_ID
Pressure Sewer Main	HDPE	S-3004-PSM-510	2009	90	510
Pressure Sewer Main	HDPE	S-3004-PSM-519	2009	40	519

Table 27.20: 2100 Erosion Hazard Scenario 2 (remove seawalls) - Sewer Pressure Mains

DESCRIPT	MATERIAL	ASSET_ID	CONST_YEAR	DIAMETER	ITEM_ID
Pressure Sewer Main	UPVC	S-3004-PSM-505	2009	100	505
Pressure Sewer Main	UPVC	S-3004-PSM-506	2009	100	506
Pressure Sewer Main	UPVC	S-3004-PSM-507	2009	100	507
Pressure Sewer Main	UPVC	S-3004-PSM-508	2009	100	508
Pressure Sewer Main	UPVC	S-3004-PSM-509	2009	100	509
Pressure Sewer Main	HDPE	S-3004-PSM-510	2009	90	510
Pressure Sewer Main	HDPE	S-3004-PSM-511	2009	90	511
Pressure Sewer Main	HDPE	S-3004-PSM-512	2009	90	512
Pressure Sewer Main	HDPE	S-3004-PSM-513	2009	75	513
Pressure Sewer Main	HDPE	S-3004-PSM-514	2009	75	514
Pressure Sewer Main	HDPE	S-3004-PSM-515	2009	75	515
Pressure Sewer Main	HDPE	S-3004-PSM-516	2009	75	516
Pressure Sewer Main	HDPE	S-3004-PSM-517	2009	75	517
Pressure Sewer Main	HDPE	S-3004-PSM-518	2009	75	518
Pressure Sewer Main	HDPE	S-3004-PSM-519	2009	40	519
Pressure Sewer Main	HDPE	S-3004-PSM-520	2009	40	520
Pressure Sewer Main	HDPE	S-3004-PSM-521	2009	40	521
Pressure Sewer Main	HDPE	S-3004-PSM-522	2009	40	522
Pressure Sewer Main	HDPE	S-3004-PSM-523	2009	40	523
Pressure Sewer Main	HDPE	S-3004-PSM-524	2009	40	524
Pressure Sewer Main	HDPE	S-3004-PSM-525	2009	40	525
Pressure Sewer Main	HDPE	S-3004-PSM-526	2009	63	526
Pressure Sewer Main	HDPE	S-3004-PSM-527	2009	63	527
Pressure Sewer Main	HDPE	S-3004-PSM-528	2009	63	528
Pressure Sewer Main	HDPE	S-3004-PSM-530	2009	63	530
Pressure Sewer Main	HDPE	S-3004-PSM-531	2009	50	531
Pressure Sewer Main	HDPE	S-3004-PSM-532	2009	50	532
Pressure Sewer Main	HDPE	S-3004-PSM-533	2009	40	533
Pressure Sewer Main	HDPE	S-3004-PSM-534	2009	40	534
Pressure Sewer Main	HDPE	S-3004-PSM-535	2009	40	535
Pressure Sewer Main	HDPE	S-3004-PSM-536	2009	40	536
Pressure Sewer Main	HDPE	S-3004-PSM-537	2009	40	537
Pressure Sewer Main	HDPE	S-3004-PSM-538	2009	40	538
Pressure Sewer Main	HDPE	S-3004-PSM-539	2009	50	539
Pressure Sewer Main	HDPE	S-3004-PSM-540	2009	40	540
Pressure Sewer Main	HDPE	S-3004-PSM-541	2009	40	541

Table 27.21: Immediate Erosion Hazard Scenario 1 (retain seawalls) - Sewer Rising Mains

DIAMETER	DEPTH	CONSTDATE	MATERIAL	ASSET_ID	ASSET_TYPE	CONST_YEAR
100	1.8	1/01/1973	PVC	S-3005-SRM-011	PIPE - SEWER RISING MAIN	1973

Table 27.22: Immediate Erosion Hazard Scenario 2 (remove seawalls) - Sewer Rising Mains

DIAMETER	DEPTH	CONSTDATE	MATERIAL	ASSET_ID	ASSET_TYPE	CONST_YEAR
100	1.8	1/01/1973	PVC	S-3005-SRM-011	PIPE - SEWER RISING MAIN	1973

Table 27.23: 2050 Erosion Hazard Scenario 1 (retain seawalls) - Sewer Rising Mains

DIAMETER	DEPTH	CONSTDATE	MATERIAL	ASSET_ID	ASSET_TYPE	CONST_YEAR
100	1.8	1/01/1973	PVC	S-3005-SRM-011	PIPE - SEWER RISING MAIN	1973

Table 27.24: 2050 Erosion Hazard Scenario 2 (remove seawalls) - Sewer Rising Mains

DIAMETER	DEPTH	CONSTDATE	MATERIAL	ASSET_ID	ASSET_TYPE	CONST_YEAR
100	1.8	1/01/1973	PVC	S-3005-SRM-011	PIPE - SEWER RISING MAIN	1973

Table 27.25: 2100 Erosion Hazard Scenario 1 (retain seawalls) - Sewer Rising Mains

DIAMETER	DEPTH	CONSTDATE	MATERIAL	ASSET_ID	ASSET_TYPE	CONST_YEAR
100	1.8	1/01/1973	PVC	S-3005-SRM-011	PIPE - SEWER RISING MAIN	1973

Table 27.26: 2100 Erosion Hazard Scenario 2 (remove seawalls) - Sewer Rising Mains

DIAMETER	DEPTH	CONSTDATE	MATERIAL	ASSET_ID	ASSET_TYPE	CONST_YEAR
100	1.8	1/01/1973	PVC	S-3005-SRM-011	PIPE - SEWER RISING MAIN	1973

Table 27.27: 2100 Erosion Hazard Scenario 2 (remove seawalls) - Stormwater Drains

ASSET_TYPE	MATERIAL	CONST_YEAR	CATCHMENT	ASSET_ID
Dish Drain	Concrete	2008	CAVVANBAH	D-BYR-UDD-0246
Dish Drain	Concrete	2008	CAVVANBAH	D-BYR-UDD-0247
Drain	Unlined	2009	KENDALL	D-BYR-UDR-0646

Table 27.28: Immediate Hazard Scenario 1 - Stormwater Mains

MATERIAL	SUBTYPE	ASSET_ID	ITEM_ID	PIPE_DIAME	YEAR_CONST
Concrete	Pipe	D-BYR-UPI-2319	2319	1350	1968

Table 27.29: Immediate Hazard Scenario 2 (remove seawalls) - Stormwater Mains

MATERIAL	SUBTYPE	ASSET_ID	ITEM_ID	PIPE_DIAME	YEAR_CONST
Concrete	Pipe	D-BYR-UPI-2319	2319	1350	1968

Table 27.30: 2050 Hazard Scenario 1 (retain seawalls) - Stormwater Mains

MATERIAL	SUBTYPE	ASSET_ID	ITEM_ID	PIPE_DIAME	YEAR_CONST
Concrete	Pipe	D-BYR-UPI-2319	2319	1350	1968
Concrete	Pipe Culvert	D-BYR-UPC-2470	2470	375	1985
Concrete	Pipe Culvert	D-BYR-UPC-2471	2471	450	1985
Concrete	Pipe Culvert	D-BYR-UPC-2472	2472	450	1985

Table 27.31: 2050 Hazard Scenario 2 (remove seawalls) - Stormwater Mains

MATERIAL	SUBTYPE	ASSET_ID	ITEM_ID	PIPE_DIAME	YEAR_CONST
Concrete	Pipe	D-BYR-UPI-2319	2319	1350	1968
Concrete	Pipe Culvert	D-BYR-UPC-2470	2470	375	1985
Concrete	Pipe Culvert	D-BYR-UPC-2471	2471	450	1985
Concrete	Pipe Culvert	D-BYR-UPC-2472	2472	450	1985
Concrete	Pipe	D-BYR-UPI-3705	3705	375	2009
Concrete	Pipe	D-BYR-UPI-3706	3706	375	2009

Table 27.32: 2100 Hazard Scenario 1 (retain seawalls) - Stormwater Mains

MATERIAL	SUBTYPE	ASSET_ID	ITEM_ID	PIPE_DIAME	YEAR_CONST
Concrete	Pipe	D-BYR-UPI-2315	2315	450	1973
Concrete	Pipe	D-BYR-UPI-2316	2316	375	1973
Concrete	Pipe	D-BYR-UPI-2318	2318	450	1973
Concrete	Pipe	D-BYR-UPI-2319	2319	1350	1968
Concrete	Pipe Culvert	D-BYR-UPC-2470	2470	375	1985
Concrete	Pipe Culvert	D-BYR-UPC-2471	2471	450	1985
Concrete	Pipe Culvert	D-BYR-UPC-2472	2472	450	1985
Concrete	Pipe Culvert	D-BYR-UPC-2473	2473	450	1985
Concrete	Pipe	D-BYR-UPI-3705	3705	375	2009
Concrete	Pipe	D-BYR-UPI-3706	3706	375	2009

Table 27.33: 2100 Hazard Scenario 2 (remove seawalls) - Stormwater Mains

MATERIAL	SUBTYPE	ASSET_ID	ITEM_ID	PIPE_DIAME	YEAR_CONST
Concrete	Pipe	D-BYR-UPI-2315	2315	450	1973
Concrete	Pipe	D-BYR-UPI-2316	2316	375	1973
Concrete	Pipe	D-BYR-UPI-2318	2318	450	1973
Concrete	Pipe	D-BYR-UPI-2319	2319	1350	1968
Concrete	Pipe Culvert	D-BYR-UPC-2470	2470	375	1985
Concrete	Pipe Culvert	D-BYR-UPC-2471	2471	450	1985
Concrete	Pipe Culvert	D-BYR-UPC-2472	2472	450	1985
Concrete	Pipe Culvert	D-BYR-UPC-2473	2473	450	1985
Concrete	Pipe	D-BYR-UPI-2478	2478	450	1985
Not Verified	Pipe	D-BYR-UPI-2501	2501	Not Verified	1982
Concrete	Pipe	D-BYR-UPI-3699	3699	375	2009
Concrete	Pipe	D-BYR-UPI-3700	3700	450	2009
Concrete	Pipe	D-BYR-UPI-3701	3701	375	2009
Concrete	Pipe	D-BYR-UPI-3702	3702	375	2009
Concrete	Pipe	D-BYR-UPI-3703	3703	375	2009
Concrete	Pipe	D-BYR-UPI-3704	3704	375	2009
Concrete	Pipe	D-BYR-UPI-3705	3705	375	2009
Concrete	Pipe	D-BYR-UPI-3706	3706	375	2009
Concrete	Pipe	D-BYR-UPI-3707	2707	375	2009

Table 27.34: Immediate Erosion Hazard Scenario 1 (retain seawalls) - Other Significant Infrastructure

Other Significant Infrastructure at Risk
Border Street
Bay Street Footpath

Table 27.35: Immediate Erosion Hazard Scenario 2 (remove seawalls) - Other Infrastructure

Other Significant Infrastructure at Risk
Border Street
Manfred Street
Don Street
Bay Street Footpath
Picnic Tables at Bay Street

Table 27.36: 2050 Erosion Hazard Scenario 1 (retain seawalls) - Other Infrastructure

Other Significant Infrastructure at Risk
Border Street
Bay Street Footpath
Picnic Tables at Bay Street

Table 27.37: 2050 Erosion Hazard Scenario 2 (remove seawalls) - Other Infrastructure

Other Significant Infrastructure at Risk
Border Street
Manfred Street
Don Street
Bay Street Footpath
Public Shower at Middleton Street
Picnic Tables at Bay Street

Table 27.38: 2100 Erosion Hazard Scenario 1 (retain seawalls) - Other Infrastructure

Other Significant Infrastructure at Risk
Border Street
Roundabout at Border Street
Bay Street Footpath
Bay Street
Bay Street Carpark
Covered Barbecue Facilities at Massinger Street
Massinger Street Carpark
Telstra Public Payphone at Massinger Street
Playground at Massinger Street
Massinger Street
Covered Picnic Tables at Massinger Street
Amenities Block at Massinger Street
Massinger Street Footpath
Lighthouse Road Carpark
Amenities Block at Lighthouse Road
Lighthouse Road
Pedestrian Footbridge at Lighthouse Road
Public Shower at Middleton Street
Picnic Tables at Bay Street

Table 27.39: 2100 Erosion Hazard Scenario 2 (remove seawalls) - Other Infrastructure

Other Significant Infrastructure at Risk
Border Street
Childe Street
Giaour Street
Manfred Street
Don Street
Roundabout at Border Street
Rail Crossing at Border Street
Railway Track at Border Street
Cavvanbah Street (East) Footpath 1 of 2
Cavvanbah Street (West)
Cavvanbah Street (East)
Cavvanbah Street (East) Footpath 1 of 2
Shirley Street
Bay Street Footpath
Bay Street
Bay Street Carpark
Covered Barbecue Facilities at Massinger Street
Massinger Street Carpark
Telstra Public Payphone at Massinger Street
Playground at Massinger Street
Covered Picnic Tables at Massinger Street
Massinger Street
Amenities Block at Massinger Street
Massinger Street Footpath
Lighthouse Road Carpark
Amenities Block at Lighthouse Road
Lighthouse Road
Pedestrian Footbridge at Lighthouse Road
Public Shower at Middleton Street
Childe Street Footpath
Border Street Footpath 2 of 2
Border Street Footpath 1 of 2
Shirley Street Footpath
Picnic Tables at Bay Street

28. Appendix J: Probabilistic Erosion and Recession for Economic Assessment

28.1 Overview

Risk is defined as *likelihood (or probability)* times *consequence.* Probability is generally expressed in the following formats:

- Average Recurrence Interval (ARI);
- Annual Exceedance Probability (AEP);
- Encounter Probability (EP) over the planning horizon.

The acceptable likelihood or acceptable risk for private dwellings is considered in several documents, but well accepted or legislated values for coastal hazards are not presently available.

It is noteworthy that the Building Code of Australia lists the following acceptable design probabilities for freestanding detached private houses:

- Water entry into building: 100 year ARI (1% AEP);
- Wind Load: 500 year ARI (0.2% AEP); and
- Earthquake load: 500 year ARI (0.2% AEP).

The coastal defences in parts of the Netherlands are designed to a 1% encounter probability, which is equivalent to a 10,000 year ARI over a 100 year planning period (Delta Commission, 1962).

28.2 Probabilistic versus Conventional Assessment of Coastal Hazards

In a conventional approach, each of the input variables is assigned a single value and a single estimate (prediction) of recession and erosion is produced. This is usually a "design", "100 year ARI", "best estimate" or "conservative" value. In a probabilistic approach, each independent input variable is allowed to (randomly) vary over a range of values pre-defined through probability distribution functions (pdf). This range covers both uncertainty and error in a heuristic manner. By implementing a stochastic method to the recession model (Monte Carlo simulations) a probabilistic range of estimates (forecasts) of future recession is produced. Probabilities of storm demand are also included in this assessment by combining them randomly with the recession probabilities in a further Monte Carlo simulation. Note that by assuming that the storm demand represents a deviation from the long term average trend, and by expressing the combined probability as an AEP, the probability (AEP) of an eroded shoreline position each year does not need to consider beach recovery. The bounding still relies somewhat on engineering judgement and experience.

28.3 Erosion and Recession Hazards for Byron Bay Embayment

In the BMT WBM (2013) Byron Shire Coastline Hazards Assessment Update the coastal hazard lines (present, 2050 and 2100) are equivalent to the landward extent of the *Zone of Slope Adjustment* (ZSA) as depicted in Nielsen et al (1992, Figure 28.1). This position is analogous to a theoretical position of the "erosion escarpment". There are four (4) main components forming the position of the "coastal hazard line" in deterministic assessments. Numerous other sub-components may aggregate to form these.

The four main components are:

- Recession due to sediment budget differentials;
- Sea level rise and the recession response to sea level rise;
- Storm erosion; and
- Dune stability or zone of reduced foundation capacity.

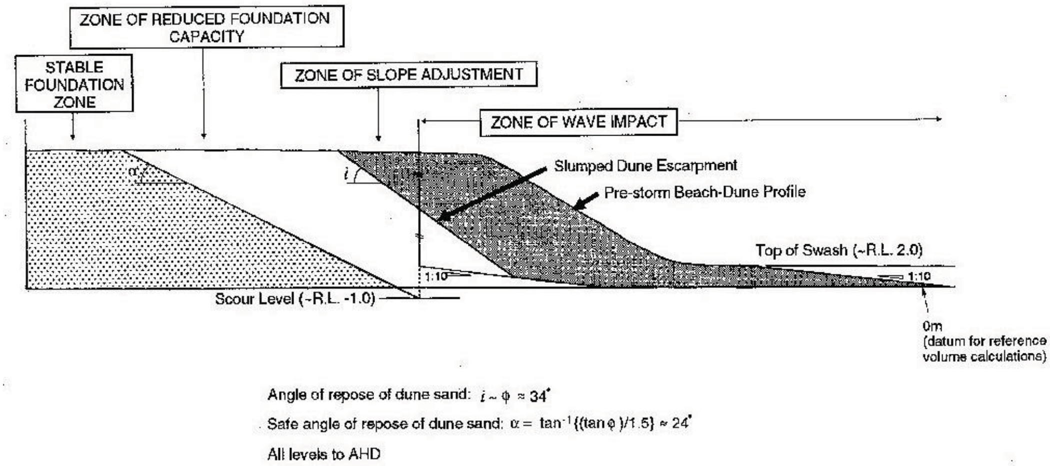


Figure 28.1: Zone of Slope Adjustment (Nielsen et al, 1992)

Storm erosion is fully reversible on a non-receding coast, and partly reversible on a receding coast such as the Byron Bay embayment. The timescale of a single storm erosion event is of the order of days, while the timescale of recovery/accretion is of the order of weeks to months to years (Thom and Hall, 1991). In the Land and Environment Court judgement "John Van Haandel v Byron Shire Council [2006] NSW LEC 394", Commissioner Brown (Brown, 2006), accepted that the erosion escarpment for application of a 20 m setback was the historical erosion escarpment from the 1970s or 1980s. That is, recovery of the beach (whether natural or through mechanical intervention) did not advance the setback line in a seaward direction. Furthermore, Commissioner Brown noted that *"… the 20 m requirement must be applied cumulatively with the requirement for relocation otherwise it would have no purpose."*

Therefore, for the purposes of the probabilistic assessment of coastal hazards for the economic assessment of planned retreat, progradation/accretion following storm events is not considered to be a "gain" of private land, since this land has reached its planned retreat trigger and cannot be redeveloped.

The BMT WBM (2013) work used a combination of numerical modelling, accepted empirical techniques and engineering judgement to determine the coastal hazard lines, and were based on the sea level rise benchmarks in the (now rescinded) NSW Sea Level Rise Policy Statement (2009).

The numerical modelling of BMT WBM (2013) showed that there is interaction between components, however, this is less apparent for the 2050 modelling than for 2100. A comprehensive reassessment of probabilistic coastal hazards would require the modelling of BMT WBM to be re-run for a range of scenarios. A reassessment would be best undertaken within the framework of a sediment budget.

Factors which could be considered (Mariani et al, 2012) include:

- Storm erosion;
- Storm clustering;
- The short and long term erodibility of the substrate;
- Beach rotation;
- Littoral drift differentials;
- Offshore sand losses (currents and mega rips);
- Cross embayment transport;
- Sea level rise;
- Beach closure depth;
- Onshore (shelf) sand supply;
- Biogenic (shell) production;
- Losses into (or supply from) estuaries; and
- Wind-blown sand losses.

For the purposes of economic assessment, given that BMT WBM's (2013) modelling considered long term change measured from photogrammetry, WRL has assumed that all the above factors are somewhat aggregated into the BMT WBM hazard lines at a stated or inferred probability.

28.4 Probability Distributions of Variables used by WRL

Parameters have been set based on the accepted values and ranges of the BMT WBM (2013) study where possible. This included feeder documents or other well accepted synthesis publications where necessary. WRL used engineering judgement to simplify the modelling output of BMT WBM into a format suitable for probabilistic assessment.

Scientific literature contains numerous works postulating sea level rise outside the range of IPCC projections. While the adoption of post IPCC projections is advocated by some, the role of the IPCC is to synthesise these on a 5 to 7 year cycle. Therefore, post IPCC projections have not been considered in this report, apart from a small local component which was incorporated into the previous NSW Government benchmarks.

The following sources were used to determine the range of input parameters.

Sea Level Rise
The BMT WBM (2013) assessment used 0.4 m for 2050, which was based on previous NSW government benchmarks.

Hennessey et al (2004) noted *"The tool used to explore future climate is the climate scenario. A scenario is a coherent, internally consistent and plausible description of a possible future state of the world. They can range from simple to complex and from narrative descriptions of a possible future to complex mathematical description combining mean climate changes with climate extremes. A scenario is not a prediction, and has no likelihood attached beyond being plausible. However, it is the basic building block of risk assessment approaches under climate change that use scenarios, ranges of uncertainty and probability distribution functions."*

Hunter (2011) presented a similar technique for sea level rise to that used in this WRL report, however, cognisant of the scenario comment above, Hunter's work required the selection of a future global emissions scenario, and then assigned probabilities to future sea level rise <u>within</u> that emissions scenario.

WRL utilised a triangular distribution of the simplified low, mid and high curves in NCCOE (2012) Figure 7 (Figure 28.2 of this WRL report), which are comparable to IPCC (2013) across all future emissions scenarios.

The previous NSW benchmarks are comparable to the high values in NCCOE (2012), but also incorporated an additional local component for NSW in excess of the global projections.

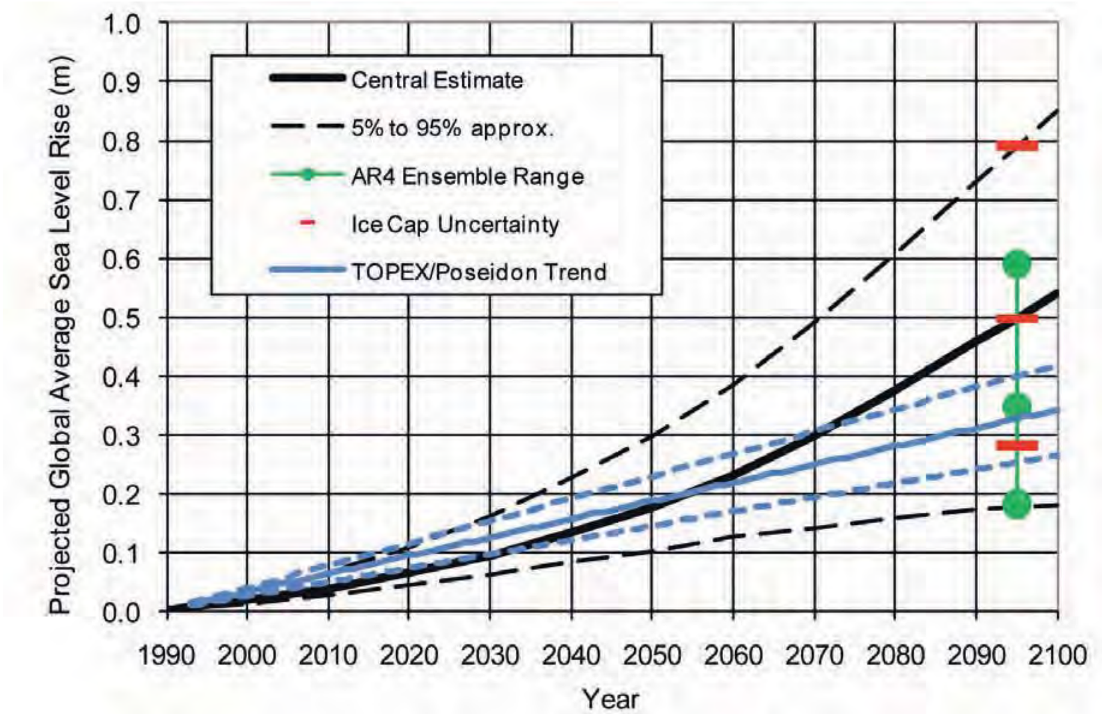


Figure 28.2: Sea Level Rise Projections (Figure 7 of NCCOE, 2012)

Recession due to Sea Level Rise
WRL primarily considered BMT WBM (2013) p49, Figure 4-34 and Table 4-2. There are minor differences between these three sources. This is partly because the BMT WBM report considered both the traditional Bruun Rule approach and more sophisticated shoreline evolution modelling. WRL utilised a triangular distribution, in which BMT WBM (2013) Table 4-2 was given precedence for the modal values.

Recession due to Sediment Budget Differentials
WRL primarily considered BMT WBM (2013) p99, Table 4-2. WRL utilised a triangular distribution.

Storm Demand
WRL primarily considered BMT WBM (2013) p92 which was based on the Gordon (1987) statistics, slightly factored up. These were extrapolated by WRL using the original log linear relationship of Gordon. While there could be considerable debate regarding storm demand probabilities beyond 100 year ARI, the low probability of their occurrence means that for the economic assessment of coastal hazards in the Byron Bay embayment, the consequences of these rare events are relatively minor compared with the more frequent events.

A summary of all values used for probabilistic hazards is shown in Table 28.1.

Table 28.1: Probability Functions of Input Variables (relative to 2010)

Parameter/ precinct	**Unit**	**Storm Demand, ARI**					**Underlying Recession**			**Sea Level Rise (2, 4)**			**SLR Bruun Factor (3)**		
	years	**1**	**10**	**100**	**1000**	**10000**	**Min**	**Mode**	**Max**	**Min**	**Mode**	**Max**	**Min**	**Mode**	**Max**
2050	m									0.1	0.2	**0.4**			
Clarkes	m3/m	5	78	**150**	222	295									
	-												70	**88**	105
(1)	m/yr						0.16	**0.20**	0.24						
	-														
Main	m3/m	5	78	**150**	222	295									
	-												30	**38**	45
(1)	m/yr						0.08	**0.10**	0.12						
Cavvanbah	m3/m	45	147	**250**	353	455									
Jonson to	-												66	**83**	99
Border	m/yr						0.38	**0.48**	0.57						
Belongil	m3/m	45	147	**250**	353	455									
Border to	-												48	**60**	72
N Belongil	m/yr						0.36	**0.45**	0.54						
North	m3/m	45	147	**250**	353	455									
Belongil	-												34	**43**	52
	m/yr						0.32	**0.40**	0.48						
North	m3/m	45	147	**250**	353	455									
Beach	-												32	**40**	48
	m/yr						0.28	**0.35**	0.42						

Notes:

(1) BMT WBM (2013) Figure 4-34 shows a considerable gradient in recession due to SLR from Clarkes to Jonson Street (due to headland effect of Jonson Street works). However, the asset values at risk there are low, so for economic modelling the impacts of the simplifying assumptions are small.

(2) Values shown in **bold** were the basis of the best estimate hazard lines in BMT WBM (2013).

(3) The apparently high Bruun Factor values are the result of shoreline modelling by BMT WBM of the downdrift effects of structures and headlands.

(4) NCCOE upper figure is 0.3 m, however, previous NSW benchmarks used 0.4 m which was adopted for BMT WBM study. Strictly speaking the SLR is relative to 1990.

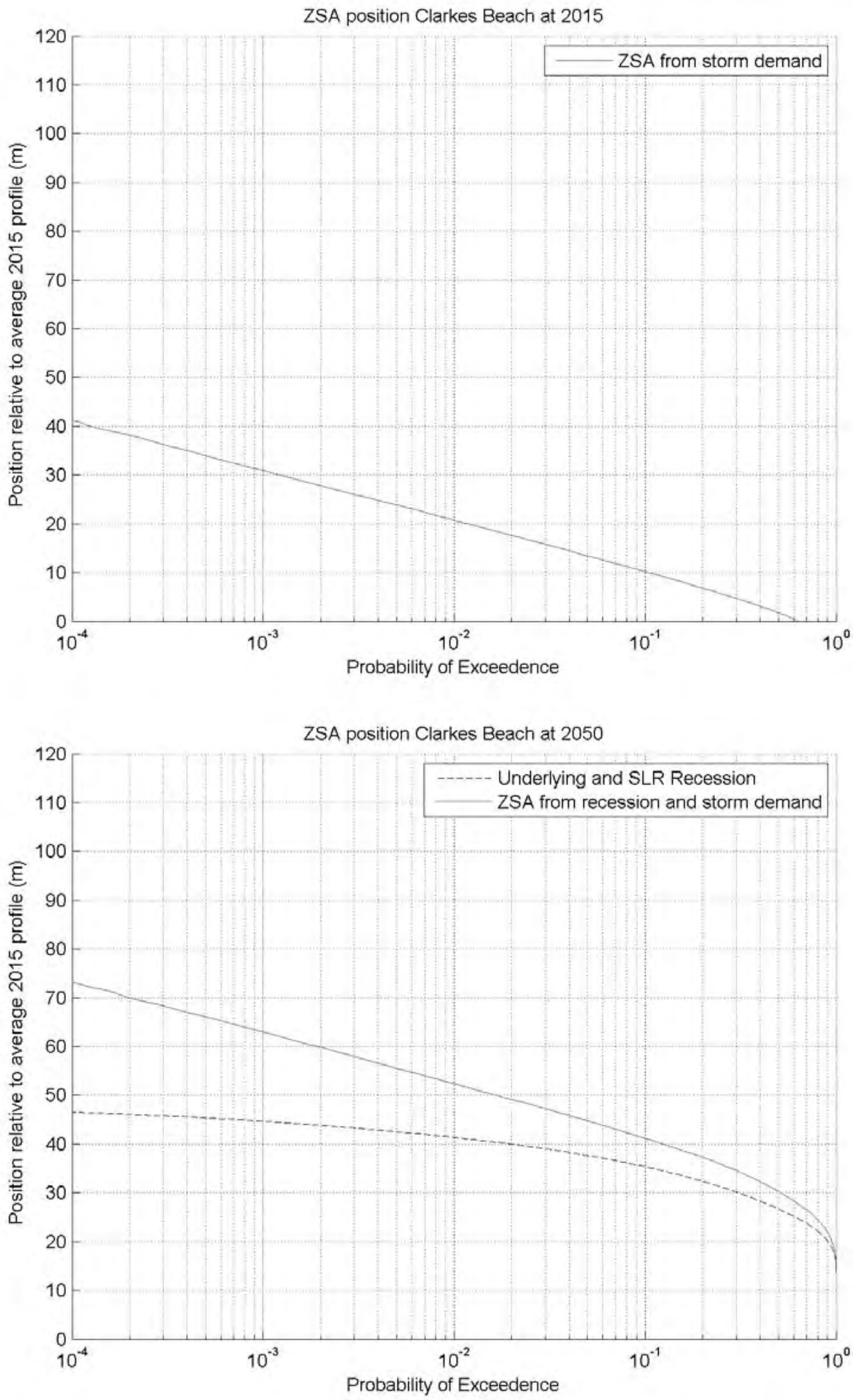
28.5 Probabilistic Hazard Curves

Linear distances relative to the BMT WBM (2013) lines were based on the assumption of a 7 m AHD dune height.

Present day 2015 erosion hazard distances (including the Zone of Slope Adjustment ZSA) with probabilities of occurrence are shown in the upper graphs of Figure 28.3 to Figure 28.8 for Clarkes Beach to North Beach, with the present day line presented in BMT WBM (2013) based on an AEP of 10^{-2} (1%).

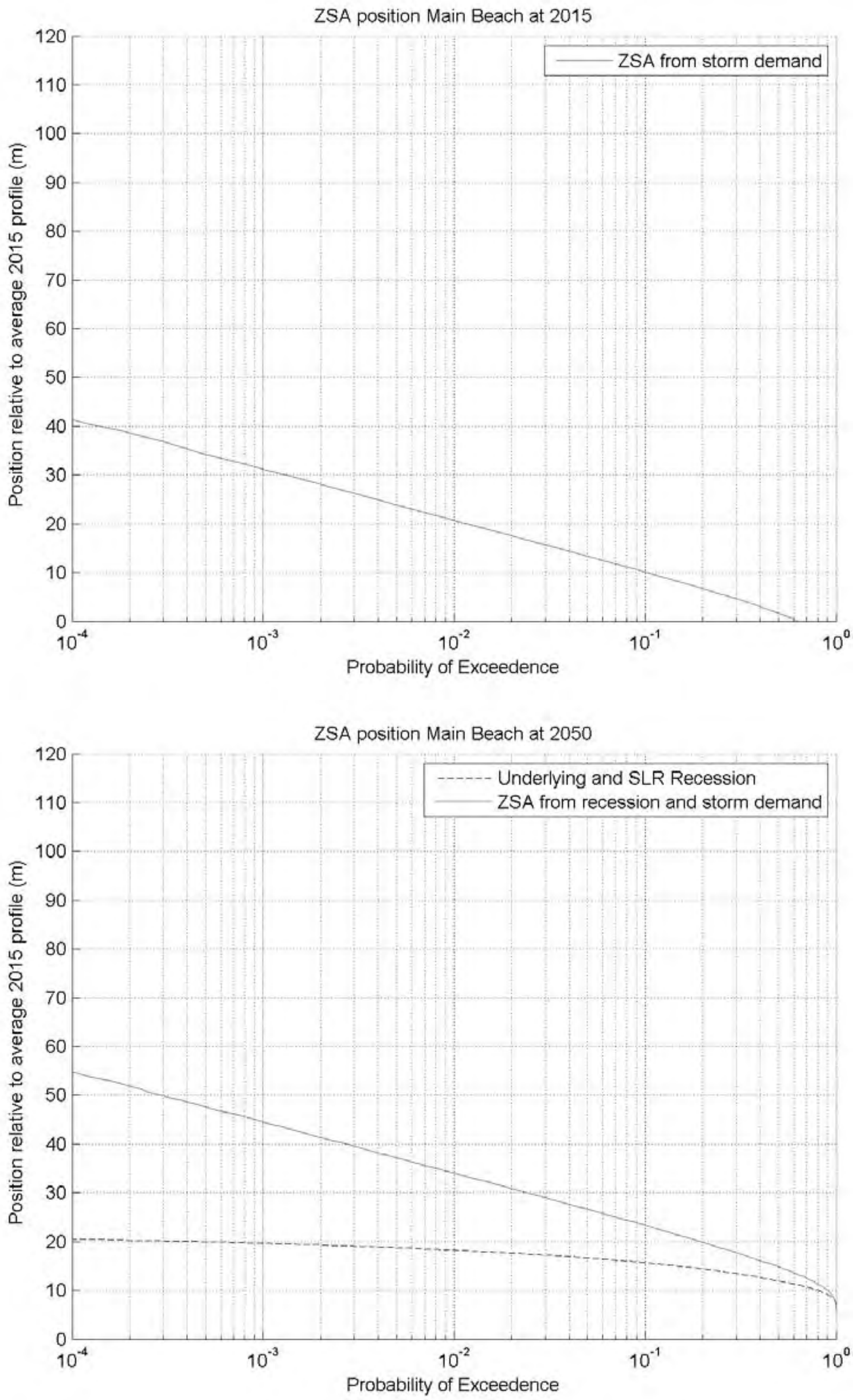
For 2050, each of the above variables were considered to be independent, and were combined through a *Monte Carlo* (Mariani et al 2013) simulation using 10^{6} iterations. For 2050 the lower graphs in Figure 28.3 to Figure 28.8 show the recession (underlying and sea level rise) and ZSA hazard distances (recession plus storm demand) with probabilities of occurrence for Clarkes Beach to North Beach. The BMT WBM (2013) best estimates indicated in the figures for 2050 are based on a storm demand AEP of 10^{-2} (1%) and a relatively high ("conservative") value of sea level rise, so have an approximate combined AEP (for Belongil) of 2×10^{-3} (0.2%).

The probability of the zone of slope adjustment reaching a given landward position for each beach from Clarkes Beach to North Beach was then interpolated for each year between 2015 and 2050 – the 2015 values are shown in the top panel and the 2050 values are shown in the bottom panel of Figure 28.3 to Figure 28.8.



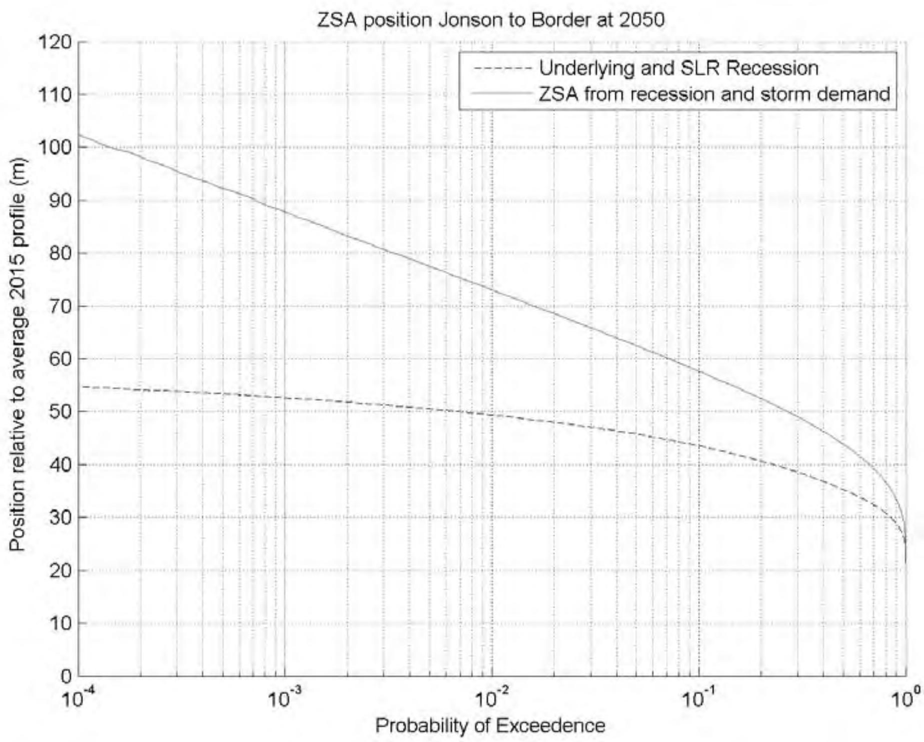
Note: BMT WBM 2050 best estimate 2050 ZSA hazard line is y = 64 m

Figure 28.3: Probabilities of Erosion and Recession Hazard – Clarkes Beach



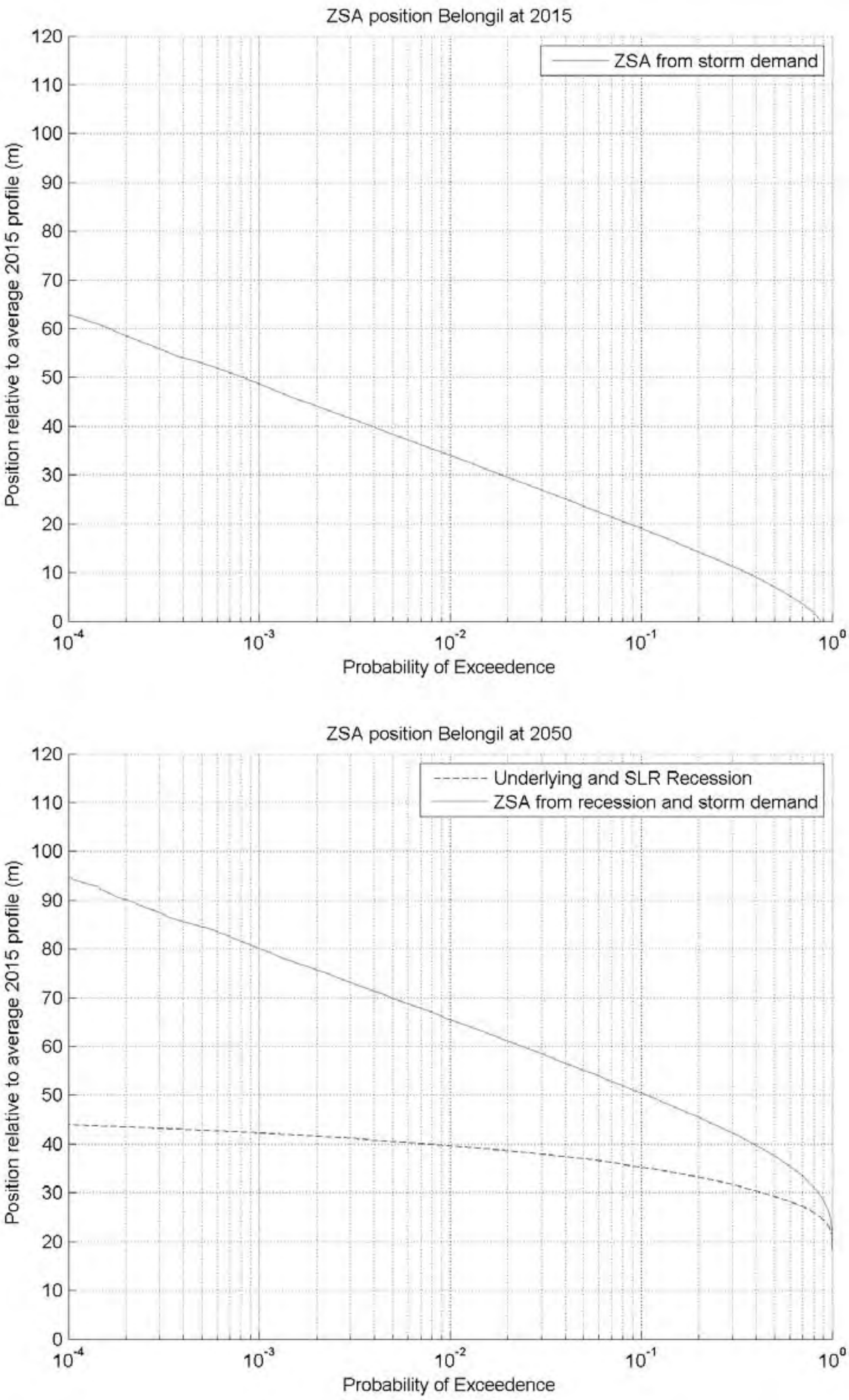
Note: BMT WBM 2050 best estimate 2050 ZSA hazard line is y = 40 m

Figure 28.4: Probabilities of Erosion and Recession Hazard – Main Beach



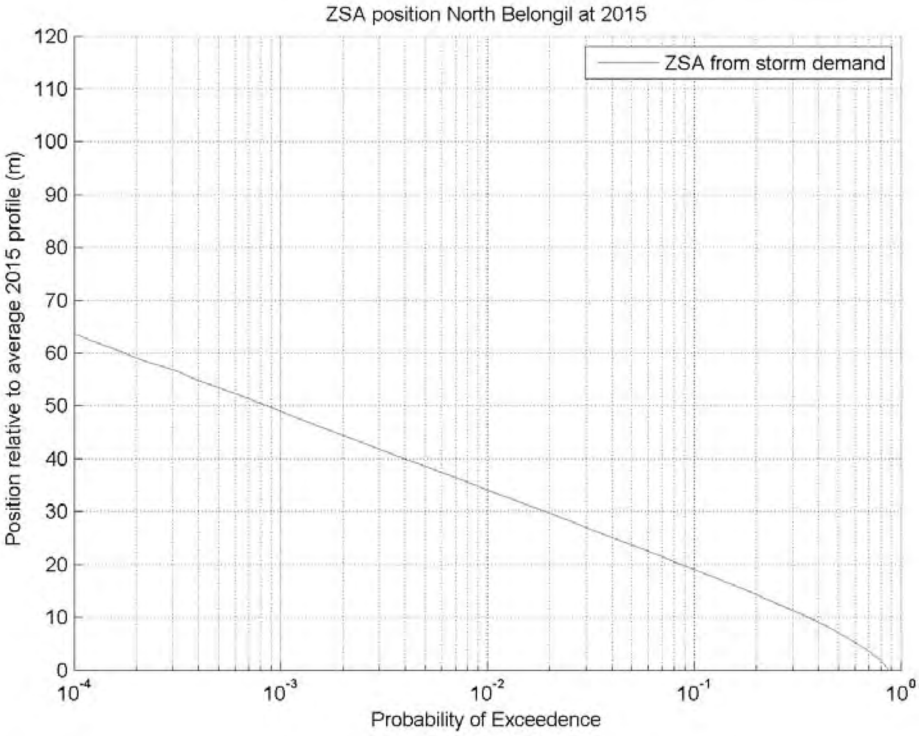
Note: BMT WBM 2050 best estimate 2050 ZSA hazard line is y = 87 m

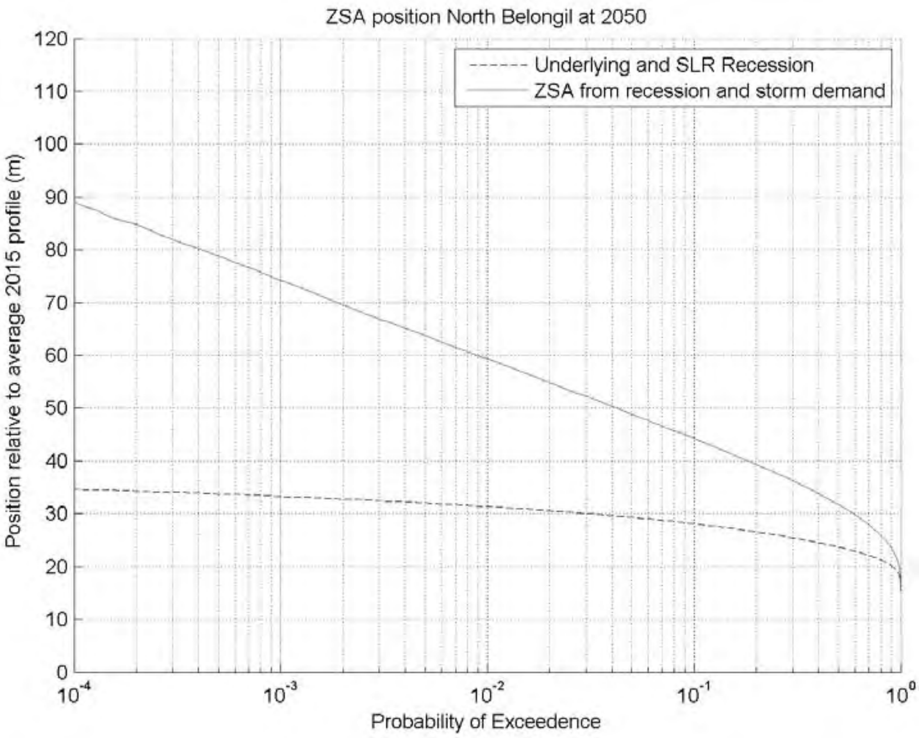
Figure 28.5: Probabilities of Erosion and Recession Hazard – Cavvanbah



Note: BMT WBM 2050 best estimate 2050 ZSA hazard line is y = 75 m

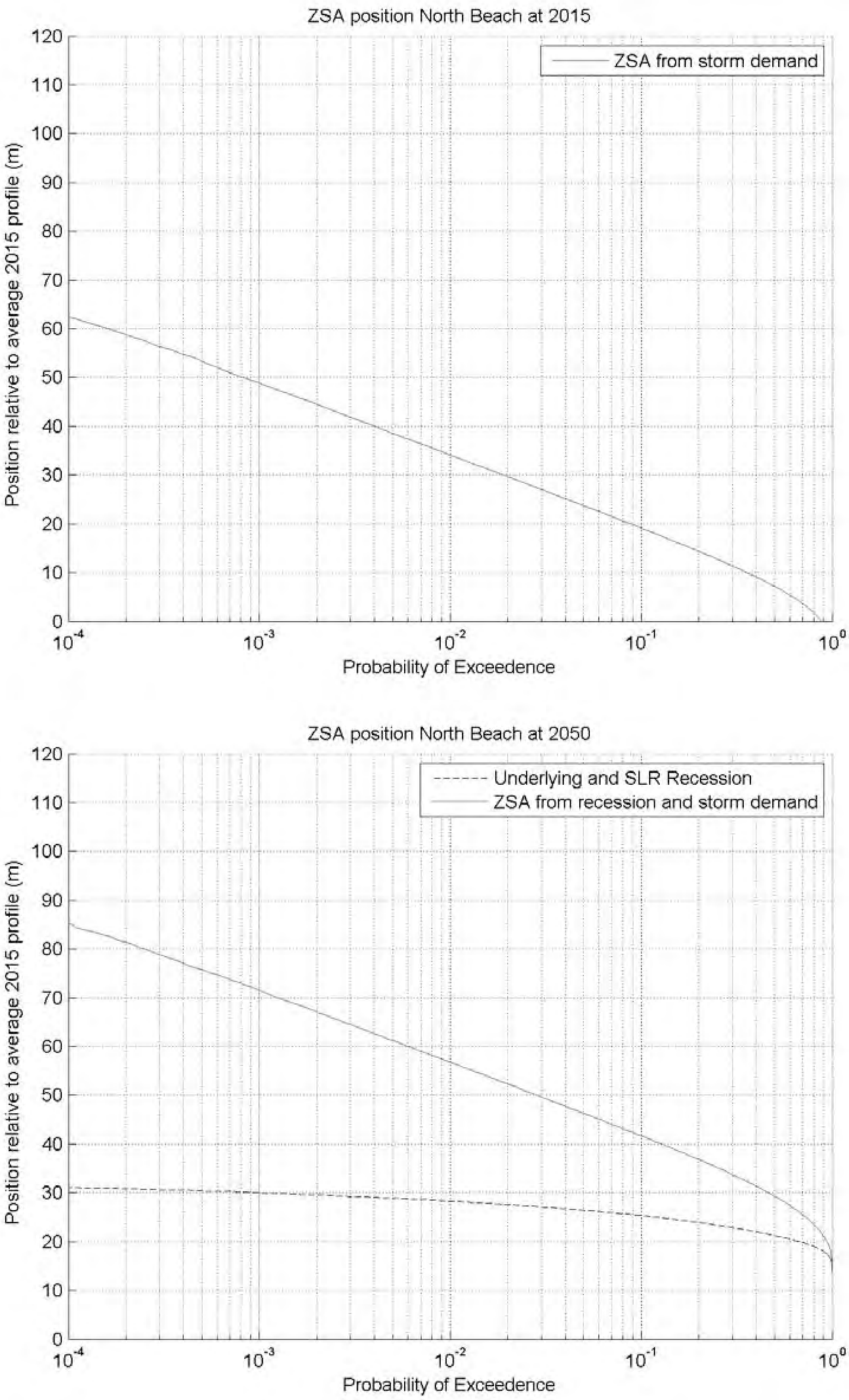
Figure 28.6: Probabilities of Erosion and Recession Hazard – Belongil





Note: BMT WBM 2050 best estimate 2050 ZSA hazard line is y = 68 m

Figure 28.7: Probabilities of Erosion and Recession Hazard – North Belongil



Note: BMT WBM 2050 best estimate 2050 ZSA hazard line is y = 65 m

Figure 28.8: Probabilities of Erosion and Recession Hazard – North Beach

28.6 Assets Impacted by Probabilistic Erosion and Recession Hazards under Planned Retreat

The probabilities of eroded land and buildings were assessed for the purpose of economic assessment of risk under a Planned Retreat scenario, that is, for the BMT WBM scenario of removal of all seawalls except Jonson Street.

It was assumed that the present valuation for each landholding was based on its present useable land area. The following deductions were made from the total cadastral area of each landholding to define the existing useable area:

- Eroded land seaward of the crest of existing seawalls;
- Land north of Manfred Street used as a private road – the "easement of necessity";
- Cadastral area within the present course of Belongil Creek.

As detailed in Appendix N, only the privately held land has high economic value. Areas of eroded/receded privately owned land for a range of probabilities are shown in Table 28.2. Note that since the 2050 values include a combination of erosion and recession, the probabilities can only be expressed as an AEP, and cannot be correctly expressed as an ARI, however, for the present day 63% AEP is equivalent to 1 year ARI and 9.5% AEP is equivalent to 10 year ARI.
These areas are relative to the following initial 2015 areas and are almost exclusively in the Belongil precinct:

- Cadastral area of private land potentially impacted by erosion: 109,227 m^2;
- Useable area (excludes areas seaward of seawalls, private road, creek): 106,441 m^2.

Based on BSC's coastal audit (2011), there are 14 private properties at Belongil subject to coastal hazards to 2050 that were purchased prior to 1988 and would be therefore be subject to publicly funded retreat under a Planned Retreat (Public-Private) model. These unrestricted title properties have the following initial areas in 2015:

- Cadastral area of private land potentially impacted by erosion: 23,227 m^2;
- Useable area (excludes areas seaward of seawalls, private road, creek): 21,777 m^2.

Table 28.2: Area of Eroded/Receded Private Land for Retreat Scenario

	Eroded land (m^2) for AEP (%)				
	63%	**9.5%**	**1%**	**0.1%**	**0.01%**
2015	11,372	32,075	43,041	51,313	62,271
2050	39,553	48,515	60,783	71,332	81,877

Note: Almost all land is within Belongil precinct, with small areas in Cavvanbah for rare AEP events in 2050

Based on BSC's coastal audit (2011) and GIS files, at Belongil there are approximately nine (9) buildings on six (6) landholdings which are relocatable. Other properties have varying restrictions regarding the lapsing of consent for the buildings, which in some cases extends to the lapsing for the upper storey only. Furthermore, other buildings have varying degrees of moveability, but in most cases this would be a major undertaking. The coastal audit also notes that a range of distances are in place for the triggering of retreat. Based on actual loss of houses observed on the coast by WRL, for the purposes of economic assessment, retreat has been assumed to be triggered when the erosion scarp (zone of slope adjustment) extends landward to the seaward face of a dwelling/building structure. If a 20 or 50 m trigger was applied, the number of buildings triggered for retreat would be substantially higher.

Table 28.3 presents the number of buildings where the zone of slope adjustment (with no additional buffer) would cause retreat of buildings to be triggered. For economic assessment, it has been assumed that the building replacement value is written off if the building is not designed to be relocatable, while relocatable structures can be moved landward at a cost of $10,000 provided there is sufficient land remaining, with an additional $10,000 for reconnection of services. Non-relocatable buildings have been allocated a value of $2500 per m^2 of building floor area. This is based on Rawlinsons (2015) for Tweed Heads "High standard framed house with no air conditioning". GIS processing was used to determine building footprints, with high resolution oblique aerial photos used to classify each building as 1, 1.5 or 2 storeys.

Table 28.3: Number of Buildings and Building Area Impacted under Retreat Scenario

	Building numbers for AEP (%)				
	63%	**9.5%**	**1%**	**0.1%**	**0.01%**
2015 relocatable	1	6	9	9	9
2015 non relocatable	9	16	25	34	44
2015 total	10	22	34	43	53
2050 relocatable	6	9	9	9	9
2050 non relocatable	23	29	41	47	49
2050 total	29	38	50	56	58

Note: Almost all buildings are within Belongil precinct, with a small number in Cavvanbah for rare AEP events in 2050

The value of land and buildings at Belongil relative to distance from the present seawall face (with and without a 20 m buffer) is shown in Figure 28.9.

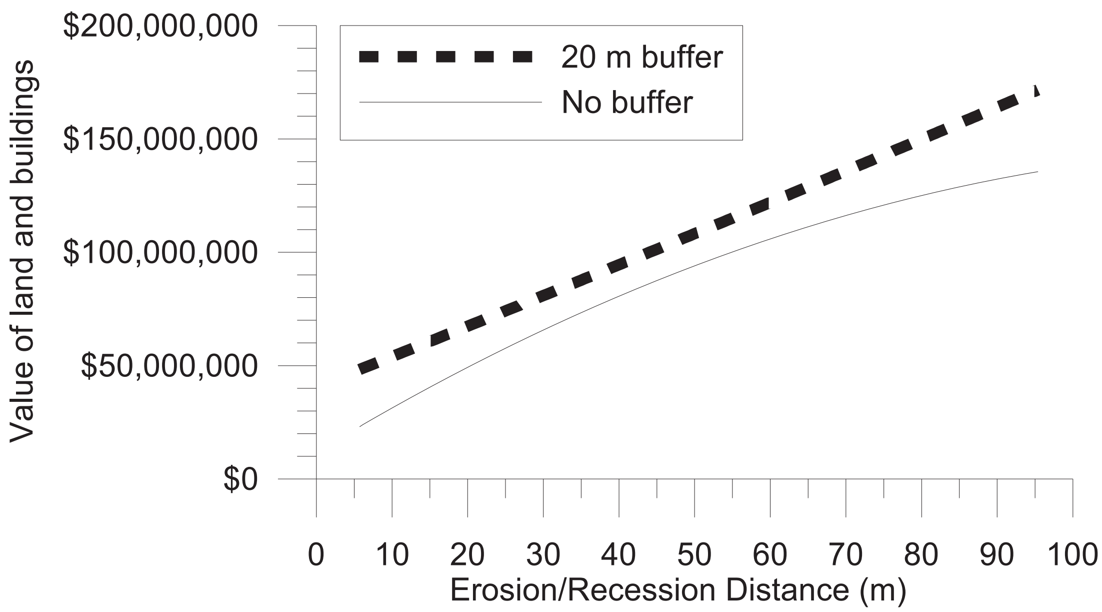
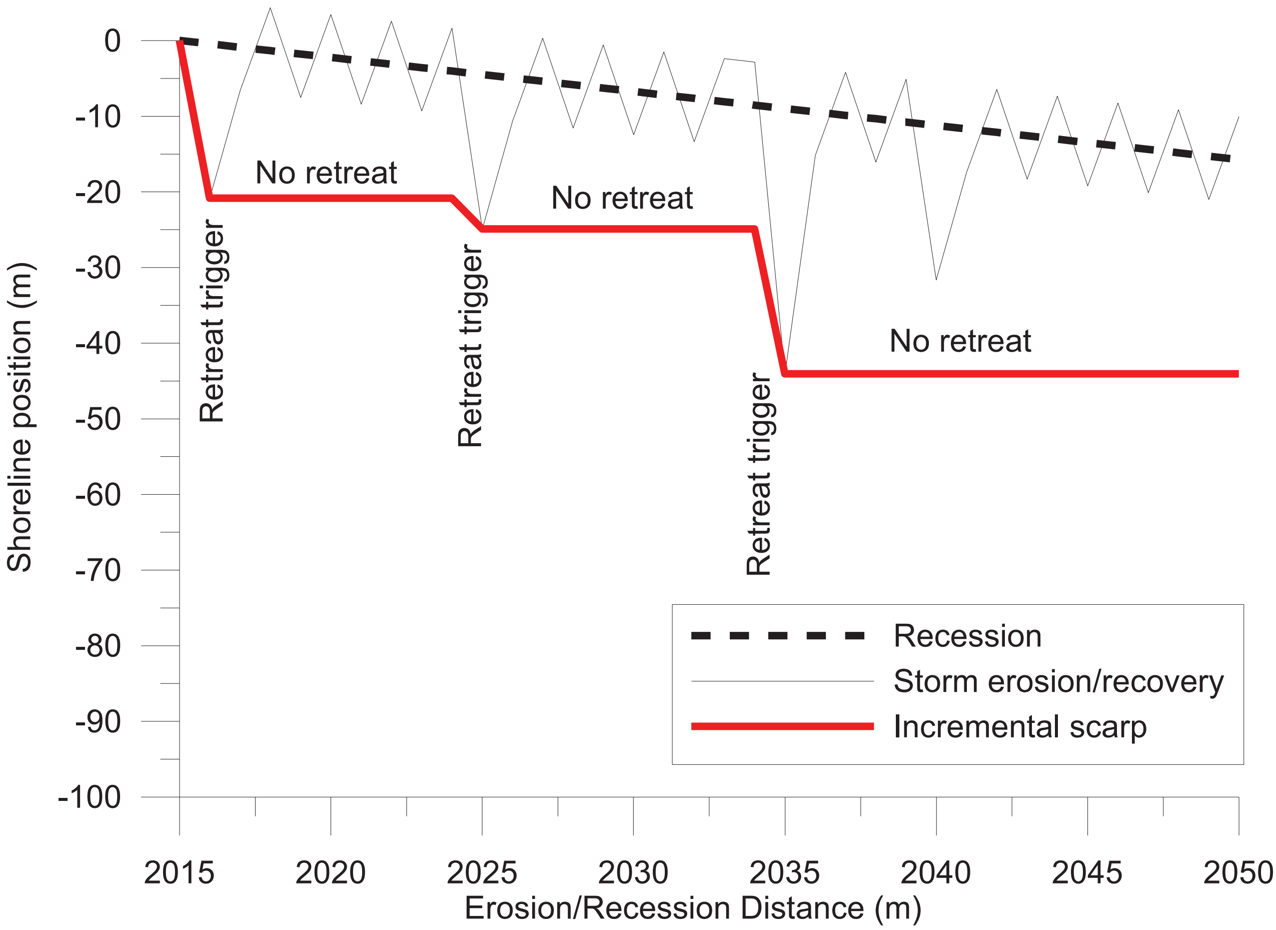


Figure 28.9: Value of Land and Buildings

All beaches undergo short term storm erosion and some recovery following the erosion. The difference between the erosion and recovery results in the long term trend, which is recession in the case of beaches in the Byron Bay embayment. As discussed above, partial beach recovery is not considered to be a net gain of private land – that is, the trigger for retreat cannot be reversed.

A hypothetical example sequence of storms, recession and retreat trigger events is shown in Figure 28.10. In the example there are three episodes of planned retreat potentially triggered, that is, the erosion scarp (ZSA) would move landwards three times. After the third episode, while a long term trend of recession continues, partial beach recovery and smaller erosion events mean that there are no additional planned retreat events triggered. That is, only future events in which the erosion scarp moves further landward would trigger a new planned retreat episode. For the purposes of economic modelling, beach recovery is assumed to occur within 1 year, which is realistic for erosion events up to about 10 year ARI. Larger erosion events may take longer to recover (Thom and Hall, 1991), however, the more dissipative nature of the beach profile following erosion events means that additional storm erosion will also be reduced (Harley et al, 2009).



Note: This is just one illustrative pathway – averages were calculated with 1,000,000 runs per year.

Figure 28.10: Hypothetical Example of Storms, Recession and Recovery

For floodplains, the NSW Floodplain Management Manual (NSW Government, 2005) recommends that damage is expressed as "average annual damages" (AAD). The AAD method in the Floodplain Manual assumes complete rebuilding after each major event, whereas under a Planned Retreat scenario, once a loss has occurred, it is assumed that the land asset value is written off, conventional buildings are written off and relocatable buildings are moved (where space is available). Therefore, while there are no precedents available, a concept of incremental average annual damages was considered for the Byron Bay embayment.

Incremental AAD was calculated by combining the following information:

- The probabilities of future shoreline recession and storm erosion (Figure 28.6 for Belongil), that is, the AEP of shoreline position for each year;
- The economic consequence of damage through erosion/recession (Figure 28.9 for Belongil)

The combination was undertaken by considering the probabilities of erosion events for each year using a Monte Carlo simulation technique with 1,000,000 iterations per year. As with the example in Figure 28.10, only events which move the erosion scarp further landward than its otherwise most landward position (over the planning/economic assessment period – not geological time) will trigger planned retreat and its consequential economic loss. The Monte Carlo results were then averaged to produce incremental AAD as shown in Figure 28.11. Note that the future dollar values are not discounted in this figure, but discounting is undertaken in Appendix N. It can be seen that substantial economic damage occurs in the early years following implementation of Planned Retreat, with approximately $28 million of damages occurring in the first year of implementation if no buffer is adopted, rising to $52 million if a 20 m buffer is adopted. This is because of the substantial loss of land and buildings which would occur in even a minor erosion event (e.g. 1 year ARI) following removal of the existing seawalls. Towards the end of the assessment period, the incremental AAD asymptotes towards the component driven predominantly by the long term recession.

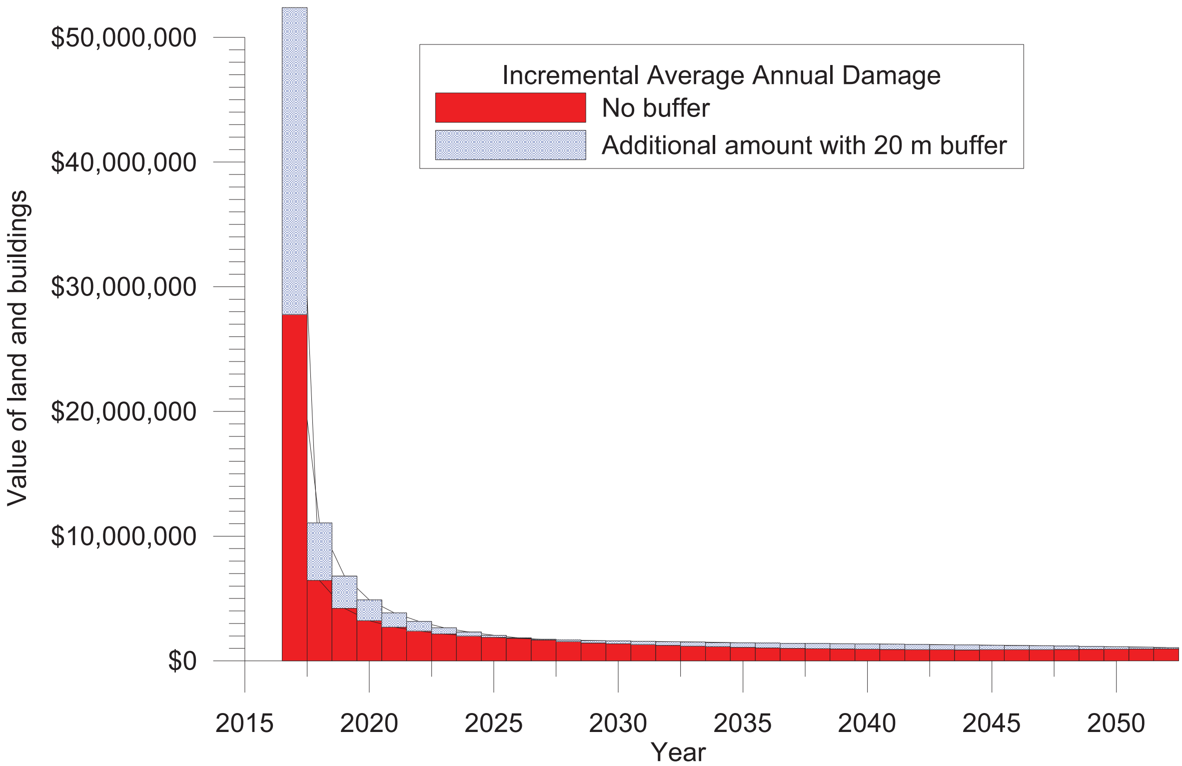


Figure 28.11: Incremental Average Annual Damages

The incremental AAD is shown cumulatively in Figure 28.12. Note that the future dollar values are not discounted in this figure, but discounting is undertaken in Appendix N. The cumulative incremental AAD is approximately $94 million (undiscounted) to 2050 if no buffer is adopted, rising to $115 million if a 20 m buffer is adopted. This compares with an estimated value of approximately $189 million (Appendix N) for the total value of private land and buildings potentially affected by coastal hazards to 2050.

The BMT WBM (2013) best estimate 2050 coastal hazard line was undertaken to contemporary coastal engineering practice, but is inherently conservative because it was based on a sea level rise of 0.4 m and assumes that a 100 year ARI erosion event occurs in 2050. Note, however, that it is not implausible for major erosion events (exceeding 100 year ARI) to occur early in the implementation period.

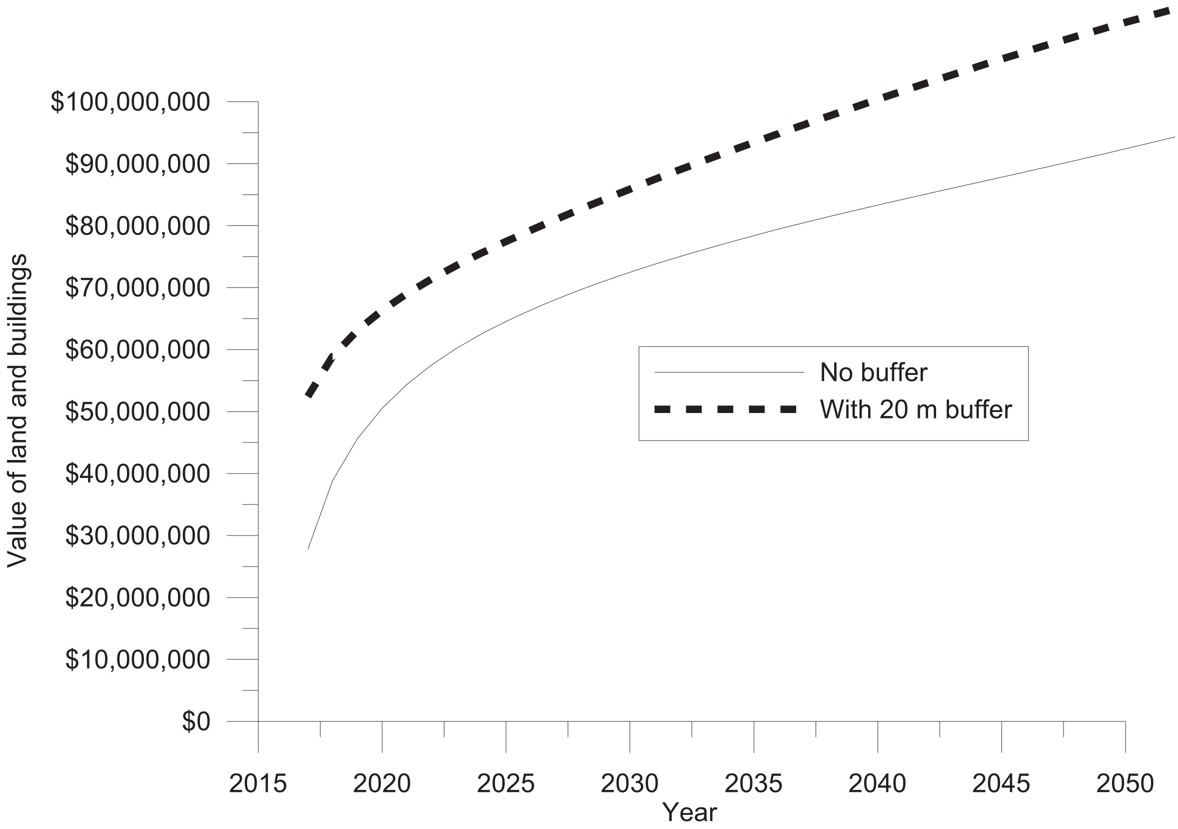


Figure 28.12: Cumulative Incremental Annual Damages

28.7 Probability of Breakthrough at Manfred Street

It was assumed in the modelling of BMT WBM (2013) and in this WRL report that Planned Retreat would involve the removal of all coastal protection works except Jonson Street. This could result in a breach of Belongil Spit, particularly in the vicinity of Manfred Street.

As stated previously, BMT WBM adopted nominally 100 year ARI, "design" and conservative conditions in their assessment. For the purposes of economic assessment, additional probabilities were developed by WRL.

The concept of a breach is shown in Figure 28.13. Such a breach could be initiated from the creek or ocean side. Based on dune crest elevation, BMT WBM (2013) noted that a "significant overtopping potential exists at Manfred Street", however, they did not assess the potential for overtopping or erosion breakthrough for events of less than 100 year ARI. An assessment of the potential for a breach was undertaken by Moratti/PWD (1990) who found that storm erosion of

200 m^3/m (about 80% of the design storm demand adopted by BMT WBM, 2013) would effectively remove the land comprising Manfred Street, from the ocean through to Belongil Creek.

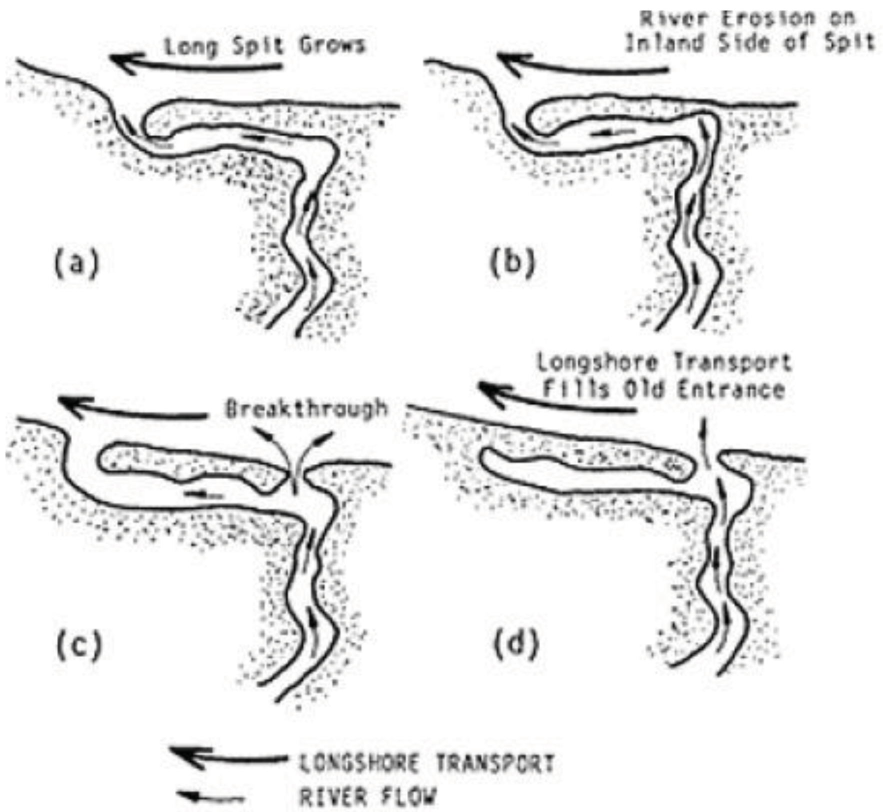
Detailed modelling of the potential for a breach would be complex as it involves interactions between wave runup, wave overtopping, cross shore erosion, longshore processes and terrestrial flooding. Removal of seawalls to the south may allow some additional sand to enter the small cove at Manfred Street, however, the low dune crest there could only be raised in the short term with mechanical intervention (beach scraping or minor nourishment).

WRL repeated the analysis of Moratti/PWD (1990) for the most recent (2012) photogrammetry profile (Figure 28.14). It should be noted that this application differs slightly from the more recent method suggested by Nielsen et al (1992), but the difference is minor. Moratti/PWD considered a range of available profiles, including 1987 photogrammetry profiles and a manual survey from 1990. The manual survey from 1990 was not available to WRL, but the 1987 photogrammetry was. The 2012 profile is more receded than the 1987 profile, and in reality is likely to contain a substantial number of geotextile containers, which would further reduce its volume if they were removed.

