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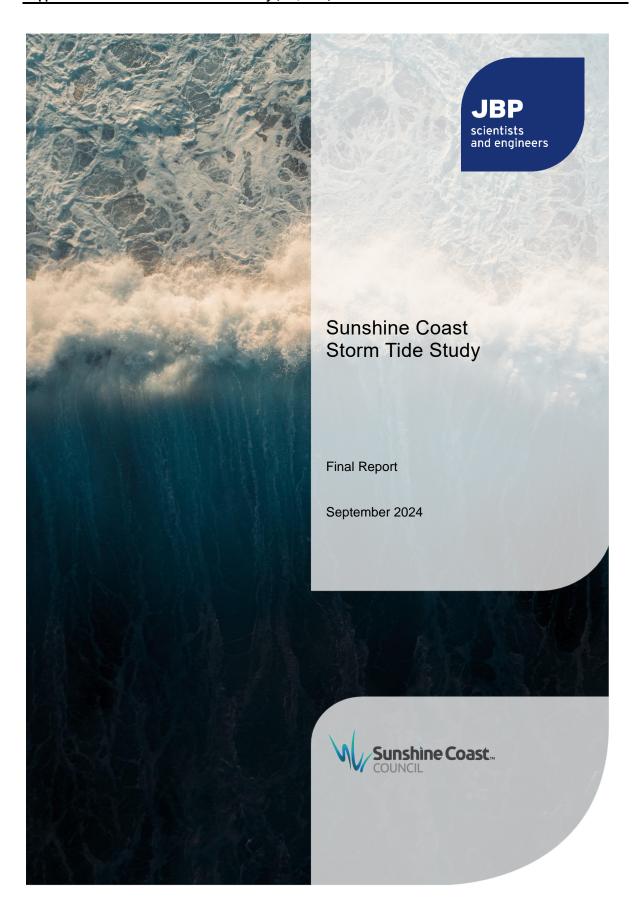
Item 8.6 & 8.7

Ordinary Meeting

Thursday, 24 October 2024

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Revision History

Revision Ref / Date Issued	Amendments	Issued to
A1-P01 / 12 September 2024	Final	CS GN

Contract

This report describes work commissioned by Crispin Smythe, on behalf of Sunshine Coast Council, by a letter dated 19 September 2022. Brian Lam, Paul Lee and Daniel Rodger of JBP carried out this work.

Approved byDaniel Rodger BSc Meng Ceng CmarEng MIEAust Director

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The methodology adopted and the sources of information used by JBP in providing its services are outlined in this report. The work described in this report was undertaken between October 2022 and January 2024 and is based on the conditions encountered and the information available during this period of time. The scope of this report and the services are accordingly factually limited by these circumstances.

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Acknowledgements

JB Pacific would like to acknowledge the provision of recorded tidal data from Sunshine Coast Council, Moreton Bay Regional Council, and Queensland Department of Environment and Science.

JB Pacific acknowledges the traditional custodians of the lands and seas where we work. We pay our respects to Elders past, present, and emerging.

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Executive Summary

This report summarises the technical investigations undertaken on behalf of the Sunshine Coast Council (SCC). Throughout 2022, new changes to coastal processes were observed within the Sunshine Coast coastal waterways which supported the need to update design storm tide information and consider the effect of waves. In early 2022, a breakthrough occurred across the northern spit of Bribie Island, which has increased the tidal range and wave action within Pumicestone Passage. Also captured throughout the year were tide records from newly installed gauges within small estuaries which showed water levels elevated beyond their neighbouring medium or large estuaries. Both occurrences have implications for existing buildings and the construction of future dwellings.

This project includes several assessments, including;

- Review of regional design storm tide levels. It is recommended to continue the use of estimates presented in the existing Sunshine Coast Storm Tide Study (Aurecon 2013).
- Revision of storm tide estimates within Pumicestone Passage as a result of the 2022 breakthrough.
- Revision of storm tide estimates in estuaries and Intermittently Closed and Open Lake or Lagoons (ICOLLs) which will experience wave effects at their entrance.
- Provision of updated guidance on the application and design wave forces for areas that may be exposed to waves. It is recommended to use a wave force of 300 kN/m at the future coastline position, which decreases with landward distance.

Recommendations have been made to allow the ongoing monitoring of tides, storm tides and estuarine levels throughout the Sunshine Coast region. This includes the use of high frequency water level recorders to capture additional data on waves propagating into small estuaries.