WRL found that for the latest available dune profile (2012):

- There was sufficient volume in the dune to withstand 1 year and 2 year ARI erosion events;
- The dune would be breached under a 5 year ARI storm erosion event.

While detailed modelling was not undertaken, it is likely that dune overwash would damage both Manfred and Childe Streets. The damage to Childe Street would potentially compromise vehicle access to approximately 15 properties to the north.



WRL note: Breach can initiate from ocean side as well as estuary/creek side

Figure 28.13: Concept of a Breach of Sand Spit (NSW Government, 1990)

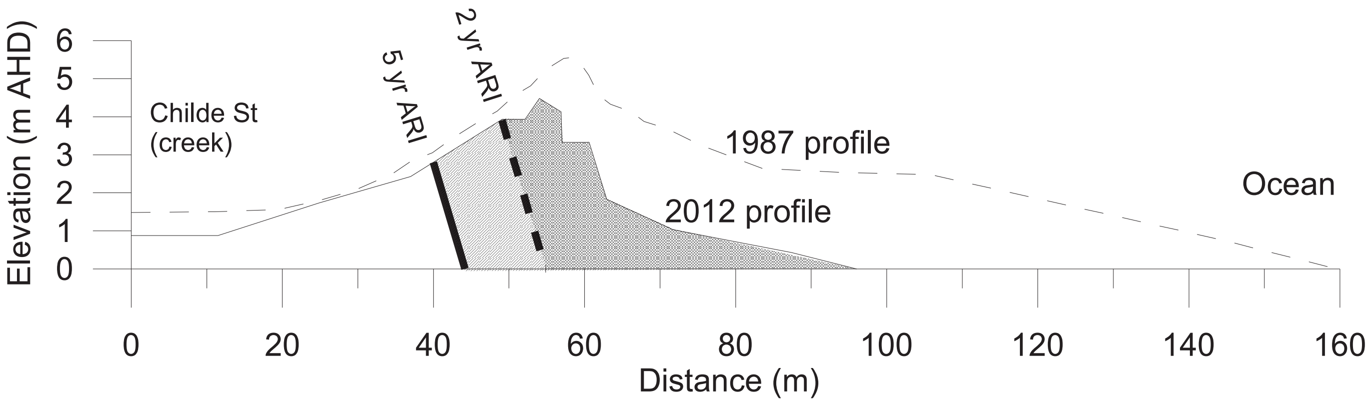


Figure 28.14: Potential Erosion Breach at Manfred Street

29. Appendix K: Sand Transfer Review and Concept Design for Byron Bay

29.1 Introduction

The work presented in this Section was undertaken as additional investigation for inclusion in Option 6: three stage managed adaptive protection scheme to investigate the technical feasibility of small scale beach nourishment. It investigates contemporary sand transfer technology and develops a preliminary concept design for a sand transfer system (bypass or backpass) for the Byron Bay embayment.

The results of the study presented in this Section include the following:

- A brief review of systems operating in Australia;
- Consideration of quantities required;
- Site options for sand and water intakes and the likely scale of these;
- Preliminary costings.

WRL's analysis was limited to technical aspects and did not extend to environmental/ecological assessment, approvals or stakeholder consultation.

This Section primarily considers the technical and economic feasibility of a sand transfer scheme. If this concept were to be progressed, it would require further design development, consultation with stakeholders, land managers and custodians. Consents, approvals and support would also need to be sought, however, these may not be forthcoming.

It should be noted that the selection of the most suitable sand transfer technique for the project has been based on an initial target annual sand transfer volume of approximately 50,000 m^3, which could be increased to 80,000 m^3 in the future. Such volumes are relatively small in comparison to existing sand transfer operations in Australia and restrict the number of technically and economically feasible solutions.

29.2 Review of Sand Transfer Systems Operating in Australia

29.2.1 Introduction

This chapter provides a presentation of the main methods available for sand transfer techniques for beach nourishment purposes. It is followed by a brief review of past and current sand transfer projects undertaken throughout Australia.

Beach nourishment using sand transfer techniques can be divided into four main categories:

- Land based mobile operations;
- Land based pumping systems;
- Offshore pumping systems; and
- Water based mobile dredging systems.

29.3 Sand Transfer Techniques

29.3.1 Land based mobile operations

Land based mobile operations are usually undertaken using conventional land based earthmoving machinery. This type of operation typically involves the use of an excavator on the beach excavating sand and stockpiling it on the beach. It is common practice to stockpile the sand excavated from the intertidal zone further up the beach face to allow it to dry out, using the excavator or a front end loader. The dry stockpiled material can be then transferred into haulage trucks, which can be off-road trucks at some locations (where they may be permitted to operate on the beach - as historically undertaken in Adelaide SA), but would probably need to be road licensed for Byron Bay. The haulage trucks then transport the material to the renourishment site. The last step requires the use of a front-end loader or excavator to level and profile the material dumped on site by the haulage trucks.

The main parameters which need to be considered for such an operation are:

- The distance between the excavation site and the renourishment beach sites;
- The infrastructure between the two sites;
- The degree to which the beach sites and connecting infrastructure are used by the public/community;
- The degree of accessibility of the beach sites to haulage trucks.

Some of the main advantages of this method are its relatively quick response time, depending predominantly on the haulage truck availability, making it extremely suitable for 'emergency' renourishment operations following a severe storm erosion event. It is also relatively economical compared to other techniques and is suitable for remote locations.

The main disadvantage of this method is its access limitation to replenishment material from land or shallow water close to the shore. Additionally, it should be noted that this operation can be unpopular within the community due to increased traffic, and its associated consequences (noise, exhaust emissions), around and between the beach sites. Because of this, it is most frequently used as an interim bypass method while a longer term solution is developed, or for very occasional sand transfer campaigns.

29.3.2 Land based pumping systems

Land based pumping systems rely on the use of onshore pumping units and a pipe network combined with conventional land based earthmoving machinery. The onshore pumping units generally consist of an integrated slurry pump and hopper unit.

Conventional land based earthmoving machinery equipment is typically used to excavate the renourishment material from the intertidal or dry beach and deliver it to the hopper on the onshore pumping unit. The hopper is generally fitted with a screen/shredder mechanism to remove unwanted material from the sand.

The onshore pumping unit mixes the sand with water (from a separate water supply pump) to form a slurry, with a typical composition of 10 to 30% sand, 70 to 90% water. The slurry is then pumped through a pipeline (with booster pumps if required) to the renourishment site. The slurry is then dispersed at the nourishment site using either direct outlets, rainbowing onto the dry beach or into the nearshore zone. Natural sediment transport processes may assist in transporting the sand to other areas.

Onshore pumping units can either be fixed or mobile systems. While fixed pumping units have the economic advantage of being able to be connected to mains power, they do rely extensively on earthmoving machinery for retrieving nourishment material. Mobile onshore pumping units are usually favoured and are typically tracked mounted hopper units (see Figure 29.1) enabling them to minimise the distance to the source material.

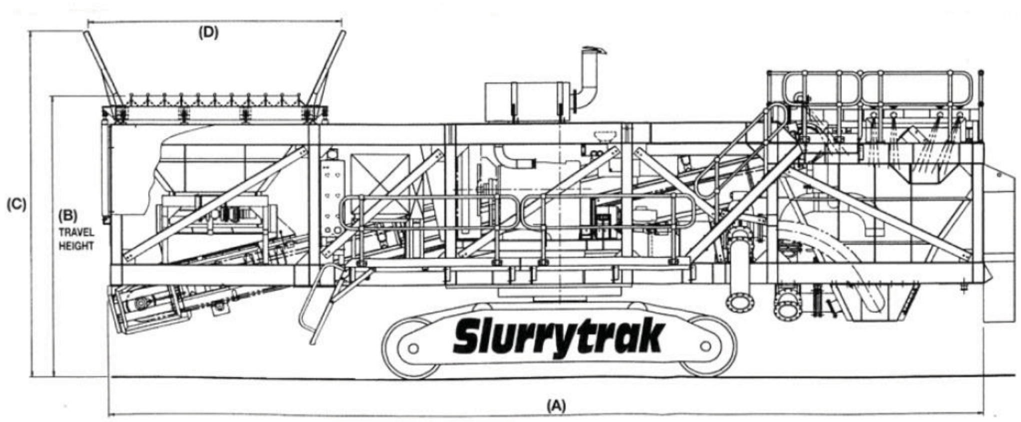


Figure 29.1: Slurrytrak Mobile Onshore Pumping Unit (Source: CGC Dredging)

The main advantages of this method are the use of a pipe to transport sand to the nourishment site instead of haulage trucks and the visual quality of the emplaced material due to screening. This method is also particularly suited for operations where the location of the source sand material varies seasonally.

The main disadvantage of this method is that it is limited to accessing sand from only the dry beach or intertidal area. It should be noted that this type of operation can be unpopular within the community due to heavy machinery activity on the source site. Finally, onshore pumping requires a clean water source to create the slurry to be pumped to the nourishment site.

29.3.3 Nearshore pumping systems

The sand transfer mechanisms are relatively similar to the techniques presented in the Section 29.3.2 with the main difference being that the nourishment material is extracted underwater directly from the seabed. The two main techniques using offshore pumping rely on the use of jet pumps or self-burying units such as "Sand Shifters".

Jet pumps

Jet pumps are hydraulically powered pumps with no moving parts at the sand source that rely on the exchange of momentum to do work.

A jet pump is a hydraulically powered pump, which operates by providing a high velocity upwards flowing jet of water which entrains the surrounding fluid and forces the mixture through the mixing chamber into the diffuser. As the suction opening of the pump is typically buried in the sand, a slurry of sand and water is drawn into the jet pump and pumped back to shore.

Because of the high water velocity in the jet it is essential that the supply water be free of sand. Jet pumps frequently include fluidisers that inject clear water into the seabed. These fluidisers are used during deployment to facilitate the burying of the pump unit and during operation to create a more mobile slurry of sand.

Jet pump operation can either have the jet pump units attached to a fixed or mobile structure. Fixed structures are usually dedicated for the project (e.g. Tweed and Nerang Rivers) or existing marine structure such as a jetty. Being attached to such a structure allows access to nourishment material to be collected in deeper water as well as offering a routing solution to the water and slurry pipelines. Alternatively, jet pump operations can be carried out from a dedicated boat pumping the slurry through a floating pipeline to the shore. In both cases, the slurry is then pumped through a pipeline (with booster pumps if required) to the renourishment site. The slurry is then dispersed at the nourishment site using either numerous outlets, rainbowing or earthmoving machinery or if offshore using natural sediment transport processes to nourish the site.

Fixed jet pump operations require either an existing suitable marine structure extending over 100 m offshore or a dedicated structure (e.g. Tweed and Nerang Rivers). This requirement typically restricts their application to relatively large operations with annual transported sand volumes of 500,000 m^3 or more. When installed, the sand sourcing process can be highly automated. Jet pump operations carried out from a boat are suitable for lower sand volumes but require nonetheless the installation of permanent onshore and offshore pipeline networks for transporting the nourishment material to the replenished target site.

Sand shifter

Figure 29.2: Sand Shifter Onsite before Installation/burial (Source: SSM)

The Sand Shifter is a proprietary system developed by Slurry Systems Marine Pty Ltd (Figure 29.3 and Figure 29.4). The unit is based on a fluidising principle that allows sand to be recovered from below the seabed. The fluidising system on the Sand Shifter consists of a fluidising pipe below an inverted channel and barrier that both traps and creates a sand-water slurry. The mobilised slurry is captured within the inverted channel and pumped along a pipeline to the disposal site. Depending on the overall travel distance, additional booster pumps onshore may be required.

Figure 29.3: Sand Shifter during Operation (Source: SSM)

Sand Shifter units are typically installed underwater but close to shore. Their long axis is generally perpendicular to the shoreline to make use of existing longshore sediment drift. After initial placement, the device goes through a self-burying period and can eventually be up to 8 m deep, as the sand is removed from the source location. After stabilisation, a basin forms around the extraction zone, naturally enhancing sand mobilisation deposition due the wave and tidal action. The onshore component consists of the water intake and water pump to drive the jet pumps (Figure 29.4).

Some of the main advantages of this system are the near shore location of the main machinery, which can facilitate maintenance operations. Moreover, being buried, most of the system is virtually invisible to the public, so is usually well accepted. The transported sediment is of high quality and does not need to be filtered and the system causes minimal disturbance to the beach environment. Such sand transfer operations can usually be undertaken throughout the year as they are not generally impeded by wave conditions. They can also be undertaken at night to minimise the disturbance to public access to the beach.

Figure 29.4: Onshore Infrastructure Required for Sand Shifter Operation (Source: SSM)

The main disadvantage of this method is the relatively high initial capital cost due to the necessary onshore infrastructure and potential high maintenance costs should the unit become blocked due to wrack or debris. The basin that forms around the operation zone can reduce beach amenity. The overall production of sediment is solely dependent of longshore drift for bringing nourishment material to the unit, reducing the flexibility of the available sand volumes and its use for emergency type operations. Finally, onshore pumping requires an available water source to create the slurry to be pumped to the nourishment site.

29.3.4 Water based mobile dredging systems

There are two basic types of floating plant suitable for beach nourishment works, a Cutter Suction Dredger (CSD) or a Trailing Suction Hopper Dredger (TSHD). The selection is generally dependent on the sand source location and the proximity to the renourishment location.

CSD based nourishment operations are typically carried in an estuarine environment or a port embayment as the dredging floating plant requires low energy wave conditions. This crucial limitation disqualifies using a CSD for Byron Bay as the potential sand sources for the study area are located east of Cape Byron in a swell dominated environment.

A detailed analysis of the suitability of a TSHD based operation for sand transfer at Byron Bay was conducted in 2006 by Patterson Britton and Partners (PBP, 2006). The size and associated costs for a TSHD are outside of the scope of this study.

29.4 Review of Sand Transfer Techniques in Use in Australia

Figure 29.5: Locations of Sand Transfer Projects in use in Australia

Based on the results of a literature review which included technical reports, academic papers, conference proceedings as well as direct discussions with sand transfer systems designers, and manufacturers and owners, a total of nine formal sand transfer systems are currently operating in Australia. These locations throughout Australia are shown in Figure 29.5. There are also numerous smaller scale informal truck-based operations.

29.4.1 Land based mobile operations

As mentioned in Section 29.3, land based mobile operations are generally favoured for emergency beach nourishment after storm erosion events. The two largest operations carried out on a semi-regular basis (i.e. 2-3 year intervals) take place in Adelaide and at Narrabeen in northern Sydney.

Until 2013, The Adelaide Living Beaches management program relied solely on a truck haulage system for transporting replenishment material, achieving unit rates of $3 to $4 per m^3 for haul distances of 2 to 3 km (sometimes directly along the beach) for annual quantities of the order of 40,000 m^3. Due to the large number of truck movements involved in the operation, the management authorities have been progressively reducing the need for truck haulage operations within Adelaide by installing a pipeline network to transport and deliver the sand material to the target beaches (see Section 29.4.2).

At Narrabeen, Warringah Council undertakes periodic removal of sand from Narrabeen Lagoon, and transports it 2 to 3 km south for placement on the beach. The removal is primarily for flood hazard reduction. The 2006 beach replenishment campaign involved 45,000 m^3 over five (5) months at a cost of $19 per m^3. The higher unit cost is due to excavating sand in an intertidal estuary entrance zone and trucking along a major arterial road with restricted haulage times and difficult truck manoeuvring.

29.4.2 Land based pumping systems

The three land based pumping systems are found in the Dawesville and Mandurah entrances in Western Australia, and along a 9 km stretch of coast in Adelaide.

Dawesville and Mandurah WA

The Dawesville and Mandurah sand transfer operations have been carried out since 1995, with typical achieved rates of 85,000 m^3 and 100,000 m^3/year for Wadesville and Mandurah respectively. Both systems use a tracked vehicle with a hopper, conveyor, slurry hopper and slurry pump. The sand hopper is filled by an excavator sieved by a vibrating grate, conveyed to a hopper continually sprayed with water, then pumped into a 315 mm diameter pipeline. The system operates in the intertidal beach whereby a 200 metre spur groyne was constructed normal to the entrance breakwater/training wall to trap sands where the mechanical extraction could be undertaken. This system extracts and pumps 250 m^3 per hour for a distance of up to 1.2 km, and the costs per cubic metre are approximately $4 (Carley et al, 2005). These bypassing operations have been successful in maintaining a largely stable coastline and navigational channels, with no significant variations in the coastal alignment up or down drift of either entrance (GHD, 2006).

Adelaide SA

The Adelaide Living Beaches – Sand Transfer Infrastructure project is a slurry pumping system that replaces trucked sand carting over 9 km of urban coastline in Adelaide (Tucker, 2013). The system was designed to transfer an average of 75,000 m^3 of sand per year, but is able to transfer up to 105,000 m^3 of sand per year. Construction began in March 2012 and full commissioning was completed in May 2013 at a total cost of $23 M. The fixed infrastructure consists of two fixed seawater intakes located on existing jetties, two fixed main slurry pump stations and three slurry booster stations. Sand is collected from the intertidal and dry beach by mobile conventional excavation machinery, screened and converted into a slurry by a custom built relocatable mobile sand collection unit (MSCU) (Figure 29.6) (Leppert, 2013).

The design peak capacity of sand transport is of 1,500 m^3 per day, with a peak capacity of 200 m^3 per hour. The system is intended to achieve the daily capacity in a single 10 hour shift allowing time to collect an initial sand stockpile, start-up and shutdown of the MSCU and pumping system. The MSCU is removed from the beach at the completion of sand collection periods, as it can be dismantled and removed from the beach by having the different components towed on large rubber tyred wheels or skids by a 500 HP tractor. During sand collection periods, the MSCU is connected to the permanent slurry and seawater pipe systems installed in the beach.

Figure 29.6: Mobile Sand Collecting Unit in Operation (Source: ABC Australia)

While the system is in its early stages of operation, it is meeting expectations. Public reaction has been generally positive at this early stage due to the reduction in truck traffic. While the total cost of the project, including installation of the slurry pipeline in a urban environment, booster pump, seawater intakes and the MSCU has been reported to be $23 M, at the time of writing no pumping unit cost rates were available.

29.4.3 Offshore pumping systems – Fixed Jet pumps

The only two sand transfer operations in Australia using this technique are located on the Gold Coast at Nerang and the Tweed River, with typical annual sand transfer rates of 500,000 m^3/year. As both systems extract the longshore drift sands, they both operate across a broad width of the surf zone. This results in the need for large infrastructure, such as a jetty and groynes or training walls. Approximate costs were $50 M for Nerang and $23 M for the Tweed, with unit rates for pumping of $1.40 per m^3 (government run) for Nerang and $4.50 per m^3 (payment to private operator) for the Tweed. As the littoral drift differential across the Byron Bay embayment is only approximately 50,000 m^3 per annum (BMT WBM, 2013), a trestle based bypassing system would be difficult to justify.

29.4.4 Offshore pumping systems – Mobile Jet pumps

Since 2012, the Port of Portland in Victoria has been undertaking their annual sand transfer operation using Jet Pump mobile system located on-board a work boat. From the work boat, sand is pumped as a slurry through a floating pipeline to a connection point and a booster station installed on a breakwater. The slurry travels through a rigid HDPE 450 mm diameter buried pipe for nearly 1.5 km, requiring the use of a second booster pump and is then directly discharged from the end of the pipeline at the intertidal zone to the nourished beach site. The 'Sand By-passing and Smelter Obligations Deed' (the Deed) enacted on 6 March 1996 requires the Port of Portland to transfer a minimum of 150,000 m^3 of sand every three years, with a minimum of 25,000 m^3 every year (WorleyParsons, 2014). The Port of Portland (personal communication with Harbour Master) estimates that 125,000 m^3 can be dredged and transported in a single three-month campaign at a cost of about $9 per m^3.

29.4.5 Nearshore pumping systems – Sand shifter

The only sand transfer system with nearshore pumps currently operating in Australia is located at Noosa in Queensland. It should be noted that this operational system has replaced a trial system designed, installed and financed by Slurry Solutions Marine (SSM). The trial system ran for 3 – 4 years, providing ~ 30,000 m^3 of beach nourishment per annum. Following the initial trial system, the present system has been operating since January 2013 and consists of two 9 metre long self-burying submarine sand shifter units placed shore parallel between high and low tide, adjacent to the Noosa River training wall groyne.

As described in Section 29.3.3, the system in operation at Noosa consists of four main components:

- A permanent pump station which houses the operating systems i.e. electric pumps, generators, trash rack and hopper;
- A water intake jetty which extracts water from the Noosa River inlet;
- Two 9 metre long self-burying submarine sand shifter units;
- A 1.4 km long delivery pipeline network to transport water to the sand shifter units and the slurry to the nourished beach.

The total cost of the permanent system from inception to construction totalled ~$2.5 M. The system was designed to provide 60,000 to 80,000 m^3 of beach replenishment sand per annum, operating an average of 2 days per week. A 15 year contract was let by Sunshine Coast Regional Council (SCRC) to the sand shifter manufacturer SSM for the operation and maintenance of the system at a cost of $13,800 per month. Sand is transported for Council at a rate of $3.50 m^3 (+ electricity).

29.5 Potential Application to Byron Bay

29.5.1 Selection Criteria

In considering the most appropriate method for beach renourishment at Byron Bay, the following key selection criteria for the system were:

- The Sand Transfer System program would likely involve approximately 50,000 m^3/year, based on the littoral drift differential identified for the Byron Bay embayment in BMT WBM (2013) and PWD (1978);
- Needs to minimise any potential detrimental impacts to the environment;
- Should minimise impacts to public infrastructure, including roads;
- Should minimise disruption and impacts to public amenity and beach access;
- Should be a cost effective solution, such that it has relatively easy maintenance and low ongoing operational costs;
- Should be robust and reliable so that it will not be susceptible to malfunctions, blockages or excessive downtime due adverse weather/ocean conditions;
- Should be as autonomous as possible, reducing the requirements for human management and operator input.

29.5.2 Sand Material Collection

The most suitable onshore sand material sourcing site is towards the northern end of Tallow Beach. In this region of the NSW coast there is a strong net northward littoral drift system due to the obliquity of the net wave energy flux to the overall coastal alignment (BMT WBM, 2013). Cape Byron locally anchors the overall coastal alignment. BMT WBM (2013) found that the "best estimate" for long term recession over the past 50 years was 0.02 m/year away from the southern hook of Tallow Beach (Broken Head).

Two additional sand source locations at Tea Tree Lake to the south and Brunswick Heads to the north were considered. Brunswick Heads would be an ideal location because of the breakwater, river water intake, stable or accreting beach, and the potential to reduce sand ingress into the river, however, the relatively long distance (up to 10 km) would make pumping uneconomic. Similarly, Tea Tree Lake would involve excessive pumping distances.

Tyagarah to the north of North Beach was also considered for backpassing, however, there is no local electricity supply, limited road access and although not covered by BMT WBM (2013), the southern portion appears to be undergoing long term recession.

Due to the high use by beachgoers and surfers of Cosy Corner, sand sourcing from Tallow Beach and infrastructure would be located as far south as practicable, notwithstanding pumping distance limitations.

It is expected that from a sediment compatibility perspective, the Tallow Beach source site would be suitable as renourishment material for Byron Bay, due to the natural littoral drift pathway connecting these two consecutive embayments.

It should be noted that the exact location of rocks or bedrock is unknown and would need to be further assessed in order to gain a better understanding of potential sand volumes available for the project.

29.5.3 Water Intake

All slurry pumping methods of sand transfer rely on a supply of clean water. In the case of jet pumps, it is essential that the supply water be free of sand because of the high water velocity in the jet, which could cause abrasive damage to the mechanism. When considering systems relying on the pumping of slurry directly to the nourishment site, it is important that the water used to transport the nourishment sand meets bathing water quality standards. Slurry is typically composed of 10% to 30% sand and 70% to 90% water. As sand nourishment operations take place only during typically short periods of time throughout the year, they impose the need for relatively large volumes of water (10 to 50 ML/day) during the operation.

29.5.4 Estuary Mouth Water Intakes

Most sand transfer projects in operation in Australia rely on water intake systems installed on existing infrastructure such as a jetty or a breakwater, usually located in an estuarine environment or a sheltered embayment. The only suitable water intake estuarine site in the vicinity of the study area would be the rock training wall (breakwater) on the southern side of the Brunswick River mouth. However, as stated above, the overall distance of 10 km to the proposed nourishment site is too far for the water to be pumped economically.

Belongil Creek has (at times) low water quality and a closed entrance.

The lack of suitable estuary mouth, water intake sites for Byron Bay means that the water intake systems typically used on similar size projects such as Noosa Heads (see Section 29.4.5) cannot be replicated.

29.5.5 Ranney Well Water Intake

WRL previously examined the feasibility of sourcing salt water from the sea via underground extraction beneath dune systems. Glamore *et al* (2004) and Anderson *et al,* (2005) showed that systems relying on a combination of central caissons located within the foreshore dune complemented by small diameter horizontal lateral wells (Ranney Wells Figure 29.7) could provide salt water abstraction rates of 15 to 20 ML/day. The use of lateral collector wells has the advantage of utilising the sand layer as a natural filter providing influent water with similar chemical properties as the water at the nourishment site, minimising the risk of ecological disruption. The cross shore location of the Ranney Well would need to be optimised during detailed design, which would include groundwater modelling. It could be located landward of coastal hazard zones, but this may involve extra costs and/or groundwater impacts. The robust reinforced concrete construction means that it can withstand occasional erosion and wave impacts, in a similar manner to the stormwater infrastructure further south at Broken Head.

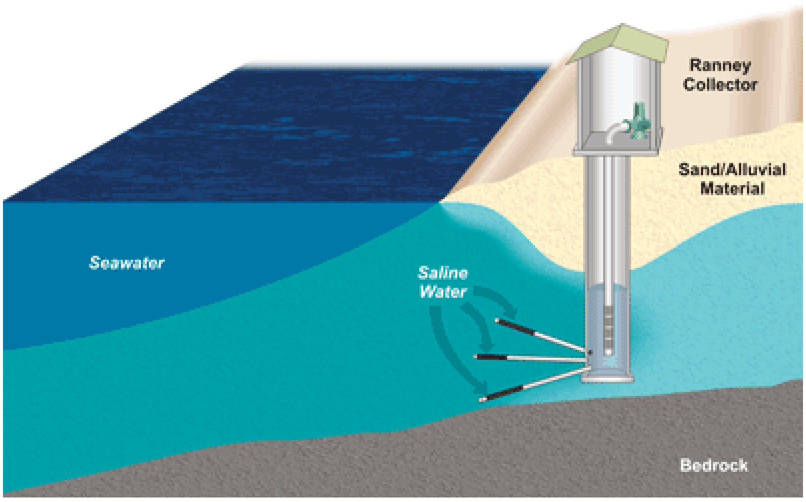


Figure 29.7: Schematic of an Horizontal Collector Well (Source: Kennedy/Jenk)

Based on the target sand transfer volume of 50,000 m^3/annum and typical water usage rates from similar sand transfer projects, the installation of two central wells on Tallow Beach, each equipped with five 80 m long lateral wells with 450 mm diameter could provide sufficient water supply for land or nearshore based pumping systems.

An alternative solution would be to install an offshore water intake pipe with an inlet in 10 to 30 m of water depth. The challenges with this approach would be the need to keep the intake above the bed, prevention of sand ingress, marine growth and biofouling, and prevention of blocking.

29.6 Assessment of Feasible Sand Transfer Solutions

29.6.1 Land based mobile operations

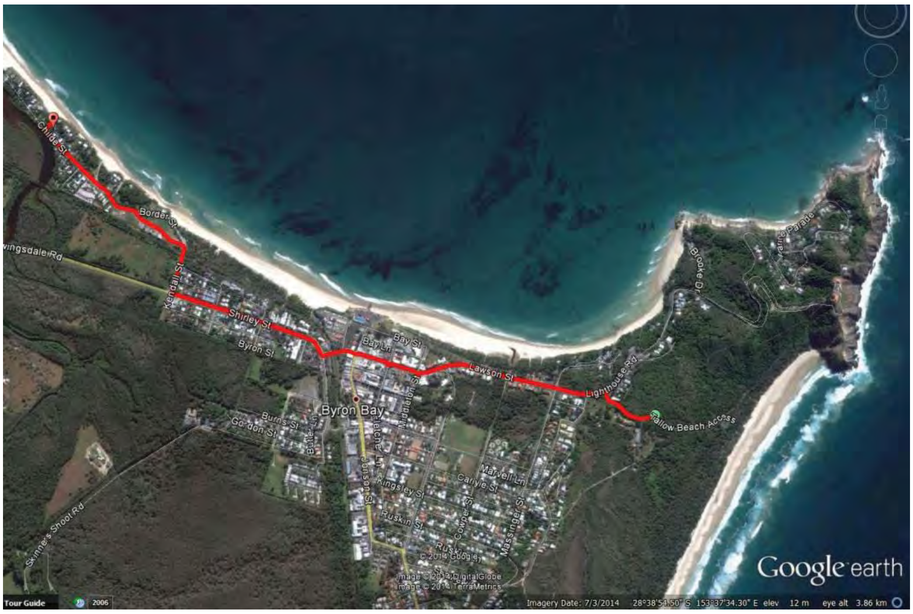


Figure 29.8: Hypothetical Haulage Route for Land Based Nourishment Technique

The basic sand transfer scheme for emergency beach nourishment operation of excavation and trucking is technically feasible for this project. Transport of sand from Tallow Beach to any potential nourishment site within the Byron Bay embayment would involve haul distances of 1 to 3 km through the town centre. The required number of individual truck trips to transport the desired volumes would exceed 6,000 per year. This is unlikely to be acceptable as a long term solution due to the physical hazard, noise levels, exhaust emissions and damage to roads.

29.6.2 Land based pumping solution

Based on the available technical information and costs from the Mandurah sand transfer project, the feasibility of a similar methodology was investigated for the project area.

The main components of this solution would include:

- 1 x Mobile Sand Collection Unit (rented from contractor);
- 2 x caissons with lateral legs for water intake;
- 200 m of Water Intake Pipe (350 mm HDPE pipe);
- 1.3 km of Slurry Pipe to Main or Clarkes Beach (350 mm HDPE pipe);
- Booster pump station;
- Storage facility; and
- Standard earth moving equipment.

Note: size of water intake and pumps is exaggerated for clarity

Figure 29.9: Schematic of a Possible Land-based Pumping System for Byron Bay

As mentioned in Section 29.5.2, the only sand material sourcing option identified is the accretion area located towards the northern end of Tallow Beach (but away from the higher use area of Cosy Corner). An advantage with using a Mobile Sand Collection Unit (MSCU) is the possibility to extend the area for sand material across a wider stretch of beach. This would allow less intensive removal of beach material as well as be adaptive to factors such as aeolian transport and the day-to day configuration of offshore sand banks.

It should be noted that both the Dawesville and Mandurah projects in WA are operated by a private contractor. As such, the unit is not purchased outright by the local authority but "rented" by the contractor. The contractor's roles include mobilising and operating the MSCU (i.e. a Slurry Track device) during the sand transfer operations, which typically last four to five months per year. This is elapsed time and includes set up and down time – operation is also not undertaken during school holidays. It is reported that up to 7,000 m^3 per week can actually be pumped during a normal working week, which would equate to approximately 7 weeks of operation to shift 50,000 m^3. The cost structure for these operations is based around fixed mobilisation/demobilisation fees and a variable sand transfer cost based on a unit cost per unit of sand material transferred.

The amenity of the beach is reduced during the operation, with visual and noise impacts, however, when the Slurry Track device is taken away from the site, all that remains visible are two exposed pipes as shown in Figure 29.10. It is possible that these pipes could be exposed or damaged during coastal erosion, but the damage would be minor and repairs could be readily undertaken. Similar pipes are used routinely for dredging operations.

Figure 29.10: MSCU Associated Pipes when not in Operation

While typical Mobile Sand Collection Units are equipped with an on-board slurry pump, such machinery relies on a supply of clear water to adjust the density of the liquid slurry to be pumped to the nourishment site. As such, in the proposed concept design, the MSCU would require connection to the two central wells on Tallow Beach, described in Section 29.5.3, using a combination of fixed pipeline (200 m for this initial design) buried in the back of Tallow Beach, to which the MSCU would be connected using flexible pipes.

At this preliminary design stage, a 1.3 km 350 mm HDPE long pipeline, following the route shown on Figure 29.9 , is proposed to transport the slurry from the collection site to Clarkes Beach, with nearly 700 m to be buried in order to minimise the visual disruption when crossing the township. This pipeline would connect at Clarkes Beach in turn to a pipeline 1 to 2 km long located along the foreshore and equipped with outlets to deliver the slurry mixture onto the beach.

Given the overall distance over which the slurry would need to be pumped, a booster station has been included in the current design. The location of this additional pumping station is proposed to be in the vicinity of the Cape Byron Marine Park works depot, on the Tallow Beach access road. This location has the advantage of having an adequate grid connection and the potential to store equipment associated with the works.

29.6.3 Nearshore based pumping solution

Based on the available technical information and costs from the Noosa Sand Shifter project, the feasibility of a similar methodology was investigated for the project area.

The main components of this solution would include:

- 2 x Sand Shifter Units;
- 2 x Caissons with Lateral Legs for water intake;
- 200 m of Water Intake Pipe (350 mm HDPE pipe);
- 1.3 km of Slurry Pipe to Clarkes Beach (350 mm HDPE pipe);
- 1 x Permanent Central Pump Station.

As mentioned in Section 29.5.2, the most viable sand material sourcing option identified is towards the northern end of Tallow Beach. An advantage with using a Sand Shifter based solution is the limited visual impact on the beach during the sand transfer operations.

Conversely, once installed at their extraction position, moving the units would be difficult. During operation, it is usual for the units to create local depressions in the sea bed approximately 15 m by 30 m in area, with the depth depending on the quantity of sand and infill rate at the time of operation. The actual strata of fluidisation is well beneath the sand surface, but the sides may be steeper than normal beach slopes, so signage is recommended. The system relies on the wave driven currents and wave action to mobilise sediment and infill the depressions. At Noosa, infill rates and production are dependent on the wave conditions and can vary from 200 m^3 to 1,000 m^3 per day of sand. It has been reported that the depressions are typically infilled every tidal cycle (CCGG, 2013).

Due to its tendency to self-bury, and given that Tallow Beach is not undergoing net recession, the main fluidisation component of the Sand Shifter is likely to remain buried after erosion events. It is possible that some pipe components could be exposed, however, these generally run cross shore and are quite robust. As stated above, subject to detailed design, the reinforced concrete Ranney Wells could be located landward of coastal erosion hazards, or could withstand occasional wave impacts if located further seaward.

Figure 29.11: Local Depression around Sand Shifter, Noosa (Source: SSM)

Note: Size of water intake and pumps is exaggerated for clarity

Figure 29.12: Schematic of a possible Sand Shifter System for Byron Bay

The central pump station required to operate the Sand Shifter units has to be located within 150 m of the units. This permanent pump station houses the operating systems, electric pumps, generators, trash rack and the hopper unit. As indicated on Figure 29.12, the best location for this pumping station would be next to the car park on the Tallow Beach access road.

Sand Shifter units rely on a supply of clear water to adjust the density of the liquid slurry to be pumped to the nourishment site. In the current design, the central pumping station would be connected to the two central wells on Tallow Beach, described in Section 29.5.3, using a combination of fixed pipeline (200 m for this initial design) buried in the back of Tallow Beach.

At this concept design stage, a 1.3 km long 350 mm HDPE long pipeline, following the route shown on Figure 29.12 is proposed to be installed to transport the slurry from the collection site to Clarkes Beach, with nearly 700 m to be buried in order to minimise the visual disruption when crossing the township. This pipeline would connect at Clarkes Beach in turn to a pipeline 1 to 2 km long located along the foreshore and equipped with outlets to deliver the slurry mixture onto the beach. Typical outlet examples are shown in Figure 29.13.

Figure 29.13: Typical Outlets – Top: Noosa (SSM); Bottom: Adelaide (DEWNR)

Given the overall distance over which the slurry would need to be pumped, a booster station has been included in the current design. The location of this additional pumping station is proposed to be in the vicinity of the Cape Byron Marine Park works depot, on the Tallow Beach access road. This location has the advantage of having an adequate grid connection and the potential to store equipment associated with the works.

Detailed design would likely aim to locate the infrastructure as far south as possible. Detailed routing of the pipes and pumps would consider land tenure, existing infrastructure, stakeholder and custodian consultation.

29.7 Cost estimates of Viable Sand Transfer Solutions

Potentially feasible sand transfer options which were considered for costing are summarised in Table 29.1. The presented options were based around the sand transfer solutions discussed in Sections 29.6.2 and 29.6.3, that is, using either a Mobile Sand Collection Unit or a Sand Shifter Unit.

The costings for each of these options also considered the possibility of renting the booster pump necessary for pumping the slurry across the distance from Tallow Beach to Clarkes Beach and along the foreshore to the nourishment outlets, as opposed to building a permanent booster pumping station. Temporary booster pumps that are usually utilised as part of dredging operations are diesel powered pumps housed in a 20 foot shipping container for easy delivery to site and with adequate muffling.

Table 29.1: Potentially Feasible Options Considered for Costing

Solution Reference	Description
MSCU-1	Mobile Sand Collection Unit and Permanent Booster Pump Station
MSCU-2	Mobile Sand Collection Unit and Temporary Booster Pump Unit
SS-1	Two Sand Shifter Units and Permanent Booster Pump Station
SS-2	Two Sand Shifter Units and Temporary Booster Pump Unit

Component costs from other projects are presented in Section 29.10, together with specific components required for Byron Bay. Summary costs are shown in Table 29.2. Cost estimates for Byron Bay have been calculated on the assumption that Council would need to outsource all elements of the works with the exception of project management. Costs do not include any initial or on-going environmental assessments, surveys, investigations or works designs.

For both MSCU solutions, costs are based on set-up and transfer of 50,000 m^3 of sand over a 4 to 6 month period. For the Sand Shifter options, actual operations would most likely involve pumping of a much smaller volume of sand on a more regular basis (weekly or fortnightly). This would minimise the extent of the ‘crater’ left behind by extraction and allow for more rapid readjustment/infilling by tides and waves.

Table 29.2: Summary of Cost Estimates for Various Methods of Undertaking Sand Transfer

Description	**MSCU-1**(1) Mobile Sand Collection Unit and Permanent Booster Pump Station	**MSCU-2**(1) Mobile Sand Collection Unit and Temporary Booster Pump Unit	**SS-1**(2) Two Sand Shifter Units and Permanent Booster Pump Station	**SS-2**(2) Two Sand Shifter Units and Temporary Booster Pump Unit
Capital Cost	$1,806,675	$1,282,675	$3,640,925	$3,116,925
Annual Recurrent Cost	$597,292	$802,292	$370,600	$575,600
Total over 5 years	$4,793,135	$5,294,135	$5,493,925	$5,994,925
Total over 10 years	$7,779,594	$9,305,594	$7,346,925	$8,872,925
Total over 20 years	$13,752,514	$17,328,514	$11,052,925	$14,628,925

Notes:

(1) Overall costs for MSCU solutions can be reduced if the excavation, loading and spreading of sand using standard earthmoving equipment is undertaken by Council staff as in-kind contribution.

(2) In addition to logistical or functional constraints on suitability, the costs adopted for the Sand Shifter assume no on-going need for recovery and maintenance of the unit due to blockage or damage to equipment. Should recovery of subaqueous equipment be required on a regular basis, these costs would be substantially higher.

Overall, it was found the costs for various options did not vary significantly when amortised over 5 years. The annual recurrent costs for all four options (2014 dollars) did however vary significantly, from $370,000/year for SS-1 to over $802,000/year for MSCU-2. A Mobile Sand Collection Unit MSCU-1 solution using a permanent booster pump station would be the cheapest option when amortised over 5 years.

When amortised over 10 years or more, the options using rented booster pump units become less cost competitive. When amortised over 10 years, the overall cost for MSCU-1 and SS-1 solutions end up very similar. When amortised over 20 years, the Sand Shifter based solution, using a permanent booster pump station is the cheapest solution, but it should be noted that a cost escalation could occur if the equipment was required to be recovered regularly. If maintenance was kept to a similar level as the Noosa project, this solution has the lowest annual operational cost at $370,000/year.

The current costing for MSCU based solution, based on recent information provided by the City of Mandurah, could be reduced if Council was to take part of the associated costs such as earth moving operations and beach security.

While the MSCU-1 solution is slightly more expensive that the SS-1 solution at the 10 and 20 years costing periods, it should be noted that the MSCU solution has the advantage of a contractor managing a higher proportion of the risk (subject to the final contractual arrangements).

29.8 Amenity and Ecological Considerations

The sand shifter technology offers less disturbance to beach amenity and less ecological perturbation, since the sand collection unit is buried, there is no need for ongoing earth moving equipment, and most infrastructure is located off the active beach.

29.9 Impacts on Nearby Beaches

29.9.1 Littoral Drift on Tallow Beach

It is well established that net littoral drift due to waves is northward in the Byron Bay area. Based on Patterson (2010), BMT WBM (2013) estimated the following sand transport rates:

- Northward net littoral drift from Tallow Beach: ~400,000 to 450,000 m^3/year;
- Southward loss from East Australian Current off Cape Byron: ~50,000 m^3/year;
- Net littoral Drift from the Pass to Belongil: ~200,000 m^3/year; and
- Cross embayment transport between Cape Byron and Belongil: ~200,000 m^3/year.

The magnitude of cross embayment transport and net littoral drift estimated by BMT WBM is considerably larger than estimated by PWD (1978).

The proposed sand transfer rate of 50,000 m^3/year is to rebalance the estimated sand deficit from the Byron Bay embayment, which is believed to be a result of loss from the East Australian Current. The proposed transfer rate is approximately 10 to 12% of the estimated northward littoral drift.

29.9.2 Bypassing of Sand Transfer Plants

Acworth (2011) noted that for Letitia Spit near the Tweed River mouth: "Modelling indicates that approximately 80% of the longshore sand transport typically occurs in shallow waters of up to 4 m depth, with less than 5% in deeper waters of 8 – 15 m".

Acworth noted that the Tweed River Sand Bypass Plant, designed to intercept approximately 500,000 m^3/year of sand, was bypassed by about 20 to 40% of the annual littoral drift volume.

29.9.3 Natural Bypassing of Cape Byron

Gordon (2011) provided the following description of coastal processes and bypassing at Cape Byron.

"Cape Byron is a rocky outcrop located more than 2 km to the east of its associated rocky hinterland ({GE} 28° 38' 20" S, 153° 38' 10" E). The broad coastal plain connecting the Cape to the hinterland, and thereby making it a headland, is the legacy of many thousands of years of accumulation of marine and terrestrial sediments. As the easternmost cape on the Australian coastline it clearly performs a role as an anchor for the shape of the east coast shoreline.

The net northerly longshore drift of sand along Tallow Beach delivers sand to Cosy Corner immediately to the south of the Cape Byron promontory. Here sand accumulates in the nearshore and offshore zone awaiting conditions favourable for its transport out, around and along, the 1 km long rocky cliff. Once reaching the north eastern tip of the Cape the sand can then theoretically spill northward around the headland and into the Byron Bay coastal compartment. Being the easternmost point of the coastline however the Cape extends sufficiently seaward to be affected by the on-shelf component of the East Australia Current (EAC), which is variable in strength but nearly always heads in a southerly direction off the Cape. As the north eastern tip is the most easterly point of the Cape, it is where the shelf current collides with the northward moving, wave induced littoral drift. Depending on the relative strengths of these two opposing currents at any particular time the sand either rounds the Cape or is stripped offshore in a south easterly direction; often in the large (approximately 200 m dia.) eddy formations shed off the northeast tip of the Cape. These eddies, which can readily be observed when in operation have sufficient angular velocity to maintain the sand in suspension *and carry it well offshore, out of range of the coastal littoral drift system. The sand is eventually deposited in a south east trending lobe which, over the Holocene has been progressively growing and now extends more than 5 km south and is up to 40 m thick [4].*

The situation at Cape Byron is further complicated by the water depths directly off the 1 km long, near vertical, face of the Cape. The seabed slopes steeply out so that relatively close to the Cape the water depth is 50 m. However the depth to the seabed at face of the Cape is dependent on the immediate prior history of wave action. When extreme events such as the cyclones experienced in the late 1960s and early 1970s occur the reflected wave action strips sand from the underwater profile near the cliff face and deposits it offshore onto the lobe region where it is then re-distributed southward by the EAC driven shelf current [4]. This means that a northward rebuilding of the subaqueous sediment profile needs to occur from the Tallow Beach supply before full by-passing can be re-established. Depending on the severity of the storm(s) this may take months or even years; a moderately heavy storm lowering the seabed by 3 m means a delay of the order of 12 months before full by-passing can be again achieved. Hence the sediment budget of the Byron Bay embayment can be subjected to a short to medium term deficit of sand. This in turn can produce apparently difficult to explain episodes of beach erosion and beach fluctuations, even under mild wave conditions.

In summary, the combination of both the intermittent interference of the southbound shelf current generated by the EAC and the stripping of sand from the subaqueous profile immediately off the face of the Cape, from time to time, impacts on the actual by-passing performance of the headland. This occurs regardless of the fact that the apparent littoral drift, as determined by considerations of wave energy flux and the apparently adequate supply of sand to the south might suggest otherwise."

29.9.4 Implications for Sand Transfer Plant

Natural sand bypassing of Cape Byron is complex and episodic, with natural processes operating at far larger scales than a proposed sand transfer plant. Removal of 50,000 m^3/year from Tallow Beach, if undertaken well to the south of Cosy Corner will still result in substantial littoral drift supply to Cosy Corner and bypassing of the Cape.

However, it is unclear whether the removal of 50,000 m^3/year via the sand transfer system would cause any change to the supply to Wategos. Detecting this would be complicated by the natural noise and variability of the system. Detailed modelling and/or sand tracer studies would be needed to comprehensively resolve this. A monitored trial bypassing episode using trucks may also provide greater certainty.

29.10 Sand Transfer Cost Details

Table 29.3: Indicative Costs for Sand Shifter Noosa (Source: SCRC)

Activity	Estimated Cost
Capital Costs	
Detailed Design	$119,500
Construction	$1,910,000
Survey	$5,000
Legal	$15,000
Geotechnical	$8,000
Project Management	$20,000
Regulatory Permits	$10,000
Coastal Engineering Advice	$8,000
Inspector Costs	$30,000
TOTAL (excluding GST)	$2,125,500
Operational Costs	
Shifting 40,000 m^3/annum	$305,600

Table 29.4: Indicative Costs for Mandurah Sand Bypassing (Source: City of Mandurah)

Activity	Estimated Cost
Capital Costs	
Mobilisation	$47,500
Insurances	$4,000
Calibration	$5,200
Legal	$15,000
Geotechnical	$8,000
Security	$10,500
Reporting	$6,500
Coastal Engineering Advice / Project Management	$44,000
Environmental Engineering Advice	$8,700
De-Mobilisation	$41,500
TOTAL (excluding GST)	$190,900
Operational Costs	
Bypassing 136,500 m^3/campaign	$932,000

Table 29.5: Input Costs for Specific Components of Byron Bay Sand Transfer

Activity	Estimated Cost
Water Pipeline (700 m) Material + Install	$25,000
2 x Caisson Wells	$150,000
Booster Pump	$125,000
Sand Pipeline	$100,000
Storage Facility	$20,000
Booster Pump Usage Power + Maintenance ($1/m^3)	$50,000/year

30. Appendix L: BMT WBM (2013) Erosion/Recession Hazard Maps

BMT WBM (2013) Figure A-4: Erosion Hazard Zones – Scenario 1 & Scenario 2: Byron Bay – Main / Clarkes Beach

BMT WBM (2013) Figure A-5: Erosion Hazard Zones – Scenario 1 (Belongil Spit seawalls retained) Belongil Spit

BMT WBM (2013) Figure A-6: Erosion Hazard Zones – Scenario 1 (Belongil Spit seawalls retained) Belongil Spit and Byron North Shore

BMT WBM (2013) Figure A-7: Erosion Hazard Zones – Scenario 2 (Belongil Spit seawalls removed) Belongil Spit

BMT WBM (2013) Figure A-8: Erosion Hazard Zones – Scenario 2 (Belongil Spit seawalls removed) Belongil Spit and Byron North Shore

31. Appendix M: Consultation Program (by Umwelt)

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BYRON BAY EMBAYMENT COASTAL HAZARD MANAGEMENT STUDY: STAKEHOLDER ENGAGEMENT

FINAL DRAFT

October 2014

BYRON BAY EMBAYMENT COASTAL HAZARD MANAGEMENT STUDY: STAKEHOLDER ENGAGEMENT

FINAL DRAFT

October 2014

Prepared by
Umwelt (Australia) Pty Limited

on behalf of
Byron Shire Council

Project Director:	**Pam Dean-Jones**
Project Manager:	**Andy Godwin**
Report No.	**3299/R01/V2**
Date:	**October 2014**

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TABLE OF CONTENTS

FIGURES

APPENDICES

1.0 Introduction

The Minister for the Environment has directed Byron Shire Council to prepare and submit a coastal zone management plan (CZMP) for the Byron Bay Embayment by 31 December 2014. The CZMP must provide information and follow processes that are consistent with the NSW Guidelines for Preparing Coastal Zone Management Plans 2013 (the NSW Guidelines) (available on the Office of Environment and Heritage website).

To inform the preparation of the CZMP, Council commissioned WRL and Umwelt to prepare a coastal hazard management study, providing analysis and information of potential measures to manage coastal hazards. The management study included consultation with community and stakeholders about the issues and options.

This report describes:

- The objectives of consultation in the current project;
- The opportunities for stakeholders and community members to contribute to the preparation of the Coastal Hazard Management Study for the Byron Bay Embayment;
- The scope of comments, suggestions and feedback provided by stakeholders and community; and
- How stakeholder and community input to date has been used in evaluating potential management responses for coastal hazards affecting the Byron Bay embayment now and in the future. In particular, the report outlines how community input has informed evaluation of the 'reasonableness' of coastal management options.

Byron Shire Council (BSC) will conduct further consultation when developing the CZMP.

1.1 Requirements for Stakeholder and Community Engagement

A prescribed minimum requirement established in the NSW Guidelines is that the CZMP must contain:

- A description of how the relevant coastal principles have been considered;
- The community and stakeholder consultation process, the key issues raised and how they have been considered; and
- How the proposed management options were identified, the process followed to evaluate the options and the outcomes of the process.

Further, the minimum requirements set out in the NSW Guidelines include:

> CZMPs are to achieve a reasonable balance between any potentially conflicting uses of the coastal zone. CZMPs must be prepared using a process that includes:
>
> - Evaluating potential management options by considering social, economic and environmental factors to identify realistic and affordable options
> - Consulting with the local community and other relevant stakeholders. The minimum requirement is a 21 day exhibition period
> - Considering all submissions made during the consultation period

In this project, consistent with Section 2.2 of the NSW Guidelines, Council has implemented a community and stakeholder engagement process which exceeds the minimum requirements of the NSW Guidelines.

1.2 Guideline Specification for Option Evaluation

The Guidelines require that in evaluating potential coastal hazard management options, a multi stage process is required.

- **Feasibility assessment** (whether they are technically feasible and physically possible to safely implement and maintain).
- **Reasonableness assessment**.
- **More detailed cost benefit analysis of defined options**

Reasonableness is further defined as taking into consideration:

- The Coastal Management Principles (see **Section 1.4** and also further discussion of the community's understanding and interpretation of these principles, in **Appendix 1**);
- The social, environmental and economic impacts of the option, including its benefits and costs and any impacts on the cultural values of the local area; and
- The views of the community and other stakeholders. Where there are differences or conflicting views, the CZMP should seek to achieve a balanced approach.

Cost and benefit analysis (introduced in dot point 2 above) is a major task in itself. For this project, the reasonableness assessment has considered the community's views in relation to conceptual coastal hazard management options (rather than detailed designs and costing). The consultation explored community views about the conceptual options in terms of social, environmental and cultural factors and in general terms relating to benefits and costs.

The third stage of option evaluation is a more detailed benefit and cost analysis of the options that are considered to be feasible and reasonable in this location.

Figure 1.1 shows how the three stages of option evaluation contribute to the preferred management responses to be included in the draft CZMP.

Further consultation is needed to provide opportunities for the community and stakeholders for consider and comment on proposed coastal risk management options, when more detailed design and cost/benefit analysis have been completed.

In accordance with the NSW Guidelines, the preferred options or specific details may be varied as new information becomes available during the planning process, including after consideration of community and stakeholder submissions made in response to the exhibition of the draft CZMP.

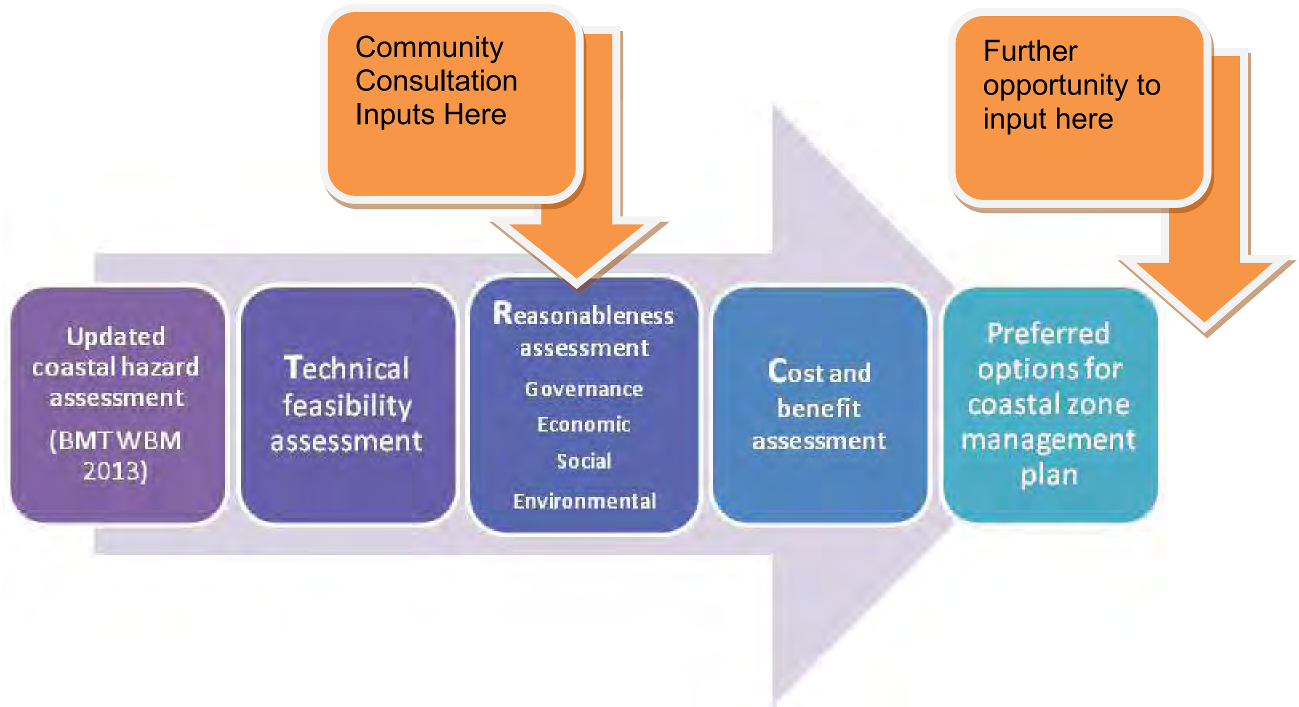


Figure 1.1 – Option Evaluation Process

1.2.1 Specific Criteria for Feasibility and Reasonableness

Table 1.1 summarises the components of feasible and reasonable stages of option evaluation. Further discussion of community perceptions of aspects of reasonableness is in **Appendix 1**.

Table 1.1 – Combined Criteria for Feasible and Reasonable Coastal Hazard Management Options

Feasible	Reasonable
• Quality engineering practice; • Evidence that the proposal can mitigate the coastal hazards and risks identified in the Coastal Hazard Study prepared by BMT WBM 2013; • Adaptable and practical to enhance or reduce the scale of the response; • The option is appropriate for more than one coastal hazard; and • Can be integrated with other management responses (as most risks will best be managed by a combination of responses).	• Consistent with the NSW Coastal Management Principles, Coastal Protection Act and NSW Coastal Policy; • Consider social, environmental and economic impacts, benefits and costs; • Consider the views of the community and other stakeholders; and • Achieve a balanced approach in the context of potential environmental, social and economic costs, impacts and benefits.

1.3 Objectives of Consultation

In the context of the Guidelines, the overall **aims** of community and stakeholder engagement conducted during this project were to:

- satisfy statutory requirements in the NSW Guidelines for Preparing Coastal Zone Management Plans (which also refer to the consistency with the objects of the *Coastal Protection Act 1979* and the NSW Coastal Policy 1997);
- document community perspectives relevant to understanding the reasonableness of potential coastal hazard management responses for the Byron Bay Embayment;
- inform Council's decision making process as it prepares the required CZMP; and
- contribute to a robust and transparent process for evaluating potential coastal hazard management responses.

BSC will conduct further community consultation as it prepares the CZMP.

The specific objective of the current consultation process was to:

- Share information, values and ideas that are relevant to appropriate, effective and efficient management of coastal hazard risks that affect the Byron bay Embayment, by:
  - Providing information about the technical evaluation of hazards, the timing over which that hazard will affect assets and options that could be applied to reduce risks, including an expert engineering evaluation of the technical feasibility of these potential management responses.
  - Providing information about the current statutory requirements – what is Council required to do and to take into account in making a decision about the way forward in managing coastal hazards risks in the Byron Bay Embayment.
  - Obtaining community input on the 'reasonableness' assessment – fleshing out the criteria listed in the NSW Guidelines for Preparing Coastal Zone Management Plans, so that there is a shared understanding of how the criteria would be applied in the local context – what information is relevant; what factors contribute to social, cultural and economic considerations in this embayment.
  - Documenting community and other stakeholder discussion about the reasonableness of the various feasible management responses, and how impacts could be managed to achieve reasonable solutions for the whole community (and the environment).

1.4 Principles, Legislation and Policies

As noted in **Section 1.1** and **Section 1.2**, the NSW Guidelines require that a CZMP is consistent with the Coastal Management Principles set out in the Guidelines. These Principles also require that the CZMP is consistent with the objects of the *NSW Coastal Protection Act 1979*. Uses of the coast are to be considered in accordance with the NSW Coastal Policy. These objects, Principles and policies are summarised in **Tables 1.2** and **1.3**.

The Objects and Principles highlight:

- the coast as a changing landscape;

- the importance of using scientific and community knowledge (and value) and updating regularly, to adapt to change;
- the right of safe public access to the coast;
- protection of natural coastal systems and values such as ecology and biodiversity;
- application of cost effective and affordable solutions (short and long term) to manage risk; and
- efficient planning and delivery, including strong cross sectoral alignment.

Table 1.2 – Objects of the *NSW Coastal Protection Act 1979*

Theme	Object
Protect enhance, maintain and restore biodiversity	To protect, maintain and restore the environment of the coastal region and its associated ecosystems, ecological processes, biological diversity and water.
Secure and orderly use of resources	To encourage, promote and secure the orderly and balanced utilisation and conservation of the coastal region and its natural and man-made resources, having regard to the principles of ecologically sustainable development.
Account for social and economic benefits	To recognise and foster the significant social and economic benefits to the State that result from a sustainable coastal environment, including: • benefits to the environment; • benefits to culture and heritage; • benefits to Aboriginal people in relation to their spiritual, social, customary and economic use of land and water; and • benefits to urban communities, fisheries, industry and recreation.
Public access, on foot	To promote public pedestrian access to the coastal region and recognise the public's right to access.
Appropriate land tenure	To provide for the acquisition of land in the coastal region to promote the protection, enhancement, maintenance and restoration of the environment of the coastal region.
Involve community	To recognise the role of the community as a partner with government, in resolving issues relating to the coastal environment.
Policy and program alignment across agencies	To ensure co-ordination of the policies and activities of the government and public authorities relating to the coastal region and facilitate the proper integration of their management activities.
Prepare for climate change	To encourage and promote plans and strategies for adaptation in response to coastal climate change impacts, including projected sea level rise.
Beach amenity	To promote beach amenity.

Table 1.3 – Coastal Zone Management Principles from the NSW Guidelines for Preparing Coastal Zone Management Plans (2013)

Principle	Details
Principle 1 Compliance	Consider the objects of the *Coastal Protection Act 1979* and relevant NSW government policies.
Principle 2 Plan alignment	Optimise links between plans relating to the management of the coastal zone.
Principle 3 Involve community	Involve the community in decision making and make coastal information publicly available.
Principle 4 Use best knowledge	Base decisions on the best available information and reasonable practice. Acknowledge relationships between catchment, estuary and open coast.
Principle 5 Long term, public benefit	The priority for public expenditure is public benefit; it should achieve cost effective, practical, long term outcomes.
Principle 6 Risk focus	Adopt a risk management approach to managing risks to public safety and assets; use a risk management hierarchy and adopt interim risk reduction measures.
Principle 7 Adaptive planning	Adopt an adaptive risk management approach if risks are expected to increase over time, or to accommodate uncertainty.
Principle 8 Protect ecological value	Maintain the value of high value coastal ecosystems.
Principle 9 Protect public access	Maintain and improve safe public access to beaches and headlands, consistent with the NSW Coastal Policy.
Principle 10 Support recreational use	Support recreational activities consistent with the NSW Coastal Policy.

The NSW Coastal Policy 1997 establishes four major themes as the framework for an ecologically sustainable coast. The Policy lists nine goals related to these themes. Themes and goals are summarised in **Table 1.4**.

Table 1.4 – NSW Coastal Policy Themes and Goals

Themes	Goals
Conservation of biological diversity and ecological integrity, for productive, stable and resilient coastal ecosystems	Protect, rehabilitate and improve natural environment Recognise and accommodate natural processes
Intergenerational equity (environmental and social)	Protect and conserve cultural heritage Provide for ecologically sustainable development and use
Improved valuation, pricing and incentive mechanisms, incorporating environmental factors into decision making processes	Protect and enhance aesthetic qualities Provide for ecologically sustainable settlement Provide for appropriate public access and use Provide information for effective management Integrated planning and management
The Precautionary Principle, or a risk averse approach to prevention of environmental degradation	

1.4.1 Good Faith Requirements

Section 733 of the *Local Government Act 1993* deals with exemptions from liability for Councils providing advice and making decisions in relation to land in the coastal zone. Councils do not incur liability if they have acted 'in good faith'. The Act defines 'good faith' as:

> 'if the thing was done or omitted to be done, substantially in accordance with the principles contained in the relevant manual most recently notified under subsection (5) at that time'

Subsection 5 states that for the coast, this means a manual relating to the management of the coastline.

Some submissions made in relation to the current coastal zone planning process have suggested that to be seen to be acting in good faith, Byron Shire Council should refer to the NSW Coastal Hazard Policy 1988 and the NSW Coastline Management Manual 1990. Whilst these documents provided good advice on coastal management and were the basis of coastal zone management in NSW for many years, they are no longer the 'manual' relevant to Section 733 of the *Local Government Act 1993*. They have been repealed and the relevant reference is now the NSW Guidelines for Preparing Coastal Zone Management Plans.

To demonstrate good faith, Councils must now demonstrate that their CZMP and coastal zone management decisions give effect to the Principles set out in the NSW Guidelines (reproduced above in **Table 1.3**) and to other matters set out in the NSW Guidelines, such as the evaluation of feasible and reasonable management solutions for complex coastal management problems. Principle 1 refers to 'relevant NSW policies'.

1.5 Approach to Consultation

In accordance with the NSW Guidelines, this project provides diverse opportunities for community members to contribute to the evaluation of reasonableness for potential management options for coastal risks affecting the Byron Bay Embayment. It builds on previous consultation about the value of the coastal environment and potential management responses (see **Section 1.5**).

The four key elements of consultation were:

- on line survey (also available from Council in hard copy, to assist people who do not have internet access) – scoping community use and values of the beaches in the Byron Bay Embayment. The survey provides simple measures of community attitudes and values but its main value is in qualitative information about defining 'end points' of what is likely to be reasonable in this community;
- stakeholder workshop;
- written submissions about the individual's preferred approach and reasons; and
- a workshop with Councillors and Council staff (note two further workshops/briefings for Councillors were conducted about other aspects of the management study).

Note that Council will extend further consultation opportunities to the broader Byron Bay Shire Community during the preparation of the CZMP. As a minimum the draft CZMP will be exhibited for further feedback on the proposed approach and priority management responses.

These four steps in consultation for the management study are summarised in **Figure 1.2** and an overview of participation to date is provided in **Table 1.5**. The responses obtained during consultation about the current project are considered within the broader context provided by previous Council strategic planning programs and other project specific consultation.

Details about the scope, method and response to each of these elements of the consultation program are provided in **Sections 2.0**, **3.0** and **4.0**.

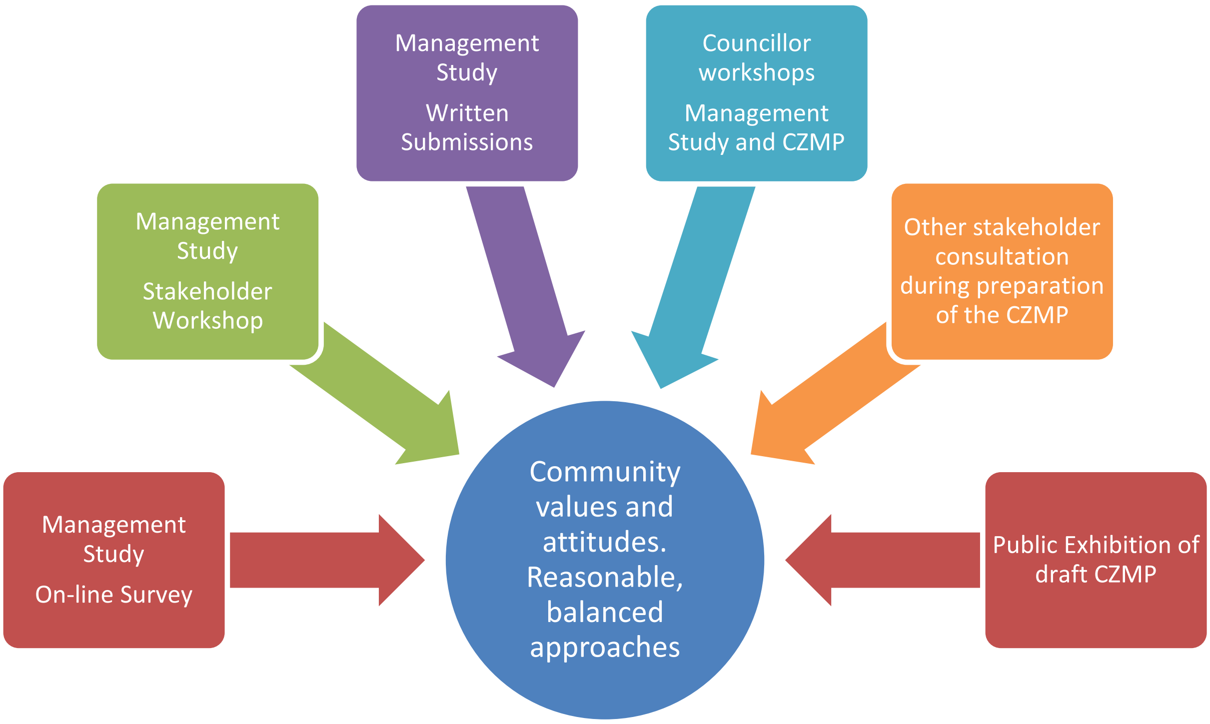


Figure 1.2 – Steps in Community and Stakeholder Engagement about Reasonable Options

Table 1.5 – Overview of Consultation Opportunities and Participation

Activity	Target Stakeholders	Participation	Intent and Timing	Section Discussed
On line Survey	All Byron residents, visitors and other interested parties	140 completed surveys	Report Values Usage Duration – mid January to 13 February 2013	**Section 2.0**

Activity	Target Stakeholders	Participation	Intent and Timing	Section Discussed
Stakeholder Workshop	Representatives of diverse interests in the BBE, including residents, coastal user groups (surf club), Aboriginal people, Councillors, environmental groups, including Landcare/Dunecare and others who have previously been active in the debate.	40	Share information Discuss and negotiate reasonableness factors and evaluation 18 February 2014	**Section 3.0**
Written Submissions	Open to anyone, but stressed as an option for those attending the workshop, to provide further comments or detail about issues of importance to them.	22	Provide detailed comments or suggestions Closed 28 February 2014	**Section 4.0**
Public Exhibition and other activities during the preparation of the CZMP	Open to everyone	tbc	Review strategy and priorities	
Government Agencies	Invited to attend the workshop; consulted regularly by Council, including: OEH Marine Parks Authority Crown Lands	Council sought initial formal advice from state agencies about their requirements by 28 February 2014.	Further consultation about the draft CZMP	In draft CZMP

1.6 Consultation Context

The permanent population of Byron Shire is approximately 29,000 people. This is increased by approximately 22% by overnight visitors (Byron Shire Community Strategic Plan 2012). The people of Byron Shire live in multiple small villages and local communities, but about 20% live in the main coastal centre, Byron Bay, which also attracts the largest number of visitors.

Tourism is the principal economic driver in the Shire (BSC Community Profile 2006), with 1.3 million visitors in 2006, contributing an estimated economic value of $370 million and tourist spending in 2009 estimated at $411 million. In this context, the coastal landscape of the Byron Bay Embayment is valued by the local community and also by people from other parts of NSW and Australia.

Byron Shire Council places a high value on providing opportunities for its residents and ratepayers to take an active role in discussion about the future of the Shire so that Council makes decisions that are well informed by community views and preferences.

Several previous projects have sought community and stakeholder input on both the broad strategic direction and principles to be applied by Council and also on specific coastline management issues and management. Consultation with the community about aspects of the coast extends back over more than 20 years.

In combination, these previous programs and projects have demonstrated important community uses, values and benefits associated with the Byron Shire coastline and specifically about the Byron Bay Embayment.

This section provides background to the consultation activities that were part of the current project, by briefly reviewing the outcomes of Council's most recent Community Strategic Plan consultation and the outcomes of consultation conducted for a Coastal Values Study (2000) and the draft Coastline Management Plan (2010).

1.6.1 Overarching Strategic Direction for Byron Shire – The Community Strategic Plan 2012-2022

The Byron Shire Community Strategic Plan (CSP) sets out Council's vision, strategic priority issues and directions and broad measures to meet community and Council objectives over the next ten years.

An appreciation of the strategic direction that Council and its community have identified for the next ten years is important in addressing the alignment objective of the *Coastal Protection Act 1979* and Coastal Principles 2 and 3 from the NSW Guideline (community involvement and alignment of plans, see **Table 1.3** in **Section 1.4**).

Another important benefit of checking the themes and values set out in the CSP is that they provide a benchmark against which the results of consultation for the Coastal Hazard Management Study can be compared. The survey and workshop for the current project (see **Sections 2.0** and **3.0**) involved a smaller sample of people with an interest in the future of the Byron Bay Embayment coastline, but the values and themes emerging in the discussion are consistent with those identified in the consultation for the CSP.

The Community Strategic Plan 2012-2022 was prepared after wide consultation with the residents of Byron Shire and reflects the views of the community about where Council should focus its attention and what it should seek to achieve in its management. Coastal Management is a specific topic addressed in the Community Strategic Plan.

This section notes key aspects of the CSP which can assist in evaluating the extent to which potential coastal management options are consistent with the strategic goals of Council and community.

The Vision for Byron Shire for the period 2012 to 2022 is:

> Culturally rich and thriving communities living in harmony, responding positively to the challenges of our world, and leading by example.

Social Justice

The Community Strategic Plan (CSP) is underpinned by four social justice principles:

- **Equity** – There is fairness in decision making and prioritising and allocation of resources.
- **Access** – All people have fair access to services, resources and opportunities to meet their basic needs and improve their quality of life.

- **Participation** – Everyone has the maximum opportunity to genuinely participate in decisions which affect their lives.

- **Rights** – Everyone's rights are recognised and promoted.

Equity and fairness were both identified by the stakeholders who participated in the workshop component of this project as important social and governance criteria to apply when evaluating coastal hazard management options. In the survey, workshop and written submissions, there were clear statements about the importance of participation opportunities and the rights and responsibilities of both landholders and beach users (see **Section 6.2** for more information). Strong views have also been expressed throughout the current project about the importance of beach access as an aspect of the quality of life of people who live in Byron Bay.

The CSP has five key themes including:

- **Society and culture** – Resilient, creative and active communities with a strong sense of local identity and place.

- **Environment** – Our natural and built environment is improved for each generation.

- **Community Infrastructure** – Services and infrastructure that sustain, connect and integrate our communities and environment.

These themes resonate with the comments made in the survey, workshop and written submissions for the current project. All stakeholders expressed a strong attachment to place; they supported the concept of intergenerational equity in environmental quality, although they had different perspective on how this could best be achieved; they recognised the importance of choosing management approaches that could connect and unite the community, rather than divide it.

1.6.1.1 Specific Environmental Matters, Concerns and Values

Table 1.6 highlights the environmental issues nominated in the CSP. Several of these have direct relevance to deliberations about reasonable coastal zone management options for the BBE. Similar perspectives on coastal management are reflected in free comments in the survey, in discussion at the workshop and in written submissions.

Table 1.6 – The Coast and Byron Shire Community Strategic Plan

Issue	Directly Relevant to Managing the Byron Bay Embayment Coastline?
Environment/biodiversity needs greater emphasis.	As this relates to coastal (beach, dune and marine) ecological communities.
Demonstrate environmental and climate change leadership by supporting local, state and national research into coastal community regeneration and protection of natural resources.	As above
Respect the beauty of the forest, beaches, and rural areas and proactively champion a 'no pollution' culture and healthy environment.	Directly related to priority of naturalness on the coast.
Insufficient affordable public transport options (look at rail, light rail or smaller buses). Support innovative practices in eco-friendly transport services for a low carbon future with low reliance on oil.	No

Issue	Directly Relevant to Managing the Byron Bay Embayment Coastline?
High priority placed by the local business community on environmental and sustainable initiatives.	No
Protect the fauna and flora of the coast through community services so that dunes and beaches are maintained in their pristine fashion. Protect the natural environment against change.	Consistent with responses to survey that direct community involvement in coastal stewardship, through Landcare/Dunecare is important.
Identify and target a sustainable population that is consistent with the community values.	No
Prevent state intervention in local planning decisions	To the extent that Council wants to make a decision that suits its local community. Note the role of the Coastal Panel in any decision about coastal management.
The impacts of the global challenges (e.g. climate change, depletion of resources, financial crisis etc).	Indirectly climate change in terms of sea level rise and other potential changes such as cyclone tracks, rainfall, etc.
Improve long term planning	Coastal planning decision must deal with long term – the next generation; not just the people who are here now.
Sustainable development in the built environment. a) Balance between increased affordable housing and sustainable development where the coastline is managed and maintained for its current beauty. b) Minimise over-development of sub-divisions in rural areas. c) No avenue for next generation to settle in this Shire due to lack of available land and increasing land prices.	As above – high value placed on aesthetic value of the coast – linked to judgements of built coastal protection structures.