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Abbreviations

AEP	. Annual Exceedance Probability
AHD	. Australian Height Datum
ARI	. Average Recurrence Interval
DES	. Department of Environment and Science
DEM	. Digital Elevation Model
GPD	. Generalised Pareto Distribution
HAT	. Highest Astronomical Tide
ICOLL	. Intermittently Closed And Open Lake And Lagoons
IG	. Infragravity Waves
LAT	. Lowest Astronomical Tide
LGA	. Local Government Area
LiDAR	. Light Detection and Ranging
SCC	. Sunshine Coast Council
MBRC	. Moreton Bay Regional Council
MHWS	. Mean High Water Springs
MSL	. Mean Sea Level
MSQ	. Maritime Safety Queensland
NDRP	. Natural Disaster Resilience Program
PoT	. Peak over Threshold
RMSE	. Root Mean Squared Error
STL	. Storm Tide Level
тс	. Tropical Cyclone

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Sunshine Coast Regional Council

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1 Introduction

Storm tide inundation poses a risk to coastal regions throughout the Sunshine Coast. This Storm Tide Study summarises the latest information available for the region for areas exposed to storm tide inundation. This report presents storm tide conditions for three coastline types shown in Figure 1-1. These three environments experience different coastal, hydrodynamic and physical processes which influence the extent and depth of inundation. They include:

- Storm tide inundation and wave impact zone (Exposure W). This considers regions exposed to both storm tide and future wave loads. Described in Section 3.
- Storm tide inundation (Exposure I). This considers regions exposed to storm tide inundation only (no waves) and includes medium to large estuaries and rivers. Described in Section 4
- Small creeks and Intermittently Closed and Open Lakes or Lagoons (ICOLLs). Described in Section 5.



Figure 1-1: Open coast with waves (top), without waves¹, and coastal creek/ICOLL (bottom).

1 Source: 1200px-Fishing_trawlers_at_the_harbour_at_Mooloolah_River,_Mooloolaba,_Queensland_01.jpg. Accessed through Wikimedia, Licenced under Creative Commons



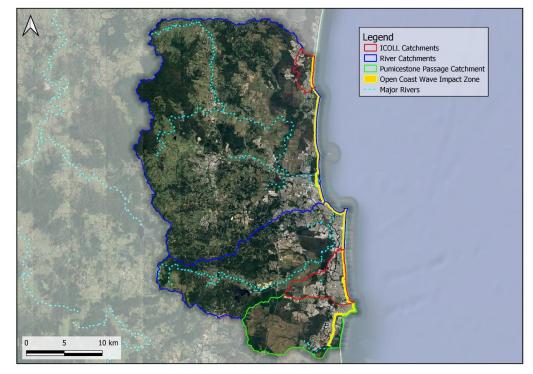


Figure 1-2: Areas with different storm tide processes

1.1 Background to the project

In 2003 and 2005, the Caloundra City and Maroochy Shire Council's commissioned storm tide and joint probability studies for the area spanning between Golden Beach to Peregian Beach. This was updated in 2013, where storm tide levels throughout the Sunshine Coast have been updated within the Sunshine Coast Storm Tide Study (Aurecon 2013). Throughout 2022, new changes to coastal processes were observed within the Sunshine Coast waterways which have supported the need to update design storm tide information and consider the effect of waves. In early 2022, a breakthrough occurred across the northern spit of Bribie Island, which has increased the tidal range and wave action within Pumicestone Passage. Also captured in recent years are new water level records from newly installed gauges within small coastal creeks. These showed water levels can become higher than the open coast. Both occurrences have implications for existing buildings and the construction of future dwellings.

Throughout this project the 2013 regional storm tide levels have been reviewed against data captured in the ten years since its completion. The magnitude of the predicted open coast storm tides and wave setup values remain suitable for the region, however further consideration was required in estuaries and ICOLLS, and to differentiate areas exposed to more direct wave impacts. This information is now presented in this report.



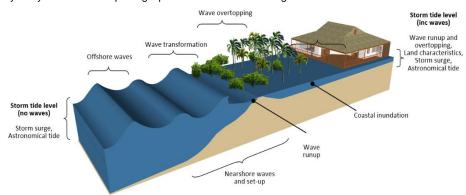
2 Storm tide processes and background information

2.1 Geographical storm tide areas

Storm tide levels will vary depending on the location along the coastline and the geographical setting. Throughout this report three settings have been considered; open coast areas that include wave effects, areas that do not include wave effects (i.e. large estuaries), and small creeks and ICOLLS.

2.2 Background to coastal processes

Before undertaking any calculations or modelling of coastal and estuarine processes it is first important to understand the processes that are driving waves, tides, currents and extreme water levels within the area. This is a complicated process, affected by a number of interacting hydrodynamic and morphologic processes as shown in Figure 2-1.





The way in which the different coastal processes interact will determine the conditions experienced during a storm event, which include the following:

- Astronomical tide: This is the regular periodic variation in water levels due to the
 gravitational effects of the moon and sun, which can be predicted with generally very high
 accuracy at any point in time (past and present) if sufficient measurements are available.
 The highest expected tide level at any location is termed the Highest Astronomical Tide
 (HAT) and occurs on average once every 18.6 years (lunar nodal cycle). Although, at some
 sites, high tide levels similar to HAT may occur several times per year and the level of HAT
 is often exceeded by the combination of a high tide and meteorological events.
- Storm surge: This is the combined result of the severe atmospheric pressure gradients and wind shear stress of the storm acting on the underlying ocean. The storm surge is a long period "wave" capable of sustaining above-normal water levels over several hours or even days. The wave travels with and ahead of the storm and may be amplified as it progresses into shallow waters or is confined by coastal features. The magnitude of the surge is affected by several factors such as storm intensity, size, speed, and angle of approach to the coast and the coastal bathymetry.
- Wind-driven waves: winds blowing across a water surface apply a shear stress which is converted to wave energy. The height (and energy) of a wave train is related to the speed, distance, and duration of the blowing wind.
- Swell waves: Waves originating from remote weather systems or distant storms are referred to as swell waves. These can propagate across the Pacific Ocean before reaching the Sunshine Coast, with regular, long wave periods (typically considered >12 seconds).
- Wave setup: As waves break, they create a localised effect to increase the sea level, known as breaking wave setup. This local increase in water level can be added to storm tide estimates if they are exposed to wave conditions. Various literature exists on the magnitude of wave setup and its area of influence, summarised in Section 2.3.



- Nearshore waves and wave run-up: If broken waves reach the shoreline any residual energy may intermittently run up and down the beach face, known as wave run-up. This may cause localised impacts as waves can reach elevations higher than the underlying storm tide level. The vertical elevation the waves may reach will be dependent on the slope of the shoreline, the porosity, vegetation and the coastal (wave and sea) conditions.
- Storm Tide: This refers to the combined effect of astronomical tide, storm surge, and wave setup. The way in which storm tide components are combined is presented in Figure 2-2.

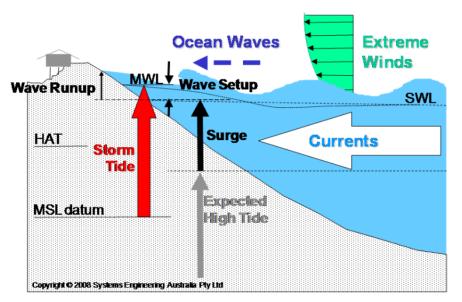


Figure 2-2: Components of Storm Tide (Systems Engineering Australia)

2.3 Coastal modelling approaches

At present there is no single numerical model capable of simulating each coastal process shown in Figure 2-1, and instead a suite of statistical or numerical models are used to quantify the extend and magnitude of impacts.

- Statistical models: Statistical models use a mathematical framework to analyse recorded information and predict extreme events. They are commonly used to estimate extreme sea level events and offshore wave conditions by using historical data, which includes records of tide measurements (e.g. at the Mooloolaba gauge) and wave buoy information. Recorded data is fit to an extreme value distribution (e.g. Generalized Extreme Value or Generalised Pereto Distribution) which allows estimation of rare events.
- Wave models: A numerical wave model is a computational tool used to simulate waves from a known point (e.g. a waverider buoy) into the nearshore, adjacent to the coastline. Various models exist to calculate different processes, for example spectral wave models (e.g. SWAN) simulate wave energy and are used over relatively large areas (e.g. whole coastlines) whilst phase resolving models simulate individual wave components and are used over smaller areas. Hybrid models like XBeach, can be used to simulate both wave groups and individual waves, and can be used at moderate scales.
- Projection-based models: Projection modelling, or "bathtub modelling," is an approach to
 estimate inundation over land during floods or extreme sea levels. It maps any land lower
 than the expected flood level, consequently only considering the peak conditions. This does
 not consider any dissipation or amplification and assumes connectivity. It provides a quick
 assessment of potential flood extents but lacks the complexity of more detailed flood
 models.



 Hydrodynamic models: These models are used to estimate the flow of water over the land surface, with the simulations considering varying water levels (e.g. rising tides, flood peaks and drawdown periods), terrain, river channels, and floodwater interactions.