From these issues, Council identified four key strategies to be implemented over the next decade. Two of these (EN1.3 and EN1.4) relate directly to coastal management.

- **EN1.3** Manage coastal processes, hazards and development so that the diversity, amenity and accessibility of the Shire's coastline is maintained.
- **EN1.4** Protect and enhance the health of the Shire's catchments, waterways and estuaries.

Of eight measures linked to these strategies, four are directly relevant to choices about the management of the coast generally and can be linked specifically to parts of the Byron Bay Embayment coastline:

- Maintain or increase the area of **robust and resilient dune systems** along the coast.
- Maintain or increase the **ecological health of dune vegetation and other coastal vegetation communities**.
- Maintain or **improve formal beach access**, decrease informal beach access.
- **Support Landcare and Dunecare** groups.

1.6.2 Coastal Values Study and 2010 Coastline Management Plan

A coastal values study for the whole of the Byron Shire coastline was completed for the Council in 2000. It was based on evidence published in the 1990s and 1980s so is now somewhat dated. It noted that at the time very little information was available to qualify and quantify many of the coastal values, particularly at the scale of individual embayments, so some description is quite generic.

The values study considered six main classes of coastal value in the community. The current project does not include a detailed update of value documentation and qualification, but has sought to confirm which coastal values remain of greatest importance to the community and are critical to understanding reasonable management options for coastal hazards and risks.

More recently, community consultation during the preparation of the draft Coastline Management Plan in 2010 included discussion about what people valued about the coast and why.

Information from both the 2000 study and 2010 consultation is included in **Table 1.7** as well as anlaysis by Umwelt concerning the relevance of this information to the preparation of the current CZMP.

Taking into account the community input, the 2010 draft CZMP presented the following objectives for managing the whole coastline of Byron Shire Council.

Coastal Zone Management Objectives – draft CZMP for Byron Shire Coastline 2010

- To protect, rehabilitate and improve the natural environment of the coastal zone.
- To recognise and accommodate the natural processes of the coastal zone.
- To protect and enhance the aesthetic qualities of the coastal zone.
- To protect and conserve the cultural heritage of the coastal zone.
- To provide for ecologically sustainable development and use of resources.
- To provide for ecologically sustainable human settlement in coastal zones.
- To provide appropriate public access and use of the foreshore areas.
- To provide information to enable effective management of the coastal zone.
- To provide for integrated planning and management of the coastal zone.

Table 1.7 – Previous Documentation of the Value of the Coastline

Value Class	Included in Discussion (Values Study, 2000)	Observations on the quality and relevance of the 2000 data for the 2014 analysis	Comments on coastal values from 2010 consultation in association with the(draft CZMP, 2010
Ecological values	• Intertidal habitats. • Terrestrial flora and fauna. • Ecological significance and management status.	Significant changes to state and national listings of threatened species and ecological communities since 2000.	Naturally vegetated dunes, no weeds.
Social, cultural and heritage values	• Aboriginal cultural heritage (archaeological sites and Aboriginal places). Limited discussion of cultural landscape values. • European cultural heritage – Cape Byron Light house and multiple shipwrecks. • Recent history and contemporary values.	Notes the loss of much of the physical evidence of Aboriginal occupation and attachment because of the sand mining history and intensive development of the Byron Bay Embayment. No detailed audit of actual sites had been conducted at that time, but strict conservation of remaining sites and places in the embayment recommended. Heads of Agreement between Byron Shire Council and Arakwal People seen as key to future management.	Beach amenity - a joyful place, not overcrowded. The coastal landscape and water loving people – makes us 'idiosyncratically coastal'. Bunjalung and Arakwal culture, as well as European heritage places – helps define the local community.
Landscape values	• Primarily visual, with other elements contributing to visual quality. • Byron Bay identified as 'an outstanding example of a zeta form bay' by the Cape Byron Trust.	Determined on distinctive landforms, naturalness, protection and visual accessibility/sensitivity. Generally at whole of shire scale (including the hinterland), not specifically about the Byron Bay Embayment. Limited data available at the time.	The natural appearance of Cape Byron area and the landscape context of Byron Bay (hinterland). Connection to the marine environment; natural topography. Great surf and clean ocean, clean sand provide a wonderful place for exercise, social interaction. The natural beach shape and dunes – a peaceful and beautiful place with changing nature.

Value Class	Included in Discussion (Values Study, 2000)	Observations on the quality and relevance of the 2000 data for the 2014 analysis	Comments on coastal values from 2010 consultation in association with the(draft CZMP, 2010
Recreation values	• Highly developed and natural recreation settings identified. Byron Bay Embayment is mostly highly developed. • Recreation value linked to accessibility, facilities, land tenure, distance from centres and the quality of the natural environment. • A wide range of recreational activities identified for the coast.	Suggested that Byron Shire had reached saturation point in peak periods, in terms of recreational carrying capacity. Limited data/sampling and now out of date.	Beachside camping and holiday parks – diversity of accommodation creates a healthy community culture. The beach offer free recreation for everyone. Clarkes Beach has easy access and easy parking, plus facilities that make it safe for leisure, swimming, walking. Belongil Beach is a quiet place where locals enjoy walking their dogs, a chat to friends. It also has good access and swimming in clean water, but sometimes no beach in front of the rocks.
Residential values	Derived from Settlement Strategy. Key values of relevance to coastal hazard management processes include: • Community participation is a vital part of Byron Bay life. • The beach front is natural, clean, safe and accessible for residents and visitors. • Tourists are welcome in Byron Bay. • Best environmental practices are encouraged.	More recent community comments on a vision for the coast, and key values are necessary.	High value attached to ocean views from residential areas.
Economic values	• Considers commercial and residential land value, tourism and recreation, environmental values, fishing, mining and agriculture.	Methodological limitations and out of date information about production, land value trends, tourism numbers etc.	Diversity in the town centre is good, but also looks a bit tired and an upgrade would be good.

2.0 Community Survey

2.1 Overview

Community members with an interest in the management of the BBE coastline were invited to complete a 20 question survey which was available on Council's web site and in hard copy between the period 15 January and 13 February 2014. A copy of the survey questions is provided in **Appendix 2**.

It is important to note that people completed the survey **before** they attended to workshop where the most up to date information about hazards and mitigation options was presented. Respondents were therefore relying on their existing knowledge of coastal hazards and management options as well as their personal preferences for coastal values.

It is possible that in identifying agreement or disagreement with statements about how the coast should be managed, the existing knowledge of respondents was not sufficient to appreciate the complex implications and interactions of values, hazards and management options. There was no opportunity in this project to test whether people would change their preferences with the benefit of more knowledge.

2.1.1 Key Questions

The survey sought information about how people use the coast, what is important to them, and their thoughts about a range of coastal zone management issues, with a focus on providing insight into:

- Who uses the Byron Bay Embayment coast?
- How do people use the coast?
- What do people value about the coast?
- What are the 'Must protect' values?
- Perspectives on managing the coast – priorities and things to avoid?

As the survey was online and voluntary, the sample of people completing the survey was 'self-selected' in terms of their interest in the coast, access to technology, and familiarity (and willingness to engage with) with the public consultation process. The survey was not intended to provide a statistical sample of Byron Shire residents, and the results have not been analysed in statistical terms as this would not be appropriate.

The survey does provide an overview or 'snap shot' of community perspectives on issues related to the NSW Coastal Management Principles. The survey asked some challenging questions and made some provocative statements, to test the strength of community views. The results of the survey highlight important values of the Byron Bay Embayment coastline, which should be taken into account when evaluating any potential management options.

2.1.2 Respondents

In total, 142 respondents completed the survey (although not all completed every question). Respondents tended to be:

- older residents and landholders (66% aged over 45 years and 6% under 30);

- employed (75% employed in business or government);
- relatively long term residents (25% more than 20 years, 31% 6-10 years); and
- property owners (55% owned property in Byron Bay), but respondents also represented a mix of residential locations, including close to BBE beaches, further away in Byron Bay, broadly within Byron Shire and across NSW. Note that less than 10% of respondents reported that they own properties currently affected by coastal erosion.

2.1.3 Knowledge of Coastal Erosion

Question 16 asked people about direct affects of coastal erosion on their property. 90% of respondents reported that they own properties that have not been affected by coastal erosion in the past compared to 9% who own properties currently affected by coastal erosion.

Question 15 asked people about future trends in erosion hazard. In relation to the potential for erosion hazards an risks to increase in the future, 73% of respondents thought coastal erosion events will get worse in the future and 11% thought erosion will get worse, but not for a long time. A small minority (2%) considered that there would be no increase in erosion hazard over time. A further 11% of respondents selected ‘I don’t know’, i.e. they were not able to offer a view about increasing erosion hazard over time.

Separately, in Question 9, people were asked to indicate the extent of their agreement or disagreement with a list of statements related to coastal zone management principles and issues for Byron Bay Embayment. Several of these statements related to the knowledge of the erosion hazards and the priority of private property protection. These are noted in **Table 2.1**.

These responses suggest that there is a clear perception amongst the respondents that coastal erosion hazard needs to be managed, because the current hazard is increasing now.

Respondents were more positive about Council having necessary knowledge to make decisions and act than they were about community understanding of coastal processes, hazards and management options. This view was also expressed at the Stakeholder Workshop (see **Section 3.0**) and in written submissions (**Section 4.0**). Note also, however, the 16% of respondents who did not know if Council had sufficient information. Both the relatively low community confidence in their own knowledge and this uncertainty about Council’s knowledge suggest that there would be value in a focus on opportunities for clear communication about coastal hazards.

Consistent with the proportion of respondents whose properties are not affected by coastal erosion now, a clear majority of respondents did not agree that protecting private property is the most important priority for Council in managing coastal hazards.

Table 2.1 – Responses to Statements about Erosion Hazard

Statement	Agree or Strongly Agree	Disagree or Strongly Disagree	Undecided	Don’t Know
The Byron Bay community has enough information to understand coastal erosion processes and options to reduce erosion risks.	34%	47%	10%	9%

Statement	Agree or Strongly Agree	Disagree or Strongly Disagree	Undecided	Don't Know
Byron Council has enough information to decide on effective management of erosion along its coastline.	41%	21%	22%	16%
The Byron coastline is affected by erosion now and it will get worse if no action is taken by Council.	66%	12%	14%	8%
Coastal erosion may get worse, but not in the next twenty years.	9%	63%	22%	6%
The most important priority about managing the Byron coast is to protect existing private property from coastal erosion.	21%	63%	16%	0%

2.2 Usage and Values

This section reviews the survey responses relating to the use of the BBE coast, what people value about the coast and how these relate to their perspectives on the focus for coastal zone management by Council.

2.2.1 Beach Use

Principle 10 of the NSW Guidelines for Preparing CZMPs requires that a complying council will:

> Support recreational activities consistent with the NSW Coastal Policy.

Question 1 asked people how often they used any one of the beaches in the Byron Bay Embayment.

Over half (55%)of the 142 people who responded to the survey reported using a BBE beach daily or at least once a week all year round. A further 26% reported using the beaches between once a week and once a month.

Respondents residing in Byron township and those living within 100 metres of the BBE coastline used the beach most frequently (daily/weekly). Respondents who used the beach less frequently (once or twice a year) tended to reside outside of the Byron Shire in the wider North Coast region or elsewhere in NSW or Australia. **Figure 2.1** shows the distribution of use.

Question 2 asked people about the frequency of individual beach use. **Table 2.2** summarises responses.

Table 2.2 – Frequency of Beach Use

Beach	Less than once a year/never	Occasionally (once a month)	Frequently (weekly/daily)	Only on holidays
Belongil	23%	33%	37%	7%
Main Beach	21%	30%	43%	6%
Clarkes Beach	22%	28%	47%	3%

These results suggest that the Main/Clarkes Beach stretch – i.e. the beach in front of the town, is more frequently used than Belongil Beach, especially by people who are on the beach at least every week. If occasional use is added to regular use, the usage across the three main beaches in BBE evens out. This is consistent with responses to Question 5, which asked people about important features of the BBE. 77% of people nominated that access to at least one beach is very important to them. 77.5% of respondents also indicated that access to a variety of beaches that are good in different conditions is important to them.

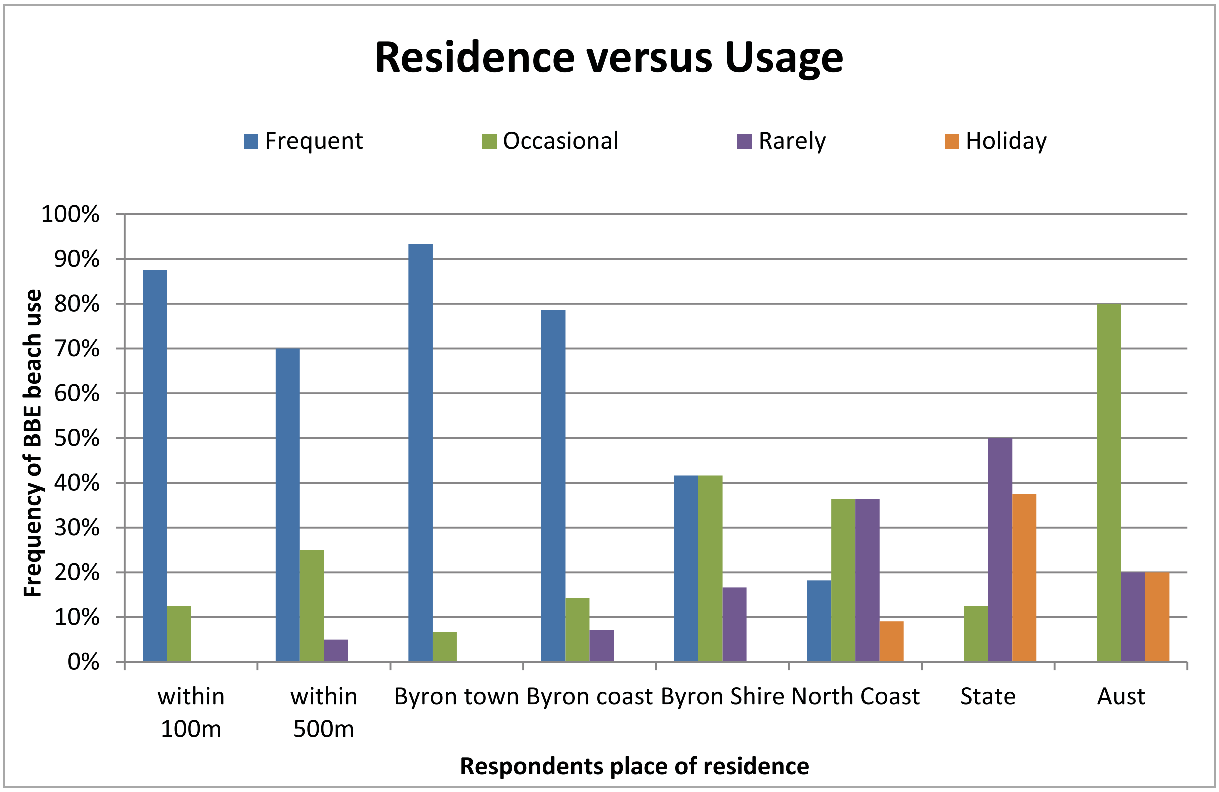


Figure 2.1 – Frequency of Beach Use with Residence Location

Question 6 asked people how they used the beach – what activities they carried out on the beach or foreshore area. The activities identified as most important (the main activity I do) and identified as minor uses are listed in **Table 2.3**. The more intense colours in this table highlight the most identified uses.

Table 2.3 – Main Activities on BBE Beaches

Activity	Main activity I do (identified as 1or 2), %	An activity I do, but less important/frequent (nominated as 4 or 5), %
Use the beach by myself (run, walk or other exercise	65	20
Use the beach with a friend/family/group or team, for exercise or relaxation	71	16
Use the beach with my pet	41	46
Use the foreshore reserve for picnics	57	37
Use the foreshore reserve for exercise	62	37
Go for a surf	62	27
Go for swim	79	12
Go fishing	30	52
Go boating/kayaking	33	52
Practice Yoga	14	66
Surfclub Activities	18	64
Socialize with friends	48	29
Commercial activities (e.g. operating a business)	7	87
Community activities (e.g. Triathalon)	18	70
Conservation activities (e.g. Dunecare)	51	32

Respondents used the beach for a range of activities, with the most frequently nominated 'main' activities across all respondents being:

- going for a swim;
- using the beach with family or friends or groups for exercise and relaxation;
- using the beach by myself – run, walk or other exercise;
- going for a surf;
- using the foreshore reserve for exercise; and
- conservation activities.

2.2.2 Coastal Values

Principles 3, 8, 9 and 10 of the NSW Guidelines for Preparing CZMPs all reference the value of the coast, to the community or in terms of environmental health and ecosystem services.

- Involve the community in decision making and make coastal information publicly available.
- Maintain the value of high value coastal ecosystems.
- Maintain and improve safe public access to beaches and headlands, consistent with the NSW Coastal Policy.
- Support recreational activities consistent with the NSW Coastal Policy.

Question 5 of the survey asked respondents to comment on the most important features of the BBE. Respondents were asked to rank by importance to them, statements about features of the coast.

Table 2.4 provides a summary of the responses, showing the 5 of responses nominating each value statement as 'very important' or 'important', and the average ranking of each statement. The colours in this Table indicate banks of ranking – more intense colours indicate more importance.

Table 2.4 – Statements about Important Features of the BBE

Statements	Combined % selecting rank 1 and 2	Average ranking (lowest score is most important)
Views of ocean, headland or beach from my home	24.6	3.74
Value of residential/commercial property	21.4	3.67
Views of ocean, headland or beach, from public reserves	60	2.24
Great surfing – good waves and reliable breaks	41	2.70
Access to at least one beach	77.3	2.02
Access to a variety of beaches that are good in different conditions	75.5	1.92
Ease of accesses to beaches	65	2.02
A flat sandy area above the tide for use e.g. walking, games etc	50	2.45
Safe swimming and surfing opportunities for young families and less able beach users	58	2.17
Good beach side facilities	49	2.41
Healthy ocean environment, with clean water and lots of marine species	105	1.46
The great social vibe on the beach or beach side reserves	37	2.73
A great place to get relax/use	61	2.31
The continuing cultural value of sea and coast country to Aboriginal people	54	2.18
The presence of heritage places and features along the coast	37	2.71

The stand out most important feature nominated by the survey respondents is:

- Healthy ocean environment with clean water and lots of marine species.

Three related features about aspects of beach access were the next most frequently nominated as the 'most important feature' of BBE:

- access to at least one beach;
- access to a variety of beaches that are good in different conditions; and

- ease of access to beaches.

The third group of important features of the coast includes a mix of social and cultural values:

- a great place to relax;
- continuing cultural values to Aboriginal people;
- safe swimming and surfing for young families and less able people; and
- great surfing breaks.

Beach side facilities and flat sandy beach for diverse activities, including along shore pedestrian passage, were mid range preferences. Question 3 also asked about beach access arrangements. Respondents strongly supported existing beach access arrangements in BBE. A total of 80% of respondents identified access arrangements as being adequate, although half of these did suggest that Council could carry out more maintenance.

The least frequently nominated as 'most important feature' were:

- views of ocean, headland or beach from my home;
- value of residential/commercial property;
- great social vibe on the beach or beachside reserves; and
- the presence of heritage places and features long the embayment.

2.2.2.1 Economic Value

Question 8 of the survey asked respondents to rate the importance of Byron Bay embayment beaches to the economic viability of the town.

As noted above, the value of residential and commercial land is not amongst the priority values identified by respondents to the survey. However, almost 80% of respondents regard the BBE beaches as highly important to the success of the local economy. They agreed that 'Byron Bay town and its beaches as synonymous (31% of responses)' and/or 'Byron Bay beaches attract people to the whole area, not just to Byron Bay town (47% of responses)'.

A further 19% of respondents regarded the beaches as a 'key part of the Byron town economy', but regarded other aspects as 'also important'. A small percentage of respondents (1.5%) regarded the beaches as not important to the economy.

2.2.2.2 Culture and Heritage

In Question 12 respondents were provided with a list of options and asked how Council could protect and promote cultural heritage values of the Byron Bay Embayment Area. Respondents strongly supported acton to protect Aboriginal cultural heritage. The four options with the strongest support were:

- by putting up signs to provide information about areas of Aboriginal or historical cultural and heritage significance (66%);
- by ensuring that all Council outdoor employees and Landcare members understand their obligations in relation to Aboriginal heritage objects (66%);

- by consulting with local Aboriginal corporations and implementing the Memorandum of Understanding (MOU) (64%); and
- by carefully managing access to important features and places (60%).

More than 50% of respondents also nominated:

- by research and monitoring to protect cultural heritage artefacts and places;
- by community awareness events to tell the stories associated with cultural places and values in the coastal landscape; and
- by creating a committee (or committees) of Aboriginal and historic cultural heritage organisations for Council to consult with on a regular basis.

2.2.3 Perspectives on Coastal Management

All ten of the Coastal Management Principles of the NSW Guidelines (see **Table 1.2** in **Section 1.0**) are relevant to how decisions should be made about appropriate and priority management responses to coastal hazards and risks.

Questions 9, 10 and 11 of the survey sought clarification of community perspectives on aspects of the choices before Council.

Question 9 asked respondents to indicate the extent to which they agreed or disagreed with a series of statements. These statements included positions on specific coastal hazard issues, governance matters and priority factors to consider when choosing management responses. Question 10 focused on management processes and particularly on how Council should best manage the BBE adaptively. Question 11 focused on management options for private property affected by coastal hazards.

2.2.3.1 What Should Be Given Weight in Decision Making Processes?

The statements in Question 8 drew strong responses from people participating in the survey. The allocation of positive and negative attitudes towards diverse issues is summarised in **Table 2.5**. The colour intensity in each column provides an indication of the strength of the response – whether positive or negative.

Table 2.5 – Respondent Views on Approaches to Coastal Zone Management at BBE

Statement	Disagree and Strongly Disagree %	Agree and Strongly Agree %	Neutral %	Don't Know %
Principle 4: Use best available information and reasonable practice				
Byron Council has enough information to decide on effective management of erosion along its coastline.	See **Section 2.1.3**			
The Byron Bay community has enough information to understand coastal erosion processes and options to reduce erosion risks.	See **Section 2.1.3**			

Statement	Disagree and Strongly Disagree %	Agree and Strongly Agree %	Neutral %	Don't Know %
Principle 6 and 7: Adopt an adaptive risk management approach, including a risk hierarchy, interim measures and actions to deal with uncertainty				
Council's sea level rise benchmarks (40cm above 1990 level by 2050 and 90cm above 1990 levels by 2100) are appropriate for planning future land use along the coastline of the Byron Bay Embayment.	22	36	26	16
The Byron coastline is affected by erosion now and it will get worse if no action is taken by Council.	12	66	15	8
Coastal erosion may get worse, but not in the next twenty years.	62	9	22	6
Council should allow existing residential and business uses of the coastline to continue, but not approve more development in areas that are affected by immediate coastal hazards (i.e. would be affected by an extreme (say 1 in 100 year) event now).	14	71	9	7
Coastal erosion and sea level rise in coming decades will damage the cultural and heritage values of the Byron Bay embayment.	17	45	26	11
Coastal erosion and shoreline recession in the coming decades will significantly impact on the ecology of the coast and nearshore marine areas.	15	53	22	9
Principle 5: Public benefit and practical long term outcomes				
The most important priority about managing the Byron coast is to protect existing private property from coastal erosion.	63	21	16	0
Coastal management options chosen should be based on the most economically efficient solutions.	49	30	22	0
If I had to choose between a rock wall (to protect built assets) and maintaining a sandy beach, I'd go for the rock wall.	68	23	8	2
Permanent coastal protection works (such as rock walls) are needed to maintain the culture and economy of Byron Bay.	46	31	15	8
The State government should provide most of the funds for building coastal protection works in Byron Bay.	17	53	26	4
Council and directly affected residents should share the cost of building a rock wall to protect private residential property.	39	42	17	1

Statement	Disagree and Strongly Disagree %	Agree and Strongly Agree %	Neutral %	Don't Know %
Council should introduce a rate levy on **all ratepayers** to cover the cost of management of the coastal zone.	56	24	18	1
Council should introduce a rate levy **only on coastal properties** to cover the cost of management of the coastal zone.	34	48	17	1
Investing in coastal management (coastal protection) should be a very high priority for Council. E.g. if Council had to choose between coastal management (protection and access management) and roads/kerb and guttering or sporting facilities, it should choose coastal management.	29	43	29	1
Principles 9 and 10 : Public access and recreational use				
Coastal tourism is one of the biggest economic activities in Byron Bay.	4	89	7	1
Tourists mostly come to Byron Bay for the beaches, swimming and surf breaks.	5	82	11	2
The most important thing about managing the Byron Bay coastline is to protect the surf breaks.	45	19	33	3
The most important thing about managing the coast at Byron Bay is to retain its reputation as a beautiful coastal landscape.	11	68	18	3
I support allowing the disturbance of the sea bed in the Marine Park to obtain sand for beach nourishment if required.	55	31	10	4
The most important thing about managing the embayment is to retain sandy beaches that are accessible and safe for everyone except in storm conditions.	16	66	16	2

Several observations can be made about this distribution of responses, including:

The Value of Coastal Tourism

The two statements with the **strongest agreement** were:

- coastal tourism is one of the biggest economic activities in Byron Bay (89% agree or strongly agree); and
- tourists mostly come to Byron Bay for the beaches, swimming and surf breaks (82% agree or strongly agree).

Supporting these strong views are two other statements:

- the most important thing about managing the coast at Byron Bay is to maintain its reputation as a beautiful coastal landscape; and
- the most important thing about managing the coast in the BBE is to retain sandy beaches that are accessible and safe for everyone at all times.

Conversely, but consistent with these sentiments, the **highest level of disagreement** was with the statement:

- If I had to choose between a rock wall (to protect built assets) and maintaining a sandy beach, I'd go for the rock wall.

Uncertainty or No strong opinion

Responses to some statements indicated a high level of uncertainty (an 'I don't know' response) and/or no strong opinion. Although the 'don't know' response was lower than clear agreement or disagreement, it was significant for specific matters, such as whether Council's sea level rise benchmarks are appropriate. This reinforces comments made elsewhere in the survey (and later at the workshop) that the community is not as well informed as it would like to be (and not informed enough to made a clear decision) about some aspects of coastal zone management. In particular, respondents seem to be uncertain about the extent to which future coastal recession will impact on ecological and cultural values and the best policy framework for considering sea level rise and its implications.

Despite a very strong view that tourism based on an attractive coastline is the major economic driver of the town, respondents were neutral or could not say whether Council should invest in coastal protection works over other priorities and whether protecting surf breaks is a high priority for coastal management.

Governance – Who Should Pay

Coastal Zone Management Principle 5 relates to choices about allocation of costs for coastal zone management activities.

> The priority for public expenditure is public benefit; it should achieve cost effective, practical, long term outcomes.

Several statements in Question 8 of the survey sought community views on the balance of investment across state and local government and community.

There was a strong positive response (53% agree or strongly agree) to the statement:

- The state government should provide most of the funds for building coastal protection works in Byron Bay.

A strong negative response was received to the statement:

- Council should introduce a rate levy on all ratepayers to cover the cost of management of the coastal zone.

The statement that directly affected landholders should contribute to the cost of coastal protection works (but not the whole of the community) received moderately strong positive (42%) and negative responses (39%), i.e. the response was polarised, although more people agreed than disagreed. There was a very strong view that protecting private property is not the highest priority for Council in coastal management in this locality.

In terms of the cost effective, long term outcomes (for coastal hazards and risks) component of Principle 5, the respondents strongly agreed with statements that erosion risks would get worse if action is not taken now; and that Council should allow existing uses to continue, but not allow new development in coastal hazard areas that would increase the risk over time.

A moderately strong negative view was presented about the value of a dominantly economic rationalist approach. Respondents did not agree that BBE management options should be based on the most economically efficient solutions.

2.2.3.2 Private Property

Council's previous position on managing the coast was set out in the 2010 draft Coastal Zone Management Plan, which included a planning objective to provide for ecologically sustainable human settlement in coastal zones (i.e. ecologically sustainable solutions should balance environmental, social, cultural and economic values, for long term benefit). This implies a fair and equitable approach to the management of public and private land affected by coastal erosion hazards and risks, which also complies with relevant state legislation and policies (balancing social, economic and environmental values as identified by the community and set out in state legislation and policy).

Question 9 of the survey asked respondents to comment on how Council should approach the management of coastal hazards affecting private property. In practice, this question asked respondents for their views about the management of hazards affecting private property at Belongil Beach, as other parts of the BBE that are or could be affected by coastal erosion hazards are primarily in public tenure.

Table 2.6 summarises the extent of agreement and disagreement with statements about the approach to managing hazards on private land and public land. Note dark green or pink text indicates more than 60% of respondents took this view. Lighter shading indicates 40%-60% of respondents took this view. If less than 40% of respondents expressed agreement or disagreement, the statement is not shown in this Table (see **Table 2.5** for all percentages of responses).

Table 2.6 – Strong Agreement and Disagreement about Managing Hazards, by Tenure

Public land - Respondent Agree	Private land - Respondents Agree
Council should maintain temporary protection works for public access and reserves and identify triggers for later construction of permanent protection works. **Investing in coastal management (coastal protection) should be a very high priority for Council. E.g. if Council had to choose between coastal management (protection and access management) and roads/kerb and guttering or sporting facilities, it should choose coastal management.**	**Council should require that buildings are removed from properties affected by erosion at a future time when certain trigger conditions are met.** **Council should allow existing residential and business uses of the coastline to continue, but not approve more development in areas that are affected by immediate coastal hazards (i.e. would be affected by an extreme (say 1 in 100 year) event now).** **Council should require private landowners to remove damaged, under-designed or ad hoc private protection works now.** **Council should do nothing and leave private landowners to make applications for privately constructed protection works on private land** **Private land holders should be allowed to repair, upgrade or construct protection works now.**

Public land - Respondents Disagree	Private land – Respondents Disagree
Council should build permanent protection works, e.g. rock walls or similar structures for public access and reserves now. Council should not maintain and/or should remove damaged protection works at public accesses and reserves now.	If a planned retreat strategy is adopted for residential properties in the Byron Bay Embayment, these (private) properties should be acquired using public funds. The most important priority about managing the Byron coast is to protect existing private property from coastal erosion.

Subject to further clarification as more details about the costs and implementation requirements of options become available, this suggests a preference among these respondents for maintenance of existing protection on public land (such as access ways) rather than major new construction. However, this position may depend on (lack of) knowledge about the capacity of existing temporary/interim works to withstand storm impacts; how much it is currently costing Council to maintain temporary structures (such as geotextile bag walls); and also on perceptions of who would be required to pay for the construction of protection works for public access ways. These are matters for further consultation.

Although the is reasonable agreement that coastal zone management is an important priority for Council, the view is that Council's investment should be for public assets, not the protection of private assets. The 'Agree' statements indicate a community view that protection of private land (and removal of private assets impacted by erosion, if necessary) should be the responsibility of private landowners, with Council providing the regulatory or policy framework.

A range of additional comments were offered in relation to this issue, supporting both coastal protection works and allowing natural processes to take their course (note, each comment below was made once):

- When people have acquired properties with the full knowledge of the erosion then it is theirs to accept the fate of their decision.
- Private landholders must retreat at own cost before mess becomes a public cost.
- People invest in coastal properties fully aware of the risks.
- Sea level rise and erosion will occur if the climate doesn't go back to colder weather. 'Let the buyer beware' and they lose their property if they were stupid.
- Dump planned retreat and adopt science and engineering.
- Implement other recommended anti erosion measures.
- I think there needs to be a balanced approach between the current landholders and Council with a view to gradually implementing some of the strategies.
- As rock walls already exist at Belongil, why not complete them to stop beaches falling into private hands as they erode.
- It's a difficult issue, I can't answer some of those questions. Erosion will always happen, retreat seems the most adaptive management. There is nothing that can be built and thought of as permanent in front of the ocean. Landscapes change, lands move, we need to adapt with the least of force. Nature always wins if we force it out of its course!
- Allow the natural erosion of the coastline to take place without interference.

The management framework and responsibilities for coastal erosion affecting private property is a matter for further consultation when more implementation details (such as about beach nourishment or design of protection structures, and costs and benefits) are available.

What Respondents Do Not Agree With

Respondents strongly disagreed with several statements which describe approaches to managing the coast, or are part of a management approach. For instance there was strong disagreement with the following statements, which relate to beach nourishment and beach amenity issues (**Table 2.7**).

Table 2.7 – Approaches with Strong Disagreement

Rock walls and beach amenity	If I had to choose between a rock wall (to protect built assets) or maintaining a sandy beach, I'd go for the rock wall.
Source of sand for beach nourishment	I support allowing the disturbance of the sea bed in the Marine Park to obtain sand for beach nourishment, if required.

These responses are consistent with strong positive views about the importance of a beautiful (natural) coastal landscape, the link between beaches and tourism and safe access to sandy beaches.

2.2.3.3 Adaptive Management

Principle 7 of the NSW Guidelines for Preparing CZMPs

> Adopt an adaptive risk management approach if risks are expected to increase over time, or to accommodate uncertainty.

The respondents to the community survey agreed that risks would increase over time in the BBE, if no action is taken. The coastal hazard study shows this from a scientific perspective, with and without assumptions about sea level rise.

Adaptive management generally refers to a cycle of continuous learning and improvement, drawing together new science, practical experience, community information and other elements to refine knowledge about the most effective, efficient and appropriate management approach.

In Question 10, respondents were given a list of management actions and asked which they thought should be part of an adaptive management approach for coastal hazards at Byron Bay. Strongest support (as 'must do' actions) was received for the activities noted in **Table 2.8**.

Table 2.8 – Strongly Agreed Components of Adaptive Management

Theme	Components
A clear and affordable plan for now and the future	Set clear objectives and management targets for physical, social and economic factors Funding strategy to provide money for investment in coastal management Schedule of actions and budget with regular progress and expenditure review Clear emergency response procedures

Theme	Components
	A formal review process at intervals of approximately 10 years Clear triggers for when Council will change its management strategy, to accommodate new or different risks
Clear policy and planning guidance	Clear polices for coastal land use and land Design guidelines for residential development in coastal positions All policy information and monitoring results published on Council's web site on a regular basis
Sound baseline information and ongoing tracking of coastal condition	Baseline assessment of the conditions of the beaches Ongoing monitoring of the condition of beaches
Involve community in looking after the coast	Support for Landcare activity

Respondents indicated least agreement with specific monitoring activities that relate to less widely held values of the coast:

- monitoring the value of coastal land and real estate;
- monitor membership and activities of surf clubs; and
- monitoring of accommodation utilisation.

2.3 Other Issues Raised in Additional Comments

The survey format provided opportunities for respondents to provide additional comment and multiple respondents took this opportunity to provide thoughtful and constructive input on issues of particular concern to them, with 52 responses in the final open question. Examples of the scope of ideas and concepts noted in these detailed comments are included below. The full comments are in **Appendix 3**.

Coastal Erosion and Management

> The instability of these beaches has been known for a long time (The 1970s?) The 1974 cyclone footage should be accessed and be shown to the community regularly to remind/inform newcomers of the dreadful threat that cyclones pose to the state of the beaches and the stability of the town. People have to be made aware of the dangers in the event of a 1954 cyclone/and accompanying storm ocean surges. Rock walls and bags are really a waste or money, they don't stop surges, but they do give people living behind them a false sense of security. Can Belongil residents be allowed to sue the BSC if the walls fail and they lose their property/lives during a cyclone event and associated storm surge. Everyone has forgotten, even the council planners, and the developers do not want to remember, because it will redefine the North Coast and that will affect property values and development into the future. Remember the footage of waves breaking over Julian Rocks and the white water pouring through the hotel and down the main street, a whole street collapsed at the Belongil and disappeared into the ocean, ...walls don't stop big waves.

> Rockwalls to stabilise access should be considered as part of the bigger picture of Byron Bay and erosion trends into the future. Maintenance costs will be rising as erosion increases. A clear vision for the Embayment should be created and followed by Council, based on wider stakeholder consultation. This survey is a great start.

Stop development to close to the beach, prevent erosion by reducing *ad hoc* access and prevent pollution rubbish plastic and broken glass.

Byron Bay is a ‘bay’ from erosion that occurs at a greater rate due to the rocky headland of Cape Byron. The ‘bay’ will keep expanding inland and with it ,buildings. To have sandy beaches can only be achieved with NO rock walls or groynes.

Belongil in particular is a established village within Byron, with many homes and businesses. The foreshore needs rock protection to defend the whole of Belongil and beyond from inundation from excessive storms. Abandon Belongil and its infrastructure will perish, its residents will suffer and the beach will suffer. Had Belongil not been settled all those years ago, it would be fair to ‘let nature take its course ‘as some people would like, but it's too late to abandon it, common sense would say to protect it in the most economically efficient way, not with sandbags which have been a waste. Rocks are used all over the world to protect cities and towns, they are natural and require minimal upkeep.

The Belongil area in particular was always prone to erosion - and therefore 'planned retreat' was a condition to build there. Private landowners need to take responsibility for their choice of location, and we need to allow the natural erosion of the coastline - as nature intended. Ratepayers + Council should not be required to pay to protect buildings in a planned retreat area.

Access, Amenity and Development Options

I do support permanent protection of coastal areas and support improvement of access points, particularly at jetty carpark Belongil beach. I am concerned about erosion of dunes at Border St. I frequently see visitors accessing beach all along this area despite there being defined access nearby. Is there a solution to this? In relation to condition of roads in town, they are in a pretty poor state - is there a way to raise revenue from all the tourists to Byron to help maintain roads and infrastructure? Maybe more paid parking or bed tax?

Development of the public foreshore land between Clarkes and Main Beach should be considered as part of this. The reserve along this strip is a vastly under-utilised asset with huge potential to create a place for locals and visitors to use, enjoy and access the beach. At the same time this would enhance our towns.

Please do not forget the things that bring tourists and people like us to Byron from Brisbane sometimes every weekend is the laid back approach to the place. Do not make it like Surfers Paradise, it needs to keeps it's laid back vibe, calm, respectful nature. Byron has changed over the last 20 years... Make sure you don't forget your roots and where you came from... That makes Byron special.

I have been a resident of the area for twenty years and have seen private interests take advantage of council and further damage amenity in so many ways. Now we only return for family reasons. Repair the dune system, rid the dunes of pest millionaires.

Although we love the aesthetics of the Byron Bay embayment. we, as the public, use it first and love it second. Appreciating the beauty of the natural form is something done typically during an activity (sitting in Federal and knowing Wategos exists doesn't do it for me). If there were no beaches in Byron then the extent of activity would be similar to that which occurs at Broken Head - a little only. A beach that is in constant sand movement is accepted by the public since activities can still take place. If there is no sand then seaside activities are greatly diminished – and so will the volume of people and their associated appreciation of the area will be greatly reduced. Hence keeping some sand is imperative to keeping high levels of appreciation.

Need for Education

The Byron Shire Council should provide financial support to non-profit groups that are helping to educate the public about marine debris and protecting our marine environment e.g. Australian Seabird Rescue and Sea Turtle Hospital.

I only observed that any time human beings try to build something that forces rivers or oceans where they are not or don't want to be, it will just be a matter of time, but nature always goes back to the course it wanted, and often it makes it worse. A clear example is what was done to the Belongil River before the wedding shack of the Beach Club went down. It was the changing of the river course that set it to eventually run even closer to the land of the beach club and destroy so much!

Governance

If sea walls reduce the volume of sand that can be walked on then an individual private owner should not be penalised for the benefit of the masses (i.e not allowed protection materially or monetarily). Council policy has been made on sea level rise for the next 90 years. The same could be done for a slowly growing Council fund (by having varying Council rates depending on your property location, or business in relation to beach tourists) to acquire portions of sea front properties at market rates over the same time period.

Council needs to undertake the research, decide the direction (strategies) and play a leadership role using best practice policies and actions. Great survey – thank you

Byron town and coast is a unique International Australian attraction [like Opera house and Uluru etc] and should get State and Federal funding for infrastructure.

2.3.1 Other Feedback about Survey Questions

A small number of people made suggestions about the form and content of the survey in their responses. Views expressed included:

- There were not sufficient categories of employment (e.g. for students) or residence type.
- Some responses also congratulated Council on the survey and welcomed the opportunity to provide input and express views about coastal zone management. They encouraged Council to offer more surveys and involvement opportunities.
- More questions should have had an 'I don't know' option. This is consistent with the view expressed in the survey that residents do not have enough information/understanding to make a decision on the best way forward.
- Options presented were 'biased or misleading or presupposed an outcome'. This feedback related particularly to some statements in the question which framed and scoped the limits of potential options, such as 'If I had to choose between a rock wall (to protect built assets) and a sandy beach, I'd go for the rock wall'; 'Investing in coastal management (protection) should be a very high priority for Council: e.g. if Council had to choose between coastal management (protection and access management) and roads/kerb and guttering or sporting facilities, it should choose coastal management'.

In relation to the fourth dot point, it is important to note that these are the choices that many in the community and Council believe they are making. The first of these statements returned a strong clear view from the respondents (68% strongly disagreed that protection is more important than sandy beach amenity), so any sustainable protection solution would need to be able to deliver continuing beach amenity as well as protection.

Responses on Council's priority for coastal management over other responsibilities were more ambivalent (29% disagree, 43% agree and 29% can't say) in relation to the statement.

2.4 Key Messages from the Survey

The responses to the survey highlighted several important areas of agreement about how coastal zone management for the Byron Bay Embayment should be approached, and what needs to be included in the coastal zone management plan. Some key messages are summarised in **Table 2.9**.

Table 2.9 – Key Messages from the Survey

Theme	Examples
Some coastal values shared across a broad spectrum of people who use the beaches of the Byron Bay Embayment, either as local residents, as absentee land owners or as occasional visitors. The positive shared values are the ones that Council must take into account when deciding on its coastal zone management strategy.	Overwhelming support for maintaining a healthy ocean environment, with clean water and lots of marine species. Strong support for maintaining safe access to and along at least one sandy beach, for a wide range of people. The important contribution that the combination of natural beauty, safe access and beach amenity makes to the economy of Byron Bay, by attracting visitors, as well as supporting the lifestyle of local people. The coastal landscape is a dynamic and changing place, with many moods and varying condition. Management options should give priority to protecting beach amenity and the beauty of the coastline.
Some coastal values are important to selected people in the community, but not to everyone	This includes a range of specific coastal uses, including surfing breaks (as opposed to general swimming, walking and recreation on sandy beaches); specific heritage features.
Some management options about which there is broad positive agreement	Community involvement in coastal management processes and activities. Beach visual and recreational amenity (sandy beach landscape, with rocky headlands) should be maintained. If beach nourishment is needed to maintain a sandy beach landscape, it should not come from within the marine park. Robust monitoring and reporting of coastal condition is essential. Clear policy and planning guidance for landholders, including clear processes, triggers and timeframes for how/when coastal management strategies will change. Existing 'temporary' protection works for public access ways and public land should be maintained until appropriate permanent protection works can be established. Private landholders should be able to maintain private protection works, and potentially construct more permanent protection works, but the broader community and Council are not responsible for costs. Existing development in coastal hazard areas should be allowed to continue, but no new development that increases risk should be allowed in high hazard areas (100 year hazard lines). The State government should make a significant

Theme	Examples
	contribution to the cost of coastal zone management in this locality. Private landholders should take responsibility for their decision to locate in coastal hazard zones.
Some management options with which the community strongly disagrees	Coastal protection works should be installed regardless of the detriment to beach amenity, which underpins the local economy. The cost of protection of private property should be shared across the community with a rate levy. Council should be responsible for buy back of private coastal properties affected by coastal hazards.

3.0 Stakeholder Workshop

3.1 Overview

A workshop for key stakeholders was held in Byron Bay Recreational Centre on the 18 February 2014. The workshop sought to obtain feedback that would inform Council's understanding of management options that are considered reasonable by the community, and the extent to which options could be consistent with the ways the community uses, enjoys and values the coastline.

The workshop was also an opportunity to further discuss issues arising from the survey, particularly those issues where there were clear differences in community views.

3.1.1 Participants

Approximately 60 stakeholders (individuals and groups) were invited to attend the workshop, with invitees selected to represent the diverse interests that the local community has an interest in the management of the coast. This included:

- cultural, recreational, environmental, social and economic interests;
- the interests of young people, traditional Aboriginal owners, long term residents, new arrivals, absentee property owners and businesses;
- people who live right on the coast of the embayment (particularly at Belongil Beach) and people who live further away;
- people who are members of community groups such as the surf club and Dunecare; and
- Shire Councillors.

36 people attended and participated directly in workshop activities, including six (6) Byron Shire Councillors. Selected Council staff also attended to help facilitate the workshop and to answer questions. State agency officers were invited participate in the workshop and provide advice on statutory requirements but some were unable to attend. OEH did not attend, but representatives of the Cape Byron Marine Park and Crown Lands did participate. Aboriginal stakeholders were not able to attend.

A full list of stakeholders invited to the workshop and stakeholders who attended is included in **Appendix 4**.

3.1.2 Background Briefing

Prior to the workshop, a Briefing Paper was distributed to workshop participants providing information regarding:

- coastal hazards and risks;
- coastal values and the results of previous studies;
- processes that Council is required to implement in selecting a preferred approach to coastal hazard and risk management;
- progress made in the current study; and

- concepts and program for the workshop.

A copy of the Briefing Paper provided to workshop participants is included in **Appendix 5**.

3.1.3 Workshop Structure

The workshop included short presentations by the Study consultants (WRL and Umwelt) followed by small and larger group discussion to identify coastal values and rank potential management options according to the OEH 'reasonableness' criteria (refer to Section 1.2.1). The WRL presentation provided participants with information about coastal hazard management options (primarily coastal protection options and planned retreat) and evidence from Australia and internationally about their capacity to deliver effective outcomes (feasibility of management options – can they work?).

A key aim of the workshop was to collaboratively assess which options were considered by community members to be 'reasonable' and 'non reasonable', and for this to feed into subsequent wider analysis regarding community attitudes and preferences regarding management options.

To do this, participants were seated in pre-determined small groups which included people with different backgrounds, perspectives and interests. As such, care was taken to seat tables with a mix of landowners, Councillors, academics, business owners and representatives from environmental, recreational or cultural organisations.

This small group structure was intended to encourage robust discussion about the rationale for different views on reasonableness and what should be given weight in making the decision. It also had the secondary benefit of demonstrating the 'real-life' context of management planning and decision making in the context of complex issues, multiple options and diverse interests.

A copy of the workshop agenda is attached at **Appendix 6**.

3.1.4 Feasible Options

WRL discussed the technical feasibility of 12 management options and also provided information about why a rage of potential management options are not considered technically feasible. Each option was explained by WRL, including their technical 'pros and cons', and participant's technical questions were addressed.

Table 3.1 lists the 12 options and a summary of the key 'pro' (benefit) and key 'con' (problems) as presented by WRL. The options were not presented in a rank order at the workshop, and are reproduced below in the same order as presented at the workshop.

Table 3.1 – Technically Feasible Management Options

	Pros (benefits)	Cons (problems)
Single Options		
Seawall alone	High certainty of protection	Loss of beach amenity
Nourishment (with End Control)	Natural beach without sea wall	Less physical protection
Groynes alone	Natural processes shape coast at less cost	Less physical protection
Offshore Breakwaters (Submerged Reef) alone	Submerged with potential surf break	Less certainty of protection and success

	Pros (benefits)	Cons (problems)
Retreat : Public/Private	Natural processes prevail Informed acceptance of hazards	Spatial and social limits
Retreat: Public Ownership	Natural processes prevail	Spatial and social limits High burden to tax/rate payers
Retreat: Private	Natural processes prevail	Spatial and social limits High burden to landholders
Hybrid Options		
Sea wall + Nourishment + End Control	Staged protection and amenity	Expense of three options
Seawall + Nourishment + Groynes	Staged protection and amenity Reduced sand requirement	Expense of three options
Nourishment + Groynes	Sand protection buffer, amenity, surfing	No structural protection
Nourishment + End Control + Emergent Offshore Breakwaters	Stable wide beaches	Safety and loss of waves
Nourishment + End Control + Submerged Reefs	Out of sight, with surf potential	Less certainty and less physical protection

3.2 Coastal Values

Participants were asked to think as individuals about what they regarded as important about the coast, and then share their ideas with their wider group (table group). A group member was invited to report back to all participants a summary of the key values identified by their group. Participants were asked to keep their summary of their individual values with them on their table for use in subsequent workshops activities.

The values identified by participants have been grouped into overall themes, as depicted in **Figure 3.1**. Many of the values were linked to multiple themes (for example, surfing as a recreational as well as an economic value, or scenic views as both a recreational and natural value) and, where relevant, have been noted under both themes.

Aspects of the values identified by participants are discussed in further detail in **Sections 3.2.1** to **3.2.5**.

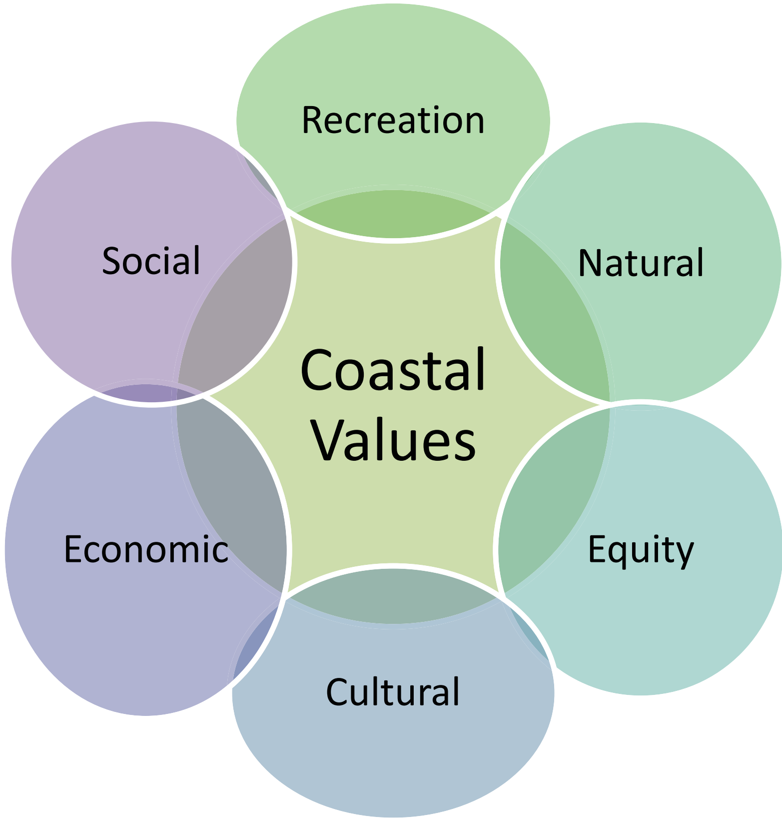


Figure 3.1 – Coastal Values – General Themes Identified by Participants

3.2.1 Recreation Values

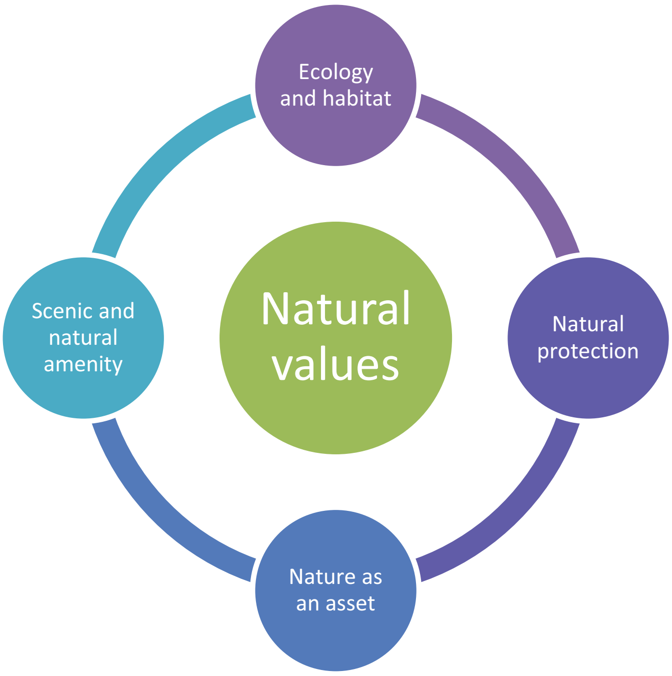
The beach and coastline as a 'community playground' was a key theme for participants, with the beach regarded as providing valuable recreational opportunities for multiple user groups.

Coastal values identified as contributing to recreational use are noted below:

- **Easy access**:
  - good connectivity – both *to* beach, and laterally *along* the coast;
  - adequate number and location of access points; and
  - maintenance to manage public safety.
- **Diverse options for activities**:
  - space and opportunity for ‘diverse recreational communities’;
  - activities to cater for residents, families, surfers and visitors to the Shire; and
  - active pursuits such as swimming and dog walking to more passive activities such as meeting friends and enjoying the beach amenity.
- **Safe swimming**:
  - clean unpolluted water;
  - safe structures;
  - adequate surf lifesaving patrols;
  - beaches free of debris; and
  - comments about Coastal Principles relating to safe recreational access and amenity.
- **Scenic quality**:
  - beauty of beaches;
  - views to and along the coast; and
  - natural amenity.
- **Good surfing breaks**:
  - surfing an iconic activity for Byron Bay;
  - surfing attracts visitors to the area (note the associated economic value); and
  - important for locals.
- **Well maintained facilities**:
  - well maintained toilets;
  - adequate carparks and access points; and
  - maintenance of rocks walls.

3.2.2 Natural Values

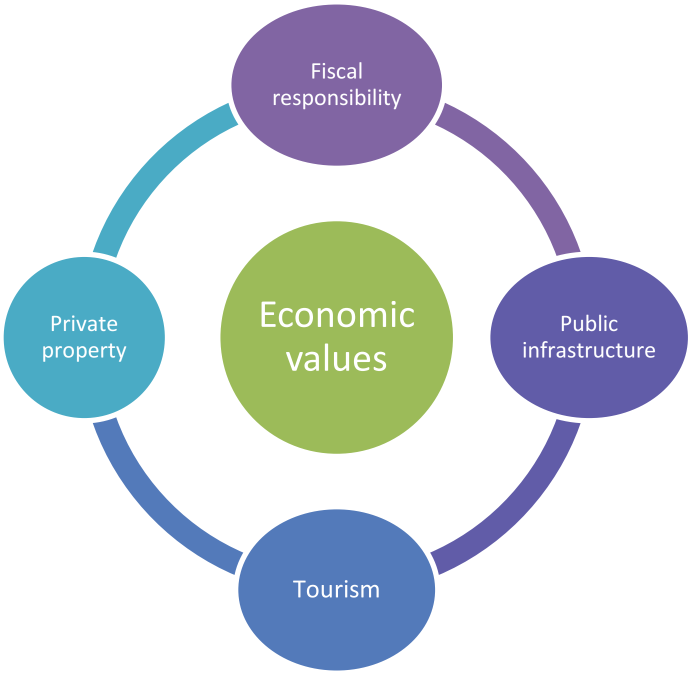
The natural value associated with the 'unbuilt quality of the coastal landform' was valued for its inherent ecological value (as habitat and natural ecosystem) as well for its more utilitarian social and economic function. Particular comments related to the matters noted below:



- **Ecology and habitat**:
  - connectivity between natural processes;
  - Belongil estuary and creek is habitat for valuable species, e.g. pipi, birds;
  - turtle hatching at Belongil; and
  - 'wild' estuary processes.
- **Natural protection**:
  - naturally protective qualities of some ecological processes/features;
  - stabilising aspects of natural physical features such as Coffee Rock; and
  - history of sand dunes providing protection from storm seas.
- **Nature as asset**:
  - 'undeveloped qualities' of coastline are a natural assets to be preserved;
  - visitors attracted by natural amenity; and
  - flow on value for a range of areas, including recreation, ecology and tourism.
- **Scenic and natural amenity**:
  - opportunities for passive recreation;
  - views to and from the beach;
  - visitors attracted by natural amenity; and
  - natural water quality – unpolluted, a 'good swim'.

3.2.3 Economic Values

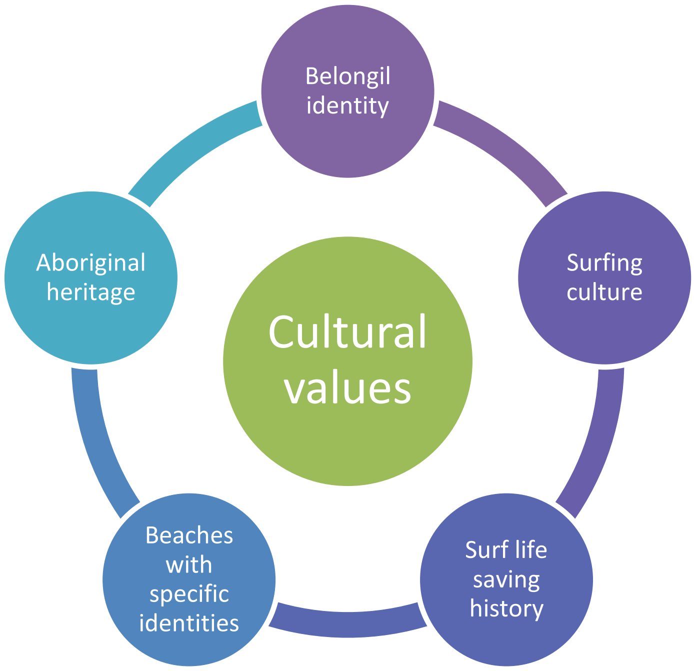
The coast's economic value was discussed in terms of both public and private interests. These included the matters noted below:



- **Fiscal Responsibility**:
  - cost effective solution required; and
  - long term economic sustainability.
- **Public infrastructure**:
  - value of coastal infrastructure, such as roads, rail, buildings, and sea wall; and
  - value further enhanced due to economic costs of loss or removal.
- **Tourism**:
  - economic contribution from tourists;
  - beach attracts tourists – flow on effect to town and wider Shire; and
  - links with other values such as public access, recreational diversity, cultural identity and natural amenity.
- **Private property**:
  - respect for private property rights; and
  - economic value of residences for landholders.

3.2.4 Cultural Values

Participants spoke of the cultural value of Belongil beach specifically, as well as cultural values relating to beaches in the area generally. Comments related to the following matters:



- **Belongil identity**:
  - strong identify of Belongil – ‘Belongil is a well known local site’; and
  - historical importance of old jetty.
- **Surfing culture**:
  - surfing synonymous with Byron Bay; and
  - beach culture attracts visitors.
- **Surf Life Saving history**:
  - strong historical role of the Surf Life Saving organisations.
- **Beaches with specific identities**:
  - dog beaches;
  - nude beaches;
  - surfing breaks; and
  - Belongil beach.
- **Aboriginal heritage**:
  - acknowledgement of Aboriginal cultural heritage values associated with the coast.

3.2.5 Social Values

Social values related to the importance of the Byron coastline as a community asset and included those noted below:

- **Equity and Inclusion**:
  - equity of beach access – availability, ease, location, maintenance, safety;
  - fairness and consistency – Belongil residents 'a part of the community too';
  - beaches as a community assets;
  - collaboration for all stakeholders – crown, community, private owners;
  - cost sharing across community – those that benefit contribute proportionally; and
  - need for 'whole of beach solution' – consideration of impacts across beach, and from existing structures.
- **Community connection**:
  - beach as community meeting place;
  - Belongil has a good community spirit;
  - importance of social 'harmony' and social 'fabric'; and
  - links to recreational and cultural values.
- **Residential value**:
  - good place to live; and
  - property owned for a long time.
- **Responsibility to future generations**:
  - need for long term view;

- short term cost might be long term gain;
- respect for long term ecological processes;
- dynamic nature of the coast – always changing; and
- natural asset of beach to be preserved (visual amenity).

3.2.6 Links with Coastal Zone Management Principles

Values identified by workshop participants align with those identified during previous Council consultation regarding coastal management (refer to **Section 1.6.1**), affirming the ongoing importance of the recreational, economic, residential and ecological considerations for the Byron Coast.

Values identified during the workshop are also consistent with relevant NSW Coastal Zone Management Principles (refer to **Section 1.4**) with key synchronicities across community involvement, public benefit, public access, recreation and ecological values.

Table 3.2 presents high level links between participant values and the relevant Coastal Zone Management Principles.

Table 3.2 – Links with Coastal Zone Management Principles

Coastal Management Principle from NSW Guidelines		Relevant Participant Values
Principle 3	Involve community	Social: Equity and inclusion
Principle 5	Long term, public benefit	Economic: Public infrastructure Economic: Fiscal responsibility Economic: Tourism Social: Responsibility to future generations Natural: Nature as an asset
Principle 6	Risk focus	Recreation: Safe swimming Social: Responsibility to future generations
Principle 7	Adaptive planning	Social: Responsibility to future generations
Principle 8	Protect ecological value	Natural: Ecology and habitat Natural: Natural protection Social: Responsibility to future generations
Principle 9	Protect public access	Recreation: Easy access Social: Equity and inclusion
Principle 10	Support recreational use	Recreation: Easy access Recreation: Diverse activities Recreation: Safe swimming Recreation: Scenic quality Recreation: Well maintained facilities Natural: Scenic amenity

3.3 Evaluation of Options

A key intention of the workshop was to collaboratively assess which options were considered by community members to be 'reasonable' and 'not reasonable'. These views would feed into subsequent wider analysis regarding community attitudes and preferences relating to management options.

Discussion focused on options that could be reasonable for Belongil Beach with agreement from participants. The focus on Belongil rather than other parts of the BBE coast was for the following reasons:

- The risks associated with Clarkes and Wategos beaches are assessed as relatively minor and straight forward, compared with significant risks involving private and public assets at Belongil Beach/Spit, now and increasing in the future.

- Council's prior decision to rebuild the Jonson Street sea wall at Main Beach in order to improve access and better manage sand transport processes (Refer Council meeting/minutes and the Worley Parsons Report) reinforced a focus on Belongil for current decision making.

- Belongil Beach has been the most contentious management issue in the community, with multiple management options perceived as being feasible and reasonable at different times across different sectors of the community. The rationale for the various options that have been presented as feasible and reasonable for Belongil in the past does not appear to be well understood in the community. Belongil is the primary source of contention on the community and is the coastal erosion 'hotspot' in Byron Shire.

3.3.1 Reasonable versus Non-Reasonable Options

Groups were provided with the list of 12 feasible options and invited to discuss and agree which that they considered to be 'reasonable' and 'not reasonable' according to the criteria discussed in **Section 1.2.1** and with reference to their values identified in **Section 3.1** above.

The option identified most frequently as reasonable by groups was a 'seawall + nourishment + end control'. 'Retreat', in all its forms, was identified most often by groups as a 'not-reasonable' option. **Table 3.3** summarises the three most frequently nominated reasonable and unreasonable options.

Table 3.4 lists all the options that were regarded as reasonable and not-reasonable by the groups (tables) and the rationale that they reported for their assessment. Groups were free to list as many (or few) options as they regarded as appropriate to the category, so not all of the possible options appear in the table. The groups reported that the discussion required participants to listen to and consider different perspectives to their own and to question their assumptions.

All feasible options were:

- identified as **reasonable** by one or more tables; and

- identified as **unreasonable** by one or more tables.

This highlights the mixed views and interests within and across the groups.

Groups provided a detailed positive and negative rationale for only some options, partly due to time constraints. Groups identified some downsides even for options broadly considered to be reasonable, confirming the importance of shared objectives, evaluating significant benefits and threats to different stakeholders and values. Groups highlighted two important filters that Council should apply in making a decision about how to proceed:

- A balanced solution. The solution should not offer protection at the expense of amenity, or assume that forgoing protection would achieve amenity objectives.
- A whole of embayment solution, providing a fair and equitable way forward for Clarkes Beach, Main Beach and Belongil Beach.
- Solutions should be able to be funded in a shared way – with some private and some public contributions to manage private and public assets respectively.

Table 3.3 – Reasonable and Unreasonable Nominations

Options Most Frequently Identified as Reasonable	Options Most Frequently Identified as not Reasonable
• Sea wall alone (upgraded) • Groynes alone • Hybrid options – sea wall and/or groyne(s), + beach nourishment	• Beach nourishment alone • Planned retreat (public or private) • Offshore breakwaters

3.3.2 Cost

Expectations of cost and preferences for funding structure were discussed as factors by most groups when evaluating reasonableness. Single options were generally considered to be more cost effective, with one group suggesting that all hybrids would be unreasonable because of high costs. However, all groups appreciated that up-front cost and overall benefit cost ratio are not the same thing, and that proper analysis would be necessary to understand the real benefits to cost ratio of key options.

Councillors subsequently discussed which options to take to a detailed benefit cost study a separate workshop, taking into account the outcomes of the Stakeholder Workshop (see **Section 5.0**).

The idea of 'Who Pays' was also discussed, with landholders present indicating a willingness to cover costs associated with coastal protection works that benefitted their property. One participant suggested that 'all the options' would be reasonable should the state government foot the bill.

Table 3.4 – Reasonable and Not Reasonable Discussion by Groups

Option	Identified as Reasonable	Rationale	Identified as Not Reasonable	Rationale Presented by Groups	Discussion
		Single Options			
Seawall alone	Yes	✓ 'Doable' ✓ Cheapest ✓ Good beach access points ✓ Maintains amenity ✓ Preserves health of beach ✓ Efficiencies due to existing wall ✓ Landowners willing to cost share ✓ The existing sea wall is an economic and practical asset	Yes	× Loss of beach more often × Downstream impacts – e.g. estuary × Increased erosion at ends of wall × Reduced public safety × Loss of access to beach × Visual impact × Impact on estuary × Lose natural values of creek – rocks are not natural	• 3 groups considered this reasonable • 1 group considered this not-reasonable • Also regarded a good component of a number of hybrid options • High net support
Nourishment (with end control) only	Yes	✓ End control helps keep the amenity of sand nourishment for longer – more cost effective	Yes	× High cost × Uncertainty re source of sand × Prohibitive costs (as per by previous technical studies) × Could cause murky water × End control has potential impacts on beaches to the north	Nourishment without an end control not supported.
Groynes alone	Yes	✓ Potential for a series of small groynes in a staged approach	Yes	× Ineffective, ugly × One group said 'anything but a groyne'	Two tables suggested reasonable, one reasonable; low net support.
Offshore Breakwaters (Submerged Reef)	Yes	No specific reasons identified	Yes	× Reefs have too high risk of being ineffective × Affect surfing amenity	Low net support.
Retreat : Public/Private	Yes	✓ Preference for natural processes	Yes	× Disruption to community	Retreat generally was identified as reasonable by 2

Option	Identified as Reasonable	Rationale	Identified as Not Reasonable	Rationale Presented by Groups	Discussion
Retreat: Public Ownership	Yes	✓ Will have to happen in time ✓ Potential for 'tertiary opportunities' (i.e. asset associated with retreated land ✓ Long term economic benefit – balances 'short term pain' against burden of ongoing protection costs	Yes	× Loss of homes and property × Cost of infrastructure removal (private/public) × Encroachment on public infrastructure × Costs of litigation and compensation × Lower investor confidence × Risk to public safety (beach debris) × Inequity – can't protect some and not the other × Loss of cultural history × Ecological damage to Belongil estuary (washover) and creek × Increased risk of flooding to other parts of Byron Bay × Futility of option – wouldn't achieve beach amenity objective	tables and unreasonable by five tables.
Retreat: Private	Yes		Yes		Lower net support.

Option	Identified as Reasonable	Rationale	Identified as Not Reasonable	Rationale Presented by Groups	Discussion
Hybrid Options					
Sea wall + Nourishment + End Control	Yes	✓ Much of seawall already exists ✓ Owners contribute to sea wall ✓ Permanent beach access ✓ Creation of possible surf break ✓ Protects property ✓ Maintains beach amenity ✓ Low cost for sea wall ✓ Landowners may pay for seawall ✓ Could be staged	Yes	× No beach during storm bite × Seawall affects natural beauty – visual impact. Rocks are not natural × Nourishment economically unviable Questions re source of sand × Lose natural values of creek × Downstream impacts of sea wall	High net support: 4 groups identified this option as reasonable and 1 group as not reasonable. Discussion about where the end control should be placed – north or south of the entrance to the Belongil estuary.
Seawall + Nourishment + Groynes	Yes	No specific benefits identified	Yes	× Nourishment believed to be economically unviable × Questions re source of sand	2 groups identified this as not reasonable, 2 groups as reasonable; low net support.
Nourishment + Groynes	Yes	No specific benefits identified	Yes	× Nourishment believed to be economically unviable × Questions re source of sand	Generally undecided and a low level of support (2 tables not reasonable), no rationale for reasonable.
Nourishment + End Control + Emergent Offshore Breakwaters	Yes	No specific benefits identified	Yes	× Nourishment believed to be economically unviable × Questions re source of sand × Affect surfing amenity	Low net level of support (3 tables not reasonable), 2 groups reasonable.
Nourishment + End Control + Submerged Reefs	Yes	Reef creates potential marine habitat diversity Should be cheaper than planned retreat	Yes	× Nourishment believed to be economically unviable × Questions re source of sand × Affect surfing amenity × Reefs have too high risk of being ineffective	Low net level of support (2 tables not reasonable), 3 tables reasonable.

Three additional coastal protection options were identified by one or two tables:

- Keep the existing sea wall (maintain status quo): This was proposed as a way to stabilise Council land and access points, if maintained. However, this option would also maintain the existing problems associated with an under-designed sea wall.

- Seawall with nourishment, but no end control: This was proposed as a way to stage the protection process and provide permanent access. However, this option does not consider the costs of along shore loss of nourished sand.

- Retreat with nourishment. This was proposed as a way to allow the community to adapt as well as land owners. This option seems counter intuitive as the general rationale for retreat is that it would allow a sandy beach to be maintained.

3.4 Key Messages from the Workshop

The conversations at the workshop were constructive and valuable. Participants noted that they had learnt something about the perspective and rationale of others and in some cases had to reconsider their assumptions.

Importantly, stakeholders with different perspectives were willing to listen to each other and look for solutions which meet shared objectives/values.

Some factors which arose from the discussion and could be followed up in further consultation about reasonable options include:

- A willingness to share costs if benefits are also shared. Landholders whose property is affected by immediate and mid-term coastal erosion hazard indicated a willingness to pay for coastal protection works for their property. They do not expect Council to pay for these works.
- In this mixed group of stakeholders, Planned Retreat of part of the Byron community/township was not favoured, primarily because of social and economic factors. Concerns from some people that Belongil land owners were over-represented at the workshop are acknowledged. However, it was noted at the workshop that as there are limited hazard issues affecting Wategos and Clarkes Beach and Council is making a decision about protection works for Main Beach separately to the CZMP process, so the key beach where there are high risk issues to be resolved is Belongil Beach.
- Participants favoured a whole of embayment solution, one that makes sense and is equitable for all beaches and residents in the embayment.
- There was strong support for flexible combinations of options. Adaptive pathways were viewed positively. This is consistent with views expressed in response to the survey that a clear policy and planning framework with steps to take if risks increase over time, and triggers for changing approach in response to risk, would be a useful part of any future coastal hazard management plan.
- After some discussion, the participants agreed that not all beaches within the embayment have to provide all values, all the time.
- Participants considered that Council should look for ways to design/manage coastal planning and protection works to maintain multiple community values (social and ecological). Reference was made to the proposed designs for sea walls at Old Bar, which feature a shared pathway along the crest of the wall, so along-beach physical and visual access is maintained.
- Costs and benefits of all options need detailed scrutiny and testing of assumptions. Economic issues are important but not the only factor in getting the best outcome for the community.
- The consequences of implementing most options are relative unknowns or are uncertain for residents. Good case studies to demonstrate how reasonable outcomes can be achieved would be useful. For instance, participants were not clear about how the various protection and retreat options would affect the health of the Belongil Creek estuary and felt that they did not have sufficient information to rank the impacts of different approaches. Comments indicated that the full process and consequences of planned retreat are not well understood. Similarly, the potential to design a coastal protection structure to minimise scour potential and to provide for ongoing access was not well understood.

4.0 Written Submissions

4.1 Overview

Community members were invited to lodge submissions detailing their thoughts about the way the coast is managed now and potential options for coastal zone management in the BBE in the future.

The invitation to submit detailed comments was promoted via Byron Council website (with the community survey), media releases and in letters to potential participants in the workshop.

Twenty five (25) submissions were received: 20 from individuals and five (5) from stakeholder groups. As for the survey, the comments received in the written submissions do not comprise a statistical sample of the Byron Bay community or those who use the beaches of the Byron Bay Embayment. The submissions do, however, elaborate in some detail on the range of views that have been publically expressed about the challenges of managing the BBE coastline for some time.

Information about the issues raised in each submission is in **Appendix 7**.

4.2 Issues Raised in Submissions

Table 4.1 outlines the comments made in the submissions. The table is organised by key themes identified across all submissions.

None of the people who made written submissions explicitly stated their assumptions, but several important assumptions are implied in their comments. These assumptions require careful consideration. They include:

- Among those promoting planned retreat, an assumption that costs would accrue unfairly to Council and/or other members of the community who would not directly benefit from coastal protection works. A related assumption that landholders would require Council (or State government) to pay for the construction and maintenance of protection works.
- Among those opposed to planned retreat an assumption of land holder rights to protect private property from natural events.
- An assumption that the existing protection works at Jonson St are creating, or at least exacerbating, the erosion along the full length (many kilometres) of Belongil Beach.
- An assumption that coastal protection structures inevitably drive beach erosion all of the time (so there is never any beach in front of them), and that no design can deliver some public benefits as well as private benefits.
- An assumption that a planned retreat decision would result in extended, expensive legal cases for compensation.
- An assumption that all sand sources for beach nourishment will require extraction in the Marine Pak and be extremely high cost.
- An assumption that existing NSW policy and legislation does not support construction of coastal protection works.