2.4 Available data from the Sunshine Coast Storm Tide Study (2013)

The latest open coast storm tide levels adopted by Council are published in the Sunshine Coast Storm Tide Study (Aurecon 2013²). As part of the current assessment, the validity of these levels has been reviewed. The 2013 study included several steps including collation and review of available tide data, an assessment of storm tide statistics, derivation of a storm tide profile, inundation modelling, and mapping of storm tide inundation extents, depths and hazard categories. A critical review of the methods used in the 2013 study concluded the following:

- The study had a high importance for gauged data, rather than synthetic data which are typically used for tropical cyclone studies.
- The study fit a Generalised Extreme Value distribution to recorded surge residuals over 0.25m at Mooloolaba to estimate extreme storm tide values, which is an appropriate method.
- Following the release of the region-wide the Storm Tide Interpolation Study funded through the Commonwealth Natural Disaster Resilience Program (NDRP) by GHD (2014)³, it was concluded that the NDRP study methodology is better suited to defining less frequent storm tide events (0.2% AEP and above) while the levels derived from storm surge observations were considered a better representation of more frequent events (2% AEP and below). A hybrid of the NDRP and Aurecon 2013-derived storm tide levels was therefore adopted.
- Wave setup has been added to storm tide levels. This used one dimensional hydraulic modelling in MIKE 21 to consider the inland progression of a storm tide along the major river/creek systems.
- The 2013 study adopted by Council relied on 25 years of recorded water level data, sourced from the Mooloolaba storm tide gauge. Since this study, an additional 10 years of water level data is available from this gauge, prompting a re-analysis of statistical extreme surge levels to consider any significant changes to the adopted storm tide levels.

2.4.1 Review of storm tide values using new data

A review of the storm tide levels presented in the Sunshine Coast Storm Tide Study (2013) has been undertaken by re-estimating coastal extremes using a longer-term dataset. This has used the same gauge-based methodology as the original report and has not included new contemporary analysis methods or probabilistic cyclone modelling, which is recommended in the next update of storm tide levels.

A time series of surge at Mooloolaba has been derived as the anomaly between the astronomical, or "predicted", tide and the observed water level. Continuous water level observations are available at Mooloolaba via MSQ from 1984 to 2022, and intermittently between 1967 and 1981. The astronomic tide series has been reconstructed from the recorded data using the Utide⁴ tidal harmonic analysis toolkit. An example of a recorded storm tide event is shown in Figure 2-3, which shows recorded, astronomic and residual levels at Mooloolaba tide gauge during Tropical Cyclone (TC) Ita in 2020 where a 0.4m surge was observed.

² Aurecon (2014) Sunshine Coast Storm Tide Study. Prepared for Sunshine Coast Council

³ GHD (2014) Natural Disaster Resilience Program (NDRP) Storm Tide Hazard Interpolation Study. Prepared for the Department of Science, Information Technology, Innovation and the Arts

⁴ Codiga, D.L., 2011. Unified Tidal Analysis and Prediction Using the UTide Matlab Functions. Technical Report 2011-01. Graduate School of Oceanography, University of Rhode Island, Narragansett, RI. 59pp

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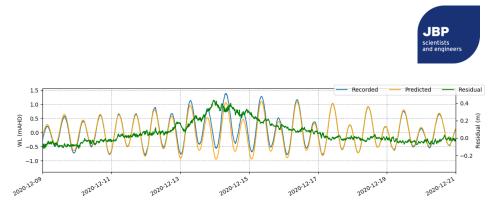


Figure 2-3: Recorded, astronomic, and residual levels at Mooloolaba during TC Ita 2020

An Extreme Value Analysis (EVA) has been conducted on the surge data. A Peak Over Threshold (POT) method has been used to isolate surge events in the record about 0.25m and a Generalised Pareto Distribution (GPD) has been fit to these upper values. Figure 2-4 shows the fitting of GPD function to surge data, and estimation of extreme surge levels. A significant outlier can be observed in the data, this is the estimated surge level associated with TC Dinah in 1967. This data point has been derived from lower-quality, hourly water level data (available from Jan. to Feb. 1967), using a simple peak-to-peak method. The high-tide peaks of the recorded and hindcast data have been compared, with the largest difference (approximately. 0.71m) attributed to the TC Dinah event. It should be noted therefore that the true surge may have been higher during this event, if the storm did not occur coincident with high tide.

The new GPD-estimated extreme surge values have been compared to those of the adopted 2013 study. This comparison shows that extreme surge estimates in Aurecon (2013) are larger than those estimated in this review, even with the inclusion of 10 additional years of recorded data. This is due to the previous study's inclusion of extreme cyclonic modelling assessed in the NDRP Storm Tide Hazard Interpolation Report (2014). However, the use of extreme value analysis that has been employed within both assessments cannot suitably consider the Aurecon (2013) and the new JBP re-estimate cannot explain the magnitude of Ex TC Dinah, which had an estimated surge of over 0.7m. This is a drawback of the analysis method.