Table 4.1 – Content and Highlights of Written Submissions

Theme	Comments
Planned retreat	**Opposed to planned retreat (19 submissions)** Long term loss/destruction of public infrastructure, such as roads, bridges, railways and sewers. Loss of private property and property rights. Loss of publicly owned land, including public parks. Environmental impact and risks to Belongil Spit, Estuary, Wetlands and the rainforest on the north of Belongil Creek. Legal consequences, including significant compensation claims from landholders whose property is affected. Increased flooding in town due to merger of ocean and Belongil Creek. High ‘social costs’, ‘social upheaval’ and ‘destruction of communities’. Too much intervention along the coast has occurred over the years to make planned retreat a viable option. Previous community support has not been for planned retreat. **Supports planned retreat (3 submissions)** Inapplicability of legal landowner rights. Legislated responsibility and ‘good faith’ principle. Potential for loss of beaches and ‘the commons’. Impact to existing natural environment, should avoid more rockwalls changing sandy beach to rock. Opportunity for new or different community assets. High costs and likely ‘futile’ effort of protection works, particularly with beach nourishment. Interim protection works will cause more beach erosion, impinging on community access rights (as per Coastal Policy).
‘Whole of beach’ approach	Need for a solution that is equitable and brings equilibrium back to coast to benefit all stakeholder groups. Need for a solution that considers and addresses impacts of existing beach structures, such as Jonson Street.
Public access	Important to maintain public access to the coast. Tourists and locals require access for a range of recreational activities. Need for safe shared space for bathers and boats, including additional resource to manage this. Emergency services require access to the beach. Not allowing landholders to maintain protective structures compromises the safety of the sea wall, with potential impacts on the safety of beach users. Existing rock walls are not significantly constraining public access along the beach, which is available most of the time. A future board walk or shared path along the crest of a sea wall would be possible (and is included in sea wall designs elsewhere). Council’s priority should be to maintain safe public access points.

Theme	Comments
Landholder interests	**Opposes planned retreat (19 submissions)** Landholders face specific erosion threats compared to other stakeholder groups. Landholders have a legal and moral right to protect their homes, investments and livelihood. **Supports planned retreat (3 submissions)** There is no legal foundation for landholder rights in this instance. Landholder legal rights cannot be the basis for repealing 'planned retreat'. **Broader community opinion should be sought** Specific consultation with Aboriginal community and with Marine Parks (Marine Estate Management Authority).
Existing protective works	Existing walls are currently protecting properties – it does not make sense to remove them. Existing walls provide opportunities and efficiencies to build on – let owners repair and maintain. Existing walls do not produce any negative effects on the Spit, and actually maintains it in position and improves habitat diversity for birds – no ecological, biodiversity or conservation reason to oppose maintenance of sea walls. Existing sea walls need to be maintained to manage public safety Jonson St structure has had an effect on 'many kilometres' along Belongil Beach and is now affecting north of Belongil Creek (see also discussion at the Stakeholder Workshop).
Ecology and habitat	The configuration of the existing sea wall does not produce impacts on the Spit – no reason to oppose maintenance of sea walls. The current lack of protection risks erosion of the Spit, Estuary and Wetlands and risks rainforest at north of Belongil Creek. The configuration of the Byron Bay Embayment beaches makes no difference to marine diversity or the marine park. Bird life is subject to a range of risks such as dogs and cats (end of Belongil Spit) and 4wd drive vehicles (Seven Mile Beach). There is high recreational value linked with maintaining the natural values of Belongil Creek, e.g. walking, paddling, swimming, etc.
Short term events	Identification of higher risk associated with short term weather events rather than long term climate processes such as sea level rise and climate change.
Hybrids	Supports hybrid option (9 submissions). Hybrids, in some form, offer best solution. Solution is to protect properties, nourish beach, complete existing rockwalls and use structure at creek mouth to trap sand similar to Jonson Street. Most common hybrid option comprised a sea wall at Belongil and Jonson St + end control structure + nourishment as required. Possibility of staged nourishment.
Need for further consultation	Several submissions noted the value of a more inclusive consultation strategy with more face to face events and more opportunities for people across the town and the local government area to express an opinion about potential coastal hazard management options.

4.3 Key Messages from the Written Submissions

A Solution for a Coastal Town – Protect Access and Amenity, Equitable Solution for All Citizens

The theme emerging most strongly across submissions was the need to find a cost-effective solution which would balance the protection of public beaches and maintenance of public access, whilst also protecting public and private property and assets. The submissions reiterated some themes from the survey and workshop, such as:

- The need to work with nature but also acknowledge the history of existing development and community in the embayment. This is consistent with Coastal Management Principles 3 (involve community) and 8 (protect ecological value).

- The value of a staged approach, involving a hybrid of protection options, which could be adapted over time. This is consistent with Coastal Management Principles 6 (risk focus) and 7 (adaptive planning), as well as the long term benefit part of Principle 5.

- A consistent approach for the whole embayment, particularly applying robust logic to decisions for both Main Beach and Belongil Beach. Residents opposed to Planned Retreat expressed the view that it was not fair that to date Council had taken the view that it would protect (and allow protection of) assets at Main Beach, but not those at Belongil, even if costs were shared. This is consistent with Coastal Management Principles 2 (plan alignment), 4 (use best knowledge) and 5 (long term, public benefit).

- Some written submissions commented that Council should not move away from its previously stated planned retreat policy and also suggested that the rationale for and practicalities of planned retreat were not discussed in sufficient detail at the workshop. Further information about a case study in implementing planned retreat is in **Appendix 1**.

- Management choices should maintain the reputation of the Byron Bay Embayment as a place of natural beauty which provides outstanding beach recreation opportunities for locals and visitors. This is an important aspect of Council's Community Strategic Plan and consistent with Coastal Management Principle 2.

- Implications of all options for public safety need to be further explored (Coastal Management Principle 9).

The written submissions also highlighted some important governance issues. Compliance with Coastal Management Principle 1 requires that the coastal hazard management approach is consistent with NSW legislation and policy. Several submissions highlighted long standing and as-yet largely unresolved matters about the application of the Coastal Protection Act, Local Government Acct and Coastal Policy. There is clearly wide ranging debate about how Council should demonstrate good faith and the balance between public and private rights on a receding coastline.

5.0 Councillor Workshop

This section reports only on the first of three proposed Councillor briefings and workshops that occurred during the preparation of the Coastal Hazard Management Study.

Six Councillors participated in the Stakeholder Workshop in February 2014. Nine Councillors participated in a separate briefing and discussion in March 2014. Relevant Council staff with coastal responsibilities also participated in this briefing and discussion, as did a representative from OEH.

The aim of this briefing and discussion was to select a short list of coastal hazard management options for the Byron Bay Embayment to be subject to detailed benefit and cost analysis.

The briefing component of the session included presentations from the consultant team on the outcomes of studies and activities completed to date:

- technical feasibility review (WRL);
- preliminary (desktop) consideration of reasonableness (WRL);
- results of the survey and how this information is being used (Umwelt);
- outcomes from the Stakeholder Workshop (Umwelt); and
- comments made in written submissions (Umwelt).

The workshop featured extensive constructive discussion of the project method (technical review and community input) and how the various lines of evidence from the community could best inform the remaining stages of the project. It was confirmed that there will be further opportunities for the community to engage in the decision making process before the draft Coastal Zone Management Plan is submitted to OEH and the Minister for approval.

The final component of the Councillor Workshop was a voting process. Ten feasible management responses were grouped in two broad categories (see below), with and without beach nourishment. This was done because Councillors recognised the legislative impediments to beach nourishment and funding issues, leading to ongoing uncertainty about the implementation of broad scale beach nourishment programs, involving offshore sand sources in NSW, particularly where the and is located in a marine reserve. Government support for approval for offshore sand extraction for beach nourishment is currently uncertain. This would need to be assessed on a case by case basis. The NSW Government has previously approved, for example, sand nourishment programs including Jimmy's Beach and dredging of Port Hacking and placement offshore Cronulla Beach. The Tweed River Sand Bypassing project has also been approved and paid for by the NSW Government. However several projects commissioned for coastal councils (including WBM 2010 at Byron Bay and Sydney Coastal Councils Group 2009 for beaches along the Sydney coastline) have demonstrated that use of offshore sand for beach nourishment could be feasible in certain circumstances. It is understood that policy discussion are continuing.

Beach profile restoration utilising sand from within the coastal compartment has been approved an implemented in some localities. Examples include sand dredged from Port Hacking being placed in the nearshore of Cronulla Beach, sand dredged from the mouth of the Myall River being placed on Jimmys Beach and sand dredged from Swansea Channel being placed on Blacksmiths Beach.

Councillors considered:

Group 1 – Options Involving Beach Nourishment

- Sea wall (resigned and completed) + nourishment + end control (single groyne, at northern end of beach).
- Sea wall + nourishment + multiple groynes, spaced along the beach to create several small compartments.
- Nourishment + multiple groynes.
- Nourishment + end control (single groyne).

Group 2 – Options without Beach Nourishment

- Multiple groynes.
- Sea wall (redesigned and completed).
- Planned retreat, public (i.e. retreat cost met by Council/State government). Planned retreat includes both planning controls for new development and forced removal of existing development when trigger conditions are met.
- Planned retreat, private (i.e. retreat costs met by private land holders).
- Planned retreat Public/Private (retreat costs shared).
- Sea wall + end control (single groyne), without nourishment.

Further information about the technical details of these options is presented in the Coastal Hazard Management Study.

Workshop participants were given three votes which they could allocate in any way they chose in Group 1 and a further three votes to allocate in any way in Group 2. This process resulted in clear choices of two options to be referred for detailed benefit and cost analysis in each group. The results are summarised in **Table 5.1**.

Table 5.1 – Coastal Hazard Management Options for Detailed Benefit and Cost Analysis

Option	Votes	Proceed to Detailed Benefit Cost Analysis
Options with Beach Nourishment		
Sea wall + nourishment + end control	21	Yes
Sea wall + nourishment + multiple groynes	7	Yes
Nourishment + groynes	2	No
Nourishment + end control	5	No
Options without Beach Nourishment		
Groynes	0	No
Sea wall	4	No
Retreat Public/Private (i.e. shared costs)	16	Yes
Retreat Public	2	No
Retreat Private	0	No

Sea wall + end control	11	Yes

6.0 Synthesis and Summary

As set out in **Section 1.2.1**, 'reasonableness' is described in the NSW Guidelines for Preparing Coastal Zone Management Plans as taking into consideration:

- the NSW Coastal Management Principles, objects of the *Coastal Protection Act 1979* and NSW Coastal Policy 1997;
- social, environmental and economic impacts, benefits and costs; and
- the views of the community and other stakeholders.

The Guidelines do not provide advice about the weighting to be given to these three primary criteria, other than the expectation that a reasonable option or response pathway will achieve **a balanced approach** in the context of potential environmental, social and economic costs, impacts and benefits. Not specifically stated, but implied in a 'balanced approach' for social environmental and economic values is that there is some equitable solution for communities affected by coastal erosion and recession along the NSW coast.

This section draws together the evidence from the four lines of inquiry (survey, stakeholder workshop, written submissions and Councillor Workshop) used in the management study to identify potential management approaches that are:

- Considered to be **reasonable** from the outcome of all four lines of inquiry. These options will be included in the cost benefit analysis which is the next stage of the project.
- Considered to be **not reasonable** from the outcome of the four lines of inquiry. These options will not be considered in the cost benefit analysis which is the next stage of the project.
- Considered to be reasonable in some parts of the evaluation process, but unreasonable in other parts. This section includes further analysis and evaluation of these unresolved management actions, to identify a justifiable selection that will be included in the short list for cost benefit analysis.

This section also includes some additional background and short case studies from the literature on coastal zone management to help resolve reasonable coastal hazard management options for the Byron Bay Embayment. In particular, further information is presented about the application of the full suite of Coastal Zone Management Principles and reasonableness criteria (from NSW Guidelines) to the possible management options for the embayment.

Discussion at the workshop and in some submissions raised the concept of equity (in the sense of fairness and consistency) as a potential criterion for evaluating coastal hazard and risk management options. Equity is not a specific criterion identified in the NSW Guidelines, but can be seen to be part of the social assessment and sustainability assessment of potential management options.

6.1 Alignment and Differences

Table 6.1 draws together the results of the three broader engagement processes, showing consistent and divergent themes. These which are related are shown in the same colour text across the three consultation opportunities. This information was considered by the Councillors in identifying options for more detailed benefit cost analysis.

There are several factors which received strong support or strong negative responses across all three consultation activities. Some matters were highlighted in only one activity (and are not shown in coloured text in **Table 6.1**), but this is in part due the slightly different focus and positioning of the discussion. There are no 'drop dead' inconsistencies between the key messages from each of the three consultation activities.

Table 6.1 – Alignment of Findings from Different Strands of Consultation

Survey – Strong Positive Views	Workshop – Strong Positive Views	Submissions – Strong Positive Views
• Overwhelming support for maintaining a healthy ocean environment, with clean water and lots of marine species. • Strong support for maintaining safe access to and along at least one sandy beach, for a wide range of people. • The important contribution that the combination of natural beauty, safe access and beach amenity makes to the economy of Byron Bay, by attracting visitors, as well as supporting the lifestyle of local people. • The coastal landscape is a dynamic and changing place, with many moods and varying condition. • Management options should give priority to protecting beach amenity and the beauty of the coastline. • Beach visual and recreational amenity (sandy beach landscape, with rocky headlands) should be maintained. • Robust monitoring and reporting of coastal condition is essential (Coastal Zone Management Principle 3). • Community involvement in coastal management processes and activities is important (Coastal Zone Management Principle 3). • Clear policy and planning guidance for landholders, including clear processes, triggers and timeframes for how/when coastal management strategies will change would be well received (Coastal Zone Management Principles 3, 4, 6 and 7).	• A visually attractive, accessible coastline is valued by everyone as part of the lifestyle of the area. • A willingness to share costs if benefits are also shared. Landholders whose property is affected by immediate and mid-term coastal erosion hazard indicated a willingness to pay for coastal protection works for their property. They do not expect Council to pay for these works. • The State government should make a significant contribution to the management of coastal hazards at Byron Bay Embayment. • Participants favoured a whole of embayment solution, one that makes sense and is equitable for all beaches and residents in the embayment. • There was strong support for flexible combinations of options (such as sea wall, plus nourishment, plus end control structure). Adaptive pathways were viewed positively (Coastal Zone Management Principles 6 and 7). • Not all beaches within the embayment have to provide all values, all the time. • Participants considered that Council should look for ways to design/manage coastal planning and protection works to maintain multiple community values (social and ecological) (Coastal Zone Management Principles 4, 8, 9). • Costs and benefits of all options need detailed scrutiny and testing of assumptions. Economic issues are important but not the only factor in getting the best outcome for the community.	• The need to work with nature but also acknowledge the history of existing development and community in the embayment. • The value of a staged approach, involving a hybrid of protection options, which could be adapted over time (Coastal Zone Management Principles 6 and 7). • A consistent approach for the whole embayment, particularly applying robust logic to decisions for both Main Beach and Belongil Beach. • Council should not move away from its previously stated planned retreat policy. • Management choices should maintain the reputation of the Byron Bay Embayment as a place of natural beauty which provides outstanding beach recreation opportunities for locals and visitors (Coastal Zone Management Principles 8, 9 and 10). • Implications of all options for public safety need to be further explored.

Survey – Strong Positive Views	Workshop – Strong Positive Views	Submissions – Strong Positive Views
• Existing 'temporary' protection works for public access ways and public land should be maintained until appropriate permanent protection works can be established. • Private landholders should be able to maintain private protection works, and potentially construct more permanent protection works, but the broader community and Council are not responsible for costs. • Existing development in coastal hazard areas should be allowed to continue, but no new development that increases risk should be allowed in high hazard areas (100 year hazard lines). • The State government should make a significant contribution to the cost of coastal zone management in this locality (Coastal Zone Management Principle 5). • Private landholders should take responsibility for their decision to locate in coastal hazard zones.	• Solutions should consider benefit and impacts on the open coast but also on sensitive habitats and assets in the Belongil Creek estuary (Coastal Zone Management Principles 4, 8).	
Survey – strong disagreement	**Workshop – strong negative views**	**Submissions – strong disagreement**
• Coastal protection works should be installed regardless of the detriment to beach amenity, which underpins the local economy. • The cost of protection of private property should be shared across the community with a rate levy. • Council should be responsible for buy back of private coastal properties affected by coastal hazards. • If beach nourishment is needed to maintain a sandy beach landscape, it should not come from within the marine park.	• In this mixed group of stakeholders, Planned Retreat of part of the Byron community/township was not favoured, primarily because of social and economic factors. • The consequences of most options are relative unknowns/uncertain for residents and they do not understand the consequences of implementation of key management options.	• Submissions opposed to Planned Retreat expressed the view that it was not fair that to date Council had taken the view that it would protect (and allow protection of) assets at Main Beach, but not those at Belongil, even if costs were shared. • Submissions in favour of planned retreat at Belongil Beach expressed a strong view that no-one could be in any doubt about Council's position, since 1988. Affected landholders do not accept this position (and certainly do not accept the DCP as the only relevant instrument).

6.2 Other Factors to be Considered

The matters raised by stakeholders and residents during this consultation process do not use the same terminology as the ten Coastal Zone Management Principles, but respondents and participants did refer to similar concepts, particularly in relation to knowledge, risk and adaptive management, as well as the integration of estuary and open coast components of the coastal zone when making decisions about future coastal zone management. Much of the discussion also addressed 'reasonable practice' without actually using those words.

There were comments at each stage of the consultation process that community stakeholders do not have a good grasp of the science, social science and policy implications/challenges of coastal zone management, and would like to have a higher capacity to contribute to the discussion in an informed manner. Issues noted included the impact of open coast management practices on the health of the Belongil Creek estuary; appropriate trigger points for service provision to residences and businesses at Belongil Beach; design options that could achieve multiple objectives; (un)safe egress for people during high storm conditions as a trigger for planned retreat.

Some aspects of reasonable practice are noted in **Appendix 1**, including discussion of public and private equity concepts in coastal zone management and a case study of implementation of a planned retreat approach (in California). This information illustrates some of the matters which need to be addressed (and of which the community needs to have knowledge in order to make an informed decision about risks).

6.2.1.1 Equity issues

Some written submissions in the current project and discussion at the Stakeholder Workshop suggested that 'equity' is a matter to be taken into consideration when evaluating potential coastal risk management options for Byron Bay Embayment. The following points were made:

- Landholders argued at the Stakeholder Workshop that equity issues arise when a council builds coastal protection works to protect public land and built assets, but does not permit private landholders to build coastal protection works to protect private land and built assets in the same embayment. In the case of the Byron Bay Embayment this is an argument as to whether it is reasonable for Council to build a sea wall and/or other protection structures at Main Beach, but not allow private protection at Belongil Beach. The argument is presented regardless of whether the works at Main Beach could increase the risk of erosion for properties at Belongil Beach.

- Landholders also argued at the Stakeholder Workshop that the equity issues related to local government paying for coastal protection works on private land (as opposed to public land) would not arise as individual private landowners were willing to pay for the works needed to protect their property.

- Submissions argued that equity issues (unfair treatment of private landholders affected by Council's planned retreat policies) do not apply to those landholders who have purchased beach front property since 1988, since the planned retreat provisions (Section J of the DCP) have been in place since that time and s149 certificates have advised property owners of the constraints applying to their land.

6.2.1.2 Planned Retreat at Byron Bay

The concept of Planned Retreat has been widely discussed in Byron Shire. Although the general concept is understood in the community, the details of how it would be implemented and how social, environmental and economic implications would be dealt with are less well understood.

The approach is consistent with widespread community views and Council's position in its Community Strategic Plan that a natural coastline, where natural coastal processes operate, is highly valued. The planned retreat approach is also aimed at limiting the financial liability of the Shire's residents, from private property impacted by coastal hazards and is based on a 'buyer beware' philosophy. Ongoing public access to and along the coast is assumed to be facilitated by planned retreat (removal of structures), as is recovery of ecological connectivity and biodiversity.

Council's publicly available information on Planned Retreat, as available in the 2010 draft Coastline Management Plan (on Council's web site) notes the following points:

- Planned retreat allows temporary use of land (which previously had 'permanent' use rights, revoked).
- Trigger points based on the proximity of the coastal erosion escarpment to different types of development set the timing of retreat. It is aimed at maintaining a 20 metre development free buffer along the coast.
- Planned retreat reduces risks to coastal development and infrastructure by requiring that they are removed before they are directly impacted.
- It is intended to maintain public access and beach amenity.

The 2010 Plan was subsequently withdrawn and Council currently has no preferred position.

6.3 The Short List

Council's Resolution 13-21 (Part 2) in which it determined to prepare a new coastline management study required all options to be on the table:

> 2. That the management options evaluation stage of preparing the draft Coastal Zone Management Plan for the Byron Bay Embayment will include consideration of a range of potential actions to manage the risks from coastal hazards, including but not limited to: building and infrastructure set-backs (planning and development controls), coastal protection works (short term or long term), beach nourishment and emergency management, as detailed in table 3 of the statutory 'Guidelines for Preparing Coastal Zone Management Plans (DECCW 2010).

The consultation process for the management study has considered community's views about the feasibility and reasonableness of various coastal zone management options, based on the technical and contextual information available. Council proposes further consultation with the community during the preparation of the Coastal Zone Management Plan and as more information about the likely costs and benefits of management options becomes available.

As noted in **Section 5.0**, the short list of potential management responses – those considered to be both feasible and reasonable based on the community consultation conducted during the management study and consideration by Councillors is:

Short list of feasible and reasonable management options

Sea wall + nourishment + end control
Sea wall + end control, without nourishment
Sea wall + nourishment + multiple groynes
Retreat Public/Private (i.e. shared costs)

These options were subsequently the subject of detailed benefit and cost analysis.

7.0 References

Australian Coastal Society, 2013. Coastal Reforms Working Group.

BMT WBM, 2010. Draft Coastline Management Plan for Byron Shire Coastline

BMT WBM, 2013. Coastal Hazard Study for the Byron Bay Embayment.

Byron Shire Council, 2006. Community Profile (as updated, with data current to 2010).

Byron Shire Council, 2012. Community Strategic Plan 2012-2022.

Byron Shire Council, 2000. Coastal Values Study.

DECCW 2010. NSW Guidelines for Preparing Coastal Zone Management Plans.

Gordon, Lord and Nielsen, 2013. NSW Coastal Protection Act, 2013. A disaster waiting to happen (Paper presented at the NSW Coastal Conference 2013).

OEH 2013. NSW Guidelines for Preparing Coastal Zone Management Plans.

.
NSW Government (Department of Planning), 1997. NSW Coastal Policy.

Svikis and Lofthouse, 2011. Planned retreat options: Are we eroding values and accreting liability for property owners? Paper presented at NSW Coastal Conference.

APPENDIX 1

Background on specific coastal principles and strategies

APPENDIX 1

BACKGROUND INFORMATION RELATING TO COASTAL PRINCIPLES AND MANAGEMENT CONCEPTS

1.0 The Role of Private and Public 'Equity' in Decision Making

There has been considerable debate during consultation to date about the rights of private and public land owners/broader community and the equity of coastal zone management options that limit the opportunities available to coastal property owners or the general public.

Table 2.1 of the main text of this report summarises the objectives of the *Coastal Protection Act 1979* and the NSW Coastal Principles as set out in the Guidelines. These sets of objectives are broadly aligned with each other and highlight the protection of key coastal zone values, such as biodiversity, aesthetics, recreational use and amenity, cultural heritage as key aspects of coastal zone management. These are all values broadly in the public domain, although they may also have specific application to individual properties. The previously adopted coastal zone management objectives (Byron Bay Coastline Management Plan 2010) also refer to coastal development.

In relation to 'development' of coastal land, the objectives identify:

- *To provide for ecologically sustainable human settlement in coastal zones* (draft Byron CMP 2010) (note that 'sustainable' is not defined here and can be taken to imply various balances between social, environmental, public and private economic benefit, now and in the long term).

- *To encourage, promote and secure the orderly and balanced utilisation and conservation of the coastal region and its natural and man-made resources, having regard to the principles of ecologically sustainable development*. (*Coastal Protection Act 1979*).

  Intergenerational equity is one of the principles of ecological sustainable development, but it makes no specific reference to equity now.

The Coastal Principles do not specifically identify coastal development (and particularly existing coastal development) as a matter to be considered in coastal zone management planning.

None of these objectives or principles specifically refer to 'equity' as a principle that should be applied to decisions about coastal zone management. To date, none of the coastal management instruments, including the products of recent coastal reforms, deal effectively with existing development that has been constructed over more than 30 years of 'sea change' coastal growth and decades of holiday development before that.

The Coastal Principles do broadly reference equity in Principle 5:

- *The priority for public expenditure is public benefit; it should achieve cost effective, practical, long term outcomes.*

This principle hints at intergenerational equity and clearly states that local and state government will not give priority to investment in coastal management measures that are only for the benefit of private landholders/individuals.

'Equity' is a consideration raised in several recent analyses and commentaries on the challenges of coastal zone management, particularly where existing private development is affected. Examples and brief context are noted in **Table 1**. These are not intended to be a comprehensive review of the treatment of 'equity' in coastal zone management, but to demonstrate that there is a range of perspectives on what is and is not equitable, and who is affected.

Table 1 – Equity Considerations in Coastal Management

Reference	Comments
Gordon, Lord and Nielsen 2013 NSW Coastal Protection Act – A disaster waiting to happen (Paper presented at the NSW Coastal Conference 2013)	Shift of liability from State government to local government and individuals in recent reforms to coastal planning and management instruments. No process to resolve the conflict between public and private rights. Equity issues around the potential application of coastal management levies – e.g. in relation to properties which already have some form of coastal protection structure. Inappropriate balance between 'emergency management' and long term management of coastal erosion and recession in hot spot areas (including Byron Bay Embayment) where coastal recession trends have been clear for many years. The authors suggest a change from freehold to leasehold as one way of managing property rights in an equitable and orderly manner.
Australian Coastal Society, Coastal Reforms Working Group 2013	The Coastal Protection act needs to balance the sustainability of the natural coastal environment in a time of uncertain future climate, the general public's right access and enjoy the amenity of the coast and the ability to manage both past and future coastal development. Equity and safety/sustainability issues around construction of 'temporary works' above MHWM, which with recession will fall below MHWM and cease to be 'real property'. Similarly, concerns about liability for piecemeal temporary protection works which may affect erosion on adjoin parcels of land (public or private). Successive governments have failed to take into account: • there is no fundamental legal right to defend an individual property against the sea; • attempts at protection works by individual property owners rather than integrated embayment scale management will result in ad hoc works which will fail and adversely affect others;

Reference	Comments
	• land below MHWM ceases to be 'real property, so not owned by any individual'; and • no compensation is payable by the State Government for loss of land to the sea.
Svikis and Lofthouse 2011 Planned retreat options: Are we eroding values and accreting liability for property owners? Paper presented at NSW Coastal Conference	Tweed Council has a DCP which is in effect a planned retreat strategy for new development. The only built assets in immediate hazard zones are public assets but there are multiple properties in the 2050 hazard zone. However, concern has been expressed by some residents (those in the 'front line' of coastal erosion and recession that they are bearing the full economic impact of processes which should in their opinion, by shared more broadly across the community. These concerns relate to equity and primarily to: • depreciation of property values, loss of development certainty; • cost of coastal risk management (for private property), affected by hazards at some time in the future; and • the balance and timing of planned retreat when hard engineering solutions may be available to the medium term. The authors suggest there are some equity issues around land acquisition, particularly when some properties may need to be acquired to maintain public access to a receding coast (which is a principle of the Guidelines, Policy and Coastal Protection Act).

2.0 The Rationale for Planned Coastal Retreat

Byron Shire has had a local planning requirement, through Section J of its DCP, which directs retreat of development in areas affected by coastal hazards (erosion and recession), since 1988. The draft Byron Bay Coastline Management Plan (2010), which was subsequently withdrawn, also proposed a planned retreat approach as the primary coastal management strategy for Belongil Beach. At the same time, Council has adopted and confirmed a coastal protection approach, involving a sea wall, for Main Beach. The seawall 'protects' public assets – a car park, beach viewing area, swimming pool, surf club etc., but is not considered to impact on beach amenity.

Planned retreat has been employed at a number of Australian and international locations, but to date, it has not been widely adopted. The principal reasons for this include:

- resistance from residents where significant development has already occurred; and
- the cost of full removal of structures (including waste disposal) and restoration of natural dune forms.

2.1 Case Study in Planned Retreat

An example from the Pacifica Coast in California illustrates these costs and the challenges that need to be overcome to deliver planned retreat. The Pacifica Coast is a favoured surfing break and a coastal retreat strategy was promoted by the local Surfrider Group. As described on the website Ocean and Coastal Resource Management (USA Department of

Commerce) (http://coastalmanagement.noaa.gov/), the project had multiple components, to address hazards such as inundation and coastal erosion:

- Restore creek bank stability and habitat in the estuary and tidal wetlands to enhance fish habitat.
- Remove multiple vulnerable structures associated with homes and businesses.
- In 2002, the City Local government) partnered with the Nature Conservancy and Pacific Land Trust to purchase two homes are surrounding land at a cost of $2.2 million. These homes were demolished and all rubble removed. Another commercial business was removed later at additional cost. Rubble removal is likely to be a significant issue for Byron Bay, in implementing planned retreat, as some building materials will be classified as hazardous waste and significant waste management fees will be involved.
- 4000 cubic metres of sand was brought in to reshape dunes (where these two houses had been removed).
- Relocation of a bike path and public parking lot (cost $3.8 million).
- Removing rip rap at the dune face.
- Restoring beach habitat.
- Maintaining public access vehicle and pedestrian).
- Providing for ongoing beach nourishment to maintain amenity.
- Potential changes to water storage dames in the catchment to reduce threats to sand supply.

The project took more than ten years and cost millions of dollars. The case study commentary notes that it could only be achieved because of strong support from local government leaders and at grass roots level. The project partners had access to sufficient capital to buy threatened structures outright.

Whilst the scale of this project is of the same order as the challenge in the Byron Bay Embayment, access to funds to generate strong community support, especially among those directly affected, is very different. For instance, in the current context, there is also no access to sand for beach nourishment in the Byron Bay Embayment.

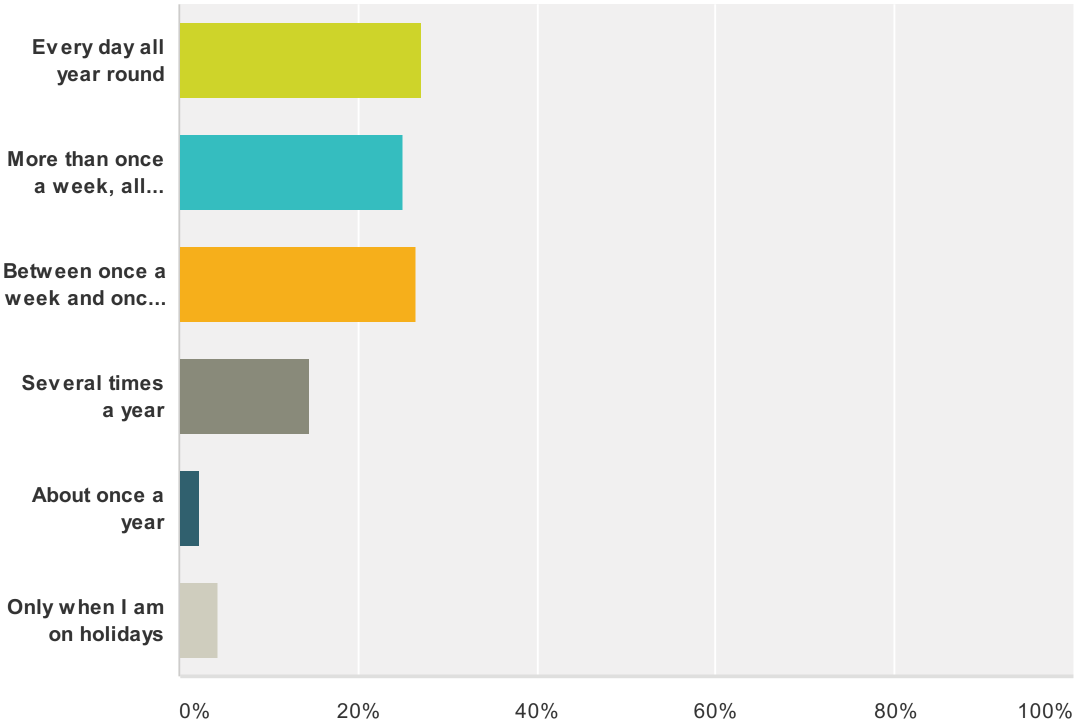
The feasibility component of the coastal hazard study provides a technical evaluation of the options that have been suggested by previous consultants and by the community for managing the coastal erosion and other hazards which affect the Byron Bay Embayment. The feasibility assessment has specifically addressed coastal protection options. The method, outcomes and rationale of the feasibility assessment were presented at the Stakeholder Workshop.

APPENDIX 2

Copy of community survey and responses

Q1 How often do you use one of the Byron Bay beaches?

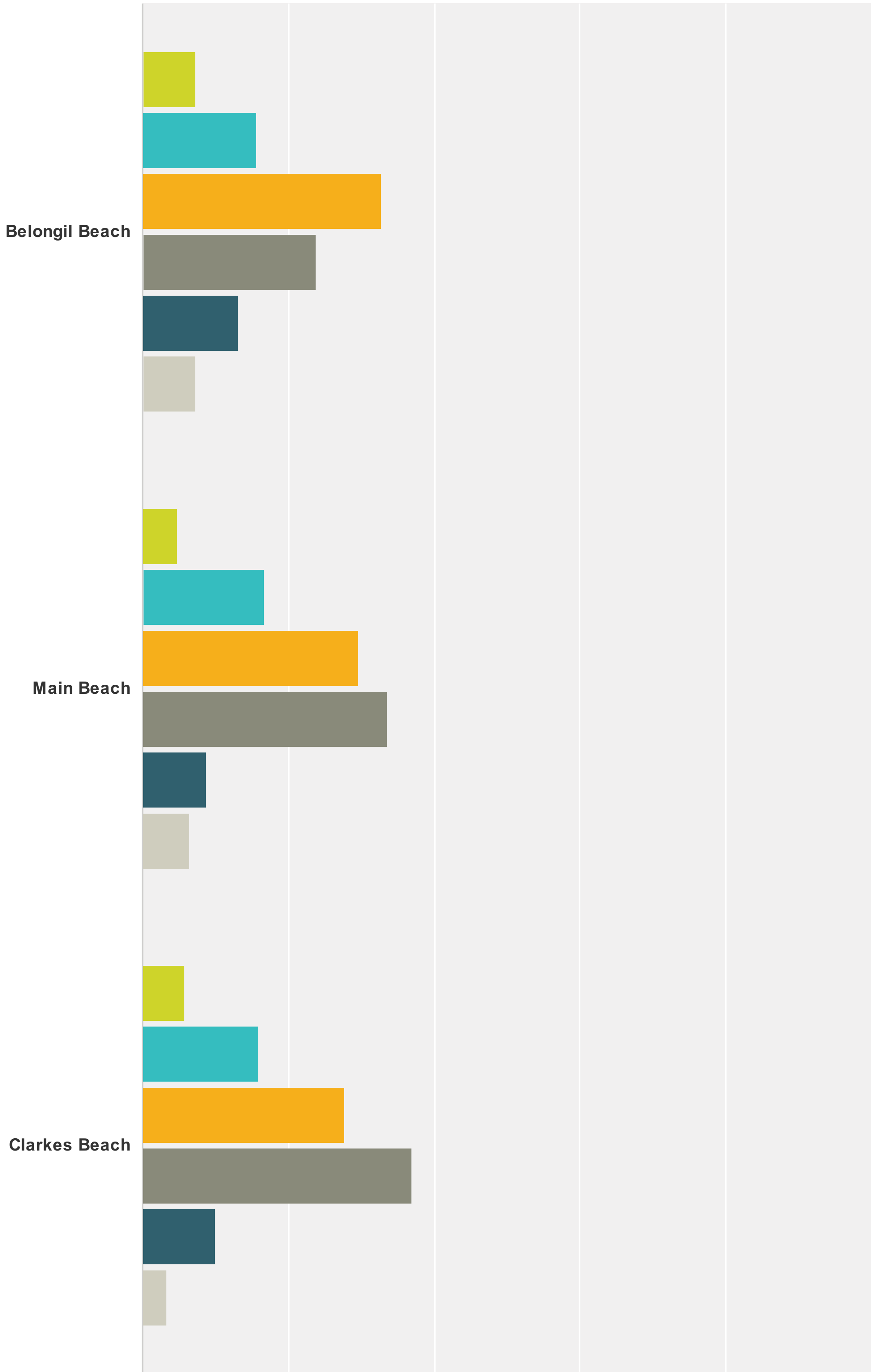
Answered: 136 Skipped: 6



Answer Choices	Responses	
Every day all year round	27.21%	37
More than once a week, all year round	25%	34
Between once a week and once a month, on average	26.47%	36
Several times a year	14.71%	20
About once a year	2.21%	3
Only when I am on holidays	4.41%	6
Total		136

Q2 Which of the Byron embayment beaches do you visit?

Answered: 135   Skipped: 7



Evaluating Options for Managing our Bay

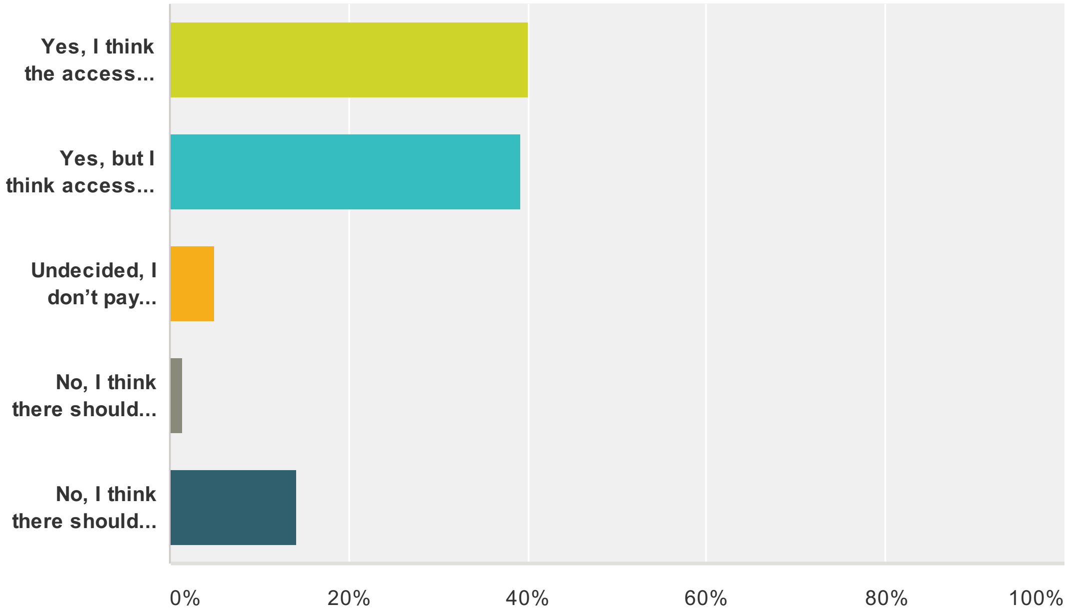
0% 20% 40% 60% 80% 100%

Never visit this beach | Visit rarely (no more than once a year) | Visit occasionally (about once a month) | Visit frequently (about weekly) | Visit daily (or more often) | I use the beach intensively in holidays, but rarely at other times

	Never visit this beach	Visit rarely (no more than once a year)	Visit occasionally (about once a month)	Visit frequently (about weekly)	Visit daily (or more often)	I use the beach intensively in holidays, but rarely at other times	Total
Belongil Beach	**7.38%** 9	**15.57%** 19	**32.79%** 40	**23.77%** 29	**13.11%** 16	**7.38%** 9	122
Main Beach	**4.80%** 6	**16.80%** 21	**29.60%** 37	**33.60%** 42	**8.80%** 11	**6.40%** 8	125
Clarkes Beach	**5.88%** 7	**15.97%** 19	**27.73%** 33	**36.97%** 44	**10.08%** 12	**3.36%** 4	119

Q3 Do you think the beach access arrangements at the beaches you visit are adequate in providing safe, ongoing access to the beach?

Answered: 140 Skipped: 2



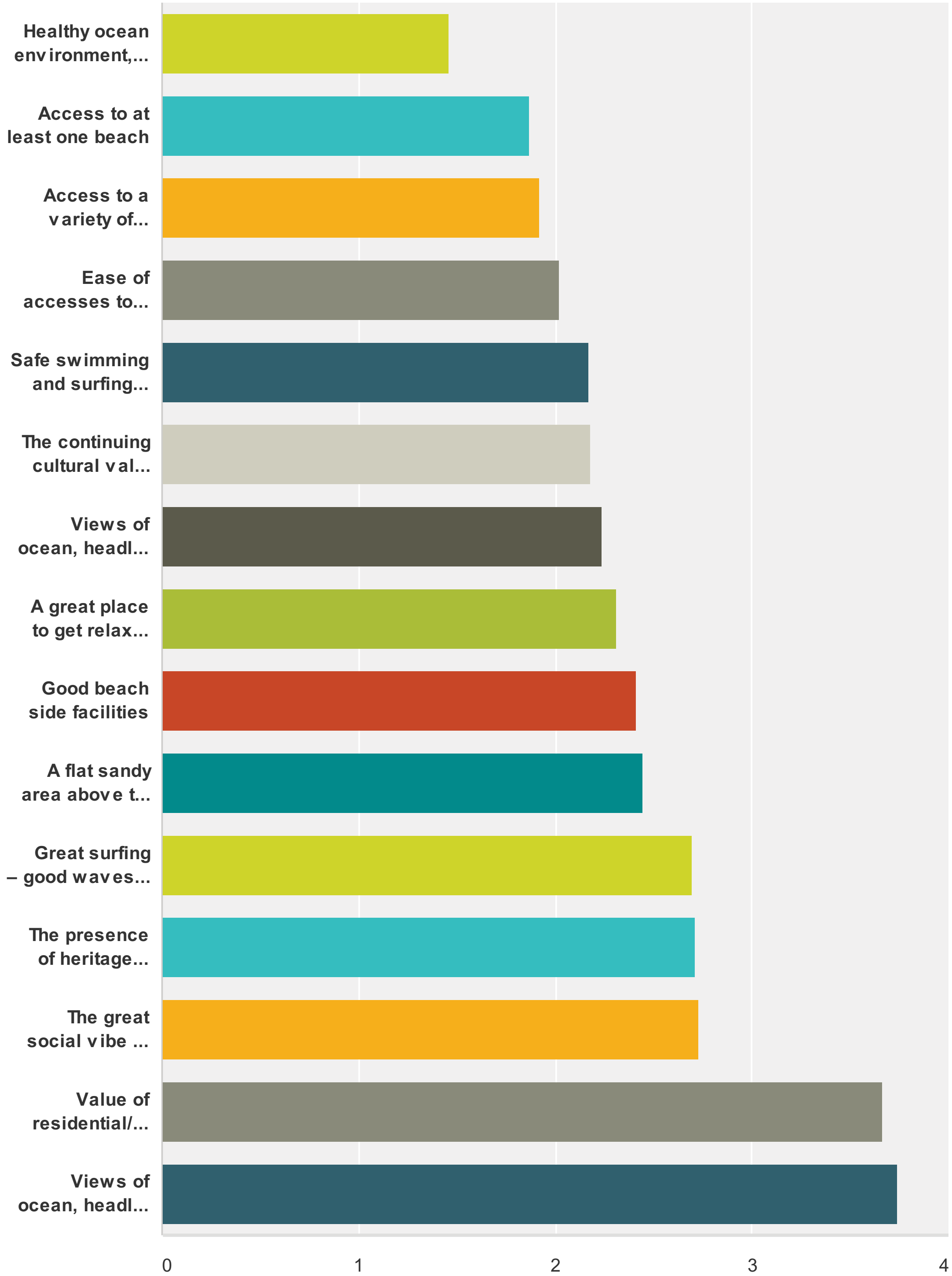
Answer Choices	Responses	
Yes, I think the access arrangements are good as they are	40%	56
Yes, but I think accesses need to be maintained more often by Council.	39.29%	55
Undecided, I don't pay attention to beach access arrangements.	5%	7
No, I think there should be less beach access available.	1.43%	2
No, I think there should be more beach access available.	14.29%	20
Total		**140**

Q4 If you think access arrangements are inadequate, please identify how you think Council should improve the beach access arrangements of the Byron Bay Embayment.

Answered: 17 Skipped: 125

Q5 What do you think are the most important features of the embayment of Byron Shire? Please select the five options from the following that are most important to you and number them in order from (1) most important to (5) least important.

Answered: 129 Skipped: 13



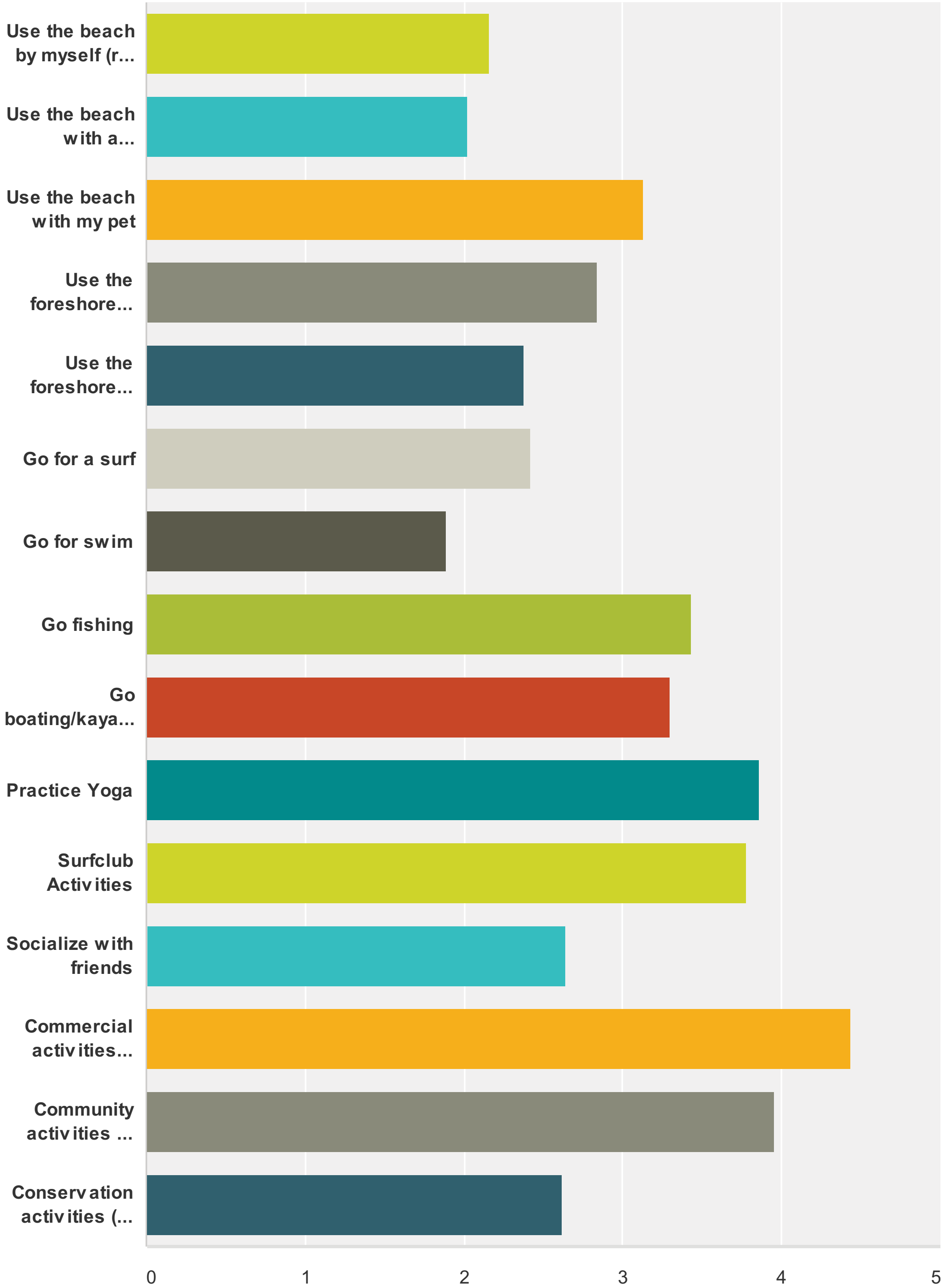
Evaluating Options for Managing our Bay

	1	2	3	4	5	Total	Average Rating
Healthy ocean environment, with clean water and lots of marine species	**77.12%** 91	**11.86%** 14	**4.24%** 5	**1.69%** 2	**5.08%** 6	118	1.46
Access to at least one beach	**60%** 45	**17.33%** 13	**8%** 6	**5.33%** 4	**9.33%** 7	75	1.87
Access to a variety of beaches that are good in different conditions	**55.10%** 54	**20.41%** 20	**8.16%** 8	**10.20%** 10	**6.12%** 6	98	1.92
Ease of accesses to beaches	**47.19%** 42	**25.84%** 23	**12.36%** 11	**6.74%** 6	**7.87%** 7	89	2.02
Safe swimming and surfing opportunities for young families and less able beach users	**45.45%** 40	**20.45%** 18	**13.64%** 12	**12.50%** 11	**7.95%** 7	88	2.17
The continuing cultural value of sea and coast country to Aboriginal people	**42.17%** 35	**22.89%** 19	**16.87%** 14	**10.84%** 9	**7.23%** 6	83	2.18
Views of ocean, headland or beach, from public reserves	**41.30%** 38	**23.91%** 22	**16.30%** 15	**6.52%** 6	**11.96%** 11	92	2.24
A great place to get relax / use	**47.37%** 45	**17.89%** 17	**9.47%** 9	**7.37%** 7	**17.89%** 17	95	2.31
Good beach side facilities	**36.05%** 31	**20.93%** 18	**23.26%** 20	**5.81%** 5	**13.95%** 12	86	2.41
A flat sandy area above the tide for use eg walking, games etc	**34.12%** 29	**24.71%** 21	**17.65%** 15	**9.41%** 8	**14.12%** 12	85	2.45
Great surfing – good waves and reliable breaks	**27.38%** 23	**21.43%** 18	**20.24%** 17	**15.48%** 13	**15.48%** 13	84	2.70
The presence of heritage places and features along the embayment	**32.05%** 25	**15.38%** 12	**21.79%** 17	**11.54%** 9	**19.23%** 15	78	2.71
The great social vibe on the beach or beach side reserves	**31.51%** 23	**19.18%** 14	**12.33%** 9	**19.18%** 14	**17.81%** 13	73	2.73
Value of residential/commercial property	**10%** 7	**11.43%** 8	**22.86%** 16	**12.86%** 9	**42.86%** 30	70	3.67
Views of ocean, headland or beach from my home	**13.04%** 9	**11.59%** 8	**14.49%** 10	**10.14%** 7	**50.72%** 35	69	3.74

Q6 What is the main activity you do when you use the beach in the Byron Bay Embayment? If you have multiple activities, please indicate up to five activities that you do most often with the numbers 1 to 5, with 1 being most important and 5 being least important of these activities.

Answered: 129 Skipped: 13

Evaluating Options for Managing our Bay

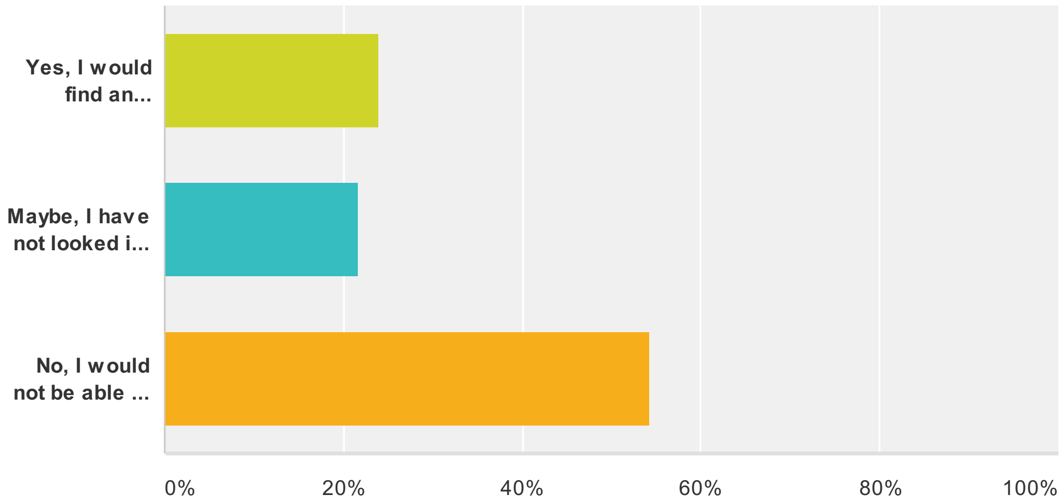


	1	2	3	4	5	Total	Average Rating
Use the beach by myself (run, walk or other exercise)	**50%** 55	**15.45%** 17	**14.55%** 16	**8.18%** 9	**11.82%** 13	110	2.16
Use the beach with a friend/family/group or team, for exercise or relaxation	**49.11%** 55	**21.43%** 24	**13.39%** 15	**10.71%** 12	**5.36%** 6	112	2.02
Use the beach with my pet	**26.47%** 18	**14.71%** 10	**13.24%** 9	**10.29%** 7	**35.29%** 24	68	3.13
Use the foreshore reserve for picnics	**19.74%** 15	**27.63%** 21	**15.79%** 12	**22.37%** 17	**14.47%** 11	76	2.84

Use the foreshore reserve for exercise	**35.29%** 24	**26.47%** 18	**13.24%** 9	**14.71%** 10	**10.29%** 7	68	2.38
Go for a surf	**42.31%** 33	**19.23%** 15	**11.54%** 9	**7.69%** 6	**19.23%** 15	78	2.42
Go for swim	**50.44%** 57	**28.32%** 32	**9.73%** 11	**4.42%** 5	**7.08%** 8	113	1.89
Go fishing	**18.33%** 11	**11.67%** 7	**18.33%** 11	**11.67%** 7	**40%** 24	60	3.43
Go boating/kayaking	**25.93%** 14	**7.41%** 4	**14.81%** 8	**14.81%** 8	**37.04%** 20	54	3.30
Practice Yoga	**8%** 4	**6%** 3	**20%** 10	**24%** 12	**42%** 21	50	3.86
Surfclub Activities	**12%** 6	**6%** 3	**18%** 9	**20%** 10	**44%** 22	50	3.78
Socialize with friends	**31.25%** 25	**16.25%** 13	**23.75%** 19	**15%** 12	**13.75%** 11	80	2.64
Commercial activities (e.g. operating a business)	**6.25%** 3	**2.08%** 1	**4.17%** 2	**16.67%** 8	**70.83%** 34	48	4.44
Community activities (eg Triathalon)	**12%** 6	**6%** 3	**12%** 6	**14.00%** 7	**56.00%** 28	50	3.96
Conservation activities (eg Dunecare)	**33.96%** 18	**16.98%** 9	**16.98%** 9	**16.98%** 9	**15.09%** 8	53	2.62

Q7 Would you be able to conduct the activity(s) identified in Question 6 in a different area/region, if you were not able to do so in the Byron Bay Embayment?

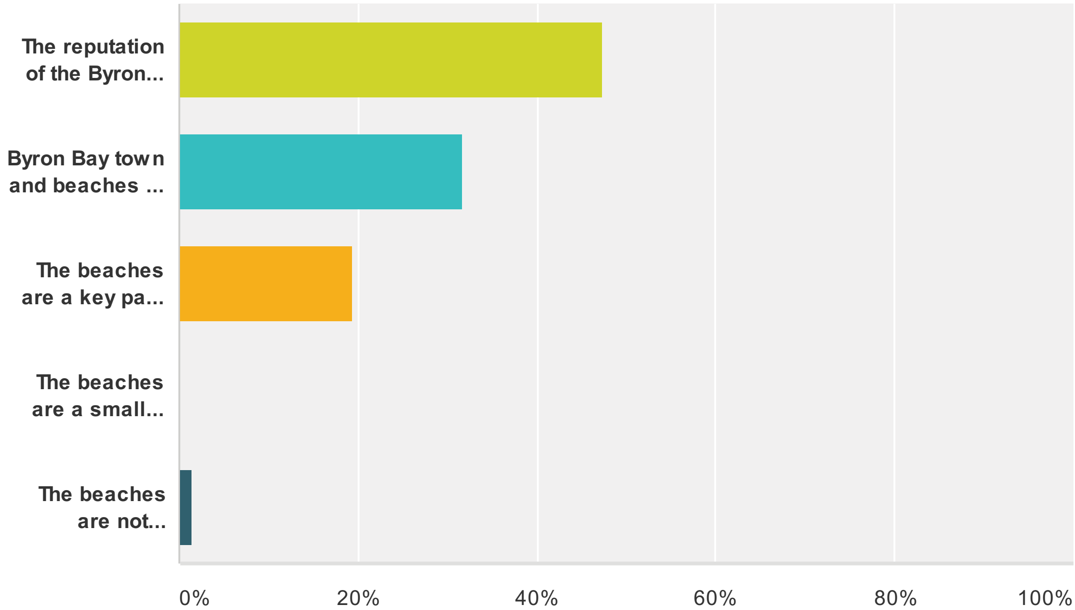
Answered: 129 Skipped: 13



Answer Choices	Responses	
Yes, I would find an alternative area easily	24.03%	31
Maybe, I have not looked into it, but would be open to doing so	21.71%	28
No, I would not be able to find an alternative area easily	54.26%	70
Total		129

Q8 How important do you think the beaches of the Byron Bay embayment are to the economy of the town and its local area?

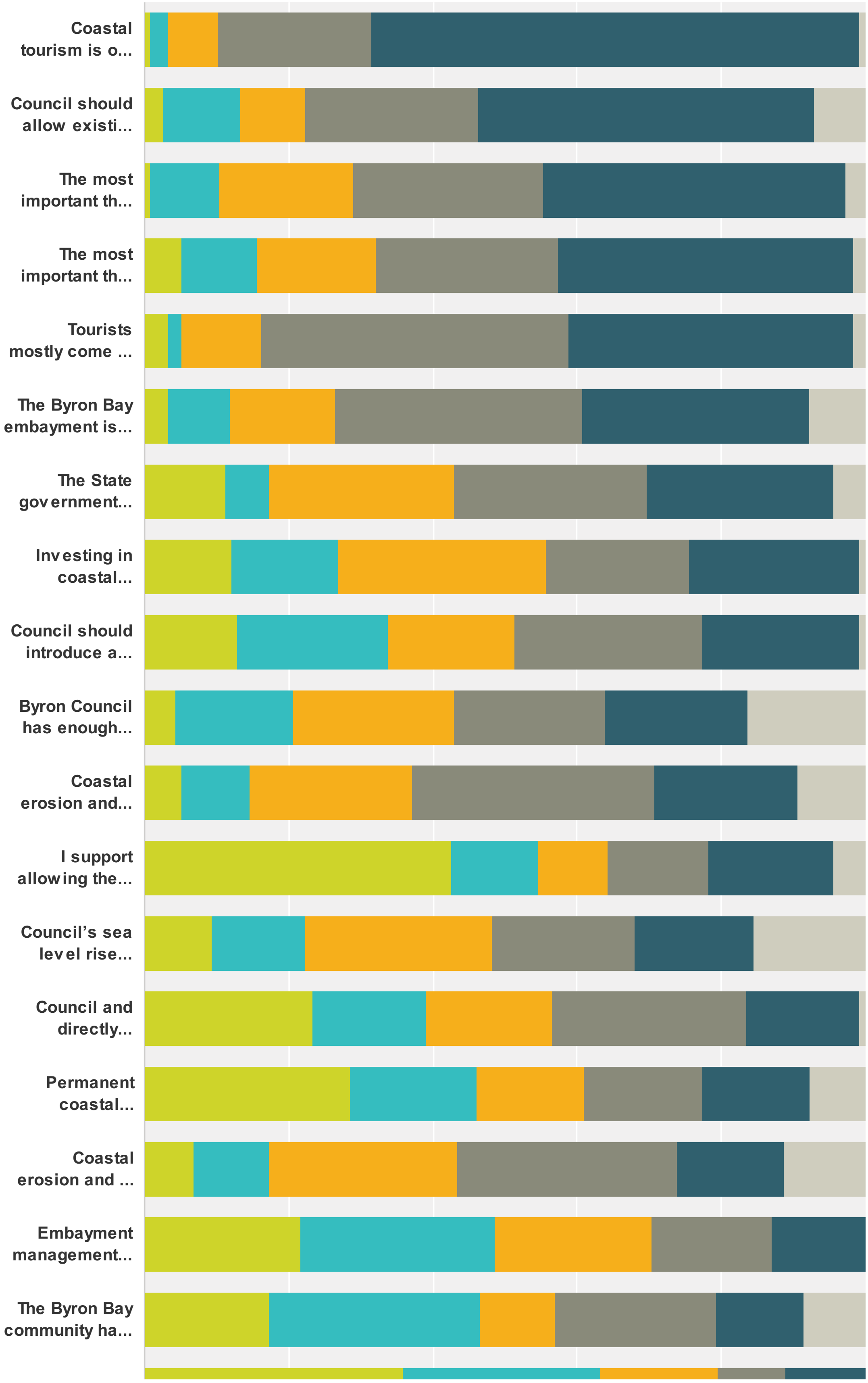
Answered: 129 Skipped: 13



Answer Choices	Responses	
The reputation of the Byron beaches attracts people to the whole local area, not just to Byron Bay town	47.29%	61
Byron Bay town and beaches are synonymous – so very important	31.78%	41
The beaches are a key part of the Byron town economy, but other aspects are also important	19.38%	25
The beaches are a small part of the economy of the town	0%	0
The beaches are not important to the economy of the town and its local area	1.55%	2
Total		**129**

Q9 Please indicate the extent to which you agree with the following statements.

Answered: 119 Skipped: 23



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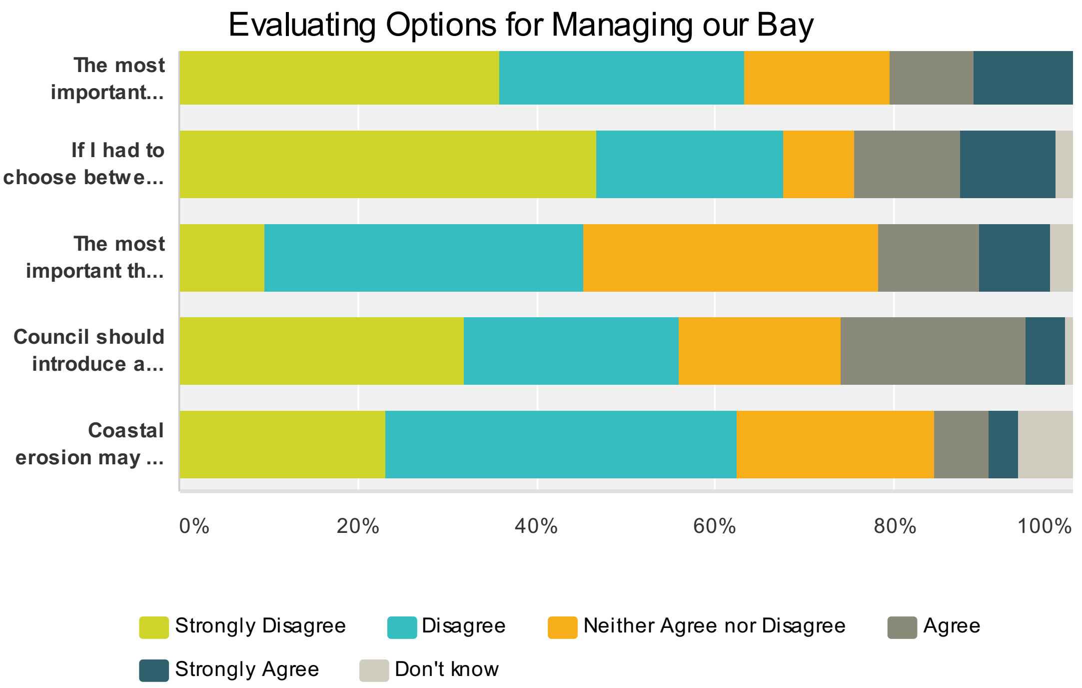
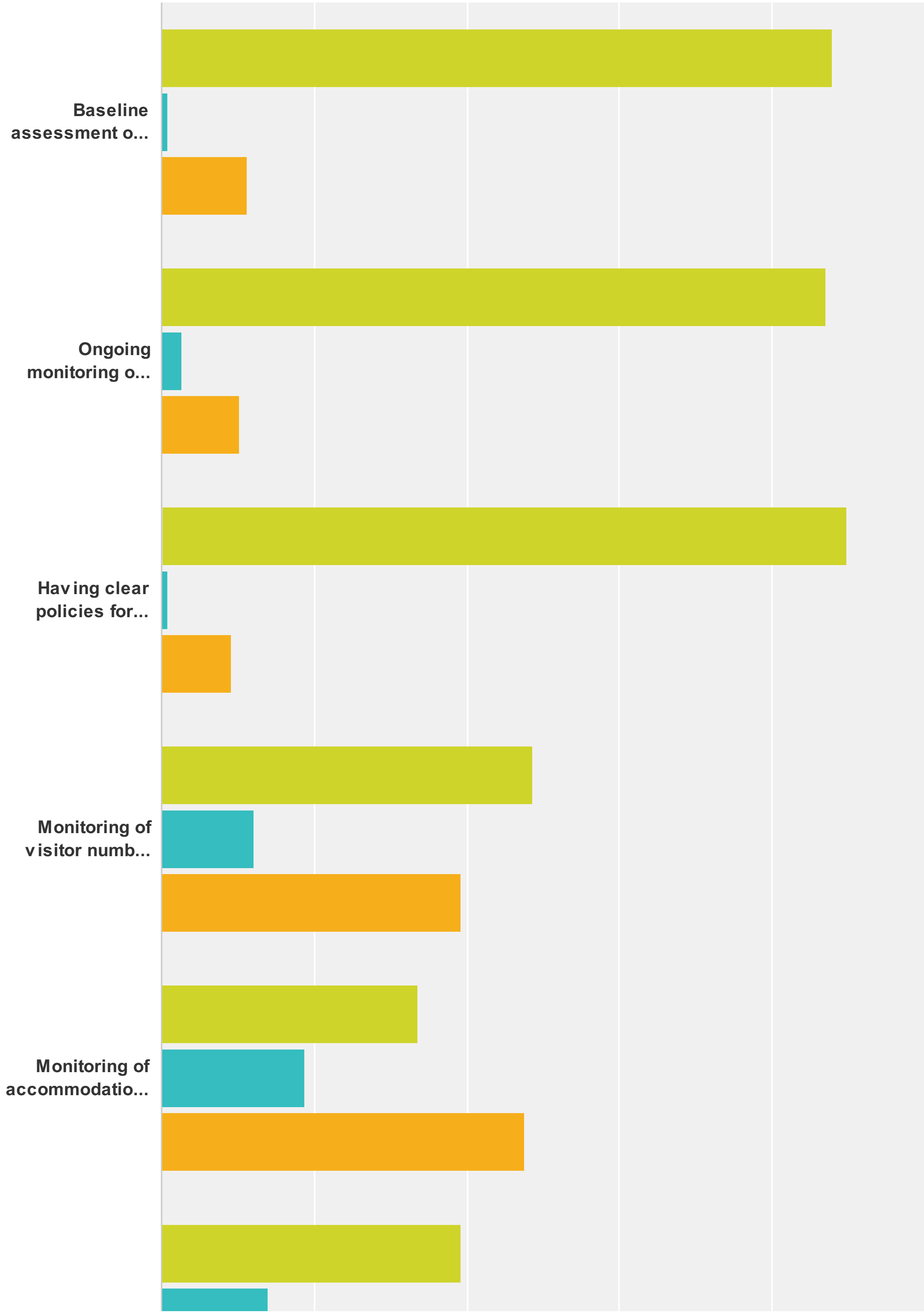


	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree	Don't know	Total
Coastal tourism is one of the biggest economic activities in Byron Bay	**0.85%** 1	**2.56%** 3	**6.84%** 8	**21.37%** 25	**67.52%** 79	**0.85%** 1	117
Council should allow existing residential and business uses of the embayment to continue, but not approve more development in areas that are affected by immediate coastal hazards (i.e. would be affected by an extreme (say 1 in 100 year) event now)	**2.68%** 3	**10.71%** 12	**8.93%** 10	**24.11%** 27	**46.43%** 52	**7.14%** 8	112
The most important thing about managing the coast at Byron Bay is to retain its reputation as a beautiful coastal landscape	**0.88%** 1	**9.65%** 11	**18.42%** 21	**26.32%** 30	**42.11%** 48	**2.63%** 3	114
The most important thing about managing the embayment is to retain sandy beaches that are accessible and safe for everyone at all times (except in storm conditions)	**5.22%** 6	**10.43%** 12	**16.52%** 19	**25.22%** 29	**40.87%** 47	**1.74%** 2	115
Tourists mostly come to Byron Bay for the beaches, swimming and surf breaks	**3.42%** 4	**1.71%** 2	**11.11%** 13	**42.74%** 50	**39.32%** 46	**1.71%** 2	117
The Byron Bay embayment is affected by erosion now and it will get worse if no action is taken by Council	**3.42%** 4	**8.55%** 10	**14.53%** 17	**34.19%** 40	**31.62%** 37	**7.69%** 9	117
The State government should provide most of the funds for building coastal protection works in Byron Bay	**11.21%** 13	**6.03%** 7	**25.86%** 30	**26.72%** 31	**25.86%** 30	**4.31%** 5	116
Investing in coastal management (coastal protection) should be a very high priority for Council. E.g. if Council had to choose between coastal management (protection and access management) and roads/kerb and guttering or sporting facilities, it should choose coastal management.	**12.17%** 14	**14.78%** 17	**28.70%** 33	**20%** 23	**23.48%** 27	**0.87%** 1	115
Council should introduce a rate levy only on coastal properties to cover the cost of management of the coastal zone	**13.04%** 15	**20.87%** 24	**17.39%** 20	**26.09%** 30	**21.74%** 25	**0.87%** 1	115
Byron Council has enough information to decide on effective management of erosion along the embayment	**4.31%** 5	**16.38%** 19	**22.41%** 26	**20.69%** 24	**19.83%** 23	**16.38%** 19	116

Coastal erosion and shoreline recession in the coming decades will significantly impact on the ecology of the coast and nearshore marine areas.	**5.17%** 6	**9.48%** 11	**22.41%** 26	**33.62%** 39	**19.83%** 23	**9.48%** 11	116
I support allowing the disturbance of the sea bed in the Marine Park to obtain sand for beach nourishment if required	**42.61%** 49	**12.17%** 14	**9.57%** 11	**13.91%** 16	**17.39%** 20	**4.35%** 5	115
Council's sea level rise benchmarks (40cm above 1990 level by 2050 and 90cm above 1990 levels by 2100) are appropriate for planning future land use along the Byron Bay embayment	**9.48%** 11	**12.93%** 15	**25.86%** 30	**19.83%** 23	**16.38%** 19	**15.52%** 18	116
Council and directly affected residents should share the cost of building a rock wall to protect private residential property	**23.48%** 27	**15.65%** 18	**17.39%** 20	**26.96%** 31	**15.65%** 18	**0.87%** 1	115
Permanent coastal protection works (such as rock walls) are needed to maintain the culture and economy of Byron Bay	**28.70%** 33	**17.39%** 20	**14.78%** 17	**16.52%** 19	**14.78%** 17	**7.83%** 9	115
Coastal erosion and sea level rise in coming decades will damage the cultural and heritage values of the Byron Bay embayment.	**6.96%** 8	**10.43%** 12	**26.09%** 30	**30.43%** 35	**14.78%** 17	**11.30%** 13	115
Embayment management options chosen should be based on the most economically efficient solutions	**21.74%** 25	**26.96%** 31	**21.74%** 25	**16.52%** 19	**13.04%** 15	**0%** 0	115
The Byron Bay community has enough information to understand coastal erosion processes and options to reduce erosion risks.	**17.24%** 20	**29.31%** 34	**10.34%** 12	**22.41%** 26	**12.07%** 14	**8.62%** 10	116
The most important priority about managing the Byron Bay embayment is to protect existing private property from coastal erosion.	**35.90%** 42	**27.35%** 32	**16.24%** 19	**9.40%** 11	**11.11%** 13	**0%** 0	117
If I had to choose between a rock wall (to protect built assets) and maintaining a sandy beach, I'd go for the rock wall	**46.85%** 52	**20.72%** 23	**8.11%** 9	**11.71%** 13	**10.81%** 12	**1.80%** 2	111
The most important thing about managing the Byron Bay embayment is to protect the surf breaks	**9.57%** 11	**35.65%** 41	**33.04%** 38	**11.30%** 13	**7.83%** 9	**2.61%** 3	115
Council should introduce a rate levy on all ratepayers to cover the cost of management of the coastal zone	**31.90%** 37	**24.14%** 28	**18.10%** 21	**20.69%** 24	**4.31%** 5	**0.86%** 1	116
Coastal erosion may get worse, but not in the next twenty years	**23.08%** 27	**39.32%** 46	**22.22%** 26	**5.98%** 7	**3.42%** 4	**5.98%** 7	117

Q10 What do you think adaptive management means for the way Council manages the Byron Bay embayment? Please indicate which actions you think would be part of an adaptive management plan for coastal hazards at Byron Bay.

Answered: 108 Skipped: 34



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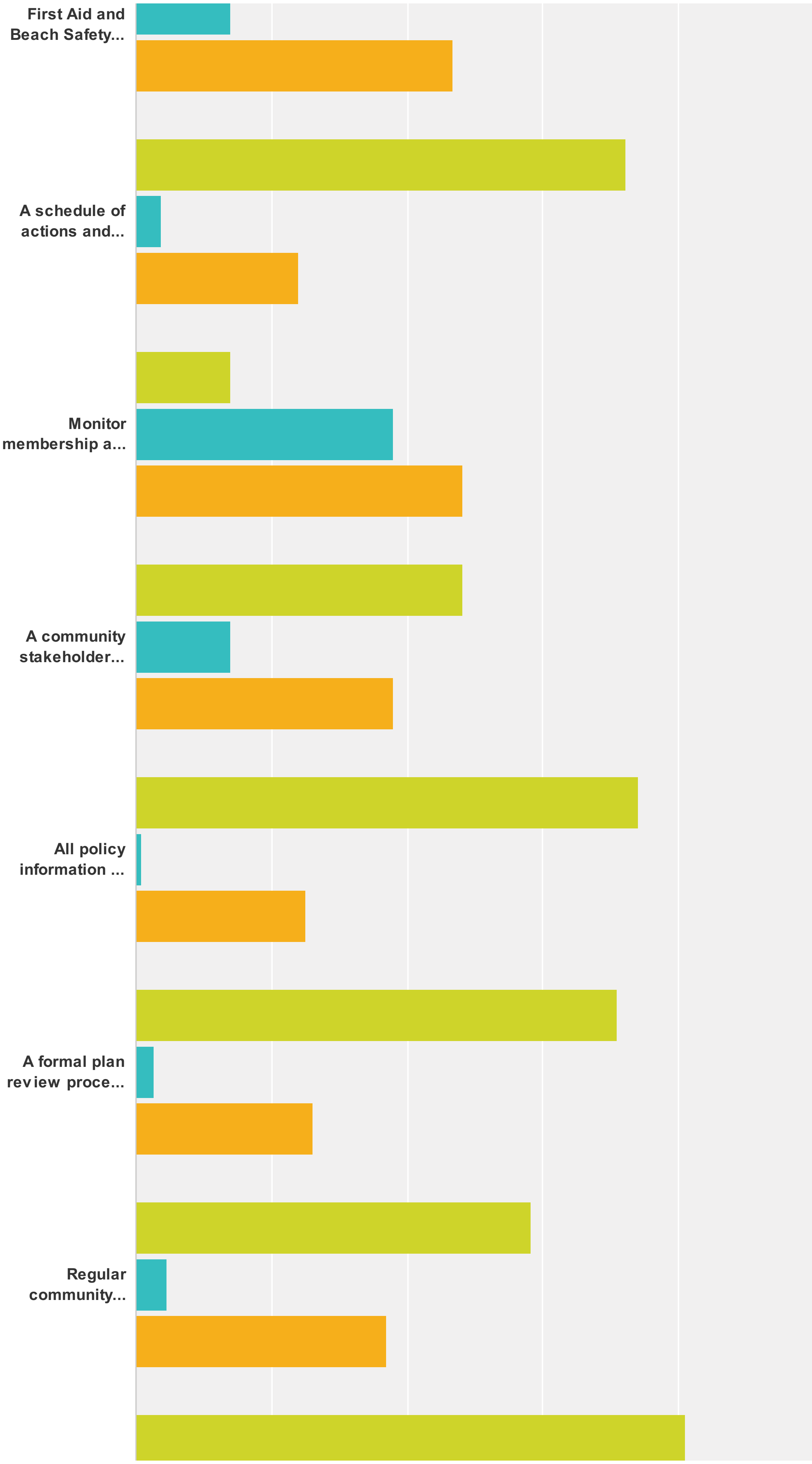

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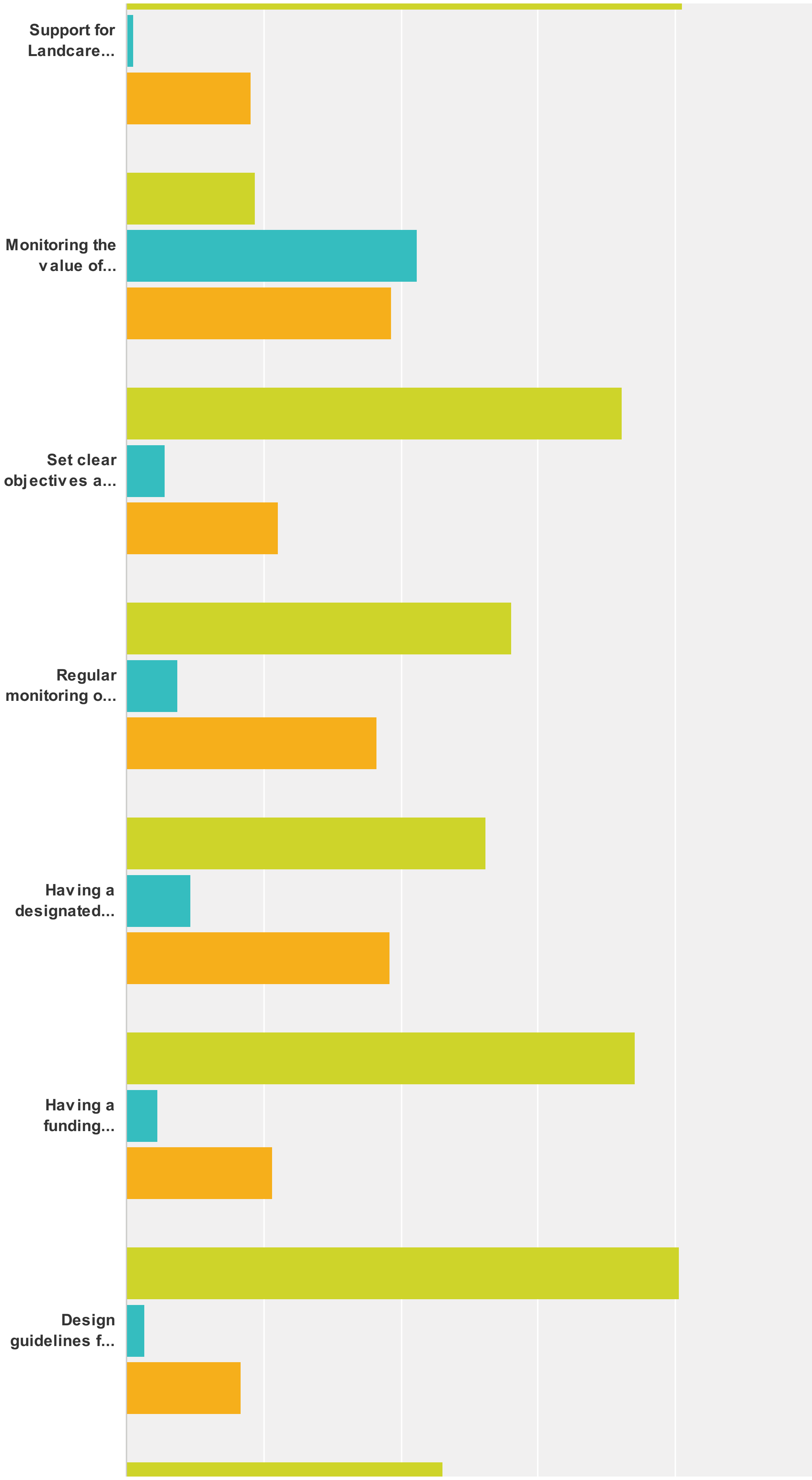
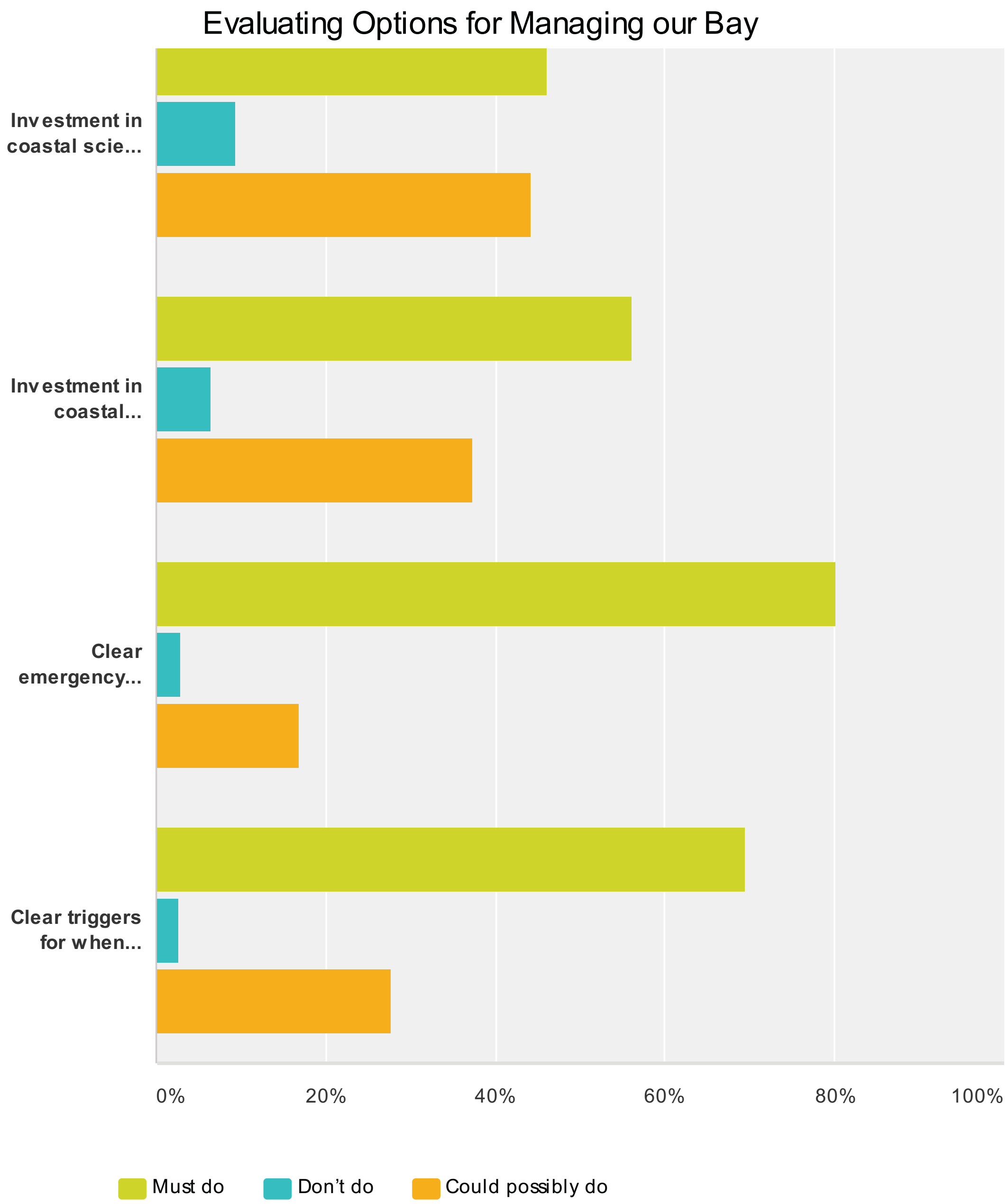




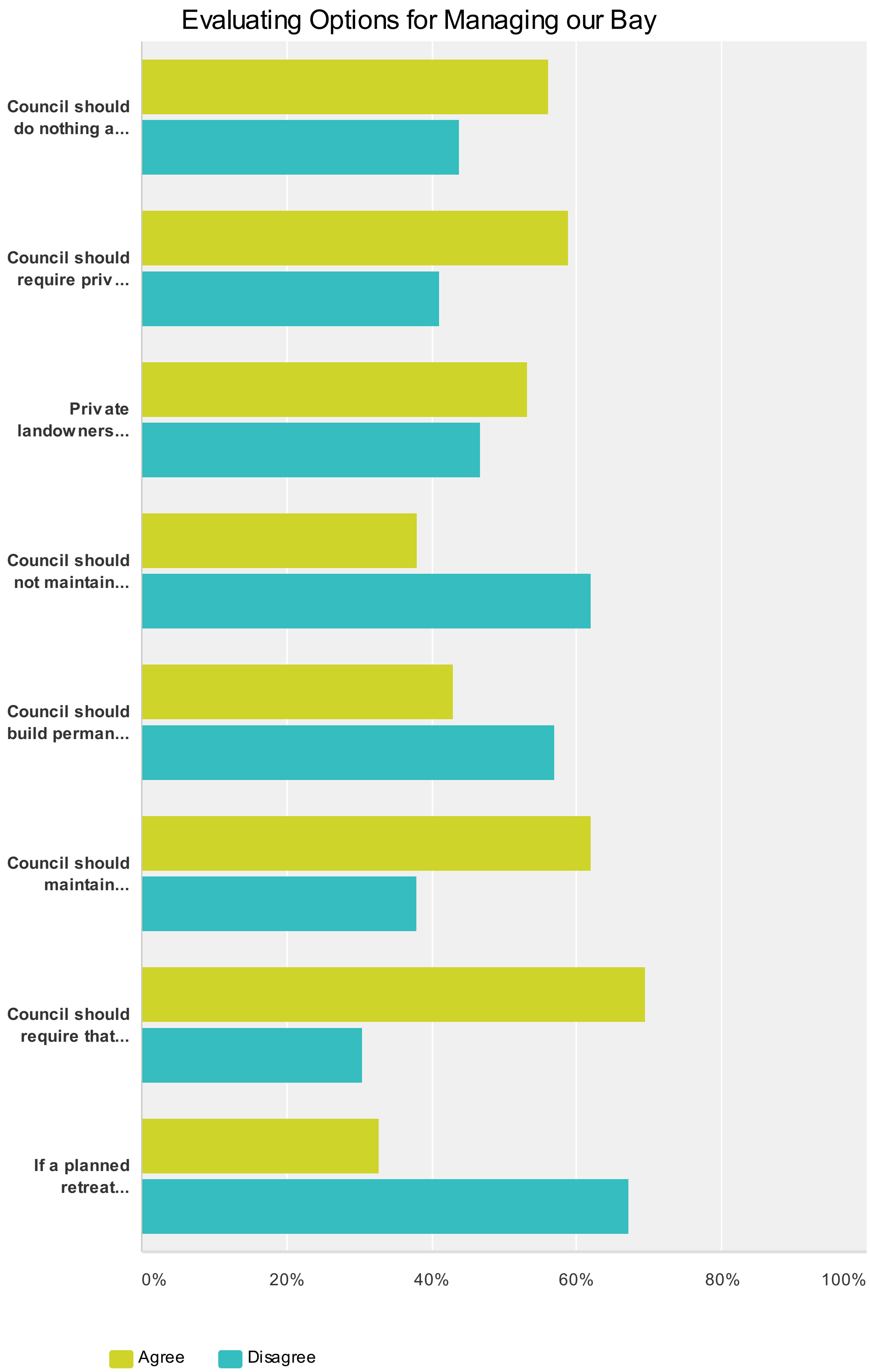
	Must do	Don't do	Could possibly do	Total
Baseline assessment of the condition of beaches	**87.85%** 94	**0.93%** 1	**11.21%** 12	107
Ongoing monitoring of the condition of beaches (e.g. volume of sand, beach profile, dune condition, presence of erosion escarpments)	**87.04%** 94	**2.78%** 3	**10.19%** 11	108
Having clear policies for coastal land use and land management	**89.81%** 97	**0.93%** 1	**9.26%** 10	108
Monitoring of visitor numbers by season and by special event	**48.60%** 52	**12.15%** 13	**39.25%** 42	107
Monitoring of accommodation utilisation	**33.64%** 36	**18.69%** 20	**47.66%** 51	107
First Aid and Beach Safety management e.g. monitoring number of rescues	**39.25%** 42	**14.02%** 15	**46.73%** 50	107

Evaluating Options for Managing our Bay

A schedule of actions and budget, with regular progress and expenditure review	**72.22%** 78	**3.70%** 4	**24.07%** 26	108
Monitor membership and activities of surf clubs	**13.89%** 15	**37.96%** 41	**48.15%** 52	108
A community stakeholder management committee or advisory committee	**48.15%** 52	**13.89%** 15	**37.96%** 41	108
All policy information and monitoring results published on Council's web site on a regular basis	**74.07%** 80	**0.93%** 1	**25%** 27	108
A formal plan review process at intervals of approximately 10 years	**71.03%** 76	**2.80%** 3	**26.17%** 28	107
Regular community forums about coastal management issues	**58.33%** 63	**4.63%** 5	**37.04%** 40	108
Support for Landcare activity on the coast and monitoring of outcomes	**80.95%** 85	**0.95%** 1	**18.10%** 19	105
Monitoring the value of coastal land (i.e. land valuations) and real estate (by sale price and length of time on the market)	**18.87%** 20	**42.45%** 45	**38.68%** 41	106
Set clear objectives and management targets for physical, social and economic factors	**72.22%** 78	**5.56%** 6	**22.22%** 24	108
Regular monitoring of community satisfaction with beach management	**56.07%** 60	**7.48%** 8	**36.45%** 39	107
Having a designated Coastal Officer within Council, who is the first point of contact for the community	**52.34%** 56	**9.35%** 10	**38.32%** 41	107
Having a funding strategy to provide money for investment in coastal management	**74.07%** 80	**4.63%** 5	**21.30%** 23	108
Design guidelines for residential development in coastal positions	**80.56%** 87	**2.78%** 3	**16.67%** 18	108
Investment in coastal science projects	**46.23%** 49	**9.43%** 10	**44.34%** 47	106
Investment in coastal awareness and education	**56.07%** 60	**6.54%** 7	**37.38%** 40	107
Clear emergency response procedures	**80.19%** 85	**2.83%** 3	**16.98%** 18	106
Clear triggers for when Council will change its management strategy, to accommodate new or different risks	**69.44%** 75	**2.78%** 3	**27.78%** 30	108

Q11 What actions should Council take in response to potential impacts of coastal hazards on private properties? Please indicate whether you agree or disagree with each statement

Answered: 108 Skipped: 34

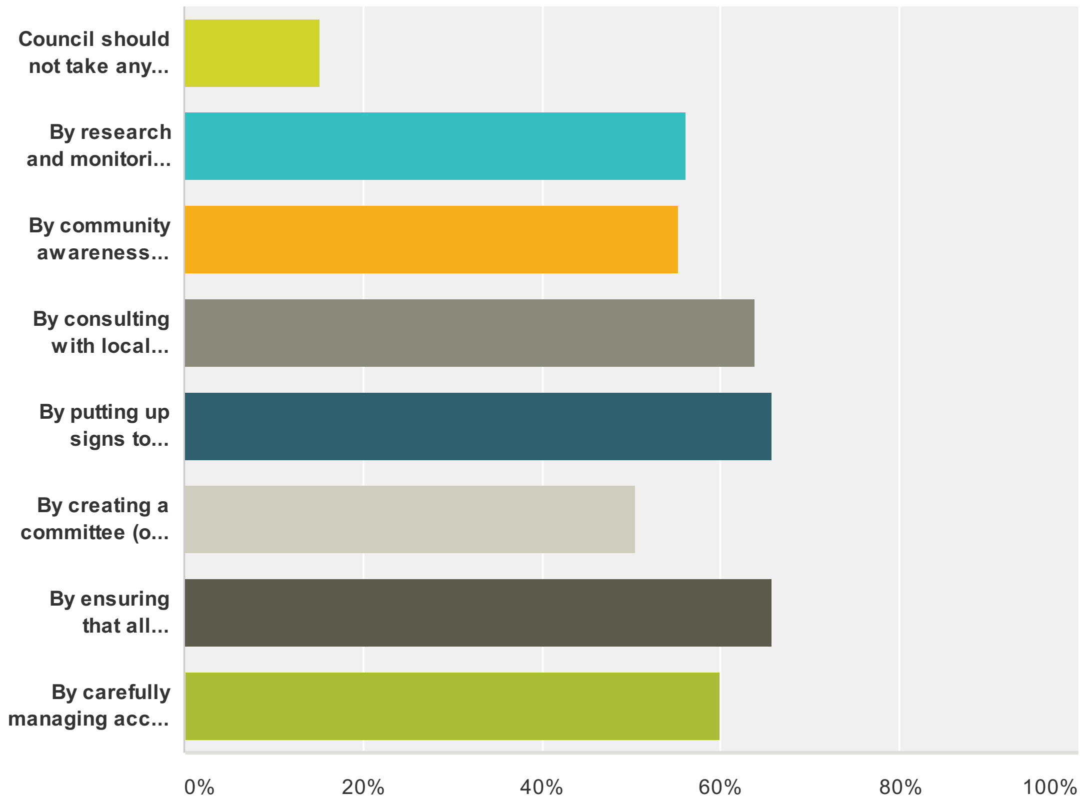


	Agree	Disagree	Total
Council should do nothing and leave landholders to make applications for privately constructed protection works (on private land)	**56.07%** 60	**43.93%** 47	107

Council should require private landowners to remove damaged, under-designed or ad hoc private protection works now	**58.88%** 63	**41.12%** 44	107
Private landowners should be allowed to repair, upgrade or construct private protection works now	**53.27%** 57	**46.73%** 50	107
Council should not maintain and/or should remove damaged protection works at public accesses and reserves now	**37.96%** 41	**62.04%** 67	108
Council should build permanent protection works, eg rock walls or similar structures. for public access and reserves now	**42.99%** 46	**57.01%** 61	107
Council should maintain temporary protection works for public access and reserves and identify triggers for later construction of permanent protection works	**61.90%** 65	**38.10%** 40	105
Council should require that buildings are removed from properties affected by erosion at a future time when certain trigger conditions are met	**69.52%** 73	**30.48%** 32	105
If a planned retreat strategy is adopted for residential properties in the Byron Bay Embayment, these properties should be acquired using public funds	**32.69%** 34	**67.31%** 70	104

Q12 How do you think Byron Shire Council could protect and promote the cultural and heritage values of the of the Byron Bay Embayment? Please mark all options that you think are relevant.

Answered: 105 Skipped: 37

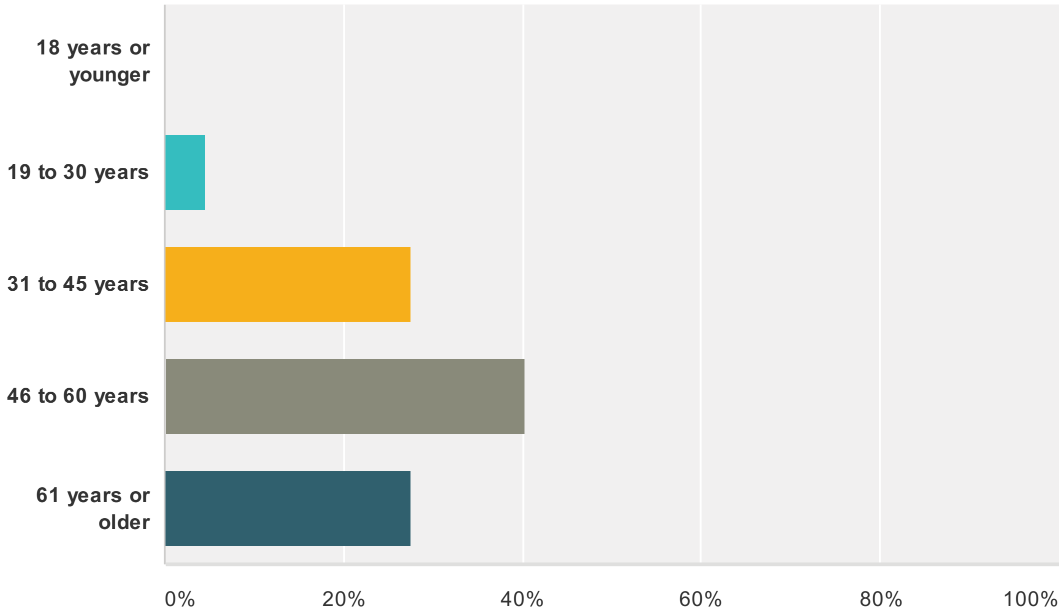


Answer Choices	Responses	
Council should not take any action in relation to cultural heritage management. Other issues are more important	15.24%	16
By research and monitoring to protect cultural heritage artefacts and places	56.19%	59
By community awareness events to tell the stories associated with cultural places and values in the coastal landscape	55.24%	58
By consulting with local Aboriginal corporations and implementing the Memorandum of Understanding (MOU)	63.81%	67
By putting up signs to provide information about areas of Aboriginal or historical cultural and heritage significance	65.71%	69
By creating a committee (or committees) of Aboriginal and historic cultural heritage organisations for Council to consult with on a regular basis	50.48%	53

By ensuring that all council outdoor employees and Landcare members understand their obligations in relation to Aboriginal heritage objects	**65.71%**	69
By carefully managing access to important features and places	**60%**	63
Total Respondents: 105		

Q13 What is your age?

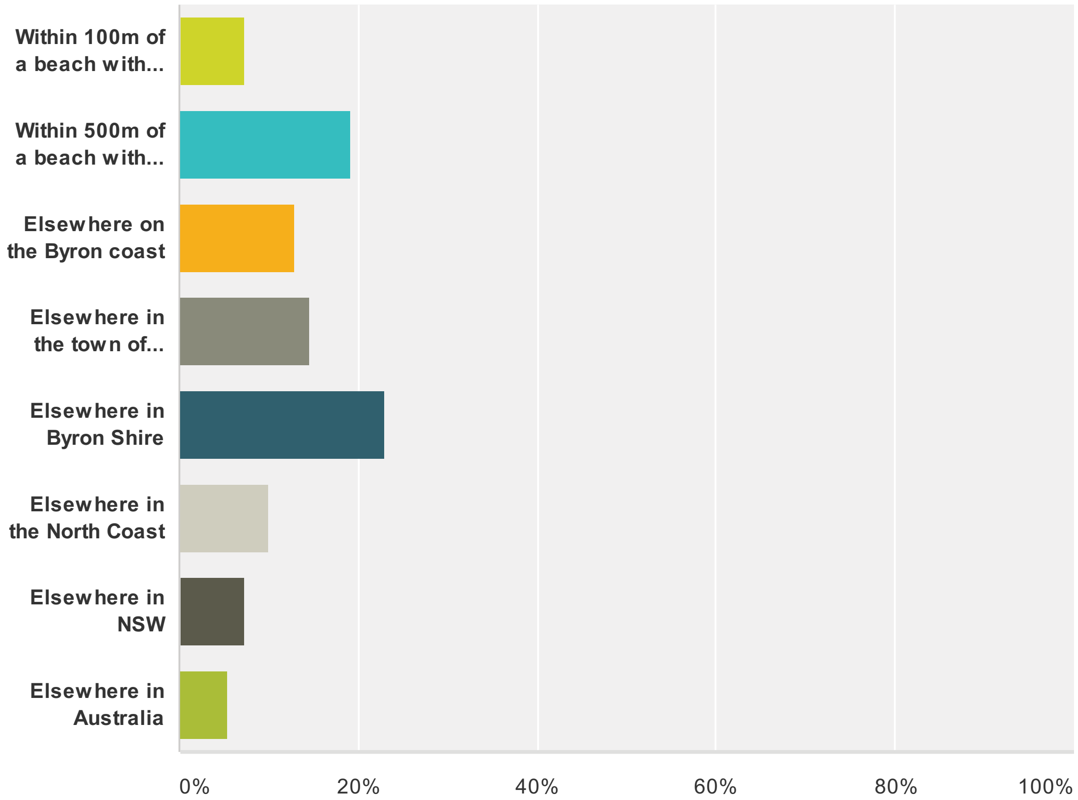
Answered: 109   Skipped: 33



Answer Choices	Responses	
18 years or younger	**0%**	0
19 to 30 years	**4.59%**	5
31 to 45 years	**27.52%**	30
46 to 60 years	**40.37%**	44
61 years or older	**27.52%**	30
Total		**109**

Q14 Where do you live?

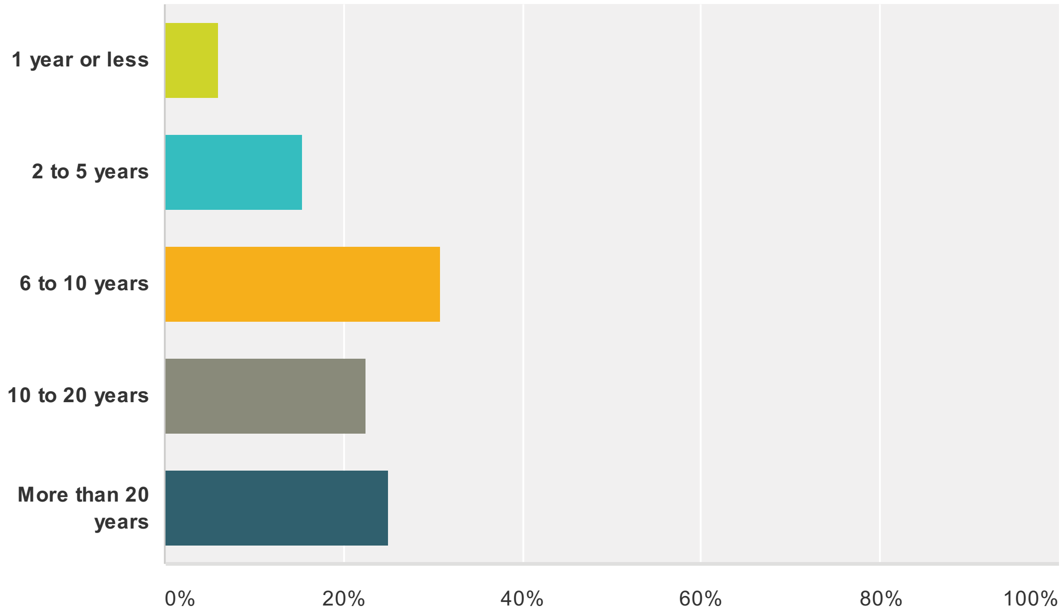
Answered: 109   Skipped: 33



Answer Choices	Responses	
Within 100m of a beach within the Byron Bay Embayment	**7.34%**	8
Within 500m of a beach within the Byron Bay embayment	**19.27%**	21
Elsewhere on the Byron coast	**12.84%**	14
Elsewhere in the town of Byron Bay	**14.68%**	16
Elsewhere in Byron Shire	**22.94%**	25
Elsewhere in the North Coast	**10.09%**	11
Elsewhere in NSW	**7.34%**	8
Elsewhere in Australia	**5.50%**	6
Total		**109**

Q15 How long have you lived in your current residence?

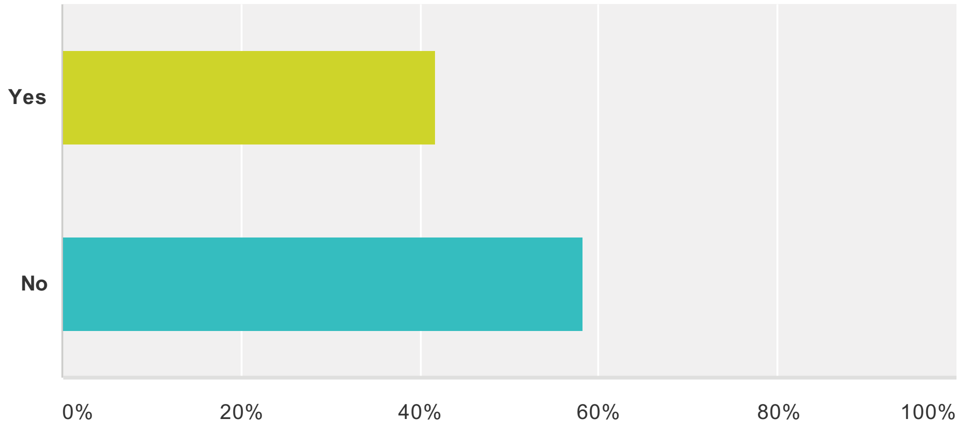
Answered: 84 Skipped: 58



Answer Choices	Responses	
1 year or less	5.95%	5
2 to 5 years	15.48%	13
6 to 10 years	30.95%	26
10 to 20 years	22.62%	19
More than 20 years	25%	21
Total		84

Q16 Do you own a property in the Byron Shire

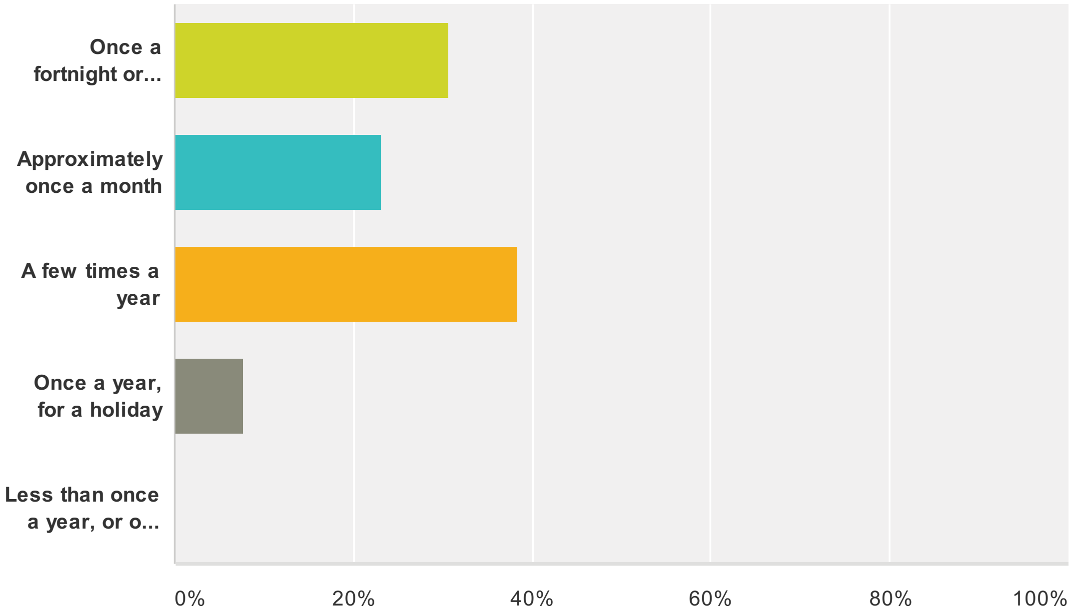
Answered: 24 Skipped: 118



Answer Choices	Responses	
Yes	**41.67%**	10
No	**58.33%**	14
Total		**24**

Q17 How often do you visit Byron Bay (on average)

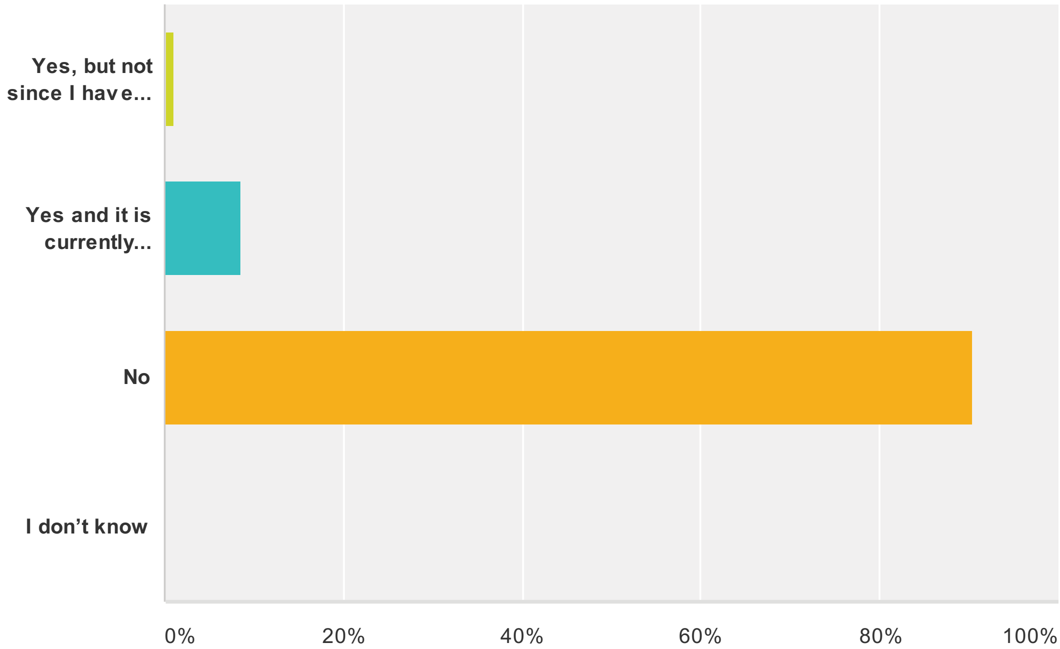
Answered: 13 Skipped: 129



Answer Choices	Responses	
Once a fortnight or more often	30.77%	4
Approximately once a month	23.08%	3
A few times a year	38.46%	5
Once a year, for a holiday	7.69%	1
Less than once a year, or only for business purposes	0%	0
Total		**13**

Q18 Has your property been directly affected by coastal erosion events in the past?

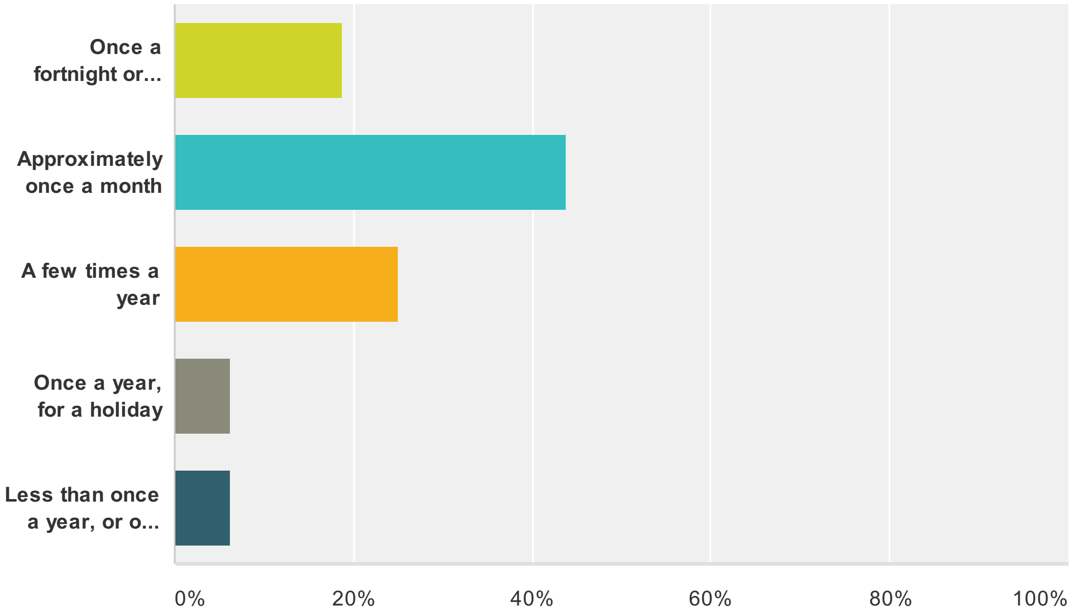
Answered: 94 Skipped: 48



Answer Choices	Responses	
Yes, but not since I have owned it	**1.06%**	1
Yes and it is currently affected	**8.51%**	8
No	**90.43%**	85
I don't know	**0%**	0
Total		**94**

Q19 How often do you visit Byron Bay (on average)

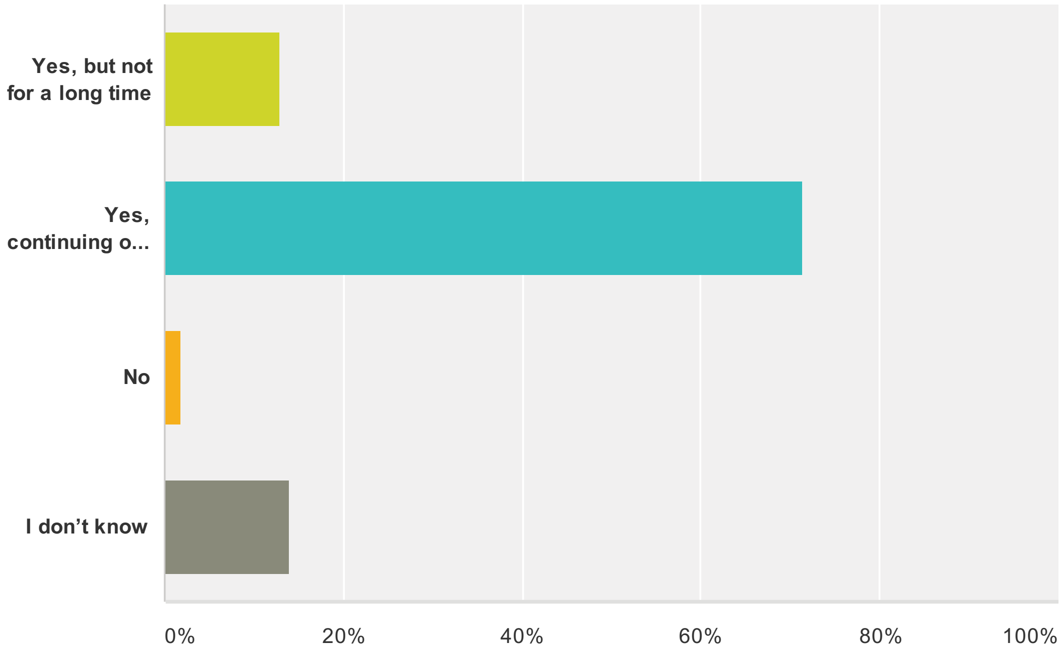
Answered: 16   Skipped: 126



Answer Choices	Responses	
Once a fortnight or more often	18.75%	3
Approximately once a month	43.75%	7
A few times a year	25%	4
Once a year, for a holiday	6.25%	1
Less than once a year, or only for business purposes	6.25%	1
Total		16

Q20 Do you expect that the Byron Bay beaches will be significantly affected by coastal erosion events in the future?

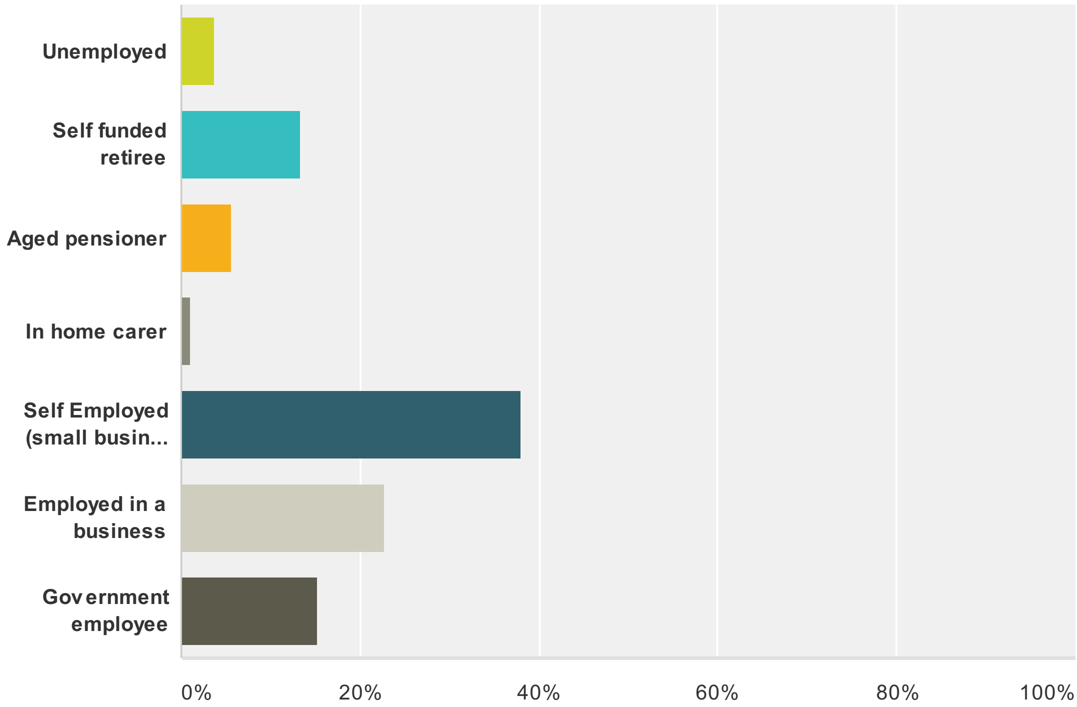
Answered: 108 Skipped: 34



Answer Choices	Responses	
Yes, but not for a long time	**12.96%**	14
Yes, continuing or worsening current situation	**71.30%**	77
No	**1.85%**	2
I don't know	**13.89%**	15
Total		**108**

Q21 What is your employment status?

Answered: 105 Skipped: 37



Answer Choices	Responses	
Unemployed	3.81%	4
Self funded retiree	13.33%	14
Aged pensioner	5.71%	6
In home carer	0.95%	1
Self Employed (small business owner)	38.10%	40
Employed in a business	22.86%	24
Government employee	15.24%	16
Total		**105**

Q22 Would you like to make other comments on coastal management at Byron Bay? Please write your comments below . Please note, you can also write directly to Council if you would like to make longer comments.

Answered: 52 Skipped: 90

Evaluating options for managing our coast

What should Byron Council take into account when making decisions about the management of the coastline?

Byron Shire Council has commenced a review of the coastal hazard management options that have been suggested to protect assets and the natural environment of the coastline of the Byron Bay Embayment.

Council has commissioned technical advice about measures to manage hazard and risk on the coast.

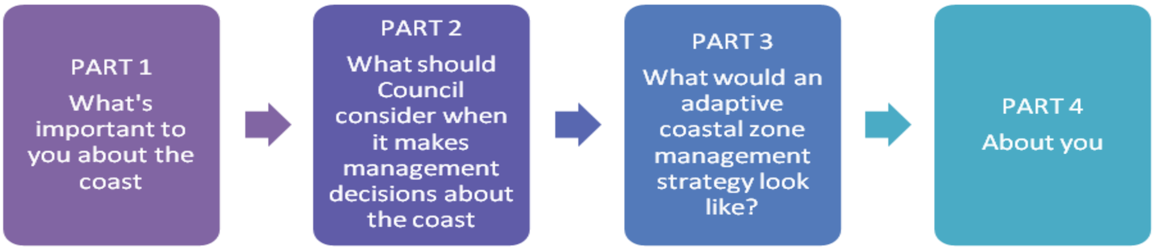
Council is also keen to hear the views of residents and beach users, to help develop a strategic framework for future coastal management that meets the needs of the community and is technically and financially viable.

This survey is the first step in seeking community views about what is important about the coast and how management priorities should be set.

Thank you for making the time to respond to the survey.

About the survey

The survey has four parts, with a total of 20 questions, and the survey should take about 15 to 20 minutes to complete.



- Your responses will help Council to:
  - understand community objectives for coastal management
  - understand what defines an acceptable management approach for this community
  - evaluate potential management responses for coastal hazards.
- The survey is open for anyone to complete until **13 February 2014**.
- All responses received by Friday 13 February will be included in the analysis.
- Results of the analysis will be available on Council's web site and will be presented at a workshop on 20 February.
- Everyone is also welcome to lodge other written comments until 28 February 2014 and submissions will be reported to Council after the workshop.

There will also be an opportunity to comment on proposed management actions when a new draft Coastal Zone Management Plan is exhibited, later in 2014

Would you like more information or to discuss any of the existing management approaches?

Please contact: Byron Shire Council on (02) 6626 7126 or at www.byron.nsw.gov.au

PART 1
WHAT'S IMPORTANT TO YOU ABOUT THE COASTLINE OF THE BYRON BAY EMBAYMENT?

Question 1
How often do you use one of the beaches of the Byron Bay Embayment?
Please select 1 option that best fits

Every day all year round	
More than once a week, all year round	
Between once a week and once a month, on average	
Several times a year	
About once a year	
Only when I am on holidays	

Question 2
Which of the beaches of the Byron Bay Embayment do you visit?
Please score the frequency of visits with the description that best fits your beach use:

0 Never visit this beach
1 Visit rarely (no more than once a year)
2 Visit occasionally (about once a month)
3 Visit frequently (about weekly)
4 Visit daily (or more often)
5 I use the beach intensively in holidays, but rarely at other times

Beaches visited	0	1	2	3	4	5
Belongil Beach						
Main Beach						
Clarkes Beach						
Other (please specify)						

Other_______________________________

Question 3
Do you think the beach access arrangements at the beaches you visit are adequate in providing safe, ongoing access to the beach?
Please select 1 option that best fits

Yes, I think the access arrangements are good as they are	
Yes, but I think accesses need to be maintained more often by Council.	
Undecided, I don't pay attention to beach access arrangements.	
No, I think there should be less beach access available.	
No, I think there should be more beach access available.	

If you think access arrangements are inadequate, please identify how you think Council should improve the beach access arrangements of the Byron Bay Embayment.
Please write your comments in the box below (maximum 200 words)

Question 4

What do you think are the most important features of the coastline of the Byron Bay Embayment?

Please select the five options from the following that are most important to you and number them in order from (1) most important to (5) least important.

Value or asset	**1**	**2**	**3**	**4**	**5**
Views of ocean, headland or beach from my home					
Value of residential/commercial property					
Views of ocean, headland or beach, from public reserves					
Great surfing – good waves and reliable breaks					
Access to at least one beach					
Access to a variety of beaches that are good in different conditions					
Ease of accesses to beaches					
A flat sandy area above the tide for use eg walking, games etc					
Safe swimming and surfing opportunities for young families and less able beach users					
Good beach side facilities					
Healthy ocean environment, with clean water and lots of marine species					
The great social vibe on the beach or beach side reserves					
A great place to get relax / use					
The continuing cultural value of sea and coast country to Aboriginal people					
The presence of heritage places and features along the coast					
Other (please specify)					

Other________________________________

Question 5

What is the main activity you do when you use the beach in the Byron Bay Embayment?

If you have multiple activities, please indicate up to five activities that you do most often with the numbers 1 to 5, 1 being most important and 5 being least important of these activities.

Use the beach by myself (run, walk or other exercise)		Go boating/kayaking	
Use the beach with a friend/family/group or team, for exercise or relaxation		Practice Yoga	
Use the beach with my pet		Surfclub Activities	
Use the foreshore reserve for picnics		Socialize with friends	
Use the foreshore reserve for exercise		Commercial activities (e.g. operating a business)	
Go for a surf		Community activities (eg Triathalon)	
Go for swim		Conservation activities (eg Dunecare)	
Go fishing		Other, Please specify	

Other_______________________

Question 6

Would you be able to conduct the activity(s) identified in Question 5 in a different area/region, if you were not able to do so in the Byron Bay Embayment?

Please select 1 option that best fits

Yes, I would find an alternative area easily	
Maybe, I have not looked into it, but would be open to doing so	
No, I would not be able to find an alternative area easily	

Question 7

How important do you think the beaches of the Byron Bay Embayment are to the economy of the town and its local area?

Please select the description that you think fits best.

The reputation of the Byron Bay Embayment beaches attracts people to the whole local area, not just to Byron Bay town	
Byron Bay town and beaches are synonymous – so very important	
The beaches are a key part of the Byron town economy, but other aspects are also important	
The beaches are a small part of the economy of the town	
The beaches are not important to the economy of the town and its local area	

PART 2
WHAT SHOULD COUNCIL CONSIDER WHEN DECIDING HOW TO MANAGE THE COAST?

Question 8
Please indicate the extent to which you agree with the following statements.

Statement	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Byron Council has enough information to decide on effective management of erosion along its coastline					
The Byron Bay community has enough information to understand coastal erosion processes and options to reduce erosion risks.					
The most important priority about managing the Byron coast is to protect existing private property from coastal erosion.					
The Byron coastline is affected by erosion now and it will get worse if no action is taken by Council					
Coastal erosion may get worse, but not in the next twenty years					
Coastal tourism is one of the biggest economic activities in Byron Bay					
Tourists mostly come to Byron Bay for the beaches, swimming and surf breaks					
Permanent coastal protection works (such as rock walls) are needed to maintain the culture and economy of Byron Bay					
The State government should provide most of the funds for building coastal protection works in Byron Bay					
Council and directly affected residents should share the cost of building a rock wall to protect private residential property					
Council should introduce a rate levy on all ratepayers to cover the cost of management of the coastal zone					
Council should introduce a rate levy only on coastal properties to cover the cost of management of the coastal zone					
Council should allow existing residential and business uses of the coastline to continue, but not approve more development in areas that are affected by immediate coastal hazards (i.e. would be affected by an extreme (say 1 in 100 year) event now)					
The most important thing about managing the coast is to retain sandy beaches that are accessible and safe for everyone at all times (except in storm conditions)					
I support allowing the disturbance of the sea bed in the Marine Park to obtain sand for beach nourishment if required					
Coastal management options chosen should be based on the most economically efficient solutions					
Coastal erosion and sea level rise in coming decades will damage the cultural and heritage values of the Byron Bay embayment.					
Coastal erosion and shoreline recession in the coming decades will significantly impact on the ecology of the coast and nearshore marine areas.					
If I had to choose between a rock wall (to protect built assets) and maintaining a sandy beach, I'd go for the rock wall					
The most important thing about managing the Byron Bay coastline is to protect the surf breaks					
The most important thing about managing the coast at Byron Bay is to retain its reputation as a beautiful coastal landscape					
Investing in coastal management (coastal protection) should be a very high priority for Council. E.g. if Council had to choose between coastal management (protection and access management) and roads/kerb and guttering or sporting facilities, it should choose coastal management.					
Council's sea level rise benchmarks (40cm above 1990 level by 2050 and 90cm above 1990 levels by 2100) are appropriate for planning future land use along the coastline of the Byron Bay Embayment					

PART 3
WHAT WOULD AN ADAPTIVE COASTAL ZONE MANAGEMENT STRATEGY LOOK LIKE FOR THE BYRON BAY EMBAYMENT?

The term 'adaptive management' is in wide use in natural resource management and coastal planning where there is uncertainty about how processes will interact, the exact timing of an expected change and/or how environmental variables will respond to a specific treatment. It usually means learning from doing and regular review of what has been achieved, to change and improve management.

Question 9
What actions should Council take in response to potential impacts of coastal hazards on private properties?
Please indicate whether you agree or disagree with each statement

Action and timing	Agree	Disagree
Council should do nothing and leave landholders to make applications for privately constructed protection works (on private land)		
Council should require private landowners to remove damaged, under-designed or *ad hoc* private protection works now		
Private landowners should be allowed to repair, upgrade or construct private protection works now		
Council should not maintain and/or should remove damaged protection works at public accesses and reserves now		
Council should build permanent protection works, eg rock walls or similar structures. for public access and reserves now		
Council should maintain temporary protection works for public access and reserves and identify triggers for later construction of permanent protection works		
Council should require that buildings are removed from properties affected by erosion at a future time when certain trigger conditions are met		
If a planned retreat strategy is adopted for residential properties in the Byron Bay Embayment, these properties should be acquired using public funds		
Another action/timing – please specify		

Other________________________________

Question 9

What do you think adaptive management means for the way Council manages the coastline of the Byron Bay Embayment?
Please indicate which actions you think would be part of an adaptive management plan for coastal hazards in the Byron Bay Embayment.

Management element	Must do	Don't do	Could possibly do
Baseline assessment of the condition of beaches			
Ongoing monitoring of the condition of beaches (e.g. volume of sand, beach profile, dune condition, presence of erosion escarpments)			
Having clear policies for coastal land use and land management			
Monitoring of visitor numbers by season and by special event			
Monitoring of accommodation utilisation			
First Aid and Beach Safety management e.g. monitoring number of rescues			
A schedule of actions and budget, with regular progress and expenditure review			
Monitor membership and activities of surf clubs			
A community stakeholder management committee or advisory committee			
All policy information and monitoring results published on Council's web site on a regular basis			
A formal plan review process at intervals of approximately 10 years			
Regular community forums about coastal management issues			
Support for Landcare activity on the coast and monitoring of outcomes			
Monitoring the value of coastal land (i.e. land valuations) and real estate (by sale price and length of time on the market)			
Set clear objectives and management targets for physical, social and economic factors			
Regular monitoring of community satisfaction with beach management			
Having a designated Coastal Officer within Council, who is the first point of contact for the community			
Having a funding strategy to provide money for investment in coastal management			
Design guidelines for residential development in coastal positions			
Investment in coastal science projects			
Investment in coastal awareness and education			
Clear emergency response procedures			
Clear triggers for when Council will change its management strategy, to accommodate new or different risks			

Question 11
How do you think Byron Shire Council could protect and promote the cultural and heritage values of the of the Byron Bay Embayment?

Cultural and heritage value and significance refer to the importance of the landscape and specific features in it to the social, cultural and spiritual values of people. These terms are often used to describe the attachment of Aboriginal people to the land and sea. Cultural heritage can also refer to the historic values of the landscape, particularly places, buildings or features that show how people lived in the area (such as shipwrecks, cemeteries or wharves). Some natural places and features are also attributed formal heritage value because of their scientific significance. This includes rare ecological communities and geological sites.

Please mark all options that you think are relevant.

Council should not take any action in relation to cultural heritage management. Other issues are more important	
By research and monitoring to protect cultural heritage artefacts and places	
By community awareness events to tell the stories associated with cultural places and values in the coastal landscape	
By consulting with local Aboriginal corporations and implementing the Memorandum of Understanding (MOU)	
By putting up signs to provide information about areas of Aboriginal or historical cultural and heritage significance	
By creating a committee (or committees) of Aboriginal and historic cultural heritage organisations for Council to consult with on a regular basis	
By ensuring that all council outdoor employees and Landcare members understand their obligations in relation to Aboriginal heritage objects	
By carefully managing access to important features and places	
Other, Please specify	

PART 4 - ABOUT YOU

Question 12

What is your age?

18 years or younger	
19 to 30 years	
31 to 45 years	
46 to 60 years	
61 years or older	

Question 13

What is your employment status?

Unemployed	
Self funded retiree	
Aged pensioner	
In home carer	
Self Employed (small business owner)	
Employed in a business	
Government employee	

Question 14

Where do you live?

Please select the description that fits best

Within 100m of a beach within the Byron Bay Embayment	
Within 500m of a beach within the Byron Bay Embayment	
Elsewhere on the Byron coast	
Elsewhere in the town of Byron Bay	
Elsewhere in Byron Shire	
Elsewhere in the North Coast	
Elsewhere in NSW	
Elsewhere in Australia	

Question 19

Do you expect that the Byron Bay beaches will be significantly affected by coastal erosion events in the future?

Please select the description that best fits your views

	Yes, but not for a long time
	Yes, continuing or worsening current situation
	No
	I don't know

Question 15

Byron Shire residents

How long have you lived in your current residence?

Please select the time period that best fit,

	1 year or less
	2 to 5 years
	6 to 10 years
	10 to 20 years
	More than 20 years

If you own property in Byron Shire, but do not live there

how often do you visit Byron Bay (on average)

Please select the visit frequency that best describes your time in Byron Bay

	Once a fortnight or more often
	Approximately once a month
	A few times a year
	Once a year, for a holiday
	Less than once a year, or only for business purposes

If you don't own property in Byron Shire

how often do you visit (on average)

Please select the visit frequency that best describes your time in Byron Bay

	Once a fortnight or more often
	Approximately once a month
	A few times a year
	Once a year, for a holiday
	Less than once a year, or only for business purposes

For land owners

Experience of coastal erosion

Has your property been directly affected by coastal erosion events in the past?

Please select the description that best fits your property

	Yes, but not since I have owned it
	Yes and it is currently affected
	No
	I don't know

Question 16

Would you like to make other comments on coastal management at Byron Bay?

Please write your comments below

Please note, you can also write directly to Council if you would like to make longer comments.

APPENDIX 3

Comments from open survey responses

Appendix 3 – Free comments from the community survey

Below are listed the comments that were made in response to an invitation in the survey to provide further information or comments about coastal management issues and options for the BBE.

- I believe that having clothing optional beaches in Byron Shire is good for visitors and locals alike. While probably not the focus of this survey, I wanted to voice my support for keeping at least one clothing optional beach in Byron. Thanks!

- The only thing I would ask you to consider, is better wheelchair access to the beach along Tallows Beach (Suffolk Park). At the moment, most of the beach tracks are soft sand, and it restricts who can use these beach accesses. Thank you.

- Wording not very clear re "erosion". Eg. For question 16: Erosion events, mild or severe, can happen any time. Average frequency and intensity likely to increase over time through climate change, but only slowly. It is the short term events which are of greatest immediate concern.

- Representative democracy is a core value of local government - it would be good if the Councillors could take this into account as one of the purposes of the Council. LGA's responsibilities are to provide physical infrastructure to protect and develop the community - roads, bridges etc., community facilities, urban planning and renewal etc, etc. The Byron Council should focus on servicing its community and rate payers, and helping the local area be the best it can be. Stop singling out areas like Belongil and not supporting them. Get on with doing your jobs properly for ALL of the locals.

- I would like to see the immediate banning of plastic water bottles and plastic bags with the future roll out of a ban on plastic and polystyrene takeaway food containers - straws, cups - these items are contaminating our waterways and harming our wildlife

- If a rock wall is built, it should include a footpath to permit access along the beach from Sunrise to town at high tide.

- Dogs on leads should be able to be taken between Sunrise and the existing dog beach at Belongil. Signage should be erected to inform homosexuals who frequent Tyaggarah and Sunrise beaches to be encouraged to frequent the apparently recognised beach at Broken Head so that women, families and others need not be irritated by their inappropriate behaviour.

- Regarding this survey question 17 needs another box - full time student.

- Leave nature alone and don't build on the sand

- council need and active sand pumping strategy to help reinstate beaches at a quicker rate after a significant erosion event

- Beach-nesting shorebirds and migratory shorebirds and terns depend on the beach for their survival, especially in and around estuaries - little regard is given to these species when developing coastal management plans - coastal plans should also have strategies for protecting the breeding, feeding and foraging places of these birds.

- The planned retreat has been in place for decades. It seems pointless to spend money fighting Mother Nature. Yes, protect the township of Byron Bay, but I'm sorry - the landowners at Belongil knew the risks when they purchased their properties. Banks and insurance companies won't protect them, so why should the Byron Shire Council?

- Controlling access - paid visitor parking at Watego's as at the pass, Clarkes and Main Beach

- Large sandbags on beaches and similar hard works are an unacceptable form of erosion management. They are dangerous when constructed and an eyesore on the beach.

- We really need a boat safety officer at The Pass on weekends and public holidays if it is good weather.

- I do support permanent protection of coastal areas and support improvement of access points, particularly at jetty carpark Belongil beach. I am concerned about erosion of dunes at Border St. - I frequently see visitors accessing beach all along this area despite there being defined access nearby. Is there a solution to this? In relation to condition of roads in town, they are in a pretty poor state - is there a way to raise revenue from all the tourists to Byron to help maintain roads and infrastructure? Maybe more paid parking or bed tax?

- I think these questions are poorly worded and make clear answers difficult. I also think the questions show a bias in the person/ group who developed them. Some of the choices are ridiculous. This is a political document not a true independent survey.

- The instability of these beaches has been known for a long time (The 1970s?) The 1974 cyclone footage should be accessed and be shown to the community regularly to remind /inform newcomers of the dreadful threat that cyclones pose to the state of the beaches and the stability of the town. People have to be made aware of the dangers in the event of a 1954 cyclone/and accompanying storm ocean surges. Rock walls and bags are really a waste or money, They don't stop surges, but they do give people living behind them a false sense of security. Can Belongil residents be allowed to sue the BSC if the walls fail and they lose their property/lives during a cyclone event and associated storm surge. Everyone has forgotten, even the council planners, and the developers do not want to remember, because it will redefine the North Coast and that will affect property values and development into the future. Remember the footage of waves breaking over Julian Rocks and the white water pouring through the hotel and down the main street, a whole street collapsed at the Belongil and disappeared into the ocean, ...walls don't stop big waves.

- Visitors have commented to me about the poor state of the toilets and few toilets available within Byron Bay.

- Development of the public foreshore land between Clarkes and Main Beach should be considered as part of this. The reserve along this strip is a vastly under utilised asset with huge potential to create a place for locals and visitors to use, enjoy and access the beach. At the same time this would enhance our towns charm as well as showcasing it's beaches, natural environment and lifestyle.

- The embayment is not a natural process. Jonson street groins effect the areas to the immediate north causing the embayment.

- THE INEQUITIES OF THE PREVIOUS BYRON SHIRE DRAFT COASTLINE MANAGEMENT PLAN WHICH WAS WITHDRAWN BY COUNCIL IN THE FACE OF POTENTIAL REJECTION BY THE STATE GOVERNMENT MUST NOT REPEATED IN THIS NEW PROPOSAL FOR MANAGEMENT OF THE BYRON BAY EMBAYMENT!

  If it is determined to provide protection works for infrastructure ,properties and business premises in the town centre then other property owners outside this Byron Bay Town centre must not be denied the right to take actions which similarly protect their assets.

- council needs to look after existing residences and allow owners to protect their properties

  using the existing rock walls and extending them otherwise the beach will fall into private ownership

  why pull good rock walls down when they've been there for 40 years

- Please do not forget the things that bring tourists and people like us to Byron from Brisbane sometimes every weekend is the laid back approach to the place. Do not make it like Surfers Paradise, it needs to keeps it's laid back vibe, calm, respectful nature. Byron has changed over the last 20 years... Make sure you don't forget your roots and where you came from... That makes Byron special.

- Byron Bay is a "bay" from erosion that occurs at a greater rate due to the rocky headland of Cape Byron. The "bay" will keep expanding inland and with it, buildings. To have sandy beaches can only be achieved with NO rock walls or groynes.

- Council received good independent advice about coastal erosion and anti erosion measures in 2003. Council should implement the most appropriate measures NOW.

- I have been unable to answer a number of questions in this survey as many of the questions are misleading or presuppose an outcome which is based on false or misleading options. The survey should refer to the most recent science. I don't believe that a lay person can legitimately undertake this misleading survey and provide Council with any meaningful information. Consequently I believe that the survey process is flawed in invalid and does not fulfill council's obligation in regards to public consultation.

- In view of the recognised importance of the beaches to the fabric of the town i am often appalled by the amount of seaweed and debris left on the beach which in other councils is very easily collected with a small grader. Particularly over holiday periods.

- Stop development to close to the beach, prevent erosion by reducing *ad-hoc* access and prevent pollution rubbish plastic and broken glass

- Council needs to undertake the research, decide the direction (strategies) and play a leadership role using best practice policies and actions. Great survey - thank you

- Main Beach car park is an eyesore and access from there to Belongil is hazardous.

- I strongly support planned retreat particularly where it was already foreshadowed, i.e. Belongil. Where other properties will become affected, they should be notified and Council amend their land deeds accordingly. Not sure Council can put planned retreat into effect due to State government rulings but more research on effect of rock walls is urgent. I have seen what happened in Noosa due to fiddling with river mouth. Nature is boss and we need to face this. All our coastline is beautiful - because it has retained its natural aspects. We must find a way to implement planned retreat. Thank you for this opportunity to have my input.

- Thanks for asking :-)

  It seems to me that Byron Bay was founded on a rich history of environmental pillage (black sand mining, mineral sand mining, whaling, etc) and I would like to assume that improving the beach with additional sand is unlikely to do anything more than unsettle a previously disturbed ecology (which may settle down again within 5-10 years). I think it would be good for council to commission a study to support that idea.

  Rock walls and more sand seem like an appropriate solution that would make everyone happy.

  I don't have any objection to civic development and would love for this town to take a few strides in the direction of modern, progressive (and sustainable) design and planning.

- Byron town and coast is a unique International Australian attraction [like Opera house and Uluru etc] and should get State and Federal funding for infrastructure and help to cope with number of tourists. We need and want more tourists and ratepayers to keep the town economically viable and progressing with vision.

- Belongil in particular is a established village within Byron,with many homes and businesses. The foreshore needs rock protection to defend the whole of Belongil and beyond from inundation from excessive storms .abandon Belongil and its infrastructure will perish its residents will suffer and the beach will suffer. Had Belongil not been settled all those years ago, it would be fair to "let nature take its course " as some people would like ,but it's too late to abandon it ,common sense would say to protect it in the most economically efficient way, not with sandbags which have been a waste. Rocks are used all over the world to protect cities and towns ,they are natural and require minimal upkeep.

- This online survey has been written in a biased manner with a considerable number of leading and inappropriately worded questions. Council should be aware that this survey is so biased, that it is likely to invalidate the public consultation process Council is required to undertake in relation to the CZMP in a fair and even-handed manner.

- Council cannot erect rock walls for its own purposes and yet not allow them for private property protecion

- Although we love the aesthetics of the Byron Bay embayment. we, as the public, use it first and love it second. Appreciating the beauty of the natural form is something done typically during a activity (sitting in Federal and knowing Wategos exists doesn't do it for me). If there were no beaches in Byron then the extent of activity would be similar to that which occurs at Broken Head - a little only. A beach that is in constant sand movement is accepted by the public since activities can still take place. If there is no sand then seaside activities are greatly diminished - and so will the volume of people and their associated appreciation of the area will be greatly reduced. Hence keeping some sand is imperative to keeping high levels of appreciation.

- If sea walls reduce the volume of sand that can be walked on then an individual private owner should not be penalised for the benefit of the masses (i.e not allowed protection materially or monetarily). Council policy has been made on sea level rise for the next 90 years. The same could be done for a slowly growing Council fund (by having varying Council rates depending on your property location, or business in relation to beach tourists) to acquire portions of sea front properties at market rates over the same time period.

- I think the community would understand the issues of each of the councils options better if they were better informed. Relying on local newspapers only creates uniformed discussions and decisions.

- a permanent rock wall should be positioned along the entire Belongil area, with seasonal sand pumping as required

- I have been a resident of the area for twenty years and have seen private interests take advantage of council and further damage amenity in so many ways. Now we only return for family reasons. repair the dune system, rid the dunes of pest millionaires.

- Keep communicating, negotiating, listening & acting with your community & rate payers. Surveys are GOOD!

- Federal government ocean level monitoring & tide chart datum clearly show sea levels are rising as the earth warms. I'm an engineer who studied Coastal Engineering at UNSW and have seen the erosion since I grew up in Byron in the 70s. The rock wall at Main Beach is too steep, should never have been built as it was & only makes erosion worse to the west as is clearly evident in the aerial photos. The Ballina training walls probably made erosion worse as they disrupt sand movement up the coast & pushes it into deeper water. I know better than most the extent of erosion from Main Beach to The Belongil as in 74-75 my best friend lived west of the meat works, I saw the houses and road lost & in 79-80 I used to soar in a hang glider along that dune line that used to be straight to the Belongil but is now far too crooked. Byron Council can not afford to replenish sand as they do on the Gold Coast & longer term it will eventually be overwhelmed unless we have a massive volcanic eruption or something similar to cool the planet again. it's unfair to force other rate payers pay for it anyway. Rock walls destroy the natural beach profile and prevent access along the beach for the public & tourism. Even after the 74 erosion, I could walk along the beach to my friends house west of the meat works but now there are too many private property protection walls that prevent longitudinal beach access.

- The general public and beach front residents do not understand coastal sand movements or sea level rise and decisions need to be based on sound understanding of the science not short term political whim and whingers. The public & land owners need to be taught about beach erosion and the history. eg Byron was mostly under water about 6,000 years ago & there's been significant erosion already over the last 120 years. They need to be taught & accept the probable future of significant erosion & rising water levels right back to the industrial estate (where I own property unfortunately).

Government must act to prevent property protection that negatively affects everyone else. There must be NO payouts to existing erosion & flood prone land owners as it's not everyone else's fault they bought in an erosion prone location. (Same for fire & every other type of natural hazard.) "Let the buyer beware" & take the consequences of their own decisions just like in almost every other type of business & life decision. Town planners and government surveyors in the past did not realise the extent of erosion and what would happen to coastal towns. Laws are needed to make sure current councils (i.e. rate payers) don't have to pay compensation for land owners' poor purchase decisions & short sightedness. Laws need to ensure property owners, councils & government don't keep trying to protect property at great expense to everyone else.

- I think there should have been a few more obvious questions in this survey, such as "do you rent or own your own home", and there could have been a 'don't know' box number 10 'What actions should Council take in response to potential impacts of coastal hazards on private properties?Please indicate whether you agree or disagree with each statement', as personally I would have answered 'don't know' to many of these questions.

- Not clear if you consider Suffolk Park/Tallows as part of the Byron embayment or not

- Rockwalls to stabilise access should be considered as part of the bigger picture of Byron Bay and erosion trends into the future. Maintenance costs will be raising as erosion increases. A clear vision for the Embayment should be created and followed by Council, based on wide stakeholder consultation. This survey is a great start.

- Maintain proper access to beaches where possible. To avoid further erosion on walkways

- I only observed that any time human beings try to build something that forces rivers or oceans where they are not or don't want to be, it will just be a matter of time, but nature always goes back to the course it wanted, and often it makes it worse. A clear example is what was done to the Belongil river before the wedding shack of the Beach Club went down. It was the changing of the river course that set it to eventually run even closer to the land of the beach club and destroy so much!

- The Belongil area in particular was always prone to erosion - and therefore 'planned retreat' was a condition to build there. Private landowners need to take responsibility for their choice of location, and we need to allow the natural erosion of the coastline - as nature intended. Ratepayers + Council should not be required to pay to protect buildings in a planned retreat area.

- the public should not be compensating private investors whom make investments fully aware of the risks, otherwise all property owners should be compensated when climate change or other erosional or storm processes affect their assets whether they live near the coast or not

- The Byron Shire Council should provide financial support to non-profit groups that are helping to educate the public about marine debris and protecting our marine environment e.g. Australian Seabird Rescue and Sea Turtle Hospital.