Based on the review, the method presented in Aurecon (2013) uses extreme value theory, whilst contemporary analysis of extreme coastal water levels should include probabilistic cyclone modelling and address the TC Dinah storm surge. During the 2013 study adoption, a review was undertaken which identified this drawback. Levels were then increased to through the inclusion of extreme cyclonic modelling assessed in the NDRP Storm Tide Hazard Interpolation Report (2014). Subsequently, the continued use of the Sunshine Coast Storm Tide Study (2013) open coast storm tide levels with additional factors applied to small coastal creeks to consider wave effects is recommended until a new probabilistic storm tide study is undertaken.

ARI (yrs)	AEP (%)	JBP (2023) re-assessed surge (m)	Aurecon (2013) surge (m)*
10	10	0.47	0.47
50	0.2	0.56	0.56
100	0.1	0.60	0.61
500	0.02	0.70	0.74
1000	0.01	0.74	0.81

Table 2-1: Comparison of surge levels. Adapted from Figure 6 of Aurecon (2013)

2.4.2 Consideration of very rare storm surges

Whilst this report primarily considers the establishment of storm tide planning levels using a 1% AEP level, larger events can, and will, occur. The NDRP (GHD 2014) storm tide study included design events up to 1 in 10,000 AEP and a Theoretical Maximum Storm Tide (TMST) estimate. From this study, the estimated TMST (tide + surge + wave setup) is around 1.5m higher than the published 1% AEP levels and can exceed 4m AHD. The TMST levels have been shown alongside the storm tide planning levels throughout this document.

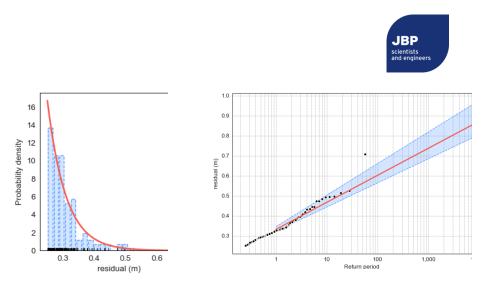


Figure 2-4: Left: GPD fit to surge values above 0.25m, Right: GPD estimation of extreme surge. Note: surge level associated with TC Dinah has been estimated from peak-peak analysis.

2.5 Recent changes in Bribie Island

In January 2022 a coastal storm event caused a breakthrough of a narrow section of northern Bribie Island, opposite Golden Beach. This occurred due to the erosion caused by unusually high tides and large waves associated with ex-tropical cyclone Seth. In the following months, this breakthrough has widened to become the new northern outlet of the Pumicestone Passage.

Analysis of breakthrough and resulting water level changes was reported by Metters et al. (2023)⁵. Figure 2-5 shows satellite images captured of the breakthrough, based on data available through Sentinel Hub (2023). The figure shows:

- (A) pre breakthrough December 2021
- (B) breakthrough January 2022
- (C) breakthrough September 2022,
- (D) breakthrough April 2023.

Analysis of tide gauges showed an increase in the tidal range of 0.46m with a fall in the mean low water level of -0.21m, and an increase in the mean high-water level of 0.23 metres. Southward of the breakthrough, the change in tidal range decreased in gradient from 0.57m to 0.06m over the historic tidal range.

The increases in observed tides reflect conditions that more closely aligns with the open coast. A similar trend is expected with storm tide levels, which are now anticipated to be more representative of open coast levels. Council has previously adopted the open coast storm tide levels for all planning within the northern Pumicestone Passage, and consequently no further change is recommended for design coastal water levels.

5 Metters, D., Ryan, D. & Daniels, R. (2023) "Change in bathymetry and tidal dynamics after the Bribie Island breakthrough", Queensland Government Hydraulics Laboratory. Proceedings of the Australasian Coasts & Ports 2023 Conference – Sunshine Coast, 15-18 August 2023.



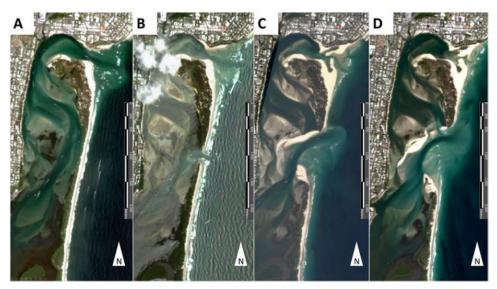


Figure 2-5: Satellite images showing the development of the breakthrough (Metters et al. 2023)



2.6 Recorded surges in small coastal creeks

A number of water level gauges are available throughout the Sunshine Coast, as shown in Figure 2-6. Whilst larger estuaries and rivers have several long-term records, data collection within the smaller coastal creeks is limited to recent years only. Table 2-2 shows differences in water levels from notable surge events, with higher water levels observed within the smaller coastal creeks of Stumers, Currimundi, Coondibah and Tooway. A range of Australian studies have been reviewed, which generally indicate wave setup is not a significant cause of increased water levels within estuaries; although its effect will vary based on offshore wave steepness, wave direction, river flow and channel geometry (see summary in Section 2.7). Gauge records, video footage and field survey is available at Stumers Creek during the January 2022 event (Ex TC Seth) which provides evidence on the mechanism for the increased water levels. This data shows:

- The Mooloolaba tide gauge peaked at 1.49m AHD. This is a high quality water level gauge.
- The Stumers Creek gauge peaked at 1.88m AHD. This is a lower quality gauge, recording one water level every 10 minutes (which is not suitable to resolve individual wave crests)
- Peak water level debris from waves washing over the northern carpark reached ~2.6m AHD.

The video shows wave groups entering the creek, with water levels increasing for at least 30 seconds before the footage ended. This is representative of an Infragravity (IG) wave, often referred to as a "surf beat," which has a longer period and lower frequency compared to the regular wind-generated waves. Short wave crests are observed within the IG wave, which are impacting the estuary banks and overtopping into the carpark.

IG waves are not a new phenomena in Australia, which have been captured in wave and tide-gauge data from Lake Conjola and videos from Manly and Avoca lagoons in New South Wales. The unsteady behaviour of an IG wave near a shoreline has only recently become understood through analysis of their resonant behaviour (Nielsen 2009⁶, Nielsen & Baldock, 2010⁷). This explains that a set of large waves can create a steady mean-water-surface depression, in addition to a 'volume-neutral' long wave that can elevate the leading waves and enhance their potential for wave overtopping.

The occurrence of IG waves within the small coastal creeks is an important feature within Storm Tide Planning which is not captured within the Sunshine Coast Storm Tide Study (2013). An additional IG wave allowance has been included within the extreme storm tide levels for coastal creeks, presented in Section 5.

⁶ Nielsen, P (2009): Coastal and Estuarine Processes, World Scientific. pp 121-123 7 Nielsen, P & T E Baldock (2010): N-shaped surf beat understood in terms of transient, forced long

waves. Coastal Engineering, Coastal Engineering, Vol 57, pp 71-73.

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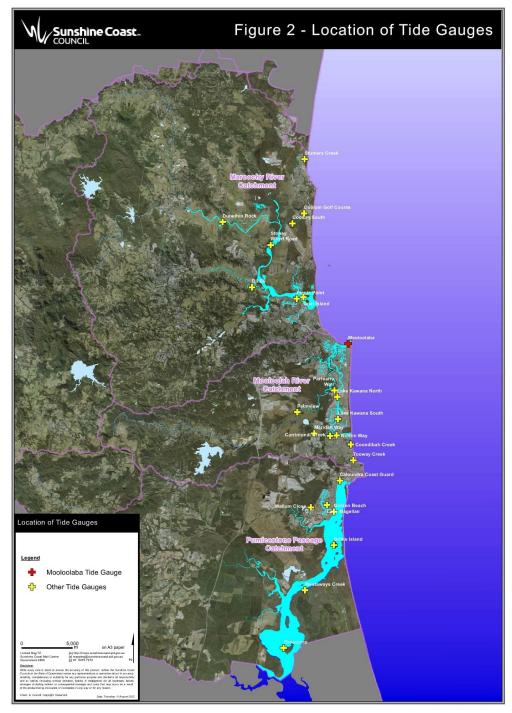


Figure 2-6: SCC tide gauges



Table 2-2: Observed Storm Tide Levels from Notable Events (red boxes identify small	ll creeks and
ICOLLS)	

Storm Tide Level (m AHD)]	
Location	June 2016	Dec 2020	Jan 2022	1% AEP	Start of Record	
Maroochy River	•			_		
Stumers Creek	N/A	N/A	1.88	1.66	09/2021	
Coolum Golf Course	N/A	1.49	1.20	1.65	06/2020	
Coolum South	N/A	1.50	1.24	1.65	03/2020	
Dunethin Rock	1.41	1.61	1.31	1.65	11/1994	
Stoney Wharf Road	0.97	1.42	1.17	1.65	09/2007	
Bli Bli	1.23	1.59	1.34	1.65	06/2011	
Picnic Point	1.26	1.56	1.36	1.65	11/1994	
Goat Island	N/A	1.58	1.40	1.65	04/2018	
Mooloolah River	•	•				
Mooloolaba	1.29	1.44	1.49	1.60	09/1978 (Continuous) 01/1967 (Manual)	
Parrearra Weir Upstream	1.21	1.42	1.42	1.60	09/2004	
Kawana Island Blvd	N/A	N/A	1.50	1.63	08/2021	
Lake Kawana North	N/A	1.72	1.51	1.63	12/2019	
Lake Kawana South	N/A	1.69	1.48	1.63	12/2019	
Currimundi Creek	N/A	1.75	1.56	1.63	04/2020	
Currimundi Creek @ Nicklin Way	1.50	1.75	1.62	1.63	02/2016	
Creeks south of Currimundi						
Coondibah Creek	N/A	N/A	2.06	1.63	02/2021	
Tooway Creek	N/A	1.98	2.02	1.63	11/2020	
Pumicestone Passage (* indicates 1% AEP storm tide level after breakthrough)						
Caloundra Coast Guard	N/A	N/A	1.47	1.65	01/2021	
Golden Beach	1.01	1.21	1.26	1.65*	04/2009	
Bribie Is., Westaways Ck, Thooloora	N/A	N/A	N/A	1.65*	05/2022	