- Question 17 does not have an option for my occupation which I would describe as full time employed educationally

- Rebuild the dunes

APPENDIX 4

Workshop invitees and attendees

No	Invitee	Attending (Yes/No)	Contact Name
1.	Ralph Lauren Pty Ltd & others	Yes	Patrick George Private landholder
2.		Yes	John James Private landholder
3.	4 The Esplanade Byron Bay Pty Ltd	Yes	Graham Dunn Private landholder
4.	Estate of Late M A O'Neil	No response received	
5.	Mr C W & Mrs L G Burke	Yes	Chris Burke Private landholder
6.	Mr J B & Mrs A Vaughan	Yes	John Vaughan Private landholder
7.	Mr M D & Mrs B M Taylor	No response received	
8.	Ms J L James	No response received	
9.	Mr R C Watson	Yes	Henry Addison for Robert Watson Private landholder representative
10.	Mr R V Dulhunty	No response received	
11.	Mrs D K Cornell	No response received	
12.	Mrs D K Trainor	No response received	
13.	Shuttlewood Properties Pty Ltd	Yes	Jonathan King Private landholder
14.	Office Environment & Heritage Ben Fitzgibbon	**No** **PLEASE PASS ON APLOLOGIES FOR OEH REP** - Ben, John Schmidt & Toong also cannot make it	
15.	Crown Lands Peter Baumann Crown Lands David McPherson	Yes	Kevin Cameron Crown Lands
16.		Yes	David McPherson Crown Lands
17.		Yes	Catherine Kerr Crown Lands
18.	DPI Fisheries Patrick Dwyer	No response received	
19.	Environment Protection Authority Brett Nudd	No	
20.	Cape Byron Marine Park Andrew Page	Yes	Andrew Page Cape Byron Marine Park Or Dave Maguire Cape Byron Marine Parks
21.	Byron United Inc Paul Waters	Yes	Adrian Nelson Byron United
22.	Byron Preservation Association Michael Siddle	Yes	John Callanan Byron Preservation Association
23.	Byron Environment Centre	No	

24.	BEACON (Byron Environment and Conservation Group) Dailan Pugh	Yes	Dailan Pugh BEACON
25.		Yes	Representative BEACON
26.	Surfriders Foundation Don Osbourne	Yes	Don Osbourne Surfriders Foundation
27.	Byron Bay Services Angling Club Peter Watts	Yes	Peter Watts Byron Bay Services Angling Club
28.	Byron Bay Surf Lifesaving Club Neil Cameron	Yes	Neil Cameron Byron Bay Surf Lifesaving
29.	Belongil Bistro Café Christian Poulsen and Mindy Halabe	No response received	
30.	Treehouse Café Nick	No response received	
31.	East on Byron	No	
32.	North Byron Beach Resort Jeremy Holmes	Yes	Jeremy Holmes North Byron Beach Resort
33.	Bunjalung of Byron Bay - Arakwal Yvonne Stewart	Yes	Yvonne Stewart Bundjalung of Byron Bay Aboriginal Corporation (Arakwal)
34.	Ken Gainger	No response received	
35.	Shannon McKelvey	No response received	
36.	Ray Darney	Yes	Ray Darney Byron Shire Council
37.	Alex Caras	Yes	Alex Caras Byron Shire Council
38.	Phil Holloway	No	
39.	Catherine Knight	Yes	Catherine Knight Byron Shire Council
40.	Jill Boschman	Yes	Jill Boschman Byron Shire Council
41.	Cr Richardson	No	
42.	Cr Cameron	No response received	
43.	Cr Woods	No	
44.	Cr Wanchap	No response received	
45.	Cr Dey	Yes	Cr Duncan Dey
46.	Cr Cubis	No response received	
47.	Cr Hunter	Yes	Cr Alan Hunter
48.	Cr Ibrahim	No response received	
49.	Cr Spooner	Yes	Cr Paul Spooner
50.	James Carley – WRL	Yes	James Carley Water Research Laboratory (UNSW)
51.	Pam Dean-Jones – Umwelt Australia	Yes	Pam Dean-Jones Umwelt Australia
52.	Melissa Kilkelly	Yes	Melissa Kilkelly Umwelt Australia
53.	Dave Anning - GCCM	Yes	Dave Anning

			Griffith Centre for Coastal Management
54.	Immer No 196	No response received	
55.	Tom Gleeson Youth Representative	Yes	Thomas Gleeson Youth Representative
56.	Scotty Harland – Byron Boardriders		Jenny King Byron Bay Board Riders
57.	Mary Gardner Ecologist/writer	Yes	Mary Gardner Ecologist/writer
58.	Karl Godsell Positive Change for Marine Life	No	
59.	Marcello Sano	Yes	Marcello Sano Griffith University Research Fellow and resident
Total		34 yes 16 – no response	

APPENDIX 5

Workshop briefing paper

Coastal Hazard Management Study for the Byron Bay Embayment

Background briefing for a stakeholder workshop on 18 February 2014
Time – 4.30pm to 8pm

1.0 Introduction

Byron Shire Council will soon prepare a draft coastal zone management plan for the Byron Bay Embayment. In preparation, Council has commissioned consultants WRL (University of NSW) to prepare a coastal hazard management study. The workshop is part of the process for evaluating options to manage coastal hazards in the Byron Bay Embayment.

Thank you for agreeing to participate in this workshop and making your time available. This briefing provides information to help everyone get the most out of the discussion.

A program for the workshop is attached on Page 16.

1.1 The study area

The Byron Bay Embayment study area is shown in **Figure 1**. The focus of this project is a subset of the Byron Shire coastline, including:

- North Beach
- Belongil Beach
- Main Beach
- Clarkes Beach
- The Pass
- Wategos Beach

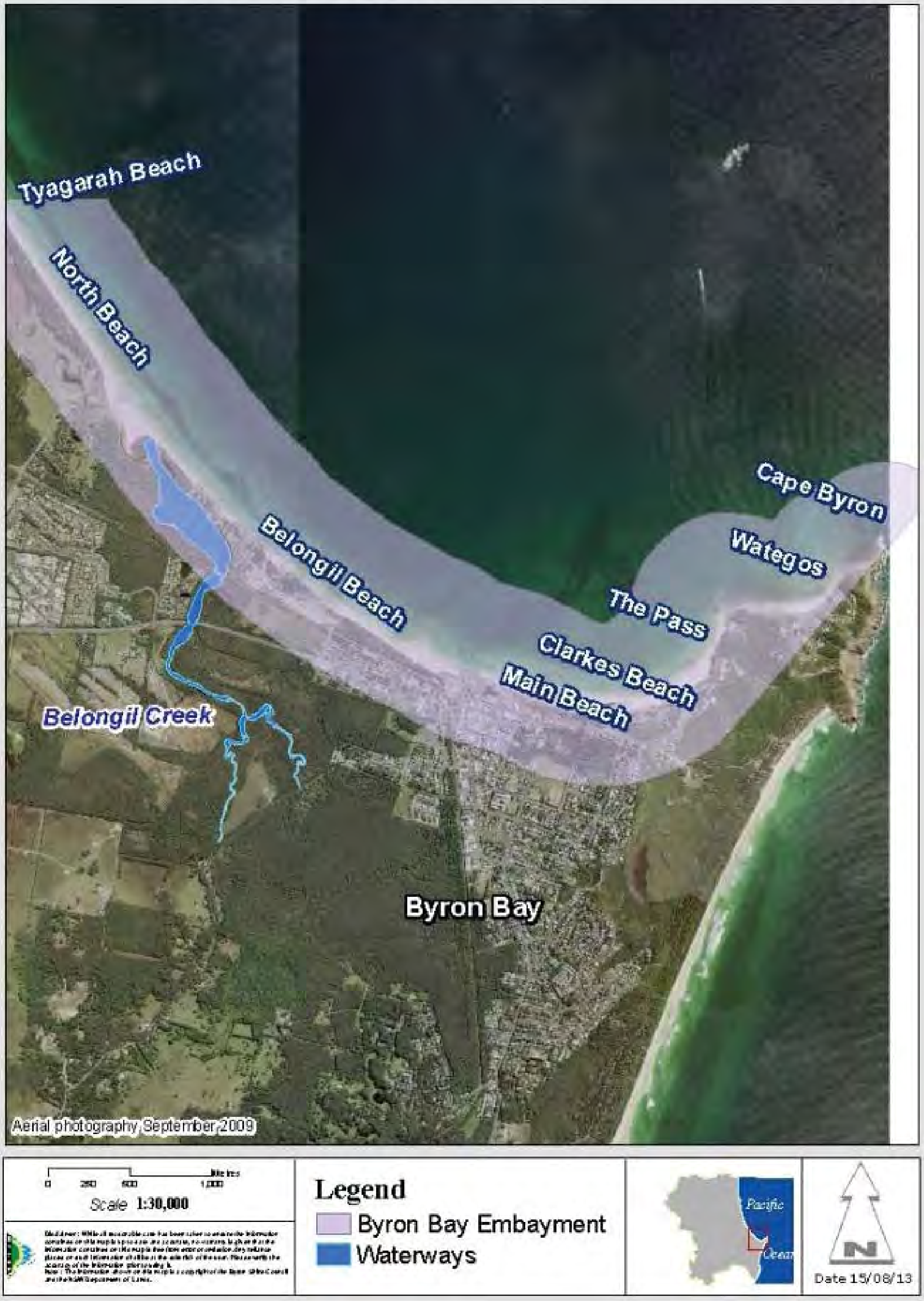
1.2 Why only consider these areas?

The Minister for the Environment has directed Byron Shire Council (BSC) to prepare a draft Coastal Zone Management Plan (CZMP) for the Byron Bay Embayment by 30 June 2014. This direction does not apply to other parts of the Byron Shire coastline. BSC will prepare a CZMP for other parts of its coast later.

1.3 What is the project about?

The project is a **coastal hazard management study**. The output is an evaluation of the potential management responses for coastal hazards affecting the Byron Bay Embayment. The project will provide Council with three lines of evidence on the best approach to the management of coastal hazards and risks in the Byron Bay Embayment: technical feasibility (T); reasonableness (R); and cost/benefits (C). Byron Shire Council will then prepare and exhibit the draft coastal zone management plan, taking into account the option evaluation conducted during the coastal hazard management study.

Figure 1 - Byron Bay Embayment Study Area



1.4 Option evaluation process

Figure 2 shows the three stage evaluation process (T+R+C). The evaluation process considers options to manage the coastal hazards that are defined and scoped in the most recent coastal hazard assessment (BMT WBM 2013, adopted by Council in October 2013).

The results will be reported to Byron Shire Council in writing and in briefings to Councillors.

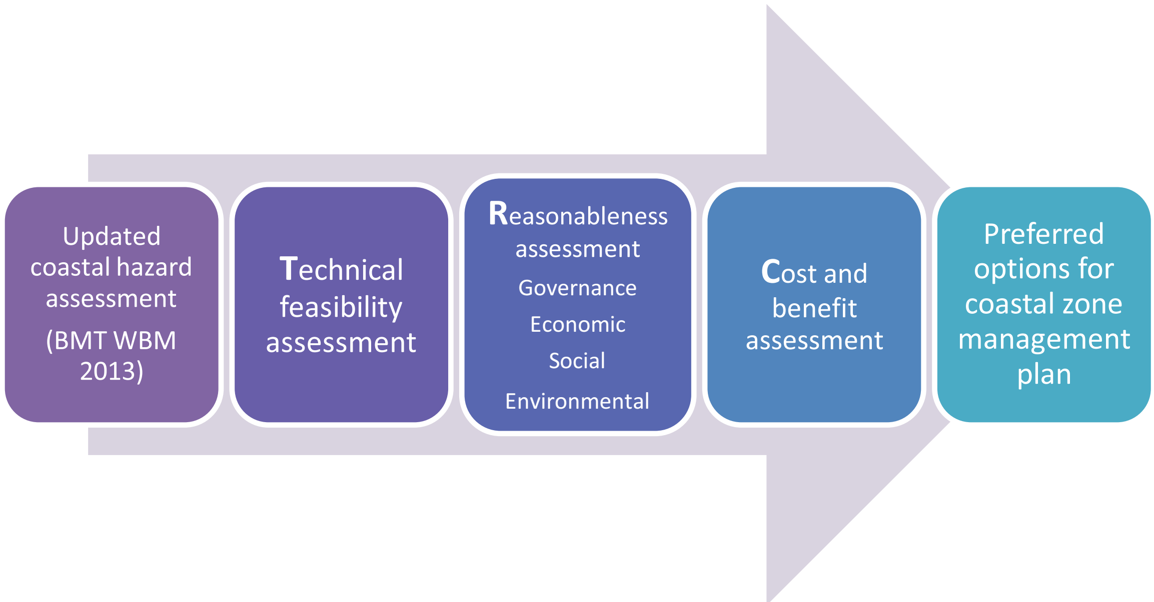


Figure 2 – Option evaluation concepts

1.5 What the workshop is about

The workshop is part of the coastal hazard management study. The discussion will focus on the extent to which potential management options could be consistent with the ways the community uses, enjoys and values the coastline. The discussion will help inform Council's understanding of management options that are considered reasonable by the community.

The workshop will include short presentations by the consultants; directed small and larger group discussion to apply the criteria (in **Section 2.2** below) to determine reasonableness; and processes to highlight benefits and constraints and to rank the reasonableness of options.

Feedback on the workshop process will be invited.

1.6 How participants were invited

Previous studies have demonstrated important community uses, values and benefits associated with the Byron Shire coastline. The Byron Bay Embayment is valued by the local community and also by people from other parts of NSW and Australia.

People invited to participate in the workshop represent the diverse interests that the local community has in the coast, including cultural, recreational, environmental, social and economic interests; the interests of young people, traditional Aboriginal owners, long term residents, new arrivals, absentee property owners and businesses; people who live right on the coast of the embayment and people who live further away; and people who are members of community groups such as the surf club and Dunecare. State agency officers will also participate in the discussion, provide advice on statutory requirements and answer questions, as necessary. Selected Council staff will also attend to help facilitate the workshop and to answer questions.

1.7 What we need you to do

Please arrive on time. Tea and coffee will be available from 4pm and sandwiches will be served during the evening.

Please be ready to participate in active listening; to think about new information and perspectives; explain what's important to you; and be part of constructive discussion with other participants, who may not have the same ideas as you.

1.8 How your input will be used

Shortly after the workshop, a report will be prepared to document how the discussion went and the conclusions that were reached. The report will be provided to Council and also made available on Council's web site.

The 'background' section below (**Section 3.0**) explains how the outcomes from the workshop will contribute to the evaluation of the reasonableness of potential management options.

1.9 Other opportunities to contribute your views

In the current project, broad community interest and opinion has been sought through a web based survey.

The on line survey is open to anyone to complete by 13 February 2014 (see **Section 2**). Written submissions explaining your concerns, suggestions or preferences are welcome until 28 February 2014. Council is also seeking formal advice from state agencies about their requirements by 28 February 2014.

When Council prepares the draft Coastal Zone Management Plan for the Byron Bay Embayment, it will be exhibited for community comment and feedback. Further submissions will be welcome at that time.

2.0 This project so far

The following tasks have been competed or are underway:

- An updated coastal hazard study (BMT WBM 2013) was adopted by Council in October 2013.
- WRL (the consultant) is preparing a draft technical feasibility assessment. This will include a review of management responses identified in the coastal hazard study (BMT WBM 2013); and an evaluation of the technical competence of the proposed options, based on engineering principles and practice, and evidence of performance in managing similar processes and hazards. WRL is also preparing a preliminary assessment of reasonableness based on known governance, environmental, social and economic factors.

- Anyone with an interest in the management of the BBE coastline was invited to complete a 20 question survey, available on Council's web site and in hard copy. The survey has been open for four weeks. Go to http://www.byron.nsw.gov.au/council-notices/2014/01/14/community-survey-for-the-coastal-hazard-management-study-of-the-byron-bay if you have not already completed the survey and would like to do so. The survey seeks information about how people use the coast, what is important to them, and what they think about a range of coastal zone management issues.

2.1 Defining feasible

In this project, 'feasible' is used to describe and assess the technical capacity of potential management options. The following aspects are considered:

- The option is consistent with quality engineering practice
- There is evidence (from applications for similar hazards in similar environmental contexts) that the proposal can mitigate identified coastal hazards and risks (as identified in the Coastal Hazard Study prepared by BMT WBM 2013)
- The option is adaptable and it is practical to enhance or reduce the scale of the response if new information shows an alternative would be more appropriate, effective and efficient. For instance, sea wall design could allow for removal or upgrading.
- The option is appropriate for more than one coastal hazard
- The proposal can be integrated with other management responses (as most risks will best be managed by a combination of responses).

2.2 Defining reasonable

A 'reasonable' option is one that meets environmental, social, economic and governance considerations in an acceptable way. For this project, it is proposed to use the criteria noted below to assess reasonableness. These criteria are based on the principles set out in the NSW Guidelines for Preparing Coastal Zone Management Plans: http://www.environment.nsw.gov.au/resources/coasts/101019GdlnsCZMPs.pdf

The Guidelines (page 9) state that in assessing whether an option is reasonable, the following should be considered:

- The NSW Coastal Management Principles and State and local government legislation and policies (see **Tables 5** and **6** for details)
- The social, environmental and economic impacts of the option, including its benefits and costs, and any impact on the cultural values of the local area
- The views of the community and other stakeholders, including those provided during exhibition of the draft CZMP. In some circumstances, there will be conflicting community and stakeholder perspectives on how to manage an issue. The CZMP should seek to achieve a balanced approach after considering the community and stakeholder views in the context of potential environmental, social and economic costs, impacts and benefits.

2.3 Next steps in the project

After the stakeholder workshop, a report on the outcomes of the survey and the workshop will be prepared, focusing on the evaluation of 'reasonable' options. The report will explain the rationale underpinning the evaluation and how the evidence from consultation has been used. The report will also inform the development of a short list of management options.

A cost benefit analysis will be conducted on the shortlist of options. Results of all three strands of the analysis (T+R+C) will be reported to Council.

3.0 Background

3.1 Previous studies and plans

Many aspects of the coastal hazards of the Byron Bay Embayment are well documented, through previous studies, such as:

- Byron Shire Coastline Hazards Assessment Update (BMT WBM, 2013)
- Byron Bay Erosion Protection Structures - Risk Assessment (WorleyParsons, 2013)
- Investigating the redesign of the Jonson Street Protection Works (WorleyParsons, in preparation)
- Results of the Byron Shire Coastal Audit conducted May 2010 to May 2011, Ordinary Meeting of Council 30 June 2011, Report No. 12.19
- Draft Coastal Zone Management Plan for Byron Shire Coastline (Byron Shire Council 2010).
- Peer review of Report on Byron Bay Coastal Modelling by Dean Patterson (University of NSW and Water Research laboratory, 2010)
- Modelling Byron Bay Erosion and Effects on Sea Walls (Patterson, 2010)
- Scoping Study on the Feasibility of Access to Cape Byron Sand Lobe for Sand Extraction for Beach Nourishment (Patterson Britton & Partners Pty Ltd, 2006)
- Byron Shire Coastline Management Study (WBM Oceanics 2004)
- Byron Coastline Values Study (Byron Shire Council 2000)
- Byron Shire Coastline Hazard Definition Study, Final report (WBM Oceanics 2000)
- Byron Bay – Hastings Point Erosion Study (PWD 1978)

Links to most of the above studies can be found on Council's website at http://www.byron.nsw.gov.au/byron-shire-coastline-management-1

In addition, useful information about requirements and factors that need to be considered in identifying and managing coastal hazards and risks is available on the OEH and Department of Planning and Infrastructure web sites.

3.2 Coastal hazards and risks

A **coastal hazard** occurs when a physical coastal process interacts with: the natural coastal environment; built environment and assets (whether public or private); or social, cultural and economic values of the coastline (such as safe access and recreation, important ecological communities, important cultural places or landscapes, tourism and businesses). A coastal hazard can also arise when human development has impeded natural coastal processes.

In 2013, BMT WBM investigated the coastal hazards relevant to the Byron Bay Embayment (see BMT WBM 2013 in the above references for details).

For the Byron Bay Embayment the coastal hazards identified include:

- Short term beach erosion (sometimes called storm bite);
- Ongoing and longer term coastal recession over the 2050 and 2100 planning horizons (with and without sea level rise);
- Coastal inundation (associated with high tides, storms and wave run-up); and
- Coastal creek entrance instability

Figure 2, from BMT WBM 2013, summarises the coastal hazards affecting beaches in the Byron Bay Embayment.

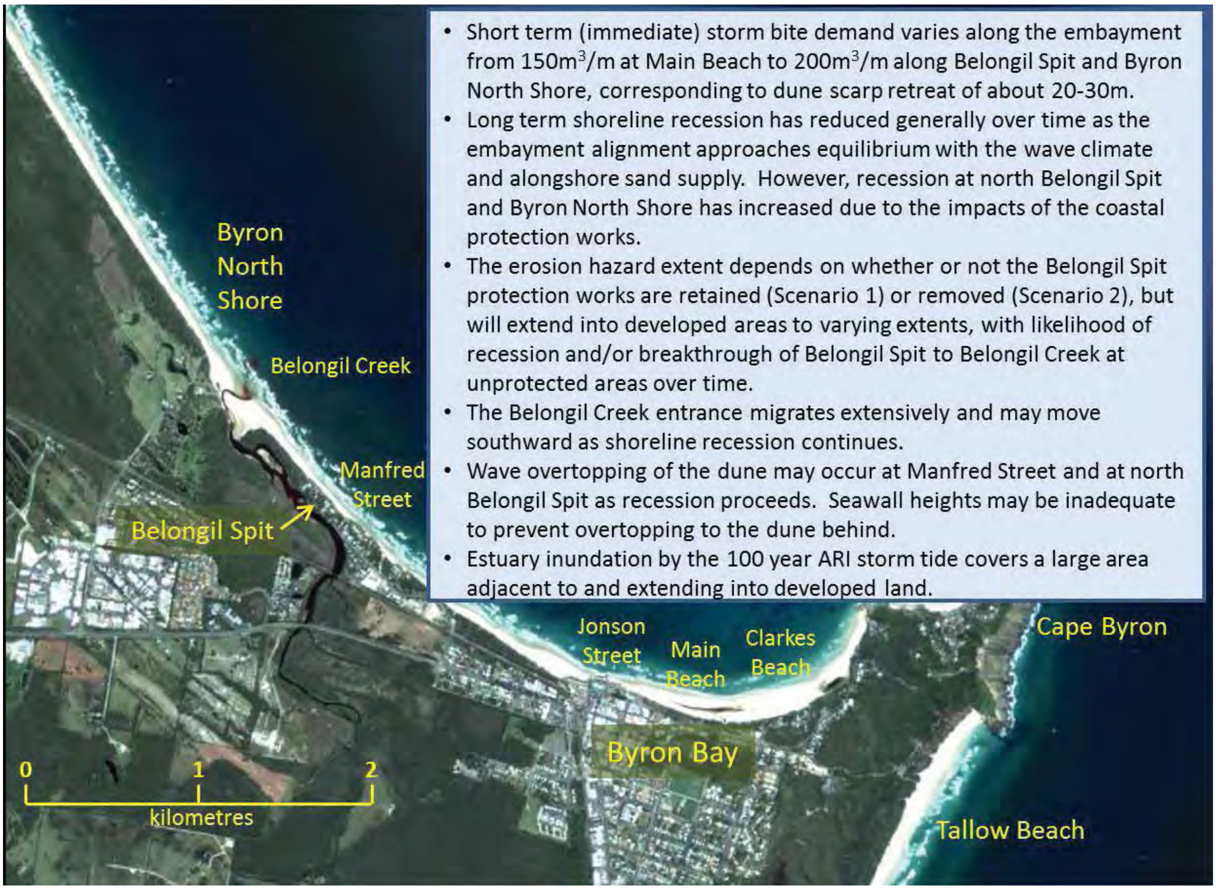


Figure 2 – Coastal hazards affecting the Byron Bay Embayment (from BMT WBM 2013, page XVI)

Coastal hazards occur in immediate and longer term timeframes. **Figure 3**, from DECCW 2010, shows conceptually immediate and longer term coastal erosion hazards that affect sandy coastlines.

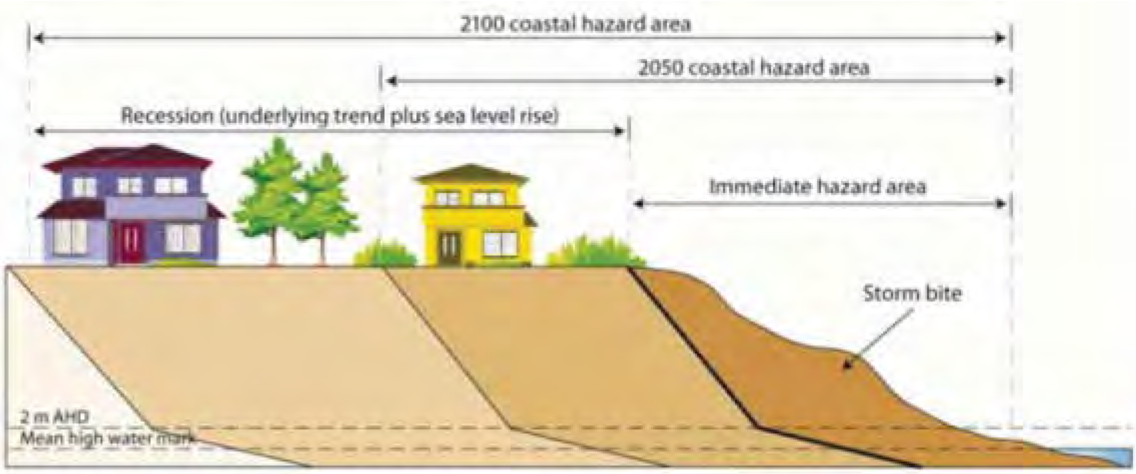


Figure 3 – Idealised schematic of a dune profile showing the immediate hazard area, 2050 coastal hazard area and 2100 coastal hazard area
(From DECCW 2010)

Coastal risks arise from the likelihood (how often?) of a coastal hazard occurring and the consequence of the hazard occurring (What would happen? What is the impact?). Consequences of coastal hazard events include: damage to beach access ways; impacts on public safety; damage to coastal vegetation and habitats; damage to cultural sites and places; loss of beach space for public recreation; damage to public infrastructure assets such as roads and sewer pump stations; damage to beach front reserves and facilities (such as surf clubs); damage to private property and dwellings; loss of tourism reputation and business revenue. Some of these consequences are much more difficult to quantify than others.

In accordance with the NSW Coastal Zone Management Principles (set out in the Guidelines for Preparing Coastal Zone Management Plans and summarised in **Table 6** of this document), high **public safety** risks take priority over risks to built assets.

Because the impact of coastal hazards is expected to change over time (e.g. see **Figure 3**), within the life of built assets, it is important to consider multiple time frames when assessing the level of risk.

Table 1 provides a summary of the types of assets and values that can be threatened by coastal hazards and the indicative risk levels which apply when coastal hazards affect these assets, now and in the future, for relevant places within the Byron Bay Embayment. This table considers built assets and other values separately, but some areas have both significant built and natural or social values. Where this is the case, the risk level for any given hazard and likelihood is expected to be higher.

Table 1 – Indicative coastal risk, linked to potential consequences and timing

Level of development or natural or cultural value	Affected by coastal hazard NOW	Affected by coastal hazard in the FUTURE*	Indicative risk level	Examples of relevant places within study area (from BMT WBM 2013)
Areas with no development or built assets/infrastructure; no significant natural, social or cultural values	No	No	**LOW**	
Areas with no development but significant ecological, social or cultural value	No	No	**LOW**	Little Wategos
Areas with no development or built assets/infrastructure but significant ecological, social or cultural value	No	Yes	**LOW**, increasing to **MEDIUM** or **HIGH** (needs detailed, site specific assessment and planning)	
Areas with no development or built assets/infrastructure, but significant ecological, social or cultural value	Yes	Yes	**MEDIUM** to **HIGH** (needs detailed, site specific assessment and planning)	North Beach North Belongil Spit - Ecological values are threatened by coastal hazards (entrance instability) now. Some Aboriginal sites at The Pass are threatened by immediate coastal erosion hazard. All beaches have significant recreational and social value.
Areas with existing development or built assets/infrastructure	No	No	**LOW**	Wategos - Erosion is constrained by bedrock and existing works along Marine Parade
Areas with existing development or built assets/infrastructure	No	Yes	**LOW**, increasing to **HIGH** (long term)	Clarkes Beach - Immediate erosion hazard affects beach access ways, but future recession extends towards roads and stormwater systems.
Areas with existing development or built assets/infrastructure	Yes	Yes	**HIGH** to **EXTREME** Urgent risk reduction action required	Belongil Beach and Spit (where private land and houses are present) Jonson Street and Main Beach area. NB: The extent of current and potential future sea wall protection affects the extent of future recession at these locations.

(*medium or long term, generally more than 40 years hence (2050), through to 2100)

3.3 Risk Management

The NSW Guidelines for Preparing Coastal Zone Management Plans outline broad options to manage coastal risk, including strategies to prevent low risks from increasing and strategies to reduce high and unacceptable risk levels. Thee Guidelines identify six broad approaches to risk management which can be relevant to managing risks associated with coastal hazards. These broad coastal risk management options are summarised in **Table 2**. In general, these options focus on risks that relate to the built environment.

For many coastal risks, the best management will involve a combination of management strategies.

Table 2 – Broad Options to Manage Coastal Risks (Based on OEH 2010)

Risk Strategy	Options	Some local examples of the application of this approach
Avoid the risk **Good for areas of low risk, or to prevent risk from escalating**	Building setbacks implemented through planning and development controls.	This is what Byron Shire Council has historically done, through identification of coastal planning precincts and application of development controls.
	Infrastructure setbacks (public assets)	
	Building design criteria such as floor levels and footing design	
Change the likelihood **Potential benefits for areas with existing development or infrastructure**	Coastal protection works (sea walls, groynes, artificial reefs).	Examples include sea walls at Jonson St and along Belongil Beach
	Beach nourishment (needs accessible sand source of appropriate scale)	Beach scraping has been used in parts of the Byron Shire coast. This is not beach nourishment.
	Revegetation on dunes to help retain a buffer of dune sand	Council, Dunecare groups and NPWS have all worked on dune revegetation programs, e.g. Main Beach.
	Compliance action in relation to illegal works on beaches	
Change the consequence	Building or infrastructure relocation or modification	Identification of coastal planning precincts and application of development controls. Border St at Belongil Beach has been realigned, further back from immediate hazard zone.
Share the risk	Insurance (note insurance is not generally available for coastal erosion impacts)	
Retain the risk by an informed decision **Necessary for immediate high risk areas**	Emergency management (including monitoring and warning systems)	Council has prepared a Draft Emergency Action Sub Plan for the Byron Shire Coastline
No regrets (actions that are good practice regardless of the risk level). These actions will not necessarily reduce the risk by themselves	Raise community awareness and education about coastal processes, risks, safety and coastal planning Revegetation on dunes to maintain ecological connectivity and visual amenity as well as provide a potential short term buffer	Signposting, consultation, field days, news articles and discussion in community groups are all part of awareness raising.

3.4 Values defined for the Byron Bay Embayment

A coastal values study for the whole of the Byron Shire coastline was completed for the Council in 2000. It was based on evidence published in the 1990s and 1980s so is now somewhat dated. It noted that very little information was available to qualify and quantify many of the coastal values, particularly at the scale of individual embayments, so some description is quite generic.

The values study considered six main classes of coastal value to the community. The current project does not include a detailed update of value documentation and qualification, but will seek to confirm which coastal values remain of greatest importance to the community and are critical to understanding reasonable management options for coastal hazards and risks.

More recently, community consultation during the preparation of the Coastline management plan in 2010 included discussion about what people valued about the coast and why.

Information from both the 2000 study and 2010 consultation is included in **Table 3**.

The workshop will provide opportunities to update, elaborate and prioritise coastal values.

Table 3 – Previous documentation of the value of the coastline

Value class	Included in discussion (2000)	Further observations	Additional comments from 2010 study
Ecological values	• Intertidal habitats • Terrestrial flora and fauna • Ecological significance and management status	Significant changes to state and national listings of threatened species and ecological communities since 2000.	Naturally vegetated dunes, no weeds
Social, cultural and heritage values	• Aboriginal cultural heritage (archaeological sites and Aboriginal places). Limited discussion of cultural landscape values. • European cultural heritage – Cape Byron Light house and multiple shipwrecks • Recent history and contemporary values	Notes the loss of much of the physical evidence of Aboriginal occupation and attachment because of the sand mining history and intensive development of the Byron Bay Embayment. No detailed audit of actual sites had been conducted at that time, but strict conservation of remaining sites and places in the embayment recommended. Heads of Agreement between Byron Shire Council and Arakwal People key to future management.	Beach amenity - a joyful place, not overcrowded. The coastal landscape and water loving people – makes us 'idiosyncratically coastal'. Buntalung and Arakwal culture, as well as European heritage places – helps define the local community.
Landscape values	• Primarily visual, with other elements contributing to visual quality. • Byron Bay identified as 'an outstanding example of a zeta form bay' by the Cape Byron Trust.	Determined on distinctive landforms, naturalness, protection and visual accessibility/sensitivity Generally at whole of shire scale (including the hinterland), not specifically about the Byron Bay Embayment. Limited data available at the time.	The natural appearance of Cape Byron area and the landscape context of Byron Bay (hinterland). Connection to the marine environment; natural topography. Great surf and clean ocean, clean sand provide a wonderful place for exercise, social interaction. The natural beach shape and dunes – a peaceful and beautiful place with changing nature.
Recreation values	• Highly developed and natural recreation settings identified. Byron Bay Embayment is mostly highly developed. • Recreation value linked to accessibility, facilities, land tenure, distance from centres and the quality of the natural environment. • A wide range of recreational activities identified for the coast.	Suggested that Byron Shire had reached saturation point in peak periods, in terms of recreational carrying capacity. Limited data/sampling and now out of date.	Beachside camping and holiday parks – diversity of accommodation creates a healthy community culture. The beach offer free recreation for everyone. Clarkes Beach has easy access and easy parking, plus facilities that make it safe for leisure, swimming, walking. Belongil Beach is a quiet place where locals enjoy walking their dogs, a chat to friends. It also has good access and swimming in clean water, but sometimes no beach in front of the rocks.
Residential values	• Derived from Settlement Strategy. Key values of relevance to coastal hazard management processes include: • Community participation is a vital part of Byron Bay life • The beach front is natural, clean, safe and accessible for residents and visitors • Tourists are welcome in Byron Bay • Best environmental practices are encouraged	More recent community comments on a vision for the coast, and key values are necessary.	High value attached to ocean views from residential areas
Economic values	• Considers commercial and residential land value, tourism and recreation, environmental values, fishing, mining and agriculture.	Methodological limitations and out of date information about production, land value trends, tourism numbers etc.	Diversity in the town centre is good, but also looks a bit tired and an upgrade would be good.

4.0 Byron Council Coastal Zone Management Objectives

4.1 Objectives stated in the previous draft Coastal Zone Management Plan for Byron Shire Coastline (BSC 2010)

The previous draft CZMP identified defined the following objectives (**Table 4**). Are these still relevant and do they best describe what the CZMP for the Byron Bay Embayment should achieve?

Table 4 – Coastal Zone Management Objectives – draft CZMP for Byron Shire Coastline 2010

To protect, rehabilitate and improve the natural environment of the coastal zone
To recognise and accommodate the natural processes of the coastal zone
To protect and enhance the aesthetic qualities of the coastal zone
To protect and conserve the cultural heritage of the coastal zone
To provide for ecologically sustainable development and use of resources
To provide for ecologically sustainable human settlement in coastal zones
To provide appropriate public access and use of the foreshore areas
To provide information to enable effective management of the coastal zone
To provide for integrated planning and management of the coastal zone.

5.0 Statutory context

5.1 Objectives and principles from NSW Government

All CZMPs in NSW must demonstrate alignment with the objectives of the Coastal Protection Act 1979 (**Table 5**) and give effect to the principles of coastal zone management (**Table 6**). Both highlight:

- The coast as a changing landscape
- The importance of using scientific and community knowledge (and value) and updating this regularly, to adapt to change
- The right of safe public access to the coast
- Protection of natural coastal systems such as biodiversity
- Application of cost effective and affordable solutions (short and long term) to manage risk
- Efficient planning and delivery, including strong cross sectoral alignment

Table 5 - Objectives of the NSW Coastal Protection Act 1979

Theme	Object
Protect enhance, maintain and restore biodiversity	To protect, maintain and restore the environment of the coastal region and its associated ecosystems, ecological processes, biological diversity and water
Secure and orderly use of resources	To encourage, promote and secure the orderly and balanced utilisation and conservation of the coastal region and its natural and man-made resources, having regard to the principles of ecologically sustainable development.
Account for social and economic benefits	To recognise and foster the significant social and economic benefits to the State that result from a sustainable coastal environment, including: • Benefits to the environment • Benefits to culture and heritage • Benefits to Aboriginal people in relation to their spiritual, social, customary and economic use of land and water • Benefits to urban communities, fisheries, industry and recreation
Public access, on foot	To promote public pedestrian access to the coastal region and recognise the public's right to access
Appropriate land tenure	To provide for the acquisition of land in the coastal region to promote the protection, enhancement, maintenance and restoration of the environment of the coastal region.
Involve community	To recognise the role of the community as a partner with government, in resolving issues relating to the coastal environment
Policy and program alignment across agencies	To ensure co-ordination of the policies and activities of the government and public authorities relating to the coastal region and facilitate the proper integration of their management activities
Prepare for climate change	To encourage and promote plans and strategies for adaptation in response to coastal climate change impacts, including projected sea level rise
Beach amenity	To promote beach amenity

Table 6 - Coastal Zone Management Principles from the NSW Guidelines for Preparing Coastal Zone Management Plans (2013)

Principle	Details
Principle 1 **Compliance**	Consider the objects of the *Coastal Protection Act 1979* and relevant NSW government policies.
Principle 2 **Plan alignment**	Optimise links between plans relating to the management of the coastal zone.
Principle 3 **Involve community**	Involve the community in decision making and make coastal information publicly available.
Principle 4 **Use best knowledge**	Base decisions on the best available information and reasonable practice. Acknowledge relationships between catchment, estuary and open coast.

Principle 5 **Long term, public benefit**	The priority for public expenditure is public benefit; it should achieve cost effective, practical, long term outcomes.
Principle 6 **Risk focus**	Adopt a risk management approach to managing risks to public safety and assets; use a risk management hierarchy and adopt interim risk reduction measures.
Principle 7 **Adaptive planning**	Adopt an adaptive risk management approach if risks are expected to increase over time, or to accommodate uncertainty.
Principle 8 **Protect ecological value**	Maintain the value of high value coastal ecosystems.
Principle 9 **Protect public access**	Maintain and improve safe public access to beaches and headlands, consistent with the NSW Coastal Policy.
Principle 10 **Support recreational use**	Support recreational activities consistent with the NSW Coastal Policy.

Byron Bay Embayment
Coastal Hazard Management Study Workshop
Program

Time	Activity	Who
4.00pm	Tea and coffee available; sign in, collect name tag	
4.30pm to 4.35pm	Welcome and meeting administration	Council
4.35pm to 4.50pm	Introductions	Facilitator and all participants, in table groups
4.50pm to 5.00pm	Confirm program and process Any questions of clarification?	Facilitator (Umwelt)
5.00pm to 5.30pm	Presentation on coastal hazard management options and technical feasibility assessment	WRL + questions
5.30pm to 5.50pm	Reasonableness and acceptability. How we define them.	Facilitator (Umwelt) + questions
5.50pm to 6.15pm	What's important about the BBE to different stakeholders?	Facilitator and all participants, in table groups
6.15pm to 6.20pm	Recap – what have we learnt? What needs further investigation or discussion?	All, lead by facilitator
6.20pm to 6.35pm	Light refreshments served	All
6.35pm to 7.05pm	The most important thing about managing the BBE coast is….?	Facilitator and all participants in table groups
7.05pm to 7.10pm	Recap where we have got to	Facilitator, plus comments from others
7.10pm to 7.45pm	How reasonable are the feasible management options?	Facilitator and all participants WRL available for questions; OEH and other agencies available for questions
7.45pm to 7.55pm	Summary and conclusions from discussion.	Facilitator and all participants
7.55pm to 8pm	Close and thanks Where to from here Feedback forms	Council

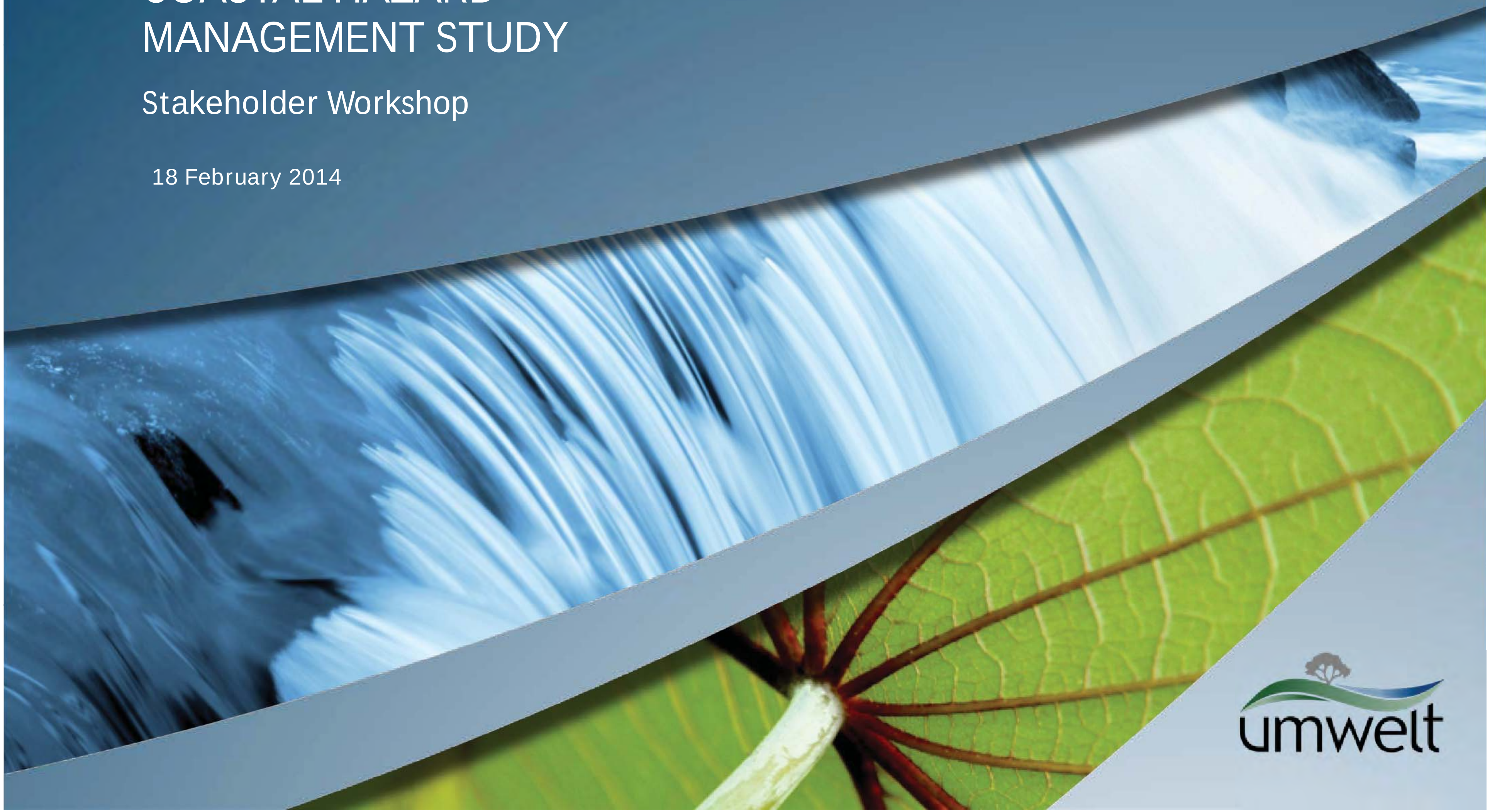
APPENDIX 6

Workshop agenda and presentation

BYRON BAY EMBAYMENT COASTAL HAZARD MANAGEMENT STUDY

Stakeholder Workshop

18 February 2014



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Welcome

Acknowledgement of Traditional Owners of Country.

Thank you for making your time available to be part of this workshop

Workshop Team:

- Umwelt – Pam Dean-Jones and Melissa Kilkelly;
- Water Research Laboratory (WRL) – James Carley and Ian Coghlan;
- Byron Shire Council (BSC)

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Purpose of the Project

- The Minister for the Environment requires BSC to prepare a Coastal Zone Management Plan (CZMP) for the Byron Bay Embayment by 30 June 2014.
- A step in the CZMP preparation process and stakeholder involvement important at each step.

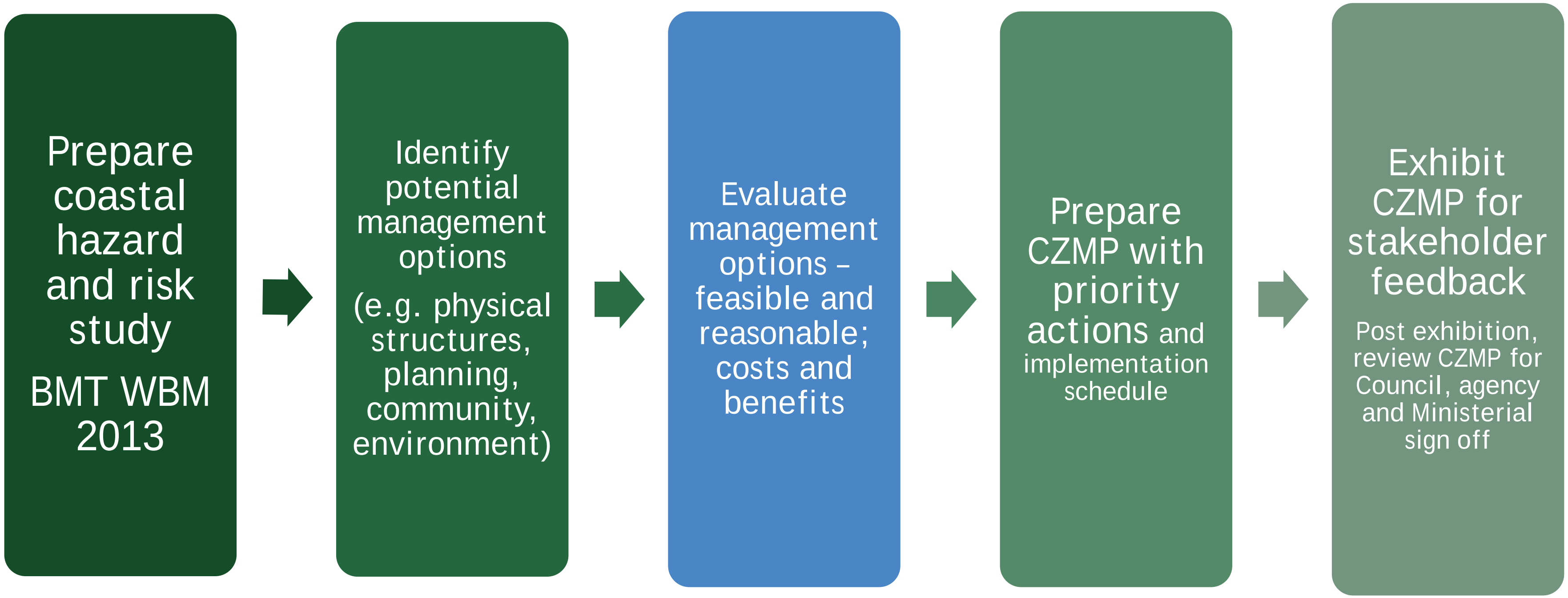

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Figure 1
Byron Bay Embayment

Aim of the Workshop

INFORMATION

- Update on progress towards preparing a Coastal Zone Management Plan for the Byron Bay Embayment;
- Feasibility assessment of potential hazard management options; and
- Preliminary results of on-line survey.

PARTICIPATION

- Contribute to the option evaluation process (reasonableness);
- Further discussion about issues affecting decisions about preferred management options; and
- Explore and reconcile different perspectives.

FEEDBACK to Council about reasonable coastal hazard management options

Program

Time	Activity
4.30pm	Welcome and meeting administration Acknowledge Traditional Owners of Country
4.35pm	Introductions, purpose of the workshop
4.50pm	Confirm program and process What do we mean by feasibility and reasonableness?
5.00pm	Presentation on coastal hazard management options and technical feasibility assessment (WRL)
5.40pm	What do the results of the on-line survey tell us about what's important in assessing management options in this community
6.00pm	What's important abut the BBE coastline for different stakeholders? How do these values overlap?
6.30pm	Recap – what have we learnt
6.35pm	Light refreshments served

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Program

Time	Activity
6.50pm	Which potential options are not reasonable?
7.10pm	Which potential hazard management options are reasonable?
7.45pm	Summary and conclusions from discussion
7.55pm	Close and thanks Where to from here Feedback forms

Introductions

Who is at your table?

- Please take a few minutes for each person at the table to introduce themselves (30 seconds each) – who they are and something special about their interest in the Byron Bay Embayment; and

- One person from each table will then introduce their table to the full group (aim for 2 minutes per group).

Coastal Hazard Management – The Story So Far

Hazard studies

- Commenced 1970s (PWD)
- Updated or more detail 2000, 2010, 2013

Value studies

- Coastal values study 2000
- Consultation about values with draft CZMP 2010

Management studies

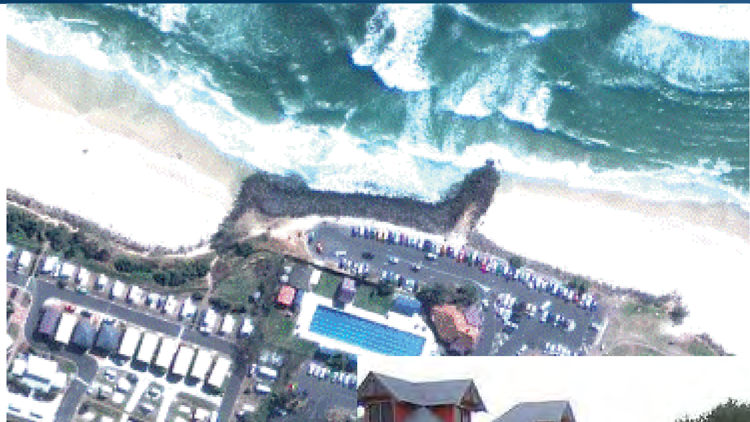
- Byron Coastline Management Study 2004
- Scoping study for sand extraction off Cape Byron 2006
- Coastal audit 2010
- Redesign of Jonson St protection works 2013
- New coastal hazard management study (option evaluation) commenced November 2013

Management Plans & Actions

- Planning provisions introduced 1988 – planned retreat approach
- Jonson St protection works 1960s, 1970s; Interim Beach Access Stabilisation Belongil 2001
- Draft Coastline Management Plan 2010
- Council directed to complete a draft CZMP for the Byron Bay Embayment by end June 2014

The Story So Far – Media Images and Storm Impacts

BYRON BAY
EMBAYMENT
COASTAL HAZARD
MANAGEMENT STUDY



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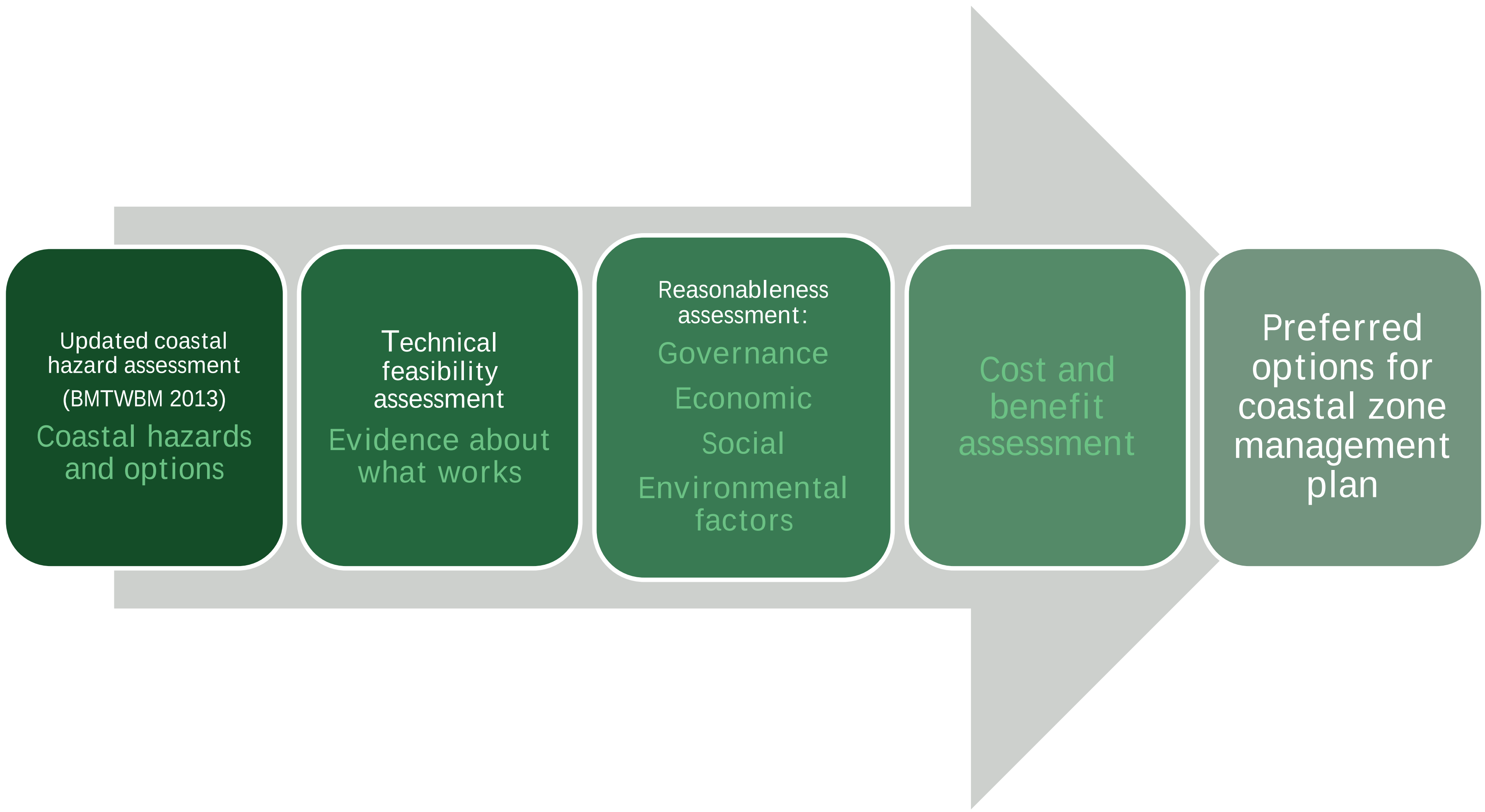
Assessing Options to Manage Coastal Hazards



Feasibility and Reasonableness

Feasible	Reasonable
• quality engineering practice; • evidence that the proposal can mitigate the coastal hazards and risks identified in the Coastal Hazard Study prepared by BMT WBM 2013; • adaptable and practical to enhance or reduce the scale of the response; • the option is appropriate for more than one coastal hazard; and • can be integrated with other management responses (as most risks will best be managed by a combination of responses).	• consistent with the NSW Coastal Management Principles, Coastal Protection Act and NSW Coastal Policy; • consider social, environmental and economic impacts, benefits and costs; • consider the views of the community and other stakeholders ; and • achieve a balanced approach in the context of potential environmental, social and economic costs, impacts and benefits.

Presentation by James Carley, WRL: 35 minutes

Questions?

Community Values, Issues and Concerns – informing ‘reasonable’ management options

Presentation by Pam Dean-Jones, Umwelt.

Initial results of the on-line community survey: 20 minutes

Augments previous studies and surveys

A voluntary process – so indicative views and food for thought.

- 133 responses - not everyone answered every question

Questions?

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Community Survey – Preliminary Results

Beach Use

- 55% use the beach at least once a week all year round
- 57% said they would not be able to find an alternative easily, if they could not access beaches in the Byron Bay Embayment
- Most frequent use – Clarkes Beach and Main Beach, followed by Belongil Beach

Nominated as most important activity and best average ratings:

- go for a swim
- use the beach by myself – run, walk or other exercise
- use the beach with family or friends for exercise and relaxation
- go for a surf
- use the foreshore reserve for exercise
- conservation activities
- socialise with friends.

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Community Survey – Preliminary Results

Most frequently nominated 'most important feature of BBE':

- healthy ocean environment with clean water and lots of marine species
- access to at least one beach; to a variety of beaches that are good in different conditions; ease of access
  - Access arrangements – 40% 'good as they are', 38% 'OK, but need to be maintained more often by Council', 14% 'there should be more beach access available'.
- a great place to relax
- continuing cultural values to Aboriginal people
- safe swimming and surfing for young families and less able people.

Least frequently nominated as 'most important feature of BBE':

Private Values

- views of ocean, headland or beach from my home
- value of residential property.

Selective Stakeholders

- great surfing – good waves and reliable breaks

Facilities and Culture

- great social vibe of beach and beach side reserves
- good beach side facilities
- presence of heritage places and features
- a flat sandy area above the tide for use

What's Your View? – Survey Results

'Strongly agree' Statements: Values, Threats and Management

- coastal tourism is one of the biggest economic activities in Byron Bay. Tourists mostly come to Byron Bay for the beaches, swimming and surf breaks
- the most important thing about managing the coast at Byron Bay is to
  - maintain its reputation as a beautiful coastal landscape
  - retain sandy beaches that are accessible and safe for everyone at all times
- the BBE is affected by erosion now and it will get worse if no action is taken by Council
- Council should allow existing uses to continue, but not approve more development in immediate coastal hazard areas
- the state government should provide most of the funds for building coastal protection works in Byron Bay.

What's Your View? – Survey responses

'Strongly disagree/disagree' Statements:

- coastal erosion may get worse, but not in the next 20 years
- the Byron community has enough information to understand coastal erosion processes and options to reduce erosion risks
- the most important priority about managing the BBE is to protect existing private property from coastal erosion
- permanent coastal protection works (such as rock walls) are needed to maintain the culture and economy of Byron Bay
- if I had to choose between a rock wall (to protect built assets) or maintaining a sandy beach, I'd go for the rock wall
- I support allowing the disturbance of the sea bed in the Marine Park to obtain sand for beach nourishment, if required
- council should introduce a rate levy on all ratepayers to cover the cost of managing the coastal zone
- BBE management options should be based on the most economically efficient solutions.

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What Values Have Shared Importance Across Different Stakeholders?

Activity 1: 30 minutes

- At your table, make a list of environmental, social, cultural and economic coastal values (on sticky notes) in BBE that your group thinks **should be safeguarded in future management decisions**. You can list up to 20 for the group.
- Put the sticky notes on the sheets out the front.

Discussion

- Which values can be clustered together?
- **Which values are relevant to everyone?**
- **Highlight any 'not negotiable' values – things that must be safeguarded.**
- How do these 'not negotiable' values relate to the reasonableness of coastal hazard management options?

Supper

Light refreshments served

15 minutes

Please feel comfortable to take food and drinks back to your table

Recap – Which Coastal Hazard Management Options Are On the Table?

- Managed retreat (private/public ownership) – planning controls
- Retreat (public ownership alone) – planning controls
- Retreat (private ownership alone) – planning controls
- Beach nourishment + end control structure + terminal seawall
- Beach nourishment + impermeable groynes + terminal seawall
- Beach nourishment + end control structure
- Beach nourishment + impermeable groynes
- Beach nourishment + end control structure + offshore breakwaters (surface piercing)
- Beach nourishment + end control structure + offshore breakwaters (submerged reef)
- Impermeable groynes alone
- Terminal sea wall alone
- Monitor actual change

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Which Coastal Hazard Management Options Are not reasonable?

Activity 2: 20 minutes

Using the knowledge you have from the technical studies, coastal management principles and the community perspectives at your table:

- Identify any options which you believe are **not reasonable** for one or all beaches in BBE and **why**; and
- Mark the **not reasonable** options on the sheet out the front.

Is there overlap between the options selected by different groups?

Which Coastal Hazard Management Options Are Most Reasonable?

Activity 3 - 35 minutes

For your table, list your views on the three most reasonable management options for coastal risk management at each beach.

- (Belongil Beach, Main Beach (both have immediate High to Extreme risks),
- Clarkes Beach, Wategos Beach, North Beach (all low to medium risks).

Use the sheets provided to help your deliberation and note why you have made these choices.

Mark your priority list for each beach on the sheets out the front.

One spokesperson from each group briefly explain how the group made their choices. What was the most important factor for you? What trade offs had to be made?

Which options are identified as the best fit with reasonableness across groups? Does anyone want to change their choices? So what's our shortlist?

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Recap and Conclusions From Today (10 minutes)

In terms of coastal hazard and risk management, what must Council do or take into consideration?:

- from the regulator's perspective
- from the community's perspective

Based on tonight's discussion, which coastal hazard and risk management options are not (or unlikely to be) reasonable for BBE beaches?

Based on tonight's discussion, do we have a shortlist of reasonable options for each beach in the BBE?

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Close

Thank you for your time and your input

Please complete a feedback sheet

Pam Dean-Jones, Umwelt

Phone 02 49505322 or 0412278201

Principles of Coastal Zone Management (NSW Government)

Ten Principles
Consider the objects of the Coastal Protection Act 1979 and relevant NSW government policies.
Optimise links between plans relating to the management of the coastal zone.
Involve the community in decision making and make coastal information publicly available.
Base decisions on the best available information and reasonable practice. Acknowledge relationships between catchment, estuary and open coast.
The priority for public expenditure is public benefit; it should achieve cost effective, practical, long term outcomes.
Adopt a risk management approach to managing risks to public safety and assets; use a risk management hierarchy and adopt interim risk reduction measures.
Adopt an adaptive risk management approach if risks are expected to increase over time, or to accommodate uncertainty.
Maintain the value of high value coastal ecosystems.
Maintain and improve safe public access to beaches and headlands, consistent with the NSW Coastal Policy.
Support recreational activities consistent with the NSW Coastal Policy.

APPENDIX 7

Issues raised in written submissions

Appendix 8

Table 1 – summary of written submissions about coastal hazard management in the Byron Bay Embayment

Stakeholder group	Location	Key points
Resident	Brisbane/ Byron Bay	• Opposed to planned retreat ▪ Destruction of valuable beach break ▪ Increased flooding of town ▪ Loss of publicly owned land including park on Childe St ▪ Loss of public infrastructure ▪ Destruction of wetlands and ecosystem
Resident	Belongil	• Opposed to planned retreat, Supports hybrid option ▪ Will lead to loss of public infrastructure ▪ Unfair as land already approved for residential purposes – will lead to massive compensation claims ▪ Coastal Protection Acts protects for public property
Resident	Byron Bay	• Opposed to planned retreat, Supports hybrid option ▪ Will create economic, environmental and social upheaval ▪ Jonson St structure has led to Belongil erosion ▪ Supports retaining Jonson St structure, filling in sea wall gaps, constructing end wall and using limited sand nourishment if required in time
Resident	Belongil	• Opposed to planned retreat, Supports hybrid option ▪ Extensive existing protective works (public/private) makes retreat unviable
Resident	Belongil	• Opposed to planned retreat, Supports hybrid option ▪ Extensive existing protective works (public/private) makes retreat unviable
Resident	Belongil	• Opposed to planned retreat, Supports hybrid option ▪ Extensive existing protective works (public/private) makes retreat unviable ▪ Need to balance protection of public beaches with the need to protect private property and assets
Resident	Belongil	• Opposes planned retreat ▪ Social, environmental and economically unacceptable (as detailed in Council's 2011 report in which over 84% of 'accepted' responses were against planned retreat)
Resident	Byron Bay	• Supports retreat ▪ Unhappy with public consultation process – too much emphasis on 'hard engineering' options and private property, ▪ Rural land discussions are about 'responsibilities' as well as 'rights' – why are coastal properties considered differently? ▪ Need for better future oriented planning ▪ Need to avoid more rockwalls at Belongil ▪ Need to plan so that the area retreated from can become a community "asset" rather than a "wasteland" ▪ Need more attention to estuary, storm/flood water ▪ Need for wider stakeholder and community involvement in decision-making, e.g. Marine Park and Aboriginal community, and expansion of consultants ▪ Need to get more State support to consider the entire Bay not just the 1.5kms ▪ Need to create a buffer zone and nature/information centre focusing on the coast

Visitor	Not specified	• Opposed to planned retreat ▪ Loss of Belongil Spit and rainforest ▪ Belongil erosion caused by Jonson Street structure
Individual (couple)	Not specified	• Opposed to planned retreat, Supports hybrid option ▪ Will destroy infrastructure, existing communities, and natural environment ▪ Support retention/improvement of Jonson St structure and existing sea wall, "support" at Belongil Creek entrance, and nourishment as required
Individual	Brisbane	• Opposed to planned retreat ▪ 'Natural disaster' for Belongil Creek and wetland ▪ All existing residents should be allowed protection ▪ Public beaches should be protected for future
Individual	Not specified	• Opposed to planned retreat ▪ No additional comments
Individual	Not specified	• Opposed to planned retreat ▪ Opportunity for 'whole of beach' solution within greater Byron Bay ▪ Need to restore "equilibrium" ▪ Needs to benefit all areas of Byron
Individual	Not specified	• Opposed to planned retreat ▪ Destruction of valuable beach break ▪ Destruction of resident's homes and constraints to property protection rights ▪ Risk created and maintained by Council
Individual	Not specified	• Opposed to planned retreat ▪ Opportunity for 'whole of beach' solution within greater Byron Bay ▪ Need to restore "equilibrium" ▪ Needs to benefit all areas of Byron
Individual		• Supports planned retreat, Opposes 'interim works' at Belongil, partly on legal grounds ▪ Planned retreat offers greats utility in protection and safety of residents and integrity of the coastal environment in the medium to long term ▪ Technological 'fixes' cannot defend against long term coastal erosion ▪ Seawalls are expensive to build and maintain, questionable in regards to effectiveness at a large scale, and create a 'false sense of security' leading to further inappropriate coastal development ▪ Beach nourishment is likely to be 'very expensive', 'temporary' and 'futile' ▪ There is no legal basis for the use of landowner 'rights' as a basis for repealing the policy of planned retreat ▪ Council must act in 'good faith' – i.e. with caution and diligence ▪ The proposed 'interim works' will create more erosion ▪ The proposed 'interim works' are outside the current legislation
Individual	Not specified	• Opposed to planned retreat ▪ Opportunity for 'whole of beach' solution ▪ Need to restore "equilibrium" ▪ Needs to benefit all areas of Byron
Individual	Not specified	• Opposed to planned retreat ▪ Destruction of valuable beach break ▪ Destruction of resident's homes and constraints to property protection rights ▪ Risk created and maintained by Council
The Greens		• Supports planned retreat

		▪ Supports Council's current and historical planning decision in relation to coastal hazards and the management tof development within the coastal hazard zone. ▪ Council's must act in "good faith" – it has responsibility to current and future communities – ultimate responsibility is to provide a safe environment ▪ A decision that purports to protect private property may risk the loss of beaches, impacts on Belongil estuary, impact to tourism and loss of 'the commons' ▪ Need to consider 'worst case' scenario which includes climate change and sea level rise ▪ Unfair that council would reverse it long held planning position and allow protection works for the benefit of a few who have for most part purchased property with full knowledge of the restrictions placed on them
Academic		• 'Small steps' - maintain sea wall first ▪ Significant erosion occurs mainly via rare extreme events, rather than larger-scale long term trends (which is also a factor) ▪ Existing seawalls have not caused any beach erosion ▪ No ecological, biodiversity of conservation reasons to oppose maintenance of existing seawall at Belongil ▪ Landowners have rights ▪ Access issues are not significant – pedestrians current use of public high tide provision, and future boardwalk possible ▪ Property owners should be encouraged to maintain seawalls for public safety and property protection ▪ Different people are in different positions – e.g. some such as landowners face more threats (ie. to home, livelihood, savings) so community opinions should be given different weight ▪ Council's current approach to manage coastal issues in 'small steps' is good and should be continued – next step is to repair and improve sea walls (Council and residents) and increase safety and permanence of public access points
Individual	Brisbane	• Supports hybrid option ▪ Support for Groynes + Nourishment (1978 PWD study) ▪ Support for Seawall + nourishment + end control structure (2003 WBM study)
Recreation Byron Bay Deep Sea Fishing Club	Byron Bay	• Ensure safe shared beach access at The Pass ▪ The Pass is the only feasible boat launch site near town – all other recreational stakeholder groups are serviced at multiple locations ▪ Access to all water users is synonymous with social diversity and public acceptance values that Byron embraces ▪ There has been a growth in mixed stakeholder usage of The Pass with associated safety concerns ▪ Need for dedicated Boat Safety Officer at peak periods to manage safety – current service is too inconsistent ▪ Encouragement for 'shared area' public education initiatives
Belongil Group Pty Ltd	Belongil	• Opposed to planned retreat ▪ Operates business in Belongil ▪ Need to maintain beach access for community and emergency services ▪ Need to implement protective works
Byron Preservation Society		• Opposed to planned retreat, supports hybrid option ▪ No legal right to remove existing protection ▪ Jonson Street structure has affected many kilometres along Belongil Beach and is no affecting north of Belongil Creek (confirmed by BMT and WBM) ▪ Concerned that Council has already limited its options to

		only two options: retention/improvement of Jonson Street Structure with either 1) retention of existing Belongil protection or 2) removal of existing Belongil protection ▪ Removal of the current protection would cause severe economic, environmental and social adverse consequences, including: destruction of valuable infrastructure; destruction of the existing environment; destruction of existing communities (social disharmony and destruction) increased threat to other parts of northern Byron; and destruction of the natural environment (including 'major and catastrophic' impact to the beach, dune and creek) and likely bankruptcy to council due to lost infrastructure, breakdown in community services and litigation costs. ▪ Removal of the current protection and refusal to permit emergency protection or extension of existing rockwalls would unlawfully interfere with property owner rights to mitigate the impacts of the Jonson Street structure ▪ Need for "whole of beach" solution - bringin equity and equilibrium for environment, economy, existing Byron Community and natural processes that have been affected by Jonson Street structure ▪ Focus on solutions that are cost effective, robust, protective of environment and beach amenity, blanced for whole of the Byron community, and addresses problems created by Jonson St and the meandering creek entrance. ▪ Supports hybrid solution involving 1) retention /improvement of Jonson St structure, the existing rock wall and completion in gaps in the wall; 2)construction of counterbalancing structure ideally at the Belongil Creek entrance, and 3) initial sand nourishment using sand available at the Belongil Creek entrance ▪ This hybrid solution is endorsed by the Association's experts, International Coastal Management, and by Council's experts WRL.
Business North Byron Beach Resort		• Opposes planned retreat, supports hybrid option, opposes end structure ▪ Supportive of management options involving positive actions to protect the subject site ▪ Need to look at Belongil Creek (ICOLL) in conjuction with options for Belongil spit, extending north of the subject property (Resort (or Belongil beach?)) where it it adjoins Tyagara Nature reserve – need a whole of beach option that includes Belongil Beach resort and the Belongil ICOLL ▪ Any proposal for an end structure at the Belongil Creek mouth will cause concern regardsing its affect on the North Byron Beach Resort property. ▪ Byron Beach Resort owners are prepared to financially contribute to any positive management options which are beneficial to their property. ▪ Too much intervention and protective works along the coastline has occurred over the years to maintain retreat as a viable option ▪ Retreat will cause significant impact to the Belongil Creek mouth and associated shoreline erosion ▪ North Byron Beach Resort has been substantially impacted to date, resulting in loss of site infrastructure as well as land area ▪ Retreat will result in variable economic costs as wll as high social costs to affected landowners ▪ A hybrid option of some description is most likely to

		potentially provide satisfactory balance between retaining public beaches and protecting existing private and public property and assets – previous studies in 1978 and 2003 also ranked hybrid options most highly.

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Appendix N: Economic Assessment (by GCCM)

Byron Bay CBA –March 2016

Table of Contents

List of Tables

Table of Figures

1. Executive Summary

This Cost-Benefit Analysis (CBA) was undertaken in accordance with the NSW Government Guidelines for Economic Appraisal (2007) and the draft guidelines included in the draft NSW Coastal Management Manual (November, 2105).[1] The analysis represented in this document is based largely on desktop analysis. A number of major knowledge gaps remain and would need to be addressed before this could be considered a complete representation of all of the costs and benefits of the various coastal management options. It should be considered as an initial investigation of the costs and benefits. This CBA focusses on aspects which can be quantified and expressed in monetary terms, and hence it is likely to favour options which preserve these values (i.e. favour protective options). Key economic figures which are employed in conducting the CBA are:

- the tourism value of beaches
- the residential recreation value of beaches
- land values of potentially eroded properties (public and private), and
- the estimated value of built structures on those properties

The valuation process **does not** provide economic estimates for:

- impacts on crown land for which valuation information is unavailable,
- environmental impacts,
- non-use values of beaches such as cultural importance,
- impacts on surfing amenity
- visual amenity impacts of the management options under consideration,
- or changes to alongshore access due to construction of groynes or end-control structures.

For further details of those values which are not quantified in monetary terms, refer to Section 5 of this appendix. These non-monetised impacts should be considered through other components of the CZMP process, as the (desktop) CBA is intended only as a decision-support tool.

A number of project parameters must be assumed in order to perform the CBA. Chief among these is the extent of protection afforded by the existing informal seawall and geobag structures. Probabilistic modelling of shoreline erosion has been undertaken for a range of events of given average recurrence intervals, but importantly it has only been completed for the Planned Retreat scenario. Under Planned Retreat the modelling assumes removal of all seawalls and geobag structures (except for the seawall at Jonson St), as per Scenario 2 in BMT WBM (2013).

[1] NSW Coastal Management Manual: Part C – Using cost-benefit analysis to assess coastal management options: Guidance for councils – Consultation draft, November 2015

Modelling of the amount of erosion of land parcels within the Byron Bay embayment (predominantly the Cavvanbah-Belongil precincts) has been conducted for erosion/recession events of given average recurrence intervals (ARIs), namely those with ARIs of 1-in1 year, 1-in-10 years, 1-in-100 years, 1-in-1 000 years and 1-10 000 years. These are related to unimproved land values and structure replacement values to estimate the loss of economic value associated with these events, and weighted by their probability of occurrence in a given year. Monte-Carlo simulation is employed to estimate the loss of land in any given year, using 10^6 (1,000,000) draws per annum. A discount rate of 7% is employed, as per NSW Treasury Guidelines, with sensitivity tested for other discount rates.

Two separate 'base-case' scenarios are presented in this executive summary. The first represents the 'best-estimate' of the consultants, and incorporates recommended adjustments by the NSW Office of Environment and Heritage (OEH) as detailed in the NSW Coastal Management Manual: Part C – Using cost-benefit analysis to assess coastal management options: Guidance for councils – Consultation draft (November, 2015) and through previous review comments. The second scenario is that requested by Byron Shire Council in Resolution 16-028, as made on 4 February 2016. Where factors were not specified by BSC, the consultants' 'best estimate' was used in the BSC base case. Descriptions of these two scenarios are provided in Table 1. The 20 m buffer refers to a trigger distance of 20 m from the erosion scarp to implement planned retreat, as per BSC Development Control Plan (DCP No 1, 1988) and previous BSC Draft CZMP (2010). The BSC coastal audit (2011) noted that the trigger distance was less than 20 m for some properties, but is 50 m for others.

A summary of the CBA results is shown in Table 2.

Table 1 Base case assumptions

Factor	Best-estimate base case assumptions	BSC base case assumptions
Land values	2015 Valuer General figures	2015 Valuer General figures
Discount rate	0.07	0.07
Tourism - producer surplus adjustment	Scaled by 0.3	Full value of tourism expenditure included
Recession of beach	Recedes to 50% availability over 35 years (from 80%)	Recedes to 50% availability over 35 years (from 80%)#
Marginal value of sand	Constant benefit (18.75% initial improvement in tourism revenue), scaled by beach availability and effectiveness factor of each option	Constant benefit (18.75% initial improvement in tourism revenue), scaled by beach availability and effectiveness factor of each option#
Retreat implementation	Year 0, all walls removed except Jonson St	Year 0, all walls removed except Jonson St
Buffer zone (20 m)	Buffer (20 m) applied	Buffer (20 m) applied
Proportion of property losses considered (based on owner-occupied ratio when <100%)	55%	100%
Property uplift factor	Not applied	Applied
Manfred St	Repaired at cost of $1m when breach occurs, only for retreat option, only for first 5 years	Repaired at cost of $1m when breach occurs, only for retreat option, only for first 5 years#

Not specified by BSC. Chosen based on consultant's best estimate or advice from OEH.

Under these two scenarios, the CBA results are summarised in Table 2.

Table 2 Summary of Cost Benefit Assessment (CBA) results

Option	Description	Net present value (NPV)* over planning period ($ million)		Benefit Cost Ratio (BCR)*	
		Best Estimate	BSC Base Case	Best Estimate	BSC Base Case
2	Planned retreat	-28.26	-40.79	0.35	0.40
3	Groyne Seawall Nourishment	-23.13	11.62	0.56	1.22
4	End Control Seawall Nourishment	-16.45	15.88	0.63	1.36
5	End control Seawall no Nourishment	-2.10	25.15	0.92	1.91
6	Adaptive management - all components	-7.25	22.51	0.79	1.66
6.1	Adaptive management- seawall only	7.24	31.94	1.42	2.87
6.2	Adaptive management - Seawall + single groyne	5.19	31.86	1.26	2.59
6.3	Adaptive management - Seawall + groyne field	-3.76	24.42	0.87	1.82

*see Appendix 1 for definition of the calculation of these figures. A project is considered economically feasible if the NPV is greater than 0 or the BCR is greater than 1.

These results must be read bearing in mind the additional assumptions detailed throughout the text of this assessment and outlined below:

- retreat and nourishment options aim to maintain a usable beach width 95% of the time, an 18.75% increase on the Status-Quo, and are estimated to vary in their capacity to achieve this objective. Planned retreat allows for the natural landward recession of the shoreline, thus restoring the beach amenity currently restricted by the existing seawalls and private infrastructure along Belongil. Nourishment (where included) is able to maintain an acceptable beach width (defined in WRL report)
- only the additional recreation and tourism benefits of this increase in beach width are included in analysis. The impact on value of wider beaches to adjacent private property is assumed to be zero. Crown land could not be valued and hence the benefit to crown reserves of wider beaches is not included in the analysis.

Variation in key parameters is tested where possible, with results included in Section 9. They are critical to the interpretation of the CBA results and these results are applicable only under the described assumptions.

2. Introduction

This report describes an economic assessment conducted to provide cost-benefit analysis (CBA) of coastal management options suggested in response to identified coastal hazards in the Byron Bay Embayment. Hazards were initially identified by BMT WBM (2013), with engineering solutions identified and costed by WRL (this report).

2.1 Summary of the proposed management options

There were five short listed coastal management options originally included in this assessment, which describe a range of hard and soft protective options and retreat from the hazards identified in the Byron Bay embayment (predominantly Belongil) case study region. The options are described in detail in the engineering component of this document, and were identified through consultation with key stakeholders (see Appendix M of main report).

1. Status Quo
2. Retreat (public-private);
3. Nourishment with seawall and single end control structure;
4. Nourishment with seawall and groyne field;
5. Seawall with end control structure (no nourishment).

The first option is not subjected to a full cost-benefit assessment, as the benefits associated with maintaining the Status Quo represent the baseline figures against which the other options are assessed. It relies upon the assumption that the Status Quo approach is continued into the future, and is able to mitigate major losses by maintaining or replacing the current non-engineered seawalls and geobag structures, and by maintaining the temporary engineered rock wall adjacent to Manfred Street.

The Planned Retreat option is a planning response to the hazards identified by the BMT WBM (2013) study, which indicated that without protection there will be substantial risk to coastal assets. If some version of retreat is to be undertaken; it is merely a choice between a planned and orderly process, and an ad-hoc response to severe storm impacts.

Options 3-5 are again variations on a theme, with terminal protection provided by a seawall in all options. The variability between the options is in the extent to which the sandy beach in front of the seawall is provided by the introduction of additional sand into the system (nourishment), or through trapping sand currently transported alongshore by natural processes.

In the absence of precise engineering designs, a number of assumptions about the response of the shoreline to erosion events and the effectiveness of sand retention efforts must be taken in order to distinguish between the options. Thus this analysis should be considered a preliminary effort based upon the evidence available at the time of preparation.

Analysis of options in this report relies upon the damage estimates provided by WRL and referenced in Appendix J of the main WRL report.

2.2 Adaptive scheme

After initial review by OEH, an additional option was added to the CBA. Option 6 describes an adaptive scheme that relies upon initial construction of a seawall, followed by a series of self-filling groynes as required, and ultimately the commissioning of a sand-transfer scheme or minor beach nourishment.

The timing of these stages has been estimated by WRL as described below:

- Initial seawall construction: years 1 and 2
- Initial groyne: year 3
- Monitor initial groyne years 3-5
- Further groynes: year 6
- Sand transfer: year 10

Given limited resources, and the results of monitoring, there is the possibility that later stages of the adaptive scheme may be delayed or not implemented at all. This has the potential to have large impacts on the results of the viability of this option, so to enable further examination the Adaptive scheme was also modelled in stages. Option 6.1 includes only the construction of the seawall, with no groynes or sand transfer. Option 6.2 includes the seawall and initial groyne, without sand transfer. Option 6.3 includes all groynes, but does not include sand transfer. For Options 6.1-6.3 the timing of implementation remains the same. Additional stages increase the security of the beach, and hence result in higher beach benefits, but are associated with higher costs.

Costs for each stage are detailed in Table 13.1 of the main report. The delay in construction of the groyne field and sand transfer system, and the lower capital costs of the sand transfer system as compared to the major nourishment option described in Options 3 and 4, mean that the NPV of the costs of this option are reduced through discounting.

2.3 The CBA process

The *NSW Treasury Guidelines for Economic Appraisal* (2007) outline the key steps in a cost benefit analysis (CBA) and guidance on factors that must be applied such as discount rates and project periods. There are a number of key steps in the CBA process:

- Definition of the project or policy
- Identification and quantification of all the effects of the policy, both intended and unintended (externalities)
- Estimation of the costs and benefits of these effects, from a societal perspective
- Discounting of costs and benefits to a common reference frame
- Comparison of benefits and costs through various measures of economic efficiency including Benefit-Cost Ratio, Internal Rate of Return, and Net Present Value (BCR, IRR, and NPV respectively).[2]

Thus the process requires both a *valuation* component, and an *evaluation* or appraisal component. In the case of coastal management option assessment, it is necessary to estimate the baseline values provided by the case study area, and then the extent to which these values will be impacted by the various options. This process requires adopting numerous assumptions, as the future state of the coast is uncertain. This report provides a comparison of values for a set of base case assumptions, and also extensive testing of the assumptions employed.

The values impacted by the coastal management options identified in the engineering assessment can be divided into three broad categories;

1) Private and public assets protected by terminal structures
2) Amenities associated with the width of the beach seaward of the protective structures
3) Values which are not linked directly to the state of the beach

This parallels with the theory within environmental economics of the total economic value (TEV) of a natural resource. There are a number of different components of the TEV of a beach or foreshore region, not all of which require access to or contact with the resource. The cultural importance of a beach, for example, may not be directly affected by erosion or shoreline recession. Figure 1 shows the potential range of values associated with a beach.

[2] See Glossary in Appendix 1 for definition of these terms

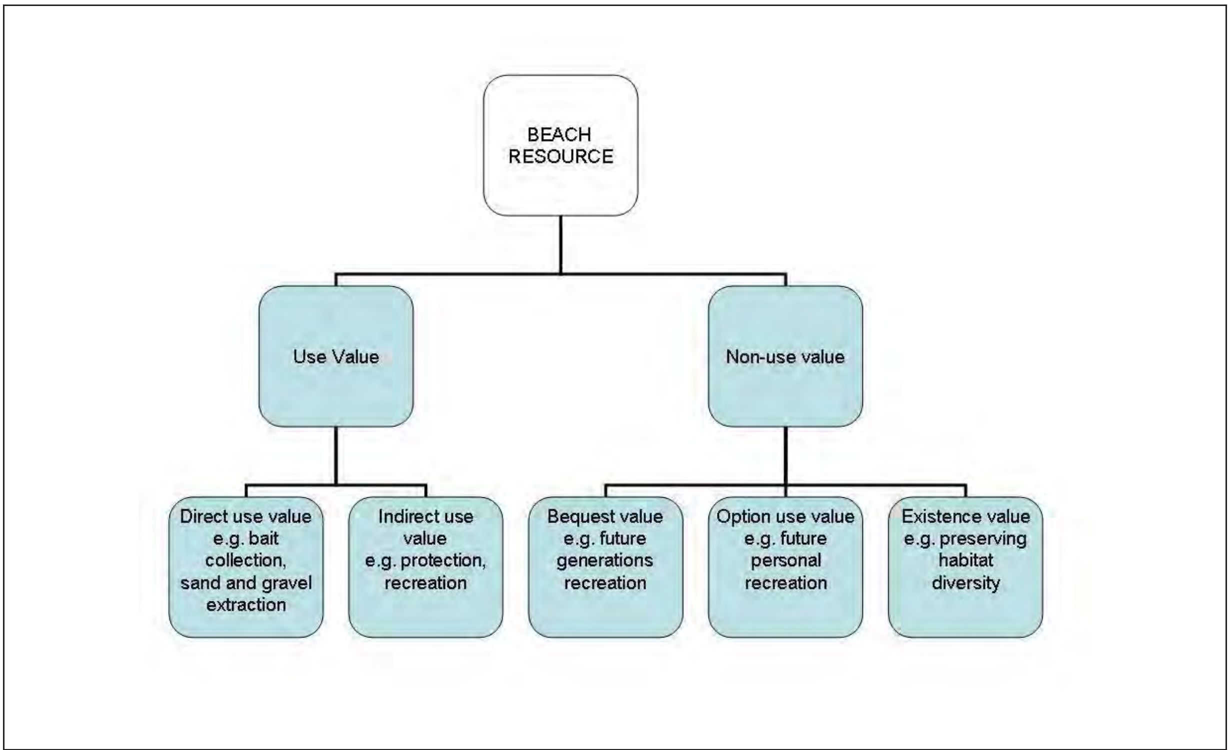

Figure 1 Components of value of a resource (Anning et al., 2009)

The majority of these values are very difficult to estimate, as there is no market value information, and hence non-market measures or proxy values must be employed. This study focusses mainly on the indirect use values due to resource constraints and technical and theoretical challenges to the robust estimation of other value components.

3. Value of protected assets

There are substantial public and private assets within the immediate and future hazard zones. These include public reserves, private residences, strata-titled accommodation, surf clubs and hotels. Road and rail infrastructure is also located within the hazard zones.

The hazard assessment recently conducted for the Byron Bay provides an estimate of the likely extent of coastal hazards (BMT WBM 2013). From this assessment it is possible to identify land parcels that are affected under different scenarios and over different time-frames. Whilst projections are provided for 2050 and 2100, the assessment period is defined as 2050 for the current management plan and economic assessment.

3.1 Property value vs rateable value

Economic theory suggests that wherever possible market values should be employed when assessing policy options, and hence a value estimate that incorporates the full value of structures and improvements to the land would be preferable. The challenge for estimating market value of beachfront property is that there is a small sample size and low rate of turnover, hence there is often little market information to inform this analysis. In addition, the value may be strongly influenced by external factors, including policy changes affecting the land in question. As a subset of the prestige property market, beachfront property is strongly influenced by things such as the recent performance of the stock market (Okunev, Wilson et al. 2000). There is also a complication at Belongil whereby many houses span multiple lots (the original 1886 subdivision comprised 33 feet, approximately 10 m frontages), and their value as a whole may be greater or less than the sum of their parts.

In estimating the losses associated with retreat or the benefits associated with protection, it would be necessary to know the market value of all properties on the peninsular. In the absence of this information, rateable values have been used in conjunction with an estimated replacement value for buildings (derived from building footprints).[3] The same calculation is not possible for public lands without a market value (due to the absence of built structures), and hence the focus of the CBA is consideration of impacts on private properties.

The use of market values would improve the accuracy of the CBA, but would not change the outcomes. Rather, it would probably exaggerate the difference between implementation of

[3] See section 8.6.1 for further details on this process.

protective options (which would likely see an increase in the value of protected property) and retreat (which would likely see a decrease in market values).

3.2 Land vs built asset values

Whilst from a welfare economics perspective the equity of distribution of losses is not important to a BCA, it is important to identify the type of asset at risk, as the assumptions about the future value of these assets is important when determining the scale of losses associated with exposure to coastal hazards or the removal of these assets from the hazard zone. This breakdown is shown in Table 3, and refers only to those assets which can be easily valued with reference to market transactions. It does not include the value of parkland and associated reserves, which is partly a function of their use and enjoyment, which is detailed in Section 4.

Table 3 Value of protected assets by category to 2050, 1-10 000 year ARI event

	Rateable value of privately-held residential land (2015 $million)	Replacement value of residential buildings (estimated, $2015 million)	Total value of protected assets (2015 $million)
Without buffer	$106.81	$31.57	**$138.38**
With buffer (20 m)	$127.81	$59.13	**$186.94**

3.3 Public asset values – natural reserves and crown land

The majority of public assets included in the case study area are recreation and natural reserves, in the form of crown land and coastal parkland. In the theoretical model of retreat, the value of coastal reserves is preserved under a retreat model, as the resumed private property is converted into public reserve. This creates a ‘rolling easement’, which ensures the maintenance of public amenity. In reality, the ability to enact this mechanism may be hindered by practical, legal or economic measures. For the purposes of this economic assessment, and given an inability to price the total asset value of these reserves, it is assumed that their non-use value is preserved and does not change under all scenarios and management options. Section 5 outlines the range of values which have not been calculated, due to theoretical and resourcing limitations.

4. Beach Benefits

This section estimates the baseline economic values associated with the presence of a sandy beach along the Belongil coastline, that is, in front of the existing protective structures. All of these values are non-market benefits, and hence environmental valuation methods must be employed in order to estimate their respective values.

It has two major components, the tourism value of Belongil and the recreational value provided to local residents.

4.1 Tourism value of Byron Bay beaches

This section provides a summary of the estimated economic values associated with the beaches of the entire Byron Bay as they relate to tourism. It employs conservative assumptions about the extent to which these values can be attributed directly to use of the beach.

Byron Bay receives millions of visits annually from day trippers and overnight domestic tourists, and a smaller but significant number of international visitors. Precise estimates of visitation are unavailable, and must be derived from proxy sources. In this instance, Tourism Research Australia (TRA) visitation data for Byron Bay is incorporated with some basic assumptions about the number of beach trips made on each visit and the proportion of expenditure that can be attributed to a beach visit.

Tourism Research Australia collects information about the visitation patterns of domestic and international tourists through the National and International Visitor Surveys, respectively. These surveys record the number of visits and also information about a number of key activities undertaken whilst visiting, including the proportion of visitors who go to the beach.

4.1.1. Number of tourist beach visits

Visitor figures were averaged over three years (Year ending December 2010- Year ending December 2012) to account for variability in recent years due to weather events and fluctuations in tourism patterns due to changes in the strength of the Australian dollar.

These visitation figures were weighted by the proportion of those visitors who visited the beach at least once during their trip (as reported in TRA survey data). Based on previous surveys of tourist beach users conducted by GCCM, a low estimate of the number of beach visits made per trip is then used to estimate the total number of beach visits made by beach users of each tourist type, based on their average trip durations (included in the first column). Results are presented in Table 4. Dedicated beach user surveys would be required to determine the number of beach visits taken by each tourist category type visiting Byron Bay, and the distribution of these visits.

Table 4 Estimated annual tourist beach visits to Byron Bay area

Visitor type (average trip duration)	Number of Visitors (per annum)	Proportion using Beach	Estimated number of beach visits during trip	Total Beach Visits (per annum)
Domestic Overnight (4 nights)	368,000	70%	3	772,800
International (7 nights)	159,462	97%	5	773,391
Day	513,000	50%	1	256,500
Total	**1,040,462**			**1,802,691**

A daytrip tourist is defined by Tourism Research Australia as someone who lives outside the region of interest, but travels less than 50 km in a return trip or are away for less than 4 hours.

Source: Tourism Research Australia – 3 year average 2010-2012

4.1.2. Value of tourist beach visits

Using total visitor expenditure data (food, accommodation etc.) from TRA it is possible to estimate the expenditure by tourists related to beach visits, and results for Byron Bay are presented in Table 5. This calculation assumes that 50% of the expenditure on the days they visit the beach is associated with the beach use. On all other days their beach-related expenditure is assumed to be zero, despite the fact they are likely to have incurred substantial additional costs in order to stay as close to the beach as possible. We believe this is an extremely conservative approach to the estimation problem. That is, real expenditure is believed to be higher than stated in this report, but there is insufficient data to confirm the higher values.

Table 5 Beach-related tourism expenditure in Byron Shire

Visitor type	Total beach visits p.a.	Value per adult visit 1	Total annual economic value
Domestic Overnight	772,800	$74.00	$57,187,200
International	773,391	$28.00	$21,654,948
Day	256,500	$55.50	$14,235,750
Total	**1,802,691**		**$93,077,898**

*50% of daily expenditure, on days when a beach visit is made.

4.2 Resident beach recreation values

The previous section details market-based transactions that can be identified and attributed to use of beaches in the Byron Bay region. A reliance on market information is likely to exclude many aspects of the TEV of a beach resource, including the value of the beach as a recreation resource for local residents.

Valuing the importance of beach and foreshore areas for recreation purposes requires the application of non-market valuation methods. Chief among these are the travel cost method (TCM) and the contingent valuation method (CVM). The CVM asks people what they would be willing to pay for a hypothetical change in the status of a good of interest. The TCM (described on the next page) is the most widely applied, and given that it is based upon real behaviour (as opposed to the CVM which relies on stated responses to hypothetical future scenarios) it is a preferred method for funding agency bodies both in Australia and internationally.

The TCM uses the relationship between costs and frequency of visitation to estimate a demand curve for visitation (Figure 2). From this, the consumer surplus associated with a (beach) visit can be calculated. Consumer surplus is the difference between the costs a (beach) visitor must incur in taking their trip, and the theoretical maximum amount they would be willing to pay (WTP) to take that same trip (Hanley, Shogren et al. 2001).

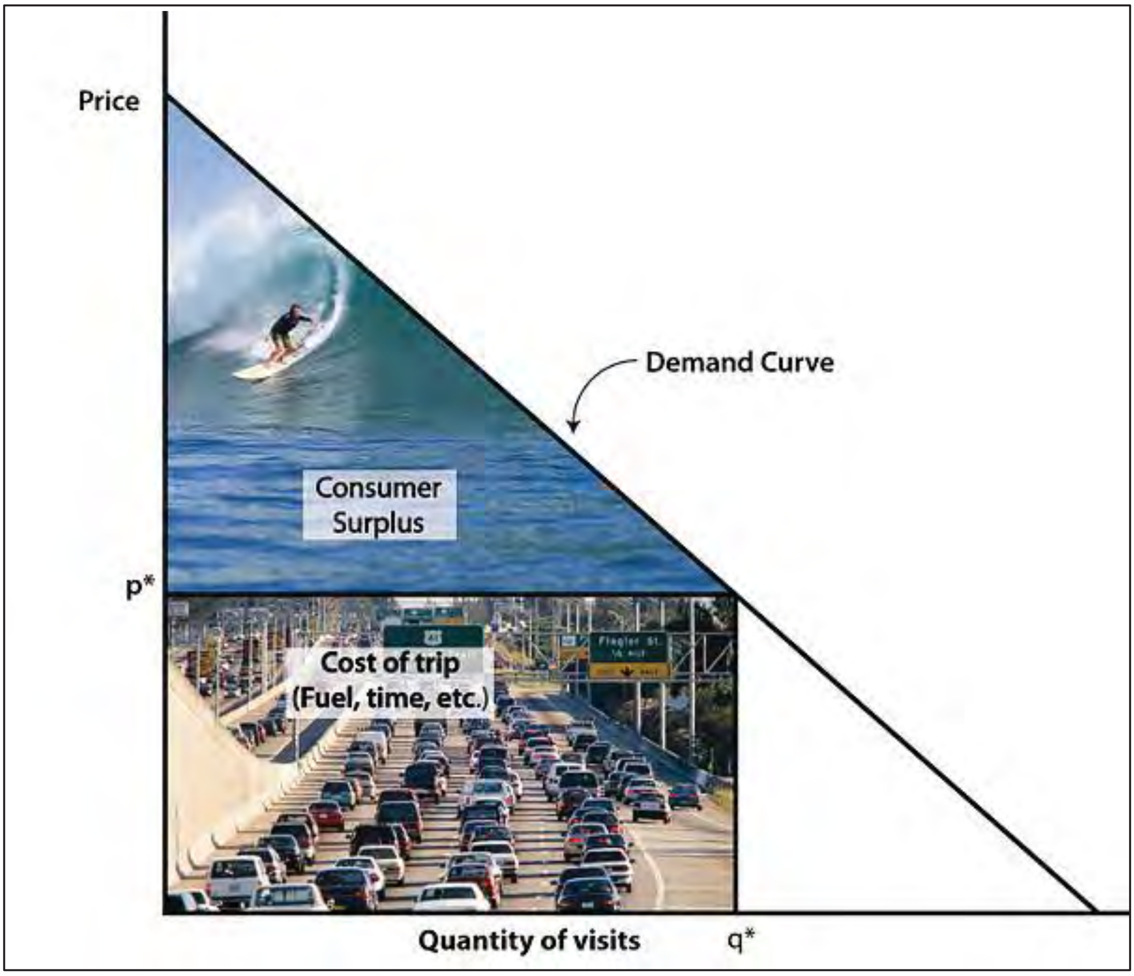

Figure 2 Relationship between price (p) and number of visits (q)

(Chad Nelson: Surfenomics)

Recreation values are estimated by examining the relationship between beach visitation rates and the costs associated with making these visits. The underlying assumption is that people will visit the beach only if they expect to experience greater benefits (utility) from the visit than the costs they must incur to make that trip. These costs can then be used to estimate the added value of the beach visit, or the consumer surplus, expressed as a dollar value per adult per trip. This is then multiplied by an estimate of beach visitation to derive an aggregate economic value for recreation in the given location.

4.2.1. Number of residential beach visits

Population figures (Age 15+) were taken from the 2011 Census for Byron Bay, with a total of 7,383 residents. Having established the likely resident user population of Byron Bay beaches, it is then necessary to estimate how frequently they visit. (Section 4.3 then attempts to determine the proportion of these total visits that can be attributed to Belongil.) Based on a large household survey, Raybould (2006) estimated around 48 visits per annum for residents of the Gold Coast, with the majority coming from within 5 km of the coastline. Using this figure produces the estimates shown in Table 6.

Table 6 Estimated resident beach visits per annum - Byron Bay total

Byron Bay case study area	Using Raybould (2006) survey data (48 visits p.a.)
Population over 15 (Census, 2011)	7,383
Visits p.a. (Raybould 2006)	48
Total beach visits p.a.	**354,384**

These figures are likely to be lower than the true visitation rates, given that beaches are visited by people who live outside the Byron Bay region, but travel less than 50 km in a return trip or are away for less than 4 hours, which is a standard definition of a daytrip tourist as employed by Tourism Research Australia[4]. It therefore represents a minimum bound for recreation visits to Byron Bay beaches.

4.2.2. Value of a residential beach visit

Having identified the number of beach visits made by residents, it is necessary to determine the economic value associated with these visits, through estimating the value of a beach visits. This section outlines available references to the likely scale of this value.

Raybould and Lazarow (2009) estimated average expenditure of Gold Coast beach visitors in two studies, separating respondents into local residents and tourists. Expenditure of residents was in the range of $0.50-$2.30 per beach day per person (2008 AUD). Estimates derived by Raybould and Lazarow for tourists were in the range of $15-$45 per beach visit (2008 AUD). The resident sample was highly localised, with around half of all respondents living within 5 km of a beach, although census data suggested that this under-represented the local population.

In the absence of any available survey information for Byron Bay beaches, it is not possible to identify the catchment for Belongil beach visits with sufficient accuracy to estimate the costs incurred in visitation. For the current study, it is assumed that the majority of beach visits to Belongil are taken by those within walking distance. Thus their actual expenditure on things like fuel and parking fees (if they were to be introduced, extended or increased) is not included in the analysis,

[4] http://www.tra.gov.au/statistics/domestic-travel-by-australians.html

due to a lack of reliable data to inform this assessment. Whilst there may not be identifiable values associated with these beach trips, people still receive benefit from these visits above and beyond the expenses they incur to make the visit.

Researchers from Bond and Griffith Universities recently completed a project titled *Beach and Surf Tourism and Recreation in Australia: Vulnerability and Adaptation* (BASTRA) (Raybould, Anning et al. 2013). This study estimated the consumer surplus for resident beach visits in the Clarence Valley Shire of NSW, which is considered a good analogue to Belongil given geographic proximity and similar wave climate. The study used a range of models and travel cost inclusions, with the truncated negative binomial (TNB) model providing the best model fit. This study provides the most recent and applicable estimate of the value of a beach day for residents of Byron Bay. The consumer surplus estimates from this study are presented in Table 7.

Table 7 Consumer surplus estimates - value of a beach day Raybould et al. (2013)

	Consumer Surplus Per Adult Per Visit
Fuel only model	$6.10
Fuel only plus time @ 40% of hourly rate	$9.30

It is typical in travel cost studies to incorporate the value of travel time, to account for the fact that this time could otherwise be spent in paid employment. There is some contention as to whether this is a valid assumption, as it implies total flexibility of working hours and payment. This assessment takes the lower estimate by not including the opportunity cost of travel time, employing the lower consumer surplus[5] (CS) estimate of $6.10 in calculations.

4.2.3. Summary of resident values

Table 8 summarises for clarity the calculations involved in the estimation of the value of residents' recreation value in Byron Bay. The next section outlines the identification of the proportion attributable to Belongil.

Table 8 Summary of annual residential recreation values in Byron Bay

Project benefits:	
Resident Visits p.a.	354,384
Resident value for a beach visit (CS values)	$6.10
Resident recreation benefits p.a. (Byron Bay)	**$2,161,742**

[5] See glossary in Appendix 1

4.3 Proportion of Byron Bay beach benefit value attributable to Belongil

The figures estimated in the previous sections are for the entire Byron Bay region, and hence it is necessary to calculate what proportion of these figures is due to the presence of a healthy beach at Belongil. This presents challenges as there is no tourism information at the case study level. The only means of estimating the relative proportion of these visits is to use lifeguard estimates of beach visitation. Whilst these estimates are known to be subject to errors and challenges (Anning, Dominey-Howes et al. 2008), they remain the only available source of beach visitation or usage estimates for most beaches in Australia. It is assumed for the sake of this analysis that the errors in estimation are systematic in nature, meaning that the estimates are all inaccurate in the same way (e.g. a uniform 20% overestimate), and hence they remain useful for deriving the proportion of total Byron Bay beach visits which are taken to Belongil beach.

Australian Lifeguard Service (ALS) provides professional lifeguard services across much of the north coast of NSW, including beaches in the Byron Bay LGA. The senior lifeguard estimates beach visitation each day, and these figures are employed in determining the relative importance of Belongil to Byron Bay beach visitors and residents. Relevant figures for Belongil are those from the First Sun lifeguard station, which is located immediately to the NW of the Jonson St seawall. There are no figures available further along the sand spit. A cumulative total is also provided, which includes all patrolled beaches within the Shire, against which the First Sun figures can be compared. This represents the best information available regarding the distribution of beach visits within Byron Bay. Surf Life Saving NSW also provides beach visitation figures for Byron Bay, although the figures are available only for the times when volunteer lifesavers are in place (typically weekends and public holidays from October to April inclusive), and previous analysis conducted by Anning for Manly beach in Sydney (2012) suggests that these figures are not reliable as they are influenced greatly by the person making the crowd estimate, whereas the professional lifeguards have more experience and are more consistent in estimating crowd numbers.

Total visitation figures for 2010, 2011 and 2012 were compiled for First Sun and for Byron Bay. It should be noted that these are calendar years, so they differ slightly from the patrol season results typically reported by the ALS[6]. Results are presented in Table 9, with averages rather than total figures presented due to the difference in the number of reports for each location.

[6] http://www.echo.net.au/2014/06/australian-lifeguard-service-summer-wrap/

Table 9 Proportion of visits to Belongil

	Average number of visits per day – number of reports in brackets			
Location	2010	2011	2012	Average
First Sun (immediately north of the Jonson St seawall)	869 (58)	839 (59)	1191 (58)	
Byron Bay beaches total	2423 (128)	3311 (175)	5164 (162)	
Percentage of estimated BB beach visits to First Sun	35.8	25.4	23.1	**28.1**

The case study area is approximately 2600m in length (from Cavvanbah to North Belongil), of which the First Sun/Cavvanbah section makes up about 1000m. There are approximately 1000m of existing terminal structures (805m of interim and temporary rock walls and 162m of geobag walls), and a further 600m to the north of the existing structures. The adaptation options considered in this CBA largely deal with the replacement or removal of the existing structures, and hence the impacts of these options is measured only over the 1000m of the case study area that will be directly impacted by the interventions. As such, the impacts on beach usage by tourists and residents should only be measured over this area. The relative length of the respective areas is used to further scale the economic value of the importance of the case study area. The average proportion (28.1%) of Byron Bay beach visits to Belongil is multiplied by 1000m/2600m to scale the recreational values previously estimated. This equates to 10.7% of the total value of Byron Bay beach visits by tourists and residents.

It should be noted that management options which include placement of end-control structures or groynes have the potential to increase impacts on down-drift locations, particularly if there is no associated nourishment or sand transfer. It is not possible to know the extent of these impacts, which would depend on the placement of the structures and the natural supply of sand.

The resultant figures represent the baseline value of beach benefits employed in analysis and are presented in Table 10.

Table 10 Estimated baseline beach benefits of Belongil – scaled by length of area directly impacted by management interventions

Resident recreation benefits p.a. (total Byron Bay)	$2,161,742
Tourism expenditure p.a. related to beach visits (total Byron Bay)	$115,610,890
Proportion of resident recreation benefits affected by management choices	0.107
Proportion of tourism benefits affected by management choices	0.107
Resident recreation benefits attributable to Belongil (p.a.)	$230,831
Total beach-related tourism benefits attributable to Belongil (p.a.)	$ 12,344,931
Total Belongil beach benefits (resident and tourist) (p.a.) – scaled by length of shoreline directly affected by management interventions	**$ 12,575,762**

It is important to highlight that it is only changes from these figures that are included in the CBA.

5. Values that cannot be estimated in the current study

There are a number of potential impacts of the proposed management options which cannot be incorporated into the CBA process with any great degree of confidence. The primary issue is that even when there is good underlying information about the existing attributes of a site (e.g. presence of endangered species), it is very difficult to predict how these values will be affected by the proposed interventions. They are listed here for consideration outside the CBA appraisal process.

5.1 Non-use values

As highlighted by the TEV figure (Figure 1), there are components of economic value which do not require contact with a resource. It is difficult to derive reliable means of estimating these values, as they require construction of a hypothetical market in which respondents must indicate how much they would be willing to pay to purchase or retain goods which are customarily provided free of charge. There is much debate within the environmental economics community as to whether the estimates provided are theoretically valid, and some conjecture as to whether they are any more useful than the underlying non-monetary preferences which they are attempting to represent. This section presents some previous estimates of the non-use value of beaches for completeness of the literature review, rather than to suggest they can be used to estimate the relative economic merit of the various coastal management options.

Anning (2012) conducted contingent valuation surveys in Sydney to determine willingness to pay (WTP) for beach erosion prevention. Survey respondents (both residents and tourists) were asked whether they were WTP to prevent erosion impacts in 2050 to prevent closure of the beach due to erosion. A summary of the results of this analysis is provided below:

- 415 contingent valuation surveys were completed at the case study beaches
- 78% of respondents believe that by the year 2050, the beach will be closed due to erosion at least 1 out of every 10 times they visit
- 57% of people would be willing to contribute to an erosion management fund to prevent this occurring
- 39% of people said they would pay the amount requested in the survey, which ranged from $5 to $500, as a once-off donation

Belief in the erosion scenario was high, equating to around three-quarters (78.3%) of the total sampled population, this did not translate directly into a positive WTP for beach erosion protection.

Protest responses accounted for approximately half of the total sample, with statistically significant differences between the case-study sites. Protest responses were defined as those from respondents who do not accept the conditions of the hypothetical donation request. They may object to the form of donation, the restriction of the fund to a single beach, the choice of agency which manages the money, or the way in which the project is to be implemented. Protest rates ranged from 36% at Collaroy-Narrabeen to 65% at Brooklyn. At Manly and Dangar Island the protest rates were 46% and 39%, respectively. These figures are related to the experience of erosion, with visitors to frequently-eroded beaches more likely to be WTP to prevent similar impacts in the future.

The median WTP for erosion protection was AUD$116.27± 69.63 per person as a once-off donation to prevent erosion occurring in AD2050. This figure is for all respondents to the question, and does not consider the reasons given for not being WTP as the question was only asked of those people who indicated in-principle support for the erosion prevention project.

Raybould (2006) explored the influence of information provision and environmental attitudes on WTP for erosion prevention on the Gold Coast. WTP values were related to the frequency of beach visitation, with statistically significant differences identified, and are presented in Table 11.

Table 11 Relationship between beach use and WTP (Raybould, 2006)

User category	Visits per month avg.	N	Mean WTP ($ per month)	Std. Dev
Non-Users	0	127	1.00	3.35
Low	1-3	276	2.07	3.20
Medium	4-8	251	2.67	3.68
High	9+	263	3.58	4.93
Total		917	2.52	4.00

F value = 14.19; $p < 0.01$

It is not possible to directly translate the figures estimated in either of these studies to the case study site, as they are influenced by a range of demographic factors. There are multiple challenges with the transferral of values from one location to another, which is commonly referred to as the Benefit Transfer (BT) method. As highlighted in Figure 3, the use of BT is only appropriate when the original study site and the new (policy) site are similar.

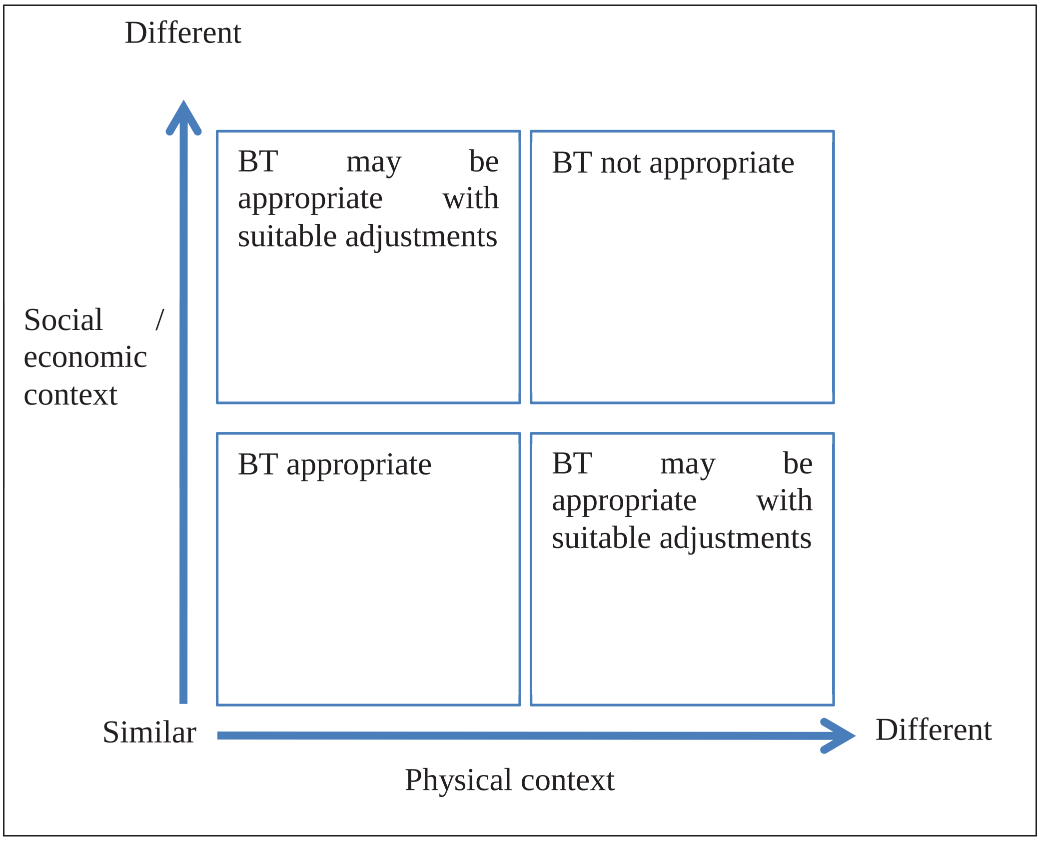

Figure 3 Suitability of benefit transfer (BT) for environmental valuation

In the case of the contingent valuation method, there are further complications due to the description of the proposed change or project.

For further information on the benefit transfer process, see Appendix 2.

5.2 Valuing access to and along the beach

There has been little research effort applied to the consideration of alongshore access, except where there are restrictions due to the presence of structures specifically designed to prevent access to private stretches of coastline or long stretches of private foreshore, as is more common in Europe and the United States. Provision of sufficient access points is a key criterion in any funding applications to the US Army Corps of Engineers for beach nourishment projects (Whitehead, Dumas et al. 2008). Access to the beach in Australia is a requirement of key legislation and policy documents, so this issue is rarely encountered.

Currently the seawalls along the Cavvanbah-Belongil foreshore periodically restrict access along the beachfront, particularly at times of high wave activity and/or during spring tides. Removal of these structures, or the placement of sand in front of them, would reduce the frequency of this restriction and thus result in a net benefit. The incorporation of an alongshore path within the seawall as proposed in the main WRL report would also provide the benefit of alongshore access. Placing an economic value on this benefit is difficult given the paucity of previous research in this area.

The detailed design of the groyne and end-control structures would need to incorporate both cross-shore and alongshore access considerations. Provision or maintenance of a sufficient number of cross-shore access points, at least as many formal points as currently provided, would mean that this lateral aspect of beach amenity would remain neutral between all design options.

The most useful proxy for the value of access alongshore is perhaps to consider the role of beach length in the selection of destination by beach users. Any structures perpendicular to the shoreline have the effect of shortening the length of the beach or beach compartment. Thus if there is a preference for longer beaches this may result in a lower aggregate benefit for the shorter beach compartments. Lew and Larson (2005) identified beach length as a strong determinant of beach selection in San Diego County. They employed both linear and non-linear length variables, with greater beach length being associated with greater WTP per beach visit.

The length of a beach is typically assumed to be constant in random utility site-choice models, and hence it is difficult to determine how reducing beach length would influence the utility of a beach visit. Longer beaches are typically associated with a number of covariables such as a more natural shoreline or reduced crowding, and the placement of groynes is specifically designed to increase the beach width within a section of the shoreline, meaning that the beach is substantially different in a number of parameters apart from simply the change in length. Thus identifying the benefit of the longer beach in isolation from these other factors is problematic, and is not attempted in this report.

5.3 Visual amenity changes associated with coastal protection

Groynes and end control structures extend across the beach and into the surf zone. This can provide disruption to the visual amenity of the unbroken shoreline and ocean. Determining whether this is a positive or negative impact is challenging, however, as there is a general preference for more variety of viewscape. For example, vision of breaking waves is preferred to that of a more homogenous view of the open ocean (Price 1995).

5.3.1. Impact of visual amenity changes on property values

In the UK, analysis of property values by real estate agency Knight Frank (Table 12) suggests that vision of an estuary is considered to be more valuable than vision of the ocean, possibly due to changes caused by tidal variation. Further research would be necessary to determine if this was the case in Australia.

Table 12 Price premiums for water views

Type of view	Price premium (%)
Estuary	82
Harbour	81
Riverside	53
Coastal	47
Lakeside	36

Source: Knight Frank[7]

The relationship between the quality of the view and the relative price premium is identified in the majority of studies attempting to place values on the presence of pleasant or unpleasant views. The relative WTP for a partial view differs between published studies. An unobstructed view of the ocean is always valued more highly than a partial or obstructed view, and hence the differential

[7] http://www.bbc.com/news/business-23255452

between them could represent the WTP for not having a structure placed within the viewshed of a given property. Benson et al. (1998) investigated the influence of view quality on the price premium for ocean views in Bellingham, Washington (USA), finding that a high quality ocean view attracted a premium of 60%, whereas a low quality view was only responsible for an eight percent price premium. Pearson et al. (2002) found that a full unobstructed view of the ocean near Noosa resulted in a price premium of 76%, indicating a strong preference for ocean views. Unfortunately from the perspective of this analysis, partial view coefficients were not statistically significant.

It is difficult to separate the benefits of ocean views from other non-aesthetic coastal amenities, however, particularly given that the benefit of a distant view has been shown to be less than that of a closer view of the same quality (Benson, Hansen et al. 1998). In simple terms, this means that in an area dominated by lowrise buildings, the majority of the benefits of a pleasant view accrue to the properties along the beachfront, but it is difficult to know how much of the price premium paid for these properties is due to the view itself rather than other factors such as direct or proximate beach access, prestige value or other unidentified components. There have been highly technical attempts (Bin, Crawford et al. 2008; Hamilton and Morgan 2010) to value minor changes in view angle, down to a one degree variation, although this is unlikely to be a measure that relates to real world purchasing decisions.

In addition to economic estimates of the value of a view there are a number of planning documents and case law judgements that attempt to define the factors which affect the reasonableness of actions which may affect the quality or extent of a view enjoyed by occupiers of a particular property. Of particular reference is the judgement in the case *Tenacity Consulting v Warringah Council (2004) NSWLEC 140*. The factors which must be considered are similar in nature to those identified in the environmental economics literature, and include defining the extent of the view currently enjoyed, and the extent to which it may be affected by proposed development. Assessing these factors lies outside the scope of the current assessment and would likely require the input of planning and heritage experts, or substantial choice modelling research incorporating visual representations of the various coastal management options.

5.3.2. Impact of visual amenity changes on beach benefits

Surprisingly, there have been few studies which have attempted to quantify the visual amenity impacts of groyne construction on beach users. The few studies conducted come from Wales and Italy, and do not provide the choice-pairs that are of greatest relevance to the current study, namely the difference between a beach with and without groynes. Brandolini et al. (2000) provide mainly qualitative measures of preference, though the relative ranking of groynes and nourishment without groynes differs substantially between interview sites, highlighting the importance of site-specific variation in shoreline preferences.

A choice experiment study conducted in Wales (Christie and Colman 2006) identified willingness to pay to avoid visual amenity changes associated with the coastal protection options under consideration for the Borth coastline in response to erosion. The options considered were Status Quo, replacement of existing timber groynes, installation of rock groynes and an artificial multipurpose reef. The study identified that the visual impacts of the groyne options resulted in a negative implicit price for those options. Implicit prices were-£19.82±£7.23 (approx. $43.47±$15.86) and £28.66±£8.06 (approx. $62.86±$17.68) for timber and rock groynes, respectively, whilst the artificial reef was considered to have a strong positive visual impact with an implicit price of £48.49±£12.84 ($106.35±$28.16).

Without detailed design and consultation, it is not possible to determine the impacts of visual amenity changes.

5.4 Value of surf tourism

Surfing can be associated with relatively high economic values, both through expenditure on surf lessons and equipment, and through non-market expenses associated with travel to desirable surf locations. Studies by Neil Lazarow and colleagues identify significant values attributable to recreational surfing and related expenditure in eastern Australia. In separate studies, expenditure associated with visiting the 'Superbank' at Coolangatta and 'The Other Side' at South Stradbroke were valued at $27 million p.a. and $20 million p.a., respectively (Lazarow, Miller et al. 2008; Lazarow 2009).

There is potential for creation of new surf breaks through the placement of protective structures perpendicular to the existing shoreline. It may also lead to disruption of the existing system of offshore banks, which are typically suitable for learner surfers. Belongil is a popular location for children and tourists to learn to surf, with a number of surf schools operating on the Cavvanbah-Belongil stretch.

Detailed modelling would need to be undertaken to estimate these physical impacts, and dedicated surveys would be required to determine the extent to which this would affect the usage of the location and associated economic values. The same is true for the localised impacts of sand placement within the case study areas for the options which incorporate nourishment.

5.5 Valuing surf amenity impacts

Whilst improved surf is not a design requirement of the coastal protection structures described in this report, the introduction of structures into the surf zone is likely to result in the creation of non-uniform sand distribution patterns typically associated with good surfing conditions.

Christie and Colman (2006) also identified that there was a marked difference in WTP for improvements in surf quality between the general public, and those that were identified as 'surfers'. It is important to note that the improved surf was only suggested by the authors as a likely outcome of the artificial reef option. This is despite research conducted by WRL which suggests that multipurpose reefs are unlikely to be successful in achieving this objective, and anecdotal evidence to suggest that the installation of groynes, training walls and end-control structures has had a much greater net positive effect on the surf quality of the east coast of Australia.

WTP for improved surf was slightly negative for the population as a whole (implicit price of -£1.95±£10.85 - AUD $4.28±23.79) but was strongly positive for surfers, with an implicit price of £70.59±£21.02 (AUD$154.77±46.09). This is not a surprising result, though it highlights that the benefits of surf improvements accrue to a relatively small population, and hence the aggregation of these benefits requires an estimation of the likely number of surfers which are likely to access the improved surf. This information is not available. The ABS estimated the level of participation in surf sports in 2011-12, with an annual total of 226,000 participants. This equates to an average participation level of around 1.3% of the adult population, although it is likely that the participation rate is much higher in coastal towns and key age groups.

5.6 Ecological impacts

There are a range of potential ecological impacts that could be caused by the implementation or non-adoption of the coastal protection options in the CZMP. Without detailed design or modelling outputs it is difficult to determine the extent of these impacts, or even whether they will be a positive or negative impact. Any design work would need to minimise impacts on the Belongil Estuary, in particular. The Belongil Estuary is an important site for endangered and migratory birds. It acts as a refuge during stormy weather and a nesting location for a number of vulnerable or iconic bird species (Olley, 2013):

- Terns (Common, crested, little) – 2000 terns and seagulls sheltered within the Estuary during Cyclone Oswald (unnamed NPWS ranger).
- Beach Stone Curlews are intermittent visitors, and two breeding pairs of Pied Oystercatchers are known to nest in the Belongil Estuary. Nesting success is impacted by erosion, high water flows, disturbance (anthropogenic, dogs) and predation by dogs and foxes.
- Osprey also nest within the estuary, though are not as restricted in feeding habitat as shorebirds.

The Review of Environmental Factors for the Belongil Entrance Opening Strategy (Integrated Ecosystem Research and Management, 2005) identifies many of these potential impacts, although it is not possible to value these impacts without further ecological studies, particularly on the impacts of construction and nourishment on birds and their food sources in the nearshore environment. As they cannot be quantified with any certainty, it is not possible to value these impacts. Failure to include these values will mean that more ecologically damaging options may be selected by the CBA.

6. Valuing the impacts of coastal management interventions

The previous sections have identified baseline economic values and the estimated economic impacts on these values due to changes that are outside the control of the coastal management options under consideration in this CBA.

6.1 Defining a status quo

An economic assessment of policy options is concerned not with the baseline values identified in Sections 3 and 4, but the extent to which these values are impacted by the selected options. In order to assess the coastal management options it is necessary to make some assumptions about the change in these values in the absence of management intervention. This provides the baseline against which the other options are assessed.

6.1.1. Current expenditure on management

It is important to recognise that the status-quo option included in the CBA is not a Do-Nothing option. Byron Shire Council has management obligations that mean that there are ongoing costs associated with the Cavvanbah-Belongil case study location, in order to provide interim beach access at several public reserves. The following costs of these management expenses are included in analysis:

- BSC has spent an average of $130,000 per year on the geotextile structures at the ends of Border, Don and Manfred Streets since 2001 (range nil to $465,000 per year).[8]
- BSC spends approximately $30,000 per year on beach access and dune maintenance.

6.1.2. Future trends in tourism and population growth

The TRA tourism forecasts[9] provide guidance on the projected growth rates of tourism nights and expenditure, separated into the tourist classes previously identified. These projections are included in Table 13.

Table 13 Projected growth rates for tourism sectors

Tourist typology	5- year projected change in revenue (% growth p.a. over period)	10-year projected change in revenue (% growth p.a. over period)
Day-tripper	1.4	1.3
Domestic Overnight	1.4	1.1
International	4.7	4.0

These forecasts are provided for five and ten year periods, which is shorter than the design life of the management options considered in this report. It is assumed that the 10-year figures are applicable over the life of the project. **There is no available information about the relative proportion of domestic and international visitors which visit Cavvanbah-Belongil foreshore, and hence a uniform growth rate in tourism revenue of 2% p.a. is employed.**

Resident growth rates are derived from Census figures for Byron Bay drawn from the National Regional Profile[10], which have remained stable over the past few years. A three-year average was taken over 2009-2011, with a mean of 0.06% growth p.a.

6.1.3. Private property values

The value of residential property in the Cavvanbah-Belongil case study area has been highly volatile in recent years, in line with similar volatility for the entire LGA (Figure 4). It is difficult to make reliable projections about the value of beachfront property given the intrinsic link between this market and the state of the beach at the time of the property transaction, and the potential for

[8] Note that the structure at the end of Manfred Street was recently upgraded to a temporary engineered rock wall.

[9] http://www.tra.gov.au/publications/latest-forecasts.html

[10] http://stat.abs.gov.au/Index.aspx

policy choices or external factors (such as stock market performance and the relative strength of the Australian currency) to have large influences on the attractiveness of beachfront property.

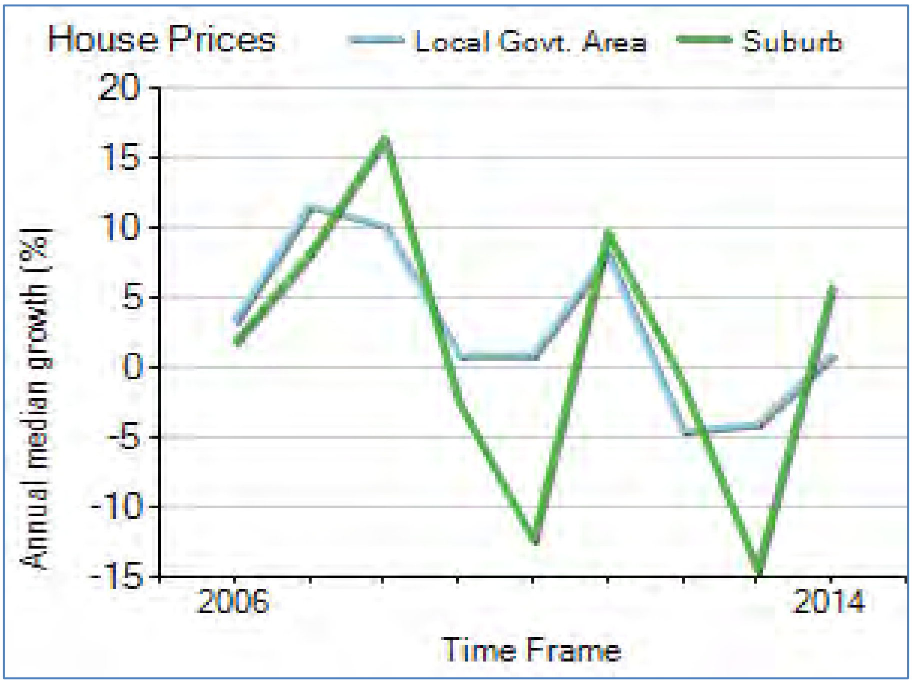

Figure 4 Recent variation in Byron Bay property values
Source: Australian Property monitors

Five year growth rates for Byron Bay taken from Realestate.com.au[11] suggest a growth rate of 1.8% p.a. or 9.4% in total. This figure is not adjusted for inflation, which has been around 10.8% over the same 5 year period. As such, the current inflation-adjusted rate of growth in property values in Byron Bay is close to zero and slightly negative (-0.28% p.a.).

For the purposes of this analysis, it is assumed that nominal property values increase at the 5-year average rate of growth (1.8% p.a.), subject to other changes associated with the implementation of nourishment or protection schemes, as detailed hereafter.

6.2 Economic estimates of erosion damage under planned retreat

Erosion estimates for the scenario of removing all seawalls (except Jonson St) were provided by WRL for ARIs of 1-in-1 year, 1-in-10 years, 1-in-100 year, 1-in-1000 year, 1-in-10 000 years for both 2015 and 2050. These were matched to the 2015 rateable value of the properties (sourced via NSW Globe) using Lot-on-Plan descriptions. The percentage of land area lost in each time period and

[11] http://www.realestate.com.au/invest/house-in-byron+bay,+nsw+2481/growth?zoom=12

under each erosion scenario was used to calculate the value of land lost in 2015 rateable value terms.

6.2.1. Cadastral vs practical area

For a number of properties the cadastral boundary extends seaward of the current location of either the ad-hoc seawalls (where present) or the erosion scarp. In valuing these properties only the usable land has been considered, such that the unimproved value is assumed to apply to the land behind the seawall or scarp.

Properties north of Manfred St also have an ‘easement of necessity’ (a private road), which allows for vehicle passage to and from the north, across the landward side (creek side) of the property. These easements restrict the ‘useable area’ of these parcels of land, as it is not possible to build on these easements. This ‘easement of necessity’ area has also been subtracted from the total cadastral area. Some properties also have boundaries which extend into the present extent of Belongil Creek, with this area also deducted from the cadastral area in the derivation of a practical area.

In most instances there is a minimum lot area beyond which it is not possible to subdivide. As such, it could be considered that the value of remaining land parcels smaller than this size (e.g. 200 m^2) would be negligible.

On the advice of planning staff from Byron Shire Council, this approach has not been taken. Instead, the proportional value of the remaining land has been retained, even when this is as little as 5 square metres, on the assumption that the land could continue to be used in some capacity, and to account for instances when this small area may be contiguous with other lots as part of the same property and occupation remains possible. This assumes that the properties remain rateable and that services and utilities remain connected.

6.2.2. Summary of erosion damage estimates

A summary of the value of erosion impacts by time period and event intensity is provided in Table 14. These figures do not factor in property value growth or discounting, but are 2015 values from the NSW Valuer General, extracted via NSW Globe (property growth rates and discounting are incorporated into the CBA but are not shown here due to complexity). It should be noted that the process of discounting and the rates suggested by NSW Treasury ensure that ‘real’ or present values of these assets is falling over time, as the rate of growth (1.8% - see section 6.1.5 for explanation) is lower than the standard discount rates (7%, with testing at 4% and 10%). This economic assessment tests a broader range of discount rates, with results presented in Section 9.3.

Table 14 Erosion damage estimates under Retreat (seawalls removed) – unimproved property value

Unweighted damage due to erosion	ARI1	ARI10	ARI100	ARI1000	ARI10000
2015	$12,319,984	$42,674,206	$57,688,995	$66,840,189	$81,430,890
2015 with 20m buffer	$39,855,365	$57,107,374	$73,866,275	$91,331,106	$105,878,119
2050	$52,571,152	$63,444,440	$79,107,073	$92,416,859	$106,806,223
2050 with 20m buffer	$67,782,399	$86,775,990	$103,740,808	$115,487,085	$127,812,810

Table 14 demonstrates that erosion impacts are greater with greater elapsed time (due to the long term trend of shoreline recession), and with more severe events. The figures shown include two scenarios. One is a simple GIS output, whereby land is assumed to be lost if it is seaward of the relevant hazard line (erosion scarp). When a 20m buffer is applied to this hazard line, as per the DCP and Draft CZMP (2010) and engineering risk practices, the damage estimates increase substantially, particularly for events of lower intensity. This buffer is assumed to be a landward shift of the hazard line and treated in the same fashion. That is, all value seaward of the buffer line is assumed to be lost.

For the purpose of the economic assessment it is assumed that the increase in the exposure of assets follows a linear increase over the project period. That is, that the exposure in a given year by an event of a given intensity is calculated by the formula:

$$V_t = V_{2015} + \frac{(t - t_0)(Vi_{2050} - Vi_{2015})}{(2050 - t_0)}$$

Where V_t is the value at year t, t_0 is the current year (2015), V_{2050} is the value of eroded assets in 2050 and Vi_{2015} is the value of assets at risk in the present day.

6.3 Existing level of coastal protection and management

Given the existence of interim geotextile walls and informal and temporary rock protective structures along the Cavvanbah-Belongil foreshore, the impacts of erosion events will be moderated, relative to the level of hazard exposure in the absence of these structures (WBM BMT 2013). Based on the engineering expertise of WRL (this report), modelling conducted by WBM BMT (2013) and previous engineering assessments of existing structures (WorleyParsons 2013) the following factors are noted for the status quo for the Cavvanbah-Belongil foreshore:

- Informal rock structures exist for most of the Cavvanbah-Belongil foreshore from Border Street to the northernmost private property. WorleyParsons (2013) estimated that these walls would fail in 1 to 10 year ARI events. Based on the WRL authors' long-term observations of the site, failure at 10 year ARI has been adopted for economic assessment (but this does not imply any endorsement of the structures).
- Interim geotextile structures are present at the ends of Border and Don Streets. WorleyParsons (2013) estimated that these walls would fail in less than 1 year ARI events. Based on the WRL authors' long-term observations of the site, failure at 5 year ARI has been adopted for economic assessment (but this does not imply any endorsement of the structures).
- A temporary engineered rock structure has been installed at the end of Manfred St. This structure was designed to have a 10 year life, remain serviceable after a 1-in-20 year ARI event and fail in a 100 year ARI event. Thus there is a 1 in 100 chance that the wall will require total replacement in a given year due to storm damage and a 1 in 20 year chance the wall will require repairs (of unspecified cost). In the absence of reliable cost estimates, and for ease of modelling, a 1-in-20 year failure has been adopted to encompass these cost components.

These return intervals are converted to annual exceedance probabilities in order to weight the costs of repair by their likelihood of occurrence in each year. The annual exceedance probability of an erosion event of a given magnitude can be estimated from the relationship between severity and frequency. The annual exceedance probability (AEP) of an event of given intensity is given by the formula:

$$AEP = 1 - EXP\left(\frac{-1}{ARI}\right)$$

where ARI is the average recurrence interval of an erosion event. The chance of experiencing events of at least the intensities important for the economic analysis are summarised in Table 15, and shown graphically in Figure 5.

Table 15 Relationship between intensity and occurrence of major storm events

Event intensity – (Average return interval-ARI)	1	5*	10	20	100	1000	10000
Statistical probability of experiencing that event within a year (Annual exceedance probability –AEP)	63%	18%	10%	5%	1%	0.1%	0.01%

* Erosion estimates were not provided for a 1-in-5 year ARI event, but an event of this severity was estimated to result in a breach of the Belongil spit at Manfred St (refer to Section 9.2 of the main report).

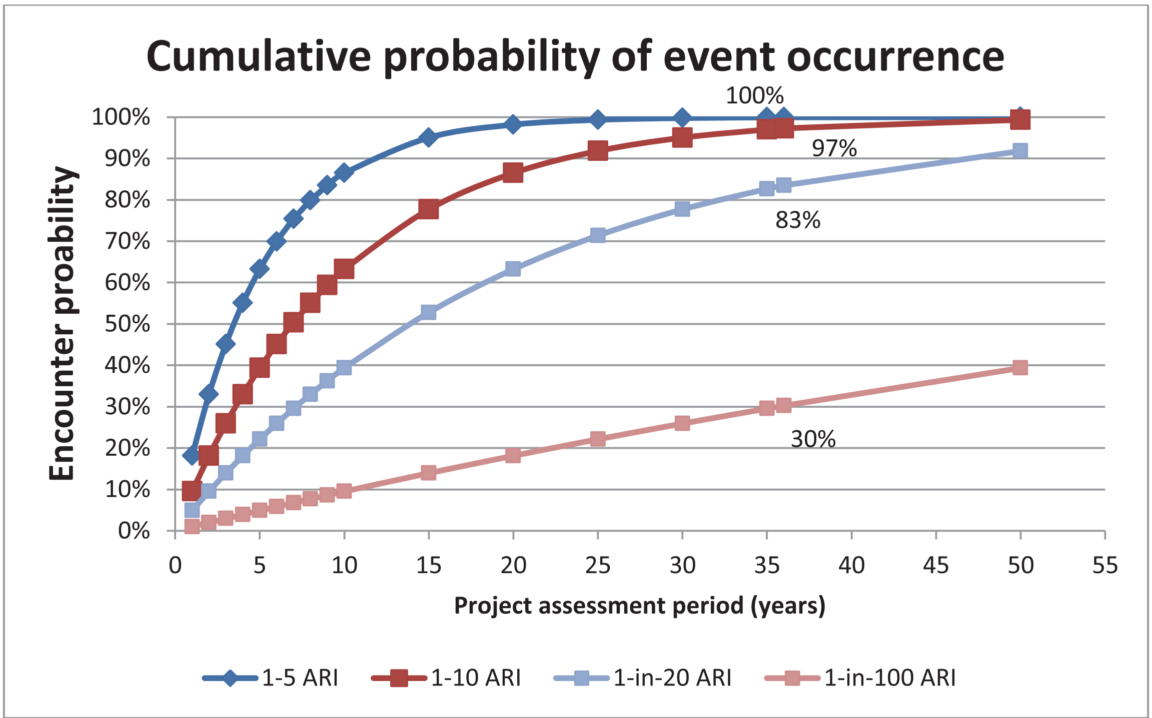

Figure 5 Cumulative exceedance probability of erosion events of given magnitude

In the event of a planned retreat management plan being implemented in the Cavvanbah-Belongil case study area, it is assumed that the expenditure on access and dune maintenance will continue for the duration of the project assessment period but that the costs associated with maintenance of the geotextile structures will be ceased once the retreat option has been implemented. Under the protection options these maintenance costs and those associated with periodic replacement of the interim works are assumed to cease, but are replaced by different upkeep costs of the new structures and renourishment costs where applicable.

7. Benefits and costs of improved protection

The introduction of terminal seawalls and groynes into the Cavvanbah-Belongil beach compartment will have impacts on both the adjacent land and the coastline. This section separates the impacts into those which affect protected assets and those which affect the beach benefits previously identified.

7.1 Value of improved protection

As identified in definition of the Status Quo option, the existing structures whilst not designed to engineering standards do provide a measure of protection (see Section 8.1 of the main report). It is therefore important to value only the **added** benefit of replacing these structures with engineered structures, which requires an estimate of the value of protection afforded by the existing structures. The existing structures are assumed to provide sufficient protection to withstand an event with an ARI of up to 10 years. Engineered structures would increase the level of protection to withstanding an event with an ARI of 1-in-100 years and a design life of 50 years. Thus it is the difference between the damage caused by a 1-in-100 year (or greater) ARI event and the damage from a 1-in-10 year ARI event that is the incremental benefit of upgrading these structures.

The key area for this assessment is the properties located between Border St and Manfred St, as this is the area in which there is the greatest difference in projected shoreline position under the different scenarios identified in the hazard assessment. It should also be noted that the existing structures merely transfer the recession further northward, and hence there is greater recession north of the northernmost private property at Belongil. This end effect, and the groyne effect at Cavvanbah, are currently reflected in the shoreline modelling by BMT WBM (2013), but may be offset by nourishment in the options where it is employed.

7.2 Impacts of a terminal seawall on beach benefit

There have been a number of studies which have explored the relative preferences for protective structures and natural shorelines, as described below. Generally, visitors and residents prefer a more natural appearance and hence seek out accommodation near unaltered shorelines. This translates into a WTP to avoid protective structures, or to seek out more natural coastlines. It should be noted that the impact appears to be linked almost entirely to whether the structure is visible. There are many locations within Australia, particularly in Sydney and the Gold Coast, where a seawall structure is present but generally obscured by an overlying dune. This dune has typically been placed artificially, yet is covered by natural vegetation. Sand nourishment/recycling schemes are also employed at some of the most highly visited beaches, in order to maintain a 'natural' appearance of the shoreline and provide sandy beach seaward of the seawall. The sand recycling system at Noosa main beach is the closest parallel for a potential scheme for Byron Bay embayment beaches.

Hamilton (2007) applied hedonic analysis to investigate the WTP of tourists to the north German coastline for hotels that were located near natural or modified shorelines, using district average hotel room rates as the dependent variable. She identified lower accommodation rates in regions with greater lengths of dykes (analogous with exposed terminal seawalls), and compared the costs of beach nourishment and dyke construction with the expected benefits associated with changes in hotel rates, and found that beach nourishment was the preferred economic option.

Whilst no economic information was collected, a survey of high school students in New Jersey found that they preferred beaches with natural dune systems to those with obvious protective structures (Nordstrom and Mitteager 2001). A recent choice modelling study by the Waikato Regional Council (Phillips 2011) of options for Buffalo Beach also identified a common negative WTP for frontal seawalls which are exposed, with some groups displaying a positive WTP for seawalls which were buried and exposed only infrequently. Respondents had an average WTP of \$65-\$92 per annum to avoid the presence of an exposed terminal seawall, dependent upon the nature of the model employed in analysis.

The payment vehicle employed in the Choice Modelling (CM) study for Buffalo Beach was a change in property rates, despite the fact that more than a third of respondents lived in Auckland, more than 200km away from the study site and within a different Council area. A third of respondents were also under the age of 18, and thus are unlikely to have any reference frame for the payment of property rates, calling into question the validity and broader application of the quantitative aspects of the results. One interesting result can be drawn from the application of the *latent class* model (a CM regression model that identifies discrete respondent groups), however, which was the identification of three key groups of respondents. These were:

1. *High involvement* – high experience of the coastal erosion issues, want something to be done, generally prefer protection but favour natural shorelines to seawalls
2. *Pro-natural beaches* – like the natural appearance, prefer removal of existing structures and maintenance of dunes and coastal reserves
3. *Low involvement* – are not substantially affected by any of the coastal management options suggested, have a low positive WTP to avoid seawalls.

This situation has strong parallels with the history of groups with conflicting views about appropriate management actions for the Belongil case study region.

8. Value of improving beach width through nourishment or planned retreat

There are two key impacts of the change in the width of the beach, as valued in this study. The first is the influence of changes in beach width on protected assets, and the second is the increased amenity provided by the dry sand itself. Each of the options will have different impacts on the width of the beach. Retreat options allow the beach to return to a natural state and thus provide amenities through the inherent processes of accretion and erosion, currently constrained by the existence of structures within the active beach zone. The protection options which include nourishment will result in an increase in the beach width along the Cavvanbah-Belongil stretch of coastline. The option which includes construction of an End-control structure (in the absence of nourishment) may also have some impact on the beach width, although this will diminish with greater distance south-eastward from the structure.

These options are discussed first with regard to the provision of additional beach benefits, and then in terms of their impacts on private property values, and the means by which to value these increases.

8.1 Relationship between beach width and beach benefits

In order to determine the benefit of any attempt to preserve or improve the state of the beach, it is necessary to explore the relationship between beach width and economic value. Previous studies of preferences for beach width indicate that the relationship between beach width and utility is convex, with lower utility derived from beaches that are both too narrow and too wide. Utility associated with beach use is minimal once the beach is reduced below a certain beach width, due to the fact that it is more difficult to access and may not be available under all tide and wave conditions. A stylised version of this relationship is presented in Figure 6.

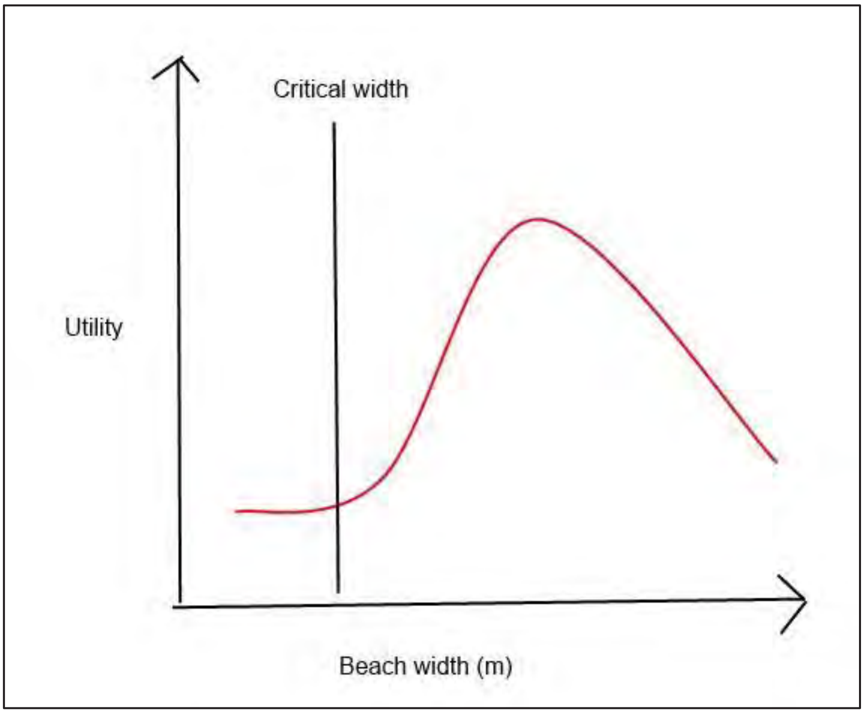

Figure 6 Beach width and utility from beach visit

Attempts to determine the willingness to pay (WTP) for beach width conducted overseas have indicated that there is an optimum beach width for each location, but that this width is influenced by the natural variability of the beach and the 'average' beach width to which the beach users are accustomed.

Once the beach erodes past a certain point (termed critical width) the amenities provided by that beach for recreation and tourism are greatly reduced. For example, when storms expose rocks and debris and the beach is closed for safety reasons. Private and public infrastructure may also be at risk of damage. The key recreational benefit of nourishment or retreat is the maintenance of beach amenity in response to minor storm events. Nourishment volumes have been designed to maintain a minimum beach width in response to a 1 year ARI beach erosion event. That is, they will ensure that beaches will maintain a critical beach width of 20m dry sand from the base of the dune or terminal seawall structure to mean sea level.

The minimum width for use of a beach is derived from studies about preferences for beach width conducted in the US and Wales. Morgan (1999) provides the most detailed analysis from studies conducted in Wales, and identifies optimum beach width of 50-200 yards (46-183m) at low tide and 20-50 yards (18-46m) at high tide. Parsons et al. (2000) identified optimum beach widths in Delaware and New Jersey as between 75ft and 200ft (23-61m), whilst in central California the ideal beach width was estimated at 100-200ft (30 to 60 m, King 2006). The stage of the tide was not noted in these studies.

8.2 Increased beach benefit value through reducing frequency of beach closures

It is assumed for the sake of this modelling process that the current beach width is above the critical beach width for most of the year but below the optimum beach width, and that an increase in average beach width would increase the benefits associated with the beach. Section 6.4 outlines the way in which this 'lost' beach benefit can be estimated.

Beach survey data for Belongil is limited and photogrammetric profiles are only available at intervals of approximately 2 to 10 years. Based on the long term qualitative observations of the WRL and GCCM authors (and advice from BSC and local OEH staff), it is estimated that there is a usable beach (see section along the Belongil foreshore approximately 80% of the time (see Section 8.3.1 of the main report for a discussion of minimum acceptable beach widths), but that a combination of high tides, erosion and wave action results in the periodic restriction of access along the beach. Thus there is potential to increase the amenity value of Byron Bay beaches via nourishment. Due to lack of data, it is not possible to know exactly where on the utility curve the existing beach width lies, and it is likely that in practice the high tide width may be more important for use considerations. Establishing the local preferences for beach width is beyond the scope of this CBA, and may not be feasible.

Widening beaches through implementing a policy of retreat or by adding additional sand is assumed to increase the frequency of beach availability to 95% of the year, representing an increase of 18.75% over the baseline figures estimated in Section 3.[12] In reality the relative increase would depend upon the time of year in which the avoided closures actually occur. An estimate of the effectiveness of the various options in achieving this improvement is used to weight the additional benefits of wider beaches through reduced frequency of beach closure.

Table 16 summarises the assumptions about improved beach amenity employed in analysis of the options in this analysis. It is important to note that these factors are only for that section of the beach within the case study location, and no down-drift effects are included for any option due to the complexities of estimating such impacts.

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[12] increase to 95% availability is calculated as 100* (95-80)/80=18.75

Table 16 Benefit of improved beach width availability

	Option	Beach benefit uplift factor	Effectiveness factor
1	Status Quo	Baseline	Baseline
2	Planned retreat	18.75%	0.95
3	Seawall, Groyne, Nourishment	18.75%	0.8
4	Seawall, End Control, Nourishment	18.75%	0.6
5	Seawall, End Control, No nourishment	18.75%	0.2
6	Adaptive management – all components	18.75%	0.7
6.1	Adaptive management – seawall only	0	0
6.2	Adaptive management – seawall and single groyne	18.75%	0.2
6.3	Adaptive management – seawall and groyne field	18.75%	0.4

8.3 Impact of moderate storms on realisation of additional beach benefits

WRL (this study) estimates that a storm of intensity 5 to 25 year ARI would erode the sand of the nourished beach to the extent that the seawall is exposed at 2m AHD. The lower level is used to estimate the likelihood of seawall exposure. The probability of encountering a storm of intensity of 5 year ARI or greater in a given year is 18% (see Table 15), and hence it is assumed that in any given year there is an 18% chance that the beach will be fully eroded and the additional beach benefits will not be realised.