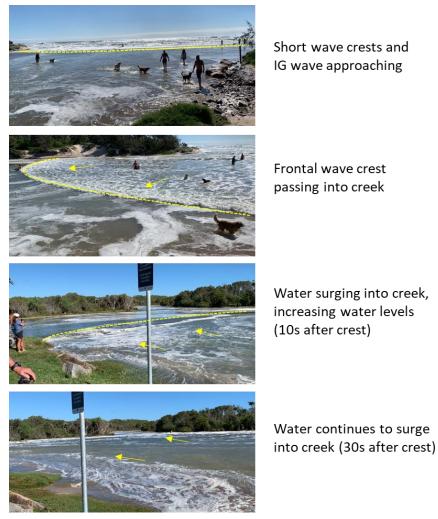


Figure 2-7: Images from recorded movie showing the progression of short wave crests and IG waves into Stumers Creek (Source: Sunshine Coast Council)



2.7 Available literature of wave setup in lagoons and estuaries

A range of Australian wave setup studies are summarised below, and generally indicate wave setup is not significant within estuaries, although its effect will vary based on offshore wave steepness, wave direction, river flow and channel geometry. Instead, the mechanism for additional waves affects within the small coastal creeks are the occurrence of IG waves.

2.7.1 Tidal amplitude and wave setup in trained and untrained river entrances (Moura et al. 2013) 8

This analysis involved the study of wave setup in untrained and trained estuaries in New South Wales. The study involved collection of field data at two estuary locations, at Cudgera Creek and Mooball Creek. The study concluded that there was an increase in water level through the entrance of the creeks, however it suggests that wave setup was not the cause of this elevated water level. Further research was recommended to resolve the cause of the elevated water levels observed.

2.7.2 Wave setup and tides at the trained and untrained river entrances of Hastings Point and Pottsville (Callaghan et al., 2013)⁹

Also using the data from Moura (2013), this study analysed the water levels along the open beach and within the untrained river entrances of Cudgera Creek during a period of large waves. The maximum open coast shoreline setup coincident with offshore wave heights approaching 4m, during which time the wave setup within the river entrance was negligible.

2.7.3 Coastal and estuarine processes (Nielsen, 2009)¹⁰

Professor Nielsens work included field work within the Gold Coast Seaway, which showed very minor (\sim 3cm) wave setup contributions in estuaries, where the textbook equations predict several tens of centimetres.

2.7.4 Wave setup in river entrances (Dunn 2001¹¹; Dunn et al., 2000¹²)

Dunn measured wave setup in river entrances for his PhD thesis at the University of Queensland. He concluded setup can be heavily restricted in narrow entrances, which was investigated within a medium-sized estuary at the Brunswick River, between a pair of rock walls.

2.7.5 Wave setup in estuary entrances (Zaki 2020) ¹³

This study of wave setup in estuaries was based on results of physical laboratory investigations with single frequency and grouped waves. The analysis consisted of exploring the opposing conclusions of two field studies which concluded that either wave setup is not able (Hanslow and Nielsen, 1992) or is able (Tanaka and Tinh 2008)¹⁴ to propagate within estuaries. The testing by Zaki showed that the results of both the Tanaka & Tinh and Hanslow & Neilson could be experienced within the physical laboratory model, under specific conditions. It was concluded that setup in estuaries is influenced by offshore wave steepness, wave direction, river flow and channel geometry.

- 10 Nielsen, P., 2009. Coastal and estuarine processes. Advanced series on ocean engineering. World Scientific, Singapore, 341 pp. 11 Dunn, S.L., 2001. Wave setup in river entrances. Ph.D. Thesis, The University of Queensland, St. Lucia, Qld., 175 pp
- 12 Dunn, S.L., Nielsen, P., Madsen, P.A. and Evans, P., 2000. Wave setup in river entrances. Proceedings of the 27th International Conference on Coastal Engineering, Sydney, Australia, 3432-3445
- 13 Zaki, M. F. (2020). Wave setup in estuary entrances. Estuarine, Coastal and Shelf Science, 235, 106593.