8.4 Impacts of changes in beach width on protected asset values

In addition to providing benefits to those using the beach itself, greater width is associated with protective and amenity values that accrue to the adjacent land. Beach width is commonly valued by examining the impacts of changes on the value of infrastructure and land in the adjacent area, through application of the hedonic pricing method (HPM). The HPM explores the influence of amenities on a distributed market (typically the labour or housing market) through multiple regression analysis. In examining many property records and controlling for factors such as land size, zoning and accessibility, it is possible to determine the proportion of purchase price that can be attributed to differences in environmental aspects such as beach proximity and erosion risk.

Minor changes in beach width have been demonstrated in previous HPM studies to have a relatively small impact on adjacent property prices. Pompe and Rinehart (1994) identified a 2.6% reduction in adjacent property prices for a 10% reduction in beach width. This is true up until the point that the beach loses sufficient width to be unable to provide the same environmental amenities that affect the price premium. Once again, without modelling of the beach width both in the presence and absence of the nourishment projects, it is not possible to include the economic impact of these minor changes in the current CBA.

The majority of HPM beach valuation studies are concerned with private residential dwellings (houses) on the beachfront with direct beach access. Given the volatility of the Belongil market in recent years, it is not possible to determine an exact estimate of the loss of this value through erosion. It is also important to note that property is typically bought with a long-term investment horizon, and may not respond to relatively short-term changes in the state of the beach due to storm events.

In analysis of the coastal housing market on the northern beaches of Sydney, Anning (2012) identified substantial price premiums for beachfront locations on Collaroy-Narrabeen beach. When compared to an otherwise similar property in the same suburb that was not located near the beach or lake, the total price premium for beachfront access was approximately 200%. Burgan (2003) updated previous work conducted with a colleague (Evans and Burgan 1993) that explored the influence of coastal proximity on the housing market in Adelaide. This study identified that beachfront locations were associated with price premiums of around 40%.

There are a number of properties along the Belongil foreshore which are used for temporary accommodation. The marginal benefit accruing to these properties due to their beachfront location may be even higher. Taylor and Smith (2000) examined rental prices paid for accommodation on a barrier island in North Carolina over a period of five years and identified that premiums of up to 60% were paid for beachfront locations, relative to properties located between the two major roads on the Outer Banks. Attempts to compile a comparison of beachfront and non-beachfront properties in the current economic analysis were stymied by a lack of comparable accommodation options (e.g. 2 bedroom cottage) common to all venues and large variations in room pricing.

Any analysis of the housing market impacts of changes in the state of the Belongil beachfront would face considerable data limitations and challenges of separating the WTP for a beachfront location from the influence of erosion risk and the existing planned retreat policy on the purchase price of these properties. Other amenities such as uninterrupted views are also difficult to isolate from the benefits of enhanced beach width. Substantial volatility exists in the Belongil market. Prices dropped substantially between the valuation cycles of 2006 and 2009 (Grigg and Allen 2010; Johnstone 2010), although the extent to which these changes were driven by the occurrence of large storms in 2009 is uncertain, and the global financial crisis also is likely to have had a large impact.

Purchasers of beachfront properties in all locations must balance the risk or erosion against the amenities provided by the proximity to the shoreline. This report takes the conservative assumption that the added amenity values accruing to landowners from wider beaches is marginal when compared to the benefits of improved protection, as outlined in the previous section of the report.

Key assumption: The benefit of wider beaches to owners of beachfront properties is assumed to be zero. These benefits are assumed to be a sub-set of the benefits of wider beaches accruing to Byron residents.

8.5 Beach benefit values when the beach is fully eroded

In the event of a design (100 year ARI) storm, there will be severe erosion of the Belongil foreshore. The beach will also be completely eroded by smaller storm events which occur more frequently. The recreational value of a beach is not completely lost however, as a substantial proportion of beach visitors may not be reliant upon sand or water access, and there are likely to be alternative useable beaches nearby. Dwight et al. (2007) found that fewer than half of the beach visitors in California entered the water, whilst Anning (2012) found that at a beach with a history of known erosion issues (Collaroy-Narrabeen), around 29% of interviewed beach users stated that they would be unaffected by the short-term closure of a beach due to erosion.

There is also substantial tourism appeal to coastal locations which do not have beaches, and hence these values are not expected to completely diminish even when severe erosion occurs. The following sections detail the results of surveys which sought to identify behavioural responses to beach erosion recently completed as part of the BASTRA project described in Section 3.2.2.

8.5.1. Response of residents to severe beach erosion

The BASTRA project described in Section 4.2 included surveys which asked residents and tourists how they would respond to severe beach erosion, however, Byron Bay was not a primary case study location for the BASTRA project, and the closest analogue was Clarence Valley Shire Council in Northern NSW. This section draws upon the results of a sample of Clarence Valley residents (n=250) recruited via mail survey in the BASTRA project. Among Clarence Valley residents 58% indicated that they would transfer their beach recreation to an alternative local beach (Figure 7). A further 8% of respondents indicated that they wouldn't be affected by the loss of sand from the beaches, possibly because they do not venture onto the sand. Thus a total of 34% of residents would be negatively impacted by severe beach erosion, and this is treated as a conservative measure of lost recreation value due to an erosion event.

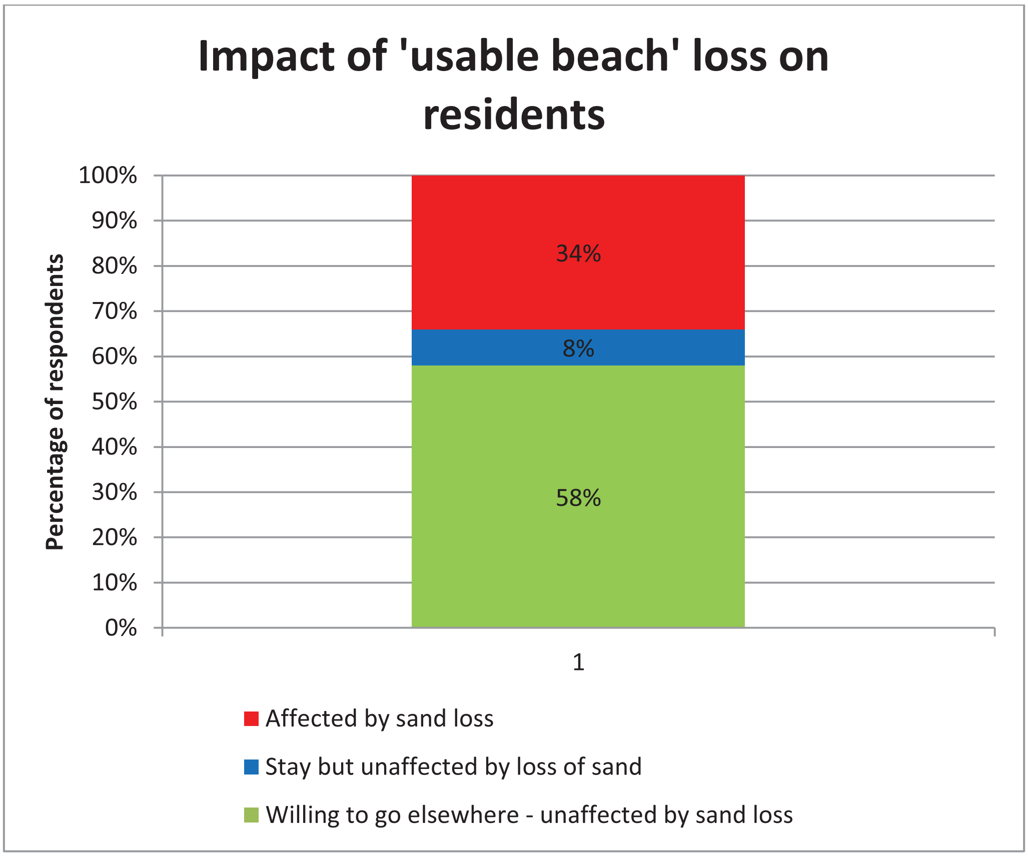

Figure 7 Resident response to beach erosion – Clarence Valley survey

It is assumed for the purpose of this CBA that the 58 % who are willing to incur some additional cost to get to a useable beach remain within the Byron Shire Council local government area (BSC LGA), which has approximately 30 km of open coast, and thus their value is not considered a 'loss' but a 'transfer' within the regional economy. This assumption is based upon analysis of maximum driving distances, as outlined in Figure 8.

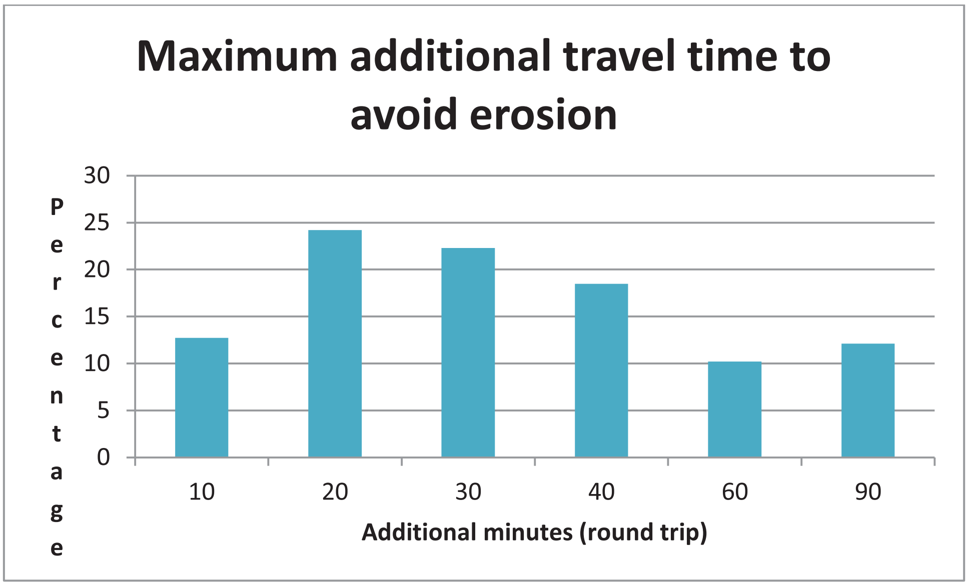

Figure 8 Willingness of Clarence Valley residents to travel to avoid erosion imapcts

It should be remembered that the resident visitation estimate is drawn only from the Byron Bay region, despite the fact that people may travel from further afield to visit Belongil. Previous studies have indicated that residents visit their favourite or local beach far more frequently than other beaches, and are reluctant to travel long distances to alternative locations. Analysis of responses from the behavioural survey (Figure 8) indicate that more than half of resident respondents would travel less than 15 minutes one way, with a weighted average of around 37 minutes as a round trip.

It is therefore unlikely that they would travel sufficient distance in this time to leave the Byron Bay region, and hence from a Council and regional economic perspective this represents a transfer of value rather than a loss. Given the similar level of exposure to storm waves within the case study area, it is likely that they will be similarly affected. The beaches of the Byron Bay Embayment are relatively well protected from large storm waves coming from the south, although exposed to more easterly and northerly swell directions. Hence the source of the erosion-inducing waves (such as Cyclone, East Coast Low) may be critical in determining the availability of alternate beaches and the extent to which erosion-induced economic impacts are felt by users of Belongil Beach.

This analysis takes the conservative assumption that residents will transfer their visits to other locations within the Byron Shire, and hence the smaller figure of a 34% loss of residential use value is employed in estimating the costs of severe erosion to Belongil.

8.5.2. Response of tourists to severe beach erosion

In the case of tourists, responses from the Clarence Valley surveys conducted in the BASTRA study are again applied (Figure 9). The surveys suggested that 78% of tourists would be willing to incur costs or time imposts to travel to another beach. It is important to note that these responses were gathered from tourists on beaches. They had therefore already made their choice of destination and accommodation, and were based in the case study area. It did not survey residents who were considering making a trip to either Byron Bay or an alternative beach destination (e.g. Noosa), and hence it does not consider impacts on repeat visitation. It is also worth noting that, while the data was collected for Clarence Valley, the attraction base for Byron Bay is more diverse and visitors to the region may be there for attractions other than the beach that are completely unaffected by the erosion event.

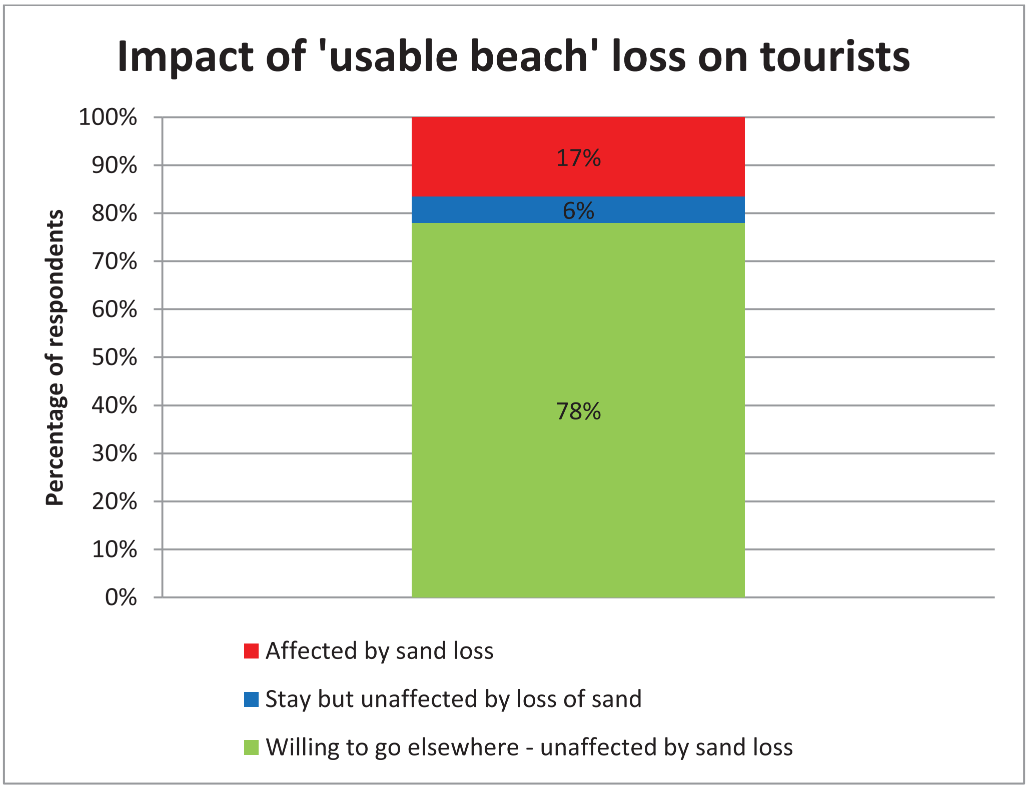

Figure 9 Erosion response by tourists – Clarence Valley

Discounting again for the proportion of remaining tourists who said that the sand was not important to their enjoyment of the beach (6%), a total of 17% indicated that they would be negatively impacted and would not be able or willing to look for an alternative beach in the region (Figure 9). **This proportion is used to scale the tourism expenditure related to the beach, to estimate the remaining lost economic value.** This proportion (17%) is approximately the same as the predicted loss of tourism receipts due to a 50 year ARI storm event, as estimated by Raybould and Mules (1999), which adds some confidence in the use of these figures for assessing the impact of a severe erosion event of imprecise magnitude.

Raybould and Mules (1999) examined historical tourism data to estimate a relationship between beach erosion events and visitation. In order to determine the economic impacts of beach erosion, they compared tourism revenue in periods immediately after known erosion events with the 'expected' revenue based on reference years with no significant erosion. This was then used in cost-benefit analysis of a proposed beached nourishment program to estimate the economic impact of these events, which required large scale beach nourishment and ongoing maintenance over a 25 year period. Whilst not a true travel cost model, this methodology has intrinsic appeal for the valuation of climate change and storm impacts on beaches. Previous studies have demonstrated strong linkages between the state of beaches and tourism revenue in coastal cities (Phillips and Jones 2006).

The studies suggested that erosion events with average recurrence intervals of 5, 10, 25 and 50 years would result in 2%, 5.5%, 13% and 20% reductions in annual tourism revenue, respectively. The authors suggested that the proposed project would reduce the impact of these erosion events, and hence generate 'savings' in lost revenue. These savings were related to the costs of the proposed project, which resulted in a benefit-cost ratio of at least 17 to 1, using relatively conservative factors in the analysis (Raybould and Mules, 1999).

It should be noted that the different types of tourists may have different responses to erosion. Day-trippers are more likely to be aware of local beach conditions and may select different destinations accordingly. Domestic overnight visitors may be influenced by media coverage and choose to holiday elsewhere, whereas international tourists are likely to have a longer lead-time in their trip planning and hence not be as flexible in responding to changes in beach state. Estimating different beach erosion response patterns between different tourism types or beach user groups is beyond the scope of this study but is recommended as a highly relevant future avenue of research for regions such as Byron Bay which receive substantial income from tourism expenditure related to the beach.

Once again, the extent to which these losses are felt by the regional economy of Byron Bay depends upon assumptions about where tourists would travel to get to a substitute site. Responses from the BASTRA study suggest that Clarence Valley tourists would be willing to travel approximately 36 minutes as a round trip to avoid erosion impacts, and incur approximately $13.20 in additional travel costs. It is again unlikely that this would take them outside the Byron LGA.

8.6 Costs and benefits of planned retreat

This analysis assumes that retreat is able to take place as a planned process in accordance with Part J of the DCP and the previous draft CZMP (2010), with removal of the existing terminal structures followed by a gradual retreat of privately-owned structures as the shoreline reaches defined trigger values outlined in individual planning consents, or the buildings are relocated or demolished due to safety considerations. There is also the potential for retreat to occur as an unplanned response to a major storm event. Given the potential for erosion of 40 m+ of shoreline in response to a design (1-in-100 year ARI) storm erosion event, this is considered a highly possible management response, but it has not been valued in this CBA.

The primary benefits of retreat are to reduce the future costs of recurrent maintenance expenditure, and to increase the availability of the beach for benefits that are linked to the state of the beach. This increase in benefits is (assumed to be) achieved in a retreat scenario through removing the existing rock and geobag structures to allow the beach to move naturally in response to wave influence, thereby maintaining a sandy beach, albeit further landward.

Under the Planned Retreat option, a staggered retreat is assumed. Land is lost once eroded, regardless of recovery post-storm. It is assumed that the Status Quo maintenance expenses and damages will continue to be incurred up until the decision is made to remove the existing protective structures. Once these structures are removed, all maintenance is assumed to cease, with corresponding reductions in expenditure. It is also assumed that the shoreline begins each year at the same location, meaning that there are no cumulative impacts.

Lengthening the retreat planning period has the effect of diminishing the present value of these losses through discounting, but also delays the financial benefits associated with reduced expenditure and increased availability of usable beach width.

8.6.1. Costs associated with loss of buildings

In addition to the loss of land, retreat would require the removal of built structures as they become affected by erosion. Table 17 shows the number of residential buildings affected by varying erosion events and time horizons. Note that there may be more than one building per land title, given the modular nature of buildings. There are also owners with more than one property, and dwellings commonly span across more than one lot.

Table 17 Number of buildings lost to erosion, in the absence of existing protective structures

Number of buildings lost (total number in case study are is 58, or 74 if a 20m buffer is applied as per DCP)	ARI1	ARI10	ARI100	ARI1000	ARI10000
2015 – number of buildings	**10**	**22**	**34**	**43**	**53**
2015 – number of buildings (with 20m buffer)	25	36	47	56	58
2050 – number of buildings	**29**	**38**	**50**	**56**	**58**
2050 – number of buildings (with 20m buffer)	45	54	58	58	74

Table 18 shows that by the year 2050, and in the absence of the existing protective structures, half of the total number of buildings would be predicted to be affected by a storm with an average return period of 1 year. When a 20m buffer is applied, as per the DCP and previous draft CZMP (2010) and engineering risk practices, approximately two thirds of buildings are assumed to be lost within the first year after removal of the existing walls and geobag structures.

In the absence of reliable market values, the replacement value of residential buildings is estimated from Rawlinson's Construction Cost Guide 2015, using building footprints digitised in GIS. Using the Tweed Heads index, construction costs of $2500 per square metre of floor area were employed. The number of levels was estimated by WRL using oblique aerial photography, with buildings classified as having 1, 1.5 or 2 levels.

Buildings were assumed to be lost based on two separate scenarios. The first includes the costs of building damage only when the predicted erosion scarp intersects the building footprint. This is a non-precautionary assumption given that safety considerations and enforcement of planning consent conditions would be likely to see properties removed (or protected) long before such an event occurred. The second scenario includes the 20m safety buffer enshrined under the Byron DCP and BSC draft CZMP (2010), such that a building is required to be removed once it is within 20m of the erosion scarp. Demolition and removal costs of $10 000 per property have been assumed.

Importantly, some houses in the study area have been designed to be relocatable if threatened by erosion. For these properties, relocation costs of $20k have been estimated, to account for disconnection and reconnection of essential services. It is assumed that relocation can occur if the remaining land area is larger than the building footprint, at which time the total building value is assumed to be lost.[13]

A summary of the economic value of expected damage under a retreat scenario (removal of all seawalls except Jonson St) is presented in Table 18. These figures are added to the land value impacts outlined in the next section.

Table 18 Estimated damage to residential buildings under retreat scenario

Unweighted damage to buildings	ARI1	ARI10	ARI100	ARI1000	ARI10000
2015	$6,472,944	$12,978,402	$18,979,741	$22,517,971	$29,122,477
2015 (with 20m buffer)	$12,150,572	$16,119,710	$21,728,574	$29,740,052	$30,897,613
2050	$13,561,750	$17,632,961	$23,952,630	$29,506,365	$31,570,504
2050 (with 20m buffer)	$20,618,065	$28,730,903	$30,897,613	$30,897,613	$59,131,454

8.7 Probability weighting of erosion impacts

Whilst the impacts of severe erosion events are substantial, the statistical probability of these events occurring in a given year is low. As such, the estimated damage caused by these events should be weighted by the chance of them occurring. The annual exceedance probability of an erosion event of a given magnitude can be estimated from the relationship between severity and frequency. The annual exceedance probability (AEP) of an event of given intensity is given by the formula:

$$AEP = 1 - EXP\left(\frac{-1}{ARI}\right)$$

where ARI is the average recurrence interval of an erosion event. The chance of experiencing events of at least the intensities important for the economic analysis were summarised in Table 15.

Table 19 shows the estimated damage costs associated with erosion of coastal residential property, assuming removal of all seawalls with the exception of Jonson Street.

[13] Note that under the advice of BSC planning staff, the land itself retains a spatially-proportional value even when the remaining lot size is too small to rebuild a normal dwelling.

Table 19 Probability weighted annual erosion damages – land value only

Weighted damage to cadastral parcels	ARI1	ARI10	ARI100	ARI1000	ARI10000
2015	$7,787,715	$4,060,988	$574,015	$66,807	$8,143
2015 with 20m buffer	$25,193,396	$5,434,485	$734,982	$91,285	$10,587
2050	$33,231,306	$6,037,537	$787,129	$92,371	$10,680
2050 with 20m buffer	$42,846,648	$8,257,827	$1,032,238	$115,429	$12,781

Whilst the absolute impact of the less-likely events is much higher (as shown in Table 14), the reduced likelihood of occurrence means that the probability-weighted damage expected each year from these rarer events is lower than that from more frequent events such as the 1-in-10 year storm. It is also these relatively minor events that are more greatly affected (in a relative sense) by the passage of time and long-term recession rates.

The probability-weighted estimates of damage for each event can then be totaled to give a measure of the likely erosion damage in a given year, analogous to the Average Annual Damages (AAD) approach in floodplain modelling. Note that in flood modeling applications the same area can experience damage multiple times, whereas in an erosion-damage context under a Planned Retreat regime, the land can only be lost once, and subsequent erosion events only result in further losses if they move the erosion scarp further landward. Recovery of the land is not considered, as this would require an estimate of recovery periods, and could be inconsistent with legal principles established in NSW Land and Environment Court proceedings.

To avoid multiple counting of erosion impacts, Monte-Carlo simulation was applied to determine the probability of a shoreline position in a given year and thus determine the economic impacts of the shoreline recession experienced in that year. Draws from a random distribution of erosion events (10^6 draws for each year) were averaged to estimate the erosion damage each year. The majority of erosion impacts are experienced in the first few years, as beyond this period it is only the incremental impacts of more severe events that are able to move the erosion scarp landward.

The estimated time series of annual average damages from the Monte-Carlo simulation is provided in Appendix 4. Two estimates are presented, showing damage cost estimates both with and without the 20m buffer discussed earlier in the report.

8.7.1. Assumed erosion impacts for non-retreat options

The revised probabilistic modelling (WRL, this report) provided erosion areas for events of varying severity, in the absence of any seawalls or structures (except for Jonson St). It is not possible to accurately model the extent of protection afforded by the existing informal walls and geobag structures, or the amount of protection that would be provided by an engineered seawall when confronted with an erosion event with a severity beyond the design thresholds of that structure. Thus some assumptions must be made in order to quantify the extent to which protection would be improved by moving from the status quo situation to an engineered protective structure.

Previous assessments (WorleyParsons, WRL) have suggested that the existing walls and geobag structures would be able to withstand a 1-in-5 year ARI event, but would be likely to fail in the event of a 1-in-10 year ARI event. The temporary rock structure recently installed at the end of Manfred Street has been assumed to fail in the event of a 1-in-20 year event. Table 20 summarises the assumed impacts of erosion events of different intensities.

Table 20 Assumed impact of erosion events

Option	1-in-1 ARI	1-in-10 ARI	1-in-100 ARI	1-in-1000 ARI	1-in-10000 ARI
Status Quo	Protection provided by existing structures – modelled damage not included	Likely failure, severity reduced to that of 1-in1 year ARI event. Modelled damage for 1-in1 year ARI event included	As per Planned Retreat	As per Planned Retreat	As per Planned Retreat
Planned Retreat	Modelled damage	Modelled damage	Modelled damage	Modelled damage	Modelled damage
Protective Options (2-6.2)	Complete protection	Complete protection	Complete protection	As per Planned Retreat	As per Planned Retreat

It should also be noted that the seawalls assumed to be present in Scenario 1 of the BMT WBM (2013) modelling do not protect the entire foreshore of the Byron Bay embayment. Of particular note is the absence of any protective structures within the Cavvanbah zone immediately to the north-west of the First Sun caravan park, which is an important location for recreation and tourist use, or to the north of the northernmost extent of private property at Belongil. These two areas would be expected to recede at different rates to those sections of coastline with structures in place, although the pattern of recession is complicated by the fact that existing structures will begin to act as an artificial headland or groyne once the land recedes to the south. Detailed projection and assessment of the potential economic impact of these differential recession rates is not possible without substantial further modelling of the proposed options, and site-specific surveys to determine the distribution of usage and the sensitivity of beach users to highly localised erosion impacts.

8.7.2. Breach at Manfred St under planned retreat– repair assumed

Modelling by WRL also estimated that in the absence of the existing interim geobag and rock structures, the Belongil peninsular would breach at Manfred St in response to an erosion event with an ARI of 5 years in the present day. By the end of the assessment period (2050), this event would be likely to occur annually. The cost of restoring the breach and road access is considered below.

It is not the role of this analysis to predict the likely practical response and policy implications of breaches of the Belongil peninsular, although the authors suggest two possible outcomes which are considered to describe the range of possible responses. The first possible response to a breach of the Belongil peninsular at Manfred St is that the breach is repaired once, and then if the breach of the peninsular was to occur again, all land on or to the north of Manfred St would be considered to no longer be useable for residential purposes. At this stage, the properties north of Manfred St would be required to be vacated, and the land in this region would revert to crown ownership. Currently there is in excess of $40 million worth of property (land only) located north of Manfred St, comprised of 20 residential properties. This does not include the value of the Manfred Street itself, nor of the private road continuation of Childe St north of the intersection with Manfred St.

Based on the value of similar parcels of crown and council-owned land in the region, this would mean that the residential lots north of Manfred St would decrease in value to around $80 000 to $100 000 per property (based on rateable values for crown land parcels in North Belongil). The total value of land north of Manfred St would then be equivalent to approximately $2 million, representing a decline in private property value of more than $35 million. Clearly an economic impact of this magnitude has the potential to exert a strong influence on the outcome of a CBA. This effect has not been tested in the current CBA.

The second option, and that considered more likely, is that the breach is repaired each time it occurs, at a cost of $1m (2015 dollars), up to the point at which it becomes unviable to do so. This cost is assumed to be inclusive of any costs associated with re-establishing utilities and services to North Belongil.[14] Thus there is an 18.13% chance (this is the annual exceedance probability of a 1-in-5 ARI event) that the breach would need to be repaired in any given year, and the weighted average expenditure to repair a breach in any given year is $181,269 ($1m per breach, multiplied by the probability of occurrence). Given the magnitude of other losses in the first five years after removal of the existing structures (see Appendix 4), it is considered unlikely that this repair would be

[14] No allowance is made for alternative accommodation or living expenses incurred by displaced residents.

undertaken unless it occurs within that period. As such, the weighted cost of repair is applied to the first five years. Any breaches that occur beyond this time period are assumed to not be repaired.

8.8 Summary of economic impacts of coastal management options

Table 21 provides a summary of the assumptions employed in the comparison of options assessed in the CBA.

Table 21 Impact of management options on key amenity values

Option	Private assets	Recreation	Tourism
1. Status Quo	Damage to land and buildings is limited by ongoing maintenance of temporary and interim walls and geobag structures.	Reduced by 34% when seawall is exposed through moderate (5<x<100 year ARI) storms, totally lost when design storm occurs with recovery within a year	Reduced by 17% when seawall is exposed by moderate (5<x<100 year ARI), totally lost when design storm occurs with recovery within a year
2. Planned retreat	Land and asset value damages are weighted by their chance of occurrence. Engineering costs incurred when retreat is implemented. Reduced maintenance costs.	Increased by 18.75% through natural beach function – 95% effective effectiveness in maintaining increased beach amenity Behavioural response to storms as per description for Status Quo option	
3. Groyne Seawall Nourishment	Improvement over existing level of protection, reduced maintenance costs	18.75% increase due to wider beaches, maintained by sand capture and nourishment – 60% effectiveness in maintaining increased beach amenity Behavioural response to storms as per description for Status Quo option	
4. End Control Seawall Nourishment	Improvement over existing level of protection, reduced maintenance costs	18.75% increase due to wider beaches, maintained by sand capture and nourishment – 80% effectiveness in maintaining increased beach amenity Behavioural response to storms as per description for Status Quo option	
5. End control Seawall no Nourishment	Improvement over existing level of protection, reduced maintenance costs	18.75% increase due to wider beaches, maintained by sand capture– 20% effectiveness in maintaining increased beach amenity Behavioural response to storms as per description for Status Quo option	
6. Adaptive management - all components	Improvement over existing level of protection, reduced maintenance costs	18.75% increase due to wider beaches, maintained by sand capture– 70% effectiveness in maintaining increased beach amenity if all stages are implemented. Behavioural response to storms as per description for Status Quo option	
6.1. Adaptive management- seawall only	Improvement over existing level of protection, reduced maintenance costs	No change in recreation or tourism value from Status Quo. Behavioural response to storms as per description for Status Quo option	
6.2. Adaptive management - Seawall + single groyne	Improvement over existing level of protection, reduced maintenance costs	18.75% increase due to wider beaches, maintained by sand capture– – 20% effectiveness in maintaining increased beach amenity once groyne is in place. Behavioural response to storms as per description for Status Quo option	
6.3. Adaptive management - Seawall + groyne field	Improvement over existing level of protection, reduced maintenance costs	18.75% increase due to wider beaches, maintained by sand capture– – 20% effectiveness of single groyne, 40% effectiveness in maintaining increased beach amenity once groyne field is implemented. Behavioural response to storms as per description for Status Quo option	

9. Cost- benefit assessment of coastal management options

This section presents results of this analysis. It should be read bearing in mind all of the assumptions which have been applied in generating the estimates, and provides sensitivity analysis of the impacts of the critical assumptions. Definitions of the key decision criteria are included in Appendix 1.

9.1 Summary of costs for Status Quo option

The Status Quo option is likely to result in substantial economic costs within the project period, with no **incremental** benefits.[15] The estimated Net Present Value of costs of continuing with the Status Quo option is -$10.18million over the project assessment period, under the base case assumptions. This estimate assumes that the beach remains largely in the current state, and continues to provide the current level of beach benefits. Any substantial change in the state of the beach would increase these costs. It also assumes that replacing and maintaining the interim geobag walls and existing non-engineered protective works, and maintaining the interim rock wall at Manfred St, would continue to provide some measure of protection to assets behind the wall (although less than that provided by engineered structures). Damages to protected assets are limited in the Status Quo option through ongoing maintenance of the existing structures.

9.2 Summary of results

Table 23 provides a summary of the results of the CBA using the two sets of base case assumptions described in Table 1, which are presented again below in Table 22.

Table 22 Base case assumptions

Factor	Best-estimate base case assumptions	BSC base case assumptions
Land values	2015 Valuer General figures	2015 Valuer General figures
Discount rate	0.07	0.07
Tourism - producer surplus adjustment	Scaled by 0.3	Full value of tourism expenditure included
Recession of beach	Recedes to 50% availability over 35 years (from 80%)	Recedes to 50% availability over 35 years (from 80%)#
Marginal value of sand	Constant benefit (18.75% initial improvement in tourism revenue), scaled	Constant benefit (18.75% initial improvement in tourism

[15] The Status Quo option is not included in the sensitivity analyses presented hereafter as it acts merely as a baseline for comparison of the other options.

	by beach availability and effectiveness factor of each option	revenue), scaled by beach availability and effectiveness factor of each option#
Retreat implementation	Year 0, all walls removed except Jonson St	Year 0, all walls removed except Jonson St
Buffer zone (20 m)	Buffer (20 m) applied	Buffer (20 m) applied
Owner-occupied ratio	55%	100%
Property uplift factor	Not applied	Applied
Manfred St	Repaired at cost of $1m when breach occurs, only for retreat option, only for first 5 years	Repaired at cost of $1m when breach occurs, only for retreat option, only for first 5 years#

Not specified by BSC. Chosen based on consultant's best estimate or advice from OEH.

Table 23 Summary of CBA base-case results

		Net present value (NPV)* over planning period ($ million)		Benefit Cost Ratio (BCR)*	
Option	**Description**	**Best Estimate**	**BSC Base Case**	**Best Estimate**	**BSC Base Case**
2	Planned retreat	-28.26	-40.79	0.35	0.40
3	Groyne Seawall Nourishment	-23.13	11.62	0.56	1.22
4	End Control Seawall Nourishment	-16.45	15.88	0.63	1.36
5	End control Seawall no Nourishment	-2.10	25.15	0.92	1.91
6	Adaptive management - all components	-7.25	22.51	0.79	1.66
6.1	Adaptive management- seawall only	7.24	31.94	1.42	2.87
6.2	Adaptive management - Seawall + single groyne	5.19	31.86	1.26	2.59
6.3	Adaptive management - Seawall + groyne field	-3.76	24.42	0.87	1.82

The costs associated with Planned Retreat are not balanced by the expected benefits and avoided losses, under the retreat mechanism described within the base case assumptions. Retreat has a benefit cost ratio (BCR) of less than 1 and a NPV well below zero, suggesting that it is not economically viable.

It should be noted that there were a number of un-costed components identified in Section 5, and that omission of these components may result in the CBA favouring options which preserve those components which can be costed, particularly options which preserve the value of privately held buildings and land within the hazard zones.

Further research would be required to establish whether these uncosted items are sufficiently valuable to result in a change in ranking of the assessed options. The uncosted components would need to be associated with benefits with a NPV of greater than $40 to $60 million over the project period in order for Planned Retreat to be ranked more favourably than any of the protection options, also assuming that these benefits accrue only to the Planned Retreat.

Under the Best Estimate scenario, none of the full options is considered economically viable. The highest ranked full option in terms of net present value (NPV) is Option 5, which is the least expensive intervention option and involves a seawall and end control structure but no sand nourishment. The option with the second highest NPV is Option 6 (incorporating staged implementation of groynes, a terminal seawall and beach nourishment through a sand transfer system).

The increased cost of the groyne field, relative to a single end control structure, means that Option 3 has a slightly lower Benefit Cost Ratio (BCR) than Option 4, and Options 5 and 6 have the highest BCRs (though still less than 1). The additional costs of the groyne field and sand transfer system are balanced against the improved likelihood of achieving the improved beach benefits, relative to Options 4 and 5, and the higher costs of the massive nourishment scheme proposed in Option 3 (and 4).

Under the BSC Base Case, all protective options are economically viable. Table 22 highlights that, based on the assumptions and omissions in the available information, the majority of benefits accrue from the protective function of the seawall, with sub-Option 6.1 having the highest NPV and BCR.

Sensitivity to a number of key components of the CBA is presented in the following sections, with a focus on the use of BCR as a decision criterion for comparison purposes and for consistency with the usage of BCR figures in the main report. It is important to highlight that the impact of changes on both NPV and BCR measures will be the same; meaning that any change which results in a downward change in BCR for an option will also reduce the NPV. Appendix 1 provides further information about the interpretation of BCR and NPV figures and the point at which options cease to be economically viable under each criterion.

9.3 Sensitivity to discount rates

The use of high discount rates will disadvantage options which have benefits accruing at a long time in the future. There is some debate about the selection of appropriate discount rates in the environmental economics literature, particularly in the assessment of projects with long duration and intergenerational equity issues. Some have argued that the use of a positive discount rate discriminates against future generations, and that a very low, zero, or negative discount rate is more appropriate. This is the approach taken in the Stern Review of the economic impacts of climate change (Stern, 2006), which adopts an effective discount rate of 1.4%, substantially lower than that typically used in government benefit cost analysis.

The selection of appropriate discount rates and sensitivity testing rates are typically suggested by Treasury guidelines issued by the relevant State Government. The base-case figure employed here is derived from the NSW Government Guidelines for Economic Appraisal (NSW Government, 2007), which suggests the use of a discount rate of 7% per annum, with sensitivity testing at rates of 4 and 10%.

The substantial influence of discount rates is to reduce the relative contribution of future costs and benefits on the NPV of each option. This is clearly demonstrated by Table 24, which shows the relative value of a dollar of benefit (or cost) at different time periods, when subject to the range of discount rates examined in this illustrative exercise. It can be seen that the relative contribution of future values to present value calculations decreases substantially at high discount rates and long time periods.

Table 24 Present value of future of future values - relative

	Discount rate (% per annum, in decimal form)										
Year	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	0.1
0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	1.00	0.95	0.91	0.86	0.82	0.78	0.75	0.71	0.68	0.65	0.62
10	1.00	0.91	0.82	0.74	0.68	0.61	0.56	0.51	0.46	0.42	0.39
15	1.00	0.86	0.74	0.64	0.56	0.48	0.42	0.36	0.32	0.27	0.24
20	1.00	0.82	0.67	0.55	0.46	0.38	0.31	0.26	0.21	0.18	0.15
25	1.00	0.78	0.61	0.48	0.38	0.30	0.23	0.18	0.15	0.12	0.09
30	1.00	0.74	0.55	0.41	0.31	0.23	0.17	0.13	0.10	0.08	0.06
35	1.00	0.71	0.50	0.36	0.25	0.18	0.13	0.09	0.07	0.05	0.04
40	1.00	0.67	0.45	0.31	0.21	0.14	0.10	0.07	0.05	0.03	0.02
50	1.00	0.61	0.37	0.23	0.14	0.09	0.05	0.03	0.02	0.01	0.01

This CBA does not attempt to resolve the theoretical or ethical issues mentioned above. The results of sensitivity testing at the mandated discount rate figures of 4% and 10% are presented in Table 25.

Table 25 Sensitivity testing of BCR to mandated discount rates – Best estimate

Option	Description	Base Case	Discount rate 4%	Discount Rate 10%
2	Planned retreat	0.35	0.43	0.29
3	Groyne Seawall Nourishment	0.56	0.66	0.49
4	End Control Seawall Nourishment	0.63	0.74	0.55
5	End control Seawall no Nourishment	0.92	1.10	0.81
6	Adaptive management - all components	0.79	0.84	0.75
6.1	Adaptive management-seawall only	1.42	1.66	1.27
6.2	Adaptive management - Seawall + single groyne	1.26	1.47	1.12
6.3	Adaptive management - Seawall + groyne field	0.87	0.97	0.81

Table 25 shows that it is the cheapest of the management interventions that are economically viable (BCR>1). This is due to lower capital and ongoing costs through omission of any measures designed to improve the availability of the beach above the Status Quo option. Option 5 is viable only at low discount rates, the Options 2-4, Option 6.3 and the full Adaptive option are not viable at any of the rates tested, whilst sub-Options 6.1 and 6.2 are viable at all tested discount rates.

9.4 Sensitivity to delaying implementation of retreat

It should be noted that this CBA considers that retreat occurs as land and buildings are lost due to storm erosion and long-term recession. Any attempt to define the most economically-efficient retreat process would need to take into consideration a number of complicating factors including, but not limited to:

- proximity of structures to the current (or future) erosion scarp at the time retreat is enacted;
- the impact of removal of existing structures on the location of the current (or future) shoreline or erosion scarp through slumping;
- variation in development and planning consent conditions relating to the building or part/s thereof;
- buildings which span multiple lots which may reach spatial triggers for retreat (e.g. distance from the erosion scarp) at different times

It is also not possible to know in advance how property values at Belongil would respond to formal adoption of a retreat approach with defined mechanisms and timeframes, and a reasonable expectation that the option will be enforced. It is likely that the planning consent conditions and current level of exposure of individual lots and buildings would affect this process in a complex manner. The means of retreat would also be major drivers of any changes. For example, adoption of a 30 year Retreat Planning Period, after which period the interim protective walls will be removed, may actually result in an increase in values, given that it provides a period of certainty for current landholders.

Given the assumption of gradual loss of land in the modelling and valuation of erosion damage under retreat, the greatest economic benefit is through earlier implementation of retreat, as this then reduces expenditure associated with maintaining the existing terminal structures, and enables the beach to respond naturally and provide additional beach benefits (See Figure 12). Incremental benefits fall to zero if retreat is not enacted in the project assessment period, as this is essentially the Status Quo model through inaction.

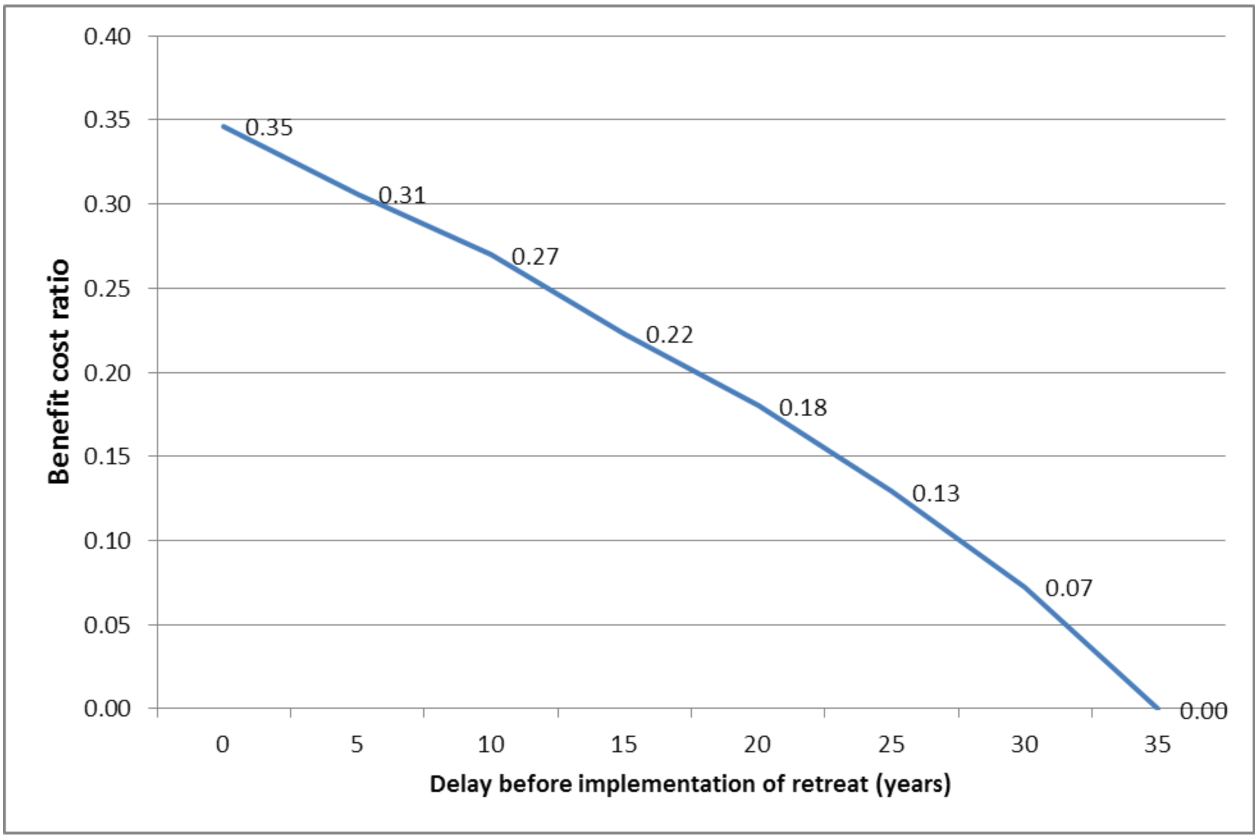

Figure 10 Benefit of delaying retreat implementation

9.5 Sensitivity to inclusion of buffer zone

As shown in Tables 18 and 19, there is a large difference between estimated damage costs depending on whether a 20m buffer is applied in estimating these figures. Table 26 shows that excluding values within this buffer zone does not change the ranking of options or the economic viability of any option, but does narrow the spread between the options.

Table 26 Impact of removing buffer zone from damage estimates

Option	Description	Base Case (20m buffer applied)	No buffer applied
2	Planned retreat	0.35	0.40
3	Groyne Seawall Nourishment	0.56	0.50
4	End Control Seawall Nourishment	0.63	0.56
5	End control Seawall no Nourishment	0.92	0.82
6	Adaptive management - all components	0.79	0.70
6.1	Adaptive management- seawall only	1.42	1.26
6.2	Adaptive management - Seawall + single groyne	1.26	1.12
6.3	Adaptive management - Seawall + groyne field	0.87	0.78

9.6 Sensitivity to inclusion of property uplift factor

Previous studies on the value of property protection have identified a strong willingness to pay for reduced erosion risk through price premiums paid for properties that have existing seawalls in place. Kriesel et al. (1993) estimated the WTP for erosion prevention structures in properties on Lake Erie in Ohio, and incorporated a measure of the quality of the existing structure. They estimated the number of years until the building would be directly exposed to erosion, terming this GEOTIME. They found that the WTP for additional protection was strongly influenced by the amount of existing protection. Table 27 outlines these premiums for additional levels of erosion protection and relates them to the mean property value of $129,000.

Table 27 Willingness to pay for additional property protection, relative to an average property price of US$129,000

	8-year increase in GEOTIME*		20-year increase in geotime*	
Current GEOTIME	Absolute increase (1993 US$)	% variation	Absolute increase (1993 US$)	% variation
1	$34,540	26.8%	$48,710	37.8%
10	$9,850	7.6%	$18,180	14.1%
20	$5,480	4.2%	$11,090	8.6%
50	$2,178	1.7%	$4,850	3.8%

Adapted from Kriesel et al. (1993).*A 20-yr increase is associated with an engineered structure or scheme, the 8-yr increment represented WTP for the existing style of ad-hoc protection.

Dorfman et al. (1996) analysed the same sample of homes using a slightly different methodology. They were interested in identifying the WTP to reduce the chance of having to spend $1000 (1993 $US) in a given year to below five percent. On average, WTP to reduce risk to this level was $16,261 relative to an average selling price of $127,800, which represents 12.7% of the property price. This varied substantially with the existing exposure of the property. Reducing the risk to zero was associated with an average price premium of $37,826 or 29.6% (Dorfman, Keeler et al. 1996). The substantial difference between these figures recognises that minor costs (<$1000 p.a.) associated with repairs to existing erosion prevention structures or schemes, or setback restoration can be a strong negative impact on property owners.

Whilst a range of other factors are likely to be key drivers of recent reductions in Belongil property values, it is expected that the provision of security through construction of an engineered seawall would provide certainty about the future of the properties within the coastal hazard zones. This is likely to result in an increase in the value of these properties, with benefits accruing both to the owners of the properties and indirectly to Council and the NSW Government through increased rates and land tax revenue.

Properties along Belongil have a higher level of exposure than those on lake shorelines, and hence it is expected that the WTP for increased property protection would be higher. Previous risk assessments (see 8.1 of the main report) identified that the ad-hoc structures within the Byron Bay Embayment provide protection against a 10 year ARI event, and hence this is used as a proxy for the existing level of protection (assume GEOTIME=10). The protective structures proposed for the Belongil foreshore are engineered structures with a design life of 50 years (see main report), and hence use of the 20-yr increment identified by Kriesel (as presented in Table 15) is considered highly conservative.

Advice received from OEH on a previous draft of this CBA suggested that the inclusion of a property uplift factor was inappropriate as there is no risk-discount noticeable in Belongil property values. As such, this adjustment was removed from the Best Estimate base case.

Byron Shire Council requested on 4 February 2016 that sensitivity to this adjustment be included in the analysis.[16] **For the purpose of this analysis, private property values are adjusted upwards by 14.1% at the time of seawall construction,** as per Kriesel et al. (1993)**. This uplift is applied to all land within the 1-in-100 year ARI event hazard zone, including buffer, as at the start of the project period.**[17] Results are shown in Table 28. It should be noted that a similar uplift is not possible for public lands, due to the absence of realistic land values for these parcels of land. This adjustment therefore favours measures which preserve private properties.

Table 28 Impact of inclusion of property uplift factor

Option	Description	Base Case (best estimate)	Property uplift factor reinstated (assumes 55% owner occupied)
2	Planned retreat	0.35	0.35
3	Groyne Seawall Nourishment	0.56	0.69
4	End Control Seawall Nourishment	0.63	0.78
5	End control Seawall no Nourishment	0.92	1.17
6	Adaptive management - all components	0.79	0.99
6.1	Adaptive management-seawall only	1.42	1.82
6.2	Adaptive management - Seawall + single groyne	1.26	1.60
6.3	Adaptive management - Seawall + groyne field	0.87	1.10

Table 28 shows that including the property uplift factor increases the viability of all protection options, such that all are economically viable except for those that include large scale nourishment (Options 3 and 4).

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[16] Resolution 16-028, 4 February 2016.

[17] It is not considered likely that property purchasers consider events of greater magnitude than 1 in 100 year ARI, nor more than 35 years of shoreline recession when considering the vulnerability of coastal property.

9.7 Sensitivity to adjustment for producer surplus

The NSW Coastal Management Manual: Part C – Using cost-benefit analysis to assess coastal management options: Guidance for councils – Consultation draft (Coastal Management Guidelines) recommend scaling tourism expenditure data by a factor of 0.3 to ensure that only producer surplus (economic benefit) is being measured, rather than economic activity.

Byron Shire Council requested on 4 February 2016 that sensitivity to this adjustment be included in the analysis.[18] As such, figures are presented in Table 29 both with and without this adjustment.

Table 29 Impact of adjusting for producer surplus

Option	Description	Base Case (Producer surplus scaled by 0.3)	Producer surplus discount not applied
2	Planned retreat	0.35	0.62
3	Groyne Seawall Nourishment	0.56	0.75
4	End Control Seawall Nourishment	0.63	0.80
5	End control Seawall no Nourishment	0.92	1.02
6	Adaptive management - all components	0.79	0.94
6.1	Adaptive management- seawall only	1.42	1.42
6.2	Adaptive management - Seawall + single groyne	1.26	1.36
6.3	Adaptive management - Seawall + groyne field	0.87	0.99

Table 28 shows that Option 5 is not viable under the recommended discounting of tourist expenditure, but is marginally viable if this discount is not applied. Option 6.1 remains the most economically favourable, but is unaffected by this adjustment as it is assumed that this option does not result in any beach-related benefits above the Status Quo option. All other options attempt to increase the availability of the beach, hence the removal of the scaling effectively increases these beach benefits by 70%, and the BCR values increase according to the expected degree of improvement above the baseline.

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[18] Resolution 16-028, 4 February 2016.

9.8 Sensitivity to adjustment for tenure status

The NSW Coastal Management Manual: Part C – Using cost-benefit analysis to assess coastal management options: Guidance for councils – Consultation draft suggests different treatment of land and property value losses dependent on ownership/occupancy status. The Australian Bureau of Statistics (ABS) estimates ownership/occupancy status for dwellings during the five-yearly census, which was last conducted on Tuesday 9 August 2011. Note that ownership/occupancy status may vary at other times of the year or days of the week.

The case study region of the Byron Bay embayment encompasses four Statistical Area Level 1 (SA1) statistical regions for the purpose of accessing ABS data about home ownership status. The extent of these regions is shown in Figure 11.

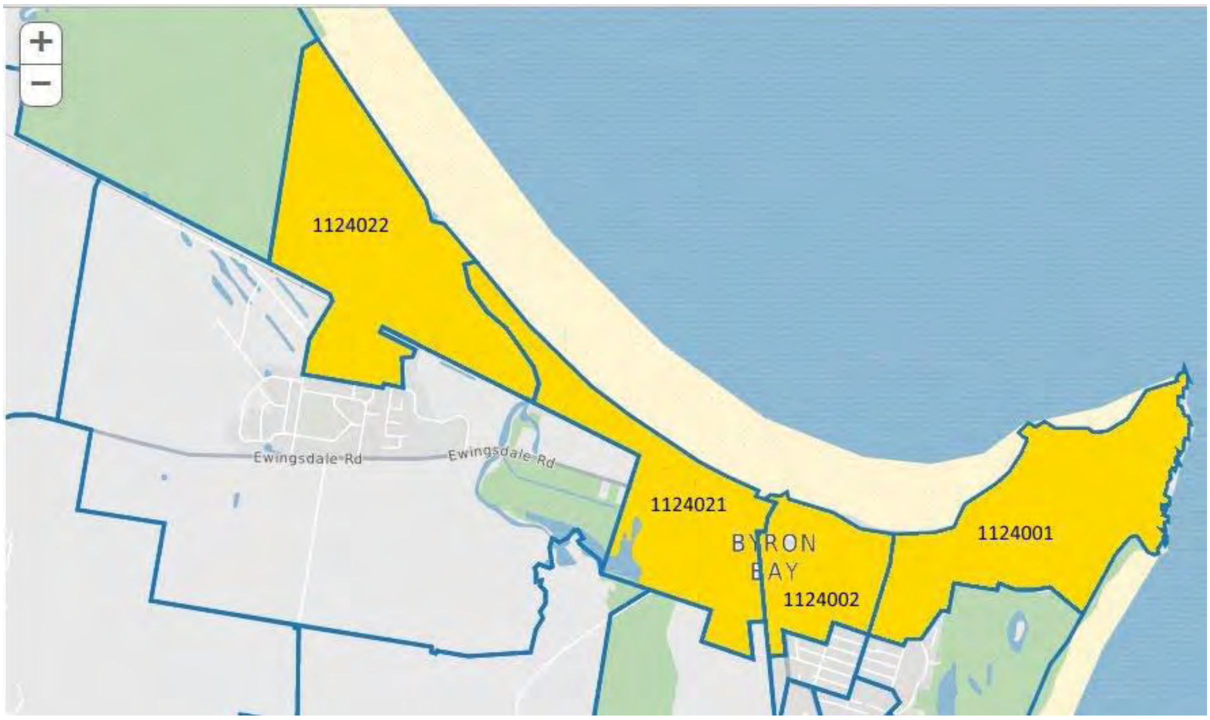

Figure 11 SA1 statistical regions, Byron Bay

Source: ASGS Boundaries Online

The Belongil case study site is located within SA1 1124021. This region extends westward of Shirley Street and includes a large number of strata titled properties, which are largely outside the region affected by erosion in the modelling conducted for this analysis. Table 30 shows the tenure status of dwellings in the four SA1 districts of interest on census day (Tuesday 9 August 2011). The tenure status for the entire embayment is estimated to be around 53% owner-occupied. Approximately 55% of properties within the SA1 district that most closely corresponds to the case study area are owner occupied. This figure (55%) is used to scale the estimated economic costs associated with the loss of land and buildings within the case study area.

Table 30 Tenure of Byron Bay beachfront SA1 regions, 2011 Census

Description	Belongil	North Beach	Central Byron beachside	Wategoes	**Total/Average**
SA1 district code	1124021	1124021	1124002	1124001	
Owned outright	65	59	13	59	**196**
Owned with a mortgage	22	63	0	13	**98**
Total owner occupied	87	122	13	72	**294**
Rented	70	99	38	51	**258**
Other tenure type	0	0	4	3	**7**
Not stated	16	3	0	9	**28**
Total	173	224	55	135	**587**
Total with known status	157	221	55	126	**559**
Owner occupied (%)	55%	55%	24%	57%	**53%**

Byron Shire Council requested on 4 February 2016 that sensitivity to this tenure-based adjustment be included in the analysis.[19] The results presented in this appendix include figures based on 100% owner-occupation, 55% owner occupation (as the best estimate base case), and 75% owner occupation of affected properties (see Table 31).

[19] Resolution 16-028, 4 February 2016.

Table 31 Impact of tenure assumptions on BCR

Option	Description	Base Case (assumes 55% owner occupied)	Owner occupied discount not applied (100% owner occupied)	75% owner occupied
2	Planned retreat	0.35	0.22	0.28
3	Groyne Seawall Nourishment	0.56	0.79	0.66
4	End Control Seawall Nourishment	0.63	0.90	0.75
5	End control Seawall no Nourishment	0.92	1.37	1.12
6	Adaptive management - all components	0.79	1.15	0.95
6.1	Adaptive management-seawall only	1.42	2.14	1.74
6.2	Adaptive management - Seawall + single groyne	1.26	1.87	1.53
6.3	Adaptive management - Seawall + groyne field	0.87	1.28	1.06

Table 31 demonstrates that this adjustment results in a change in viability for Options 5 and 6. If all properties in the Belongil Case Study area are assumed to be owner-occupied then Options 5 and 6 are viable. Option 5 is also viable when 75% of residents are assumed to be owner-occupiers, as is Option 6.3. Options 2-4 are not viable under any scenario, and Options 6.1 and 6.2 are viable under all cases.

9.9 Sensitivity to assumptions about beach recession

Detailed studies on the likely future useable beach width are not available. OEH advice suggested that long term recession of the beach at Belongil would see it recede over the project period such that it would be present only 10% of the time by 2050. Preliminary estimates of a plausible range by WRL suggested that this could be as high as 50%. It is important to examine the impact of these differing assumptions for two reasons. First of these is that the current value of tourism and recreational use of the Belongil foreshore is expected to reduce over time as the beach narrows. The second reason is that it can have a large influence on the value of any sand added into the system, or kept there for longer through the introduction of groynes or end control structures. As outlined in Section 8.1 of this appendix, the value of increasing a beach is greatest when that beach is below a critical width that precludes use. The marginal value of additional width decreases as the natural state of the beach is wider, and may turn negative at some point. Table 32 shows testing of both the assumption about more rapid recession (base case assumption is a reduction from 80% beach availability to 50% over 35 years) and the marginal value of additional beach availability provided by options 2-6, 6.2 and 6.3. Option 6.1 does not provide any beach benefits above the Status Quo, but still has the highest BCR of all options due to lower costs. Option 6.2 is also viable under all assumptions. Options 3, 5 and 6 are viable if rapid recession and greater benefit of beach width improvement is assumed, as is Option 6.2. Retreat is not viable under any assumption, and neither is Option 4.

Table 32 Impact of assumptions about beach recession and widening through interventions

Option	Description	Base Case	Beach receding to 10%	Beach receding to 50%, marginal benefit of additional sand	Beach receding to 10%, marginal benefit of additional sand
2	Planned retreat	0.35	0.32	0.51	1.01
3	Groyne Seawall Nourishment	0.56	0.54	0.67	1.02
4	End Control Seawall Nourishment	0.63	0.62	0.72	0.99
5	End control Seawall no Nourishment	0.92	0.92	0.97	1.11
6	Adaptive management - all components	0.79	0.75	0.91	1.30
6.1	Adaptive management- seawall only	1.42	1.42	1.42	1.42
6.2	Adaptive management - Seawall + single groyne	1.26	1.25	1.33	1.52
6.3	Adaptive management - Seawall + groyne field	0.87	0.86	0.96	1.22

9.10 Sensitivity to reduced tourism values

Review of a previous draft by OEH highlighted sensitivity to assumptions about tourism and recreation values, given uncertainty about the long term effectiveness of the proposed options in retaining a beach and in providing the amenities currently enjoyed by users of the case study area.

Table 33 demonstrates that given other adjustments already undertaken, reduction in tourism and recreation values has a minimal influence on BCRs for all options.

Table 33 Impact of reductions in beach use values

Description	Base Case	2.5% reduction in tourism	15% reduction in tourism
Planned retreat	0.35	0.34	0.33
Groyne Seawall Nourishment	0.56	0.55	0.54
End Control Seawall Nourishment	0.63	0.63	0.62
End control Seawall no Nourishment	0.92	0.92	0.92
Adaptive management - all components	0.79	0.78	0.78
Adaptive management- seawall only	1.42	1.42	1.42
Adaptive management - Seawall + single groyne	1.26	1.26	1.25
Adaptive management - Seawall + groyne field	0.87	0.87	0.87

10. Financial impacts- distributional analysis

Whilst retreat provides for the provision of a natural beach and the amenity values associated, there are substantial losses associated with the retreat policy. This is true whether it is enacted in a planned manner or in response to a major storm event, and these losses include both private and public costs. These include the initial loss of private property values and fixed infrastructure, and the partial or total loss of nature and recreation reserves if they are unable to roll landward as the shoreline recedes due to tenure boundaries or are spatially restricted through the presence of coffee rock, essential infrastructure or debris.

There are also ongoing costs in terms of the reduced rates and land tax income that these assets currently generate, although these are considered to be transfer payments and are not directly included in the analysis. That is, any reduction in rates revenue received by the council is associated with an equal and opposite reduction in costs incurred by the landowners. In a welfare economics CBA these two impacts cancel each other out, although they may have important implications for the cash flows of the different stakeholder groups. It is not possible to estimate these flows with total accuracy without knowing the ownership structure of the private assets at risk and the other land holdings of Belongil property owners. This information is not available due to the confidential and potentially complex nature of ownership. The following sections outline both the current value of the revenue streams associated with rates and land tax, and the extent to which this may be affected by removal, devaluation or improved valuation of properties in the Belongil case study area.

10.1 Rates revenue

Rates revenue is dependent upon the rating category of the land, and increases are limited through regulations on rate pegging. It includes a component for supply of utilities and services that is linked to usage, and a component linked to the unimproved value of the land. With the exception of one parcel of land owned by Byron Shire Council on Bayshore Drive (classified as Farming for rating purposes), all of the parcels of land within the Belongil case study area are within the *Residential* rating category.

In FY 2015-16 the variable rating factor for Byron Shire Council for *Residential* land was 0.2897%. For the purposes of estimating the rates revenue losses associated with the value of land lost under retreat is multiplied by this percentage to estimate the minimum bound for lost rates revenue once the land is no longer occupied. Given uncertainty about the future rating factor it is

assumed to be constant. The fixed component (that part which is independent of land values) is not included in calculations.

Given an unimproved value of residential land on Belongil potentially affected by erosion by 2050 (including buffer calculations) of $145.9 million (in 2015 values), estimated rates revenue from the case study area is at least $407,593 per annum (not including the fixed component of rates). Assuming property growth rates of 1.8% per annum and applying a discount rate of 7%, this revenue stream has a NPV of **$6.99 million**. Note that this figure is the total value of potentially affected parcels.

10.2 Rates revenue impacts of planned retreat

The probability-weighted estimate of lost rates revenue (per annum) through increased erosion due to removal of the existing protective structures is calculated as 0.2897% of the difference in expected Annual Average Damages (AAD) between the status quo and the AAD expected under a retreat scenario. Over the course of the project period, and using a discount rate of 7% (and property growth rates of 1.8% p.a.), the NPV of this reduced revenue stream is **$1.73 million,** relative to the status quo.

10.3 Land tax revenue

In 2016 the land tax threshold in NSW is $482,000 for privately owned property, with an exemption for the principal place of residence. The land tax scale is presented in Table 34, along with example calculations for representative rateable values of properties. It is expected that there is a substantial income stream generated from land tax at Belongil given the high value of property, the number of owners with multiple land holdings, and the number of properties which are operated as tourism accommodation or are owned by trusts or companies, which may not be entitled to the exemption threshold and be required to pay land tax on the full rateable value of the property.

Table 34 Land tax calculation for NSW property

Tax year	Threshold	Rate
2016	$482,000	$100 plus 1.6% up to the premium threshold.
	$2,947,000 and over (Premium threshold)	$39,540 for the first $2,947,000 then 2% over that.
	Land Value	**Amount per year**
	$500,000	$388
	$1,000,000	$8,388
	$1,500,000	$16,388
	$2,000,000	$24,388
	$2,500,000	$32,388
	$3,000,000	$40,600
	$4,000,000	$60,600
	$5,000,000	$80,600
	$10,000,000	$1802,600

Source: http://www.osr.nsw.gov.au/taxes/land/

This appendix estimates lower and upper bounds of land tax revenue. For the upper bound all properties are assumed to be liable for land tax, and annual revenue is estimated at $2,364,720. This figure applies the threshold to all properties for which the owner is not clearly identifiable as a company. The lower bound, which assumes that all non-company owners have claimed the land tax exemption for a primary place of residence, is estimated at $557,012 per annum. The NPVs of these revenue streams (assuming 1.8% growth p.a. in property values, and a discount rate of 7%) are **$9.6 million** and **$40.6 million** for the lower and upper bounds, respectively.

It is not possible to accurately estimate the land tax implications of retreat as this would require determining the timing at which the value of a property dips below relevant thresholds.

10.4 Impacts of protection options on revenue streams

Under the assumptions employed in the BSC base case, property values increase by 14.1% at the time of protection. This has flow-on effects for revenue streams, as detailed below:

- Rates revenue increases by $57,471 per annum, with a NPV over the project period of $985,812 in additional rates revenue.
- Land tax increases by between $78,539 (lower bound) and $333,426 (upper bound), for a total increase of NPV of between $1.35 and $5.72 million.

11. Conclusion

11.1 Summary

This report highlights that, based on the available information and the potential for omitted information and assumptions, the CBA may favour protection of private asset values, as it concludes that there is a strong economic argument for coastal management intervention in the Belongil case study area.

There are substantial economic costs associated with maintaining the Status Quo, with no improvements in benefits from ongoing expenditure of around $10 million over the project assessment period. Protective options are economically preferable to Planned Retreat, under the assumptions and omissions detailed in this report.

Under the Best Estimate base case, only Options 6.1 and 6.2 are economically viable. They have BCRs of 1.43 and 1.26 respectively. Of full Options originally proposed for assessment, Option 5 is the closest to being economically viable, with a BCR of 0.93.

All protective options have positive net present values (benefits-costs) and benefit cost ratios (benefits divided by costs) of around 1.3 or greater under the BSC Base Case assumptions. Option 5 has a BCR of 1.99, whilst option 6.1 has a BCR of 2.99. The full option with the highest BCR is Option 5, based on a lower capital cost and the assumption that an end control structure will be able to provide greater security of beach availability even in the absence of nourishment.

It is also noted that the cost estimates for the interventions are well in excess of readily available funds, and hence some form of realistic and equitable payment mechanism must be identified. Appendix 3 provides some initial notes on the potential means by which this may be achieved.

11.2 Identified data gaps and directions for further research

Given the preliminary nature of the engineering design at this stage, it is difficult to place economic values against components which may be critical to the selection of the most appropriate option. This is particularly true when comparing the protection options, as the difference between the options in terms of access and visual amenity may be the source of much debate. Non-use and environmental impacts may also be critical in selecting the most desirable option for the Belongil region and should be considered elsewhere through consultation and deliberation.

It is suggested that a number of areas of further research are undertaken, including a choice modelling exercise which explores resident and tourist preferences for groynes and end-control structures, and also different payment schemes. Whilst outside the scope of this CBA, equitable funding models which attribute costs to those that derive the most benefit from each component of the suggested options are likely to be critical in determining the adoption and acceptance of these options by both Belongil residents and the broader community.

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Appendix 1: **Glossary**

Benefit cost-ratio (BCR)

The Benefit Cost Ratio (BCR) is the ratio of the present value of benefits to the present value of costs. In algebraic terms it can be expressed as follows (using the same notation):

$$NPV = \sum_{n=0}^{N} \frac{Bn}{(1+r)^n} / \sum_{n=0}^{N} \frac{Cn}{(1+r)^n}$$

A project is potentially worthwhile if the BCR is greater than 1; ie, the present value of benefits exceeds the present value of costs. If projects are mutually exclusive, this rule would indicate that the project with the highest BCR should be chosen.

Consumer surplus (CS)

The difference between the maximum theoretical WTP, and the actual expenses that a person incurs, for example the additional expenditure a person would be WTP to make a beach visit.

Discount rate

NSW Treasury Guidelines recommend the use of a mid-range figure of 7% for government capital works projects. Sensitivity analysis is performed with discount rates of 4% and 10% to test the impact.

Internal rate of return (IRR)

This is the interest rate at which the discounted stream of benefits is exactly equal to the discounted costs, i.e. when NPV is equal to zero. As long as the IRR is higher than the test interest rate, the project will return a net benefit. This decision criterion is not suitable for projects of this nature, given the absence of upfront costs in some management options.

Net present value (NPV)

The future cash flows discounted for timing and risks less the cost of investing in the project expressed in terms of today's worth. In algebraic terms it can be expressed as follows:

$$NPV = \sum_{n=0}^{N} \frac{Bn - Cn}{(1 + r)^n}$$

Where B_n is the benefit in year n, C_n is the cost in year n, r is the discount rate in decimal form and N is the project period. Under this decision rule, a project is potentially worthwhile (or viable) if the NPV is greater than zero

Net present value per dollar of capital investment (NPV/I)

Extends the concept of NPV to include consideration of capital constraints

$$NPV/I = \sum_{n=0}^{N} \frac{(B - C)n}{(1 + r)^n} / \sum_{n=0}^{N} \frac{In}{(1 + r)^n}$$

Where I_n is the capital investment in year n

And C_n=I_n+operating costs in year n

This measure is not employed as it is not possible to separate the benefits from capital and ongoing nourishment projects, due to uncertainties about storm timing.

Willingness-to-pay (WTP)

An expressed willingness to spend money in order to achieve a desired outcome. This may be revealed through behaviour, such as expenses incurred to make a beach visit, or through responses to hypothetical scenarios, such as agreeing (in principle) to contribute to a fund to prevent beach erosion.

Appendix 2: Benefit transfer

The BT process essentially involves transferring values from one or more studies in other locations (study site/s) to the location under consideration in the policy appraisal process (the policy site). There are four stages in the process:

1. Identification of impacts that need to be valued. This step is critical in the BT process, as it is important to ensure that the correct valuation metric and method is chosen. For example, a planning decision relating to coastal rating processes may be most appropriately valued with a hedonic pricing approach, whereas a decision about investment in beach access points would typically be valued through a site-specific travel cost survey.

2. Identification of existing estimates of value. This process has been greatly assisted through the development of BT databases. Examples of such databases relevant to beach valuation include the Environmental Valuation Reference Inventory (EVRI, https://www.evri.ca/Global/Splash.aspx) maintained by Environment Canada (with assistance from other government partners such as the US EPA and Australian Government), and the National Ocean Economics Program (NOEP, http://www.oceaneconomics.org/) maintained by the Monterey Institute of International Studies.

3. Assessment of the suitability of existing studies. This is an assessment both of the quality of the original study, and also the similarity between the study and policy sites. Quality assessment may require some technical expertise in non-market valuation, although the aforementioned databases do provide some comments on data and study quality, or peer-review submission processes designed to uphold quality standards.

4. Calibration of existing value estimates. If there is sufficient information on the key factors influencing the value estimates in the original study, it may be possible to adjust the values for the policy site, based on differences in things like the local socioeconomic context or distance from a major city. Calibration of this type is not always possible, and is often overlooked.

Appendix 3: Potential payment schemes – initial notes

The California Coastal Commission imposes sunset clauses on seawalls, typically in the order of 20 years, with a reassessment at the conclusion of the period. Thus property owners are able to protect their properties, at their own cost, and must also contribute to a fund to offset the loss of sand from the beach through entrapment behind the seawall. This money is put towards nourishment schemes to replenish sand in front of the seawall and maintain the public amenities provided by the beach.

If, as expected, property prices in Belongil increase as a result of the provision of coastal protection infrastructure, the differential between the current rates and land tax revenue and the increased level of revenue do to property value increases could be set aside to fund the nourishment that would be required in order to maintain beach amenity in front of the protective structures. This would seem equitable given that the placement of the protective structures within the active beach system prevents the natural response of the shoreline to erosion and thus the landholders benefit at the expense of non-resident beach users.

Appendix 4: Monte-Carlo simulation results

Year	Average Annual Damages ($)	Average Annual Damages incorporating 20m buffer zone
1	$27,769,337	$57,618,577
2	$11,062,510	$6,878,254
3	$6,797,994	$4,467,768
4	$4,892,651	$3,416,692
5	$3,851,893	$2,850,275
6	$3,162,708	$2,497,787
7	$2,660,604	$2,255,220
8	$2,313,652	$2,082,886
9	$2,049,780	$1,958,170
10	$1,840,982	$1,849,455
11	$1,678,797	$1,795,933
12	$1,553,484	$1,731,792
13	$1,437,496	$1,683,315
14	$1,370,726	$1,652,227
15	$1,308,935	$1,614,107
16	$1,238,511	$1,583,991
17	$1,185,799	$1,553,554
18	$1,140,742	$1,519,869
19	$1,084,568	$1,495,971
20	$1,047,083	$1,479,106
21	$1,005,834	$1,448,712
22	$977,363	$1,435,560
23	$946,887	$1,403,963
24	$934,517	$1,398,647
25	$914,772	$1,369,790
26	$904,822	$1,355,508
27	$899,772	$1,339,893
28	$882,566	$1,324,448
29	$895,661	$1,301,442
30	$903,796	$1,267,135
31	$904,548	$1,250,803
32	$915,071	$1,219,680
33	$925,746	$1,196,961
34	$939,063	$1,159,578
35	$950,723	$1,134,523
36	$967,492	$1,097,577