⁸ Moura, A., Plomaritis, T. A., & Uittenbogaard, R. E. (2013). Tidal amplitude and wave setup in trained and untrained river entrances. Journal of Geophysical Research: Oceans, 118(3), 1347-1363.

⁹ Callaghan, D.P., Nielsen, P., Baldock, T.E., Moura, T., Olfateh, M. and Golshani, A., 2013. Wave setup and tides at the trained and untrained river entrances of hastings point and pottsville, The University of Queensland, St Lucia, QLD 4072.

¹⁴ Tanaka, N., & Tinh, T. (2008). Wave setup at river entrances due to extreme waves. Journal of Coastal Research, 24(1A), 249-255.

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3 Storm tide inundation and wave impact zone (Exposure W)

3.1 Introduction

The open coast includes areas adjacent or directly exposed to wave action. Two exposure zones have been considered, Exposure W (waves) and Exposure I (coastal inundation - see Section 4), as shown in Figure 3-1. This designation aligns with the National Construction Code, which requires that a building or structure must perform adequately under all reasonably expected design loads and actions and withstand extreme or frequently repeated design events.

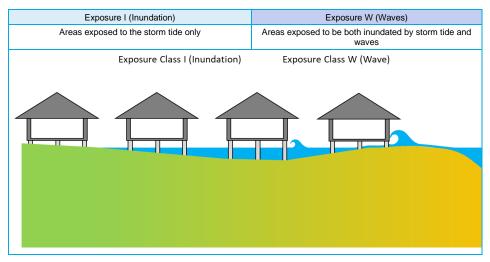


Figure 3-1: Exposure classes

3.2 Defining the wave impact zone (Exposure W - waves)

Wave exposure is influenced by offshore wave conditions, bathymetry, beach conditions, presence of structures, topography, future shoreline position, and distance behind the coast. A site-specific analysis is required to consider each element in detail, with this Storm Tide Study providing generic zones and values based on the future shoreline position and distance behind the coast.

The wave impact zone captures areas exposed to potential wave impacts under a future 2100 planning horizon and is based on a future eroded shoreline position. Coastlines naturally erode and accrete over time, driven by variations in sediment supply and climate patterns. Ongoing coastal recession and erosion is expected for the sandy beaches of the Sunshine Coast, which can lead to a landward shift of the present-day coastline. The extent of the wave impact zone is based on the following framework, described in the section below.

- Areas that are below 4.7m AHD (the expected 1% AEP wave run-up level), AND:
- Are within a 200m zone adjacent to either:
 - The 2100 1% Annual Exceedance Probability (AEP) Erosion Prone Area (EPA), or
 - The Esplanade along Golden Beach.

3.2.1 The 1% AEP 2100 Erosion Prone Area (EPA)

For the majority of the SSC LGA, the future shoreline position has been based on the position of the 1% AEP 2100 Erosion Prone Area (EPA), presented in the Sunshine Coast Coastal Hazard



Adaptation Strategy (CHAS)¹⁵. The CHAS has been developed under the State Governments QCoast2100 Program and has included updated mapping throughout the LGA to comply with the minimum standards and guidelines set by the state. In many areas this EPA reflects an undefended scenario (i.e., no coastal protection is constructed) or no intervening action occurs prior to 2100 to limit erosion. It is expected that this assumption will assist in identifying locations particularly sensitive to unconstrained beach erosion.

3.2.2 The Esplanade along Golden Beach

The protection offered by Bribie Island is not considered a permanent feature due to ongoing erosion, recession, and the recent breakthrough. All future scenarios consider the northern end of Bribie Island to be completely eroded. Under this scenario Golden Beach becomes the open coastline with a potential erosion zone extending back to The Esplanade.

3.2.3 The use of a 200m buffer

The extent of future wave impacts will be influenced by several factors, including the future wave conditions, foreshore conditions, the presence, shape and size of any coastal defence, and the local geometry of the structure being impacted. For this study, the future wave impact area has been limited to 200m inland from the future EPA zone. This arbitrary distance is generally supported by the Queensland Reconstruction Authority Storm Tide Resilient Building Guidance for Queensland Homes (QRA 2019¹⁶), which says:

"The impacts of a storm tide depend on the elevation of your property, proximity of your home to the shoreline, shape of surrounding land and roads, and height of the waves. Most storm tide damage is experienced by properties directly exposed to incoming ocean waves, which is typically those within 100 to 200 metres of the open shoreline. The presence of foreshore erosion protection (revetments or seawalls) or vegetation is unlikely to provide significant protection from storm tide impacts. The first line of houses along the shoreline is likely to experience the greatest impact" (QRA 2019).

3.2.4 Wave runup levels

Significant wave impacts are not expected at locations elevated high above the shoreline, taken as 4.7m AHD. This level reflects the typical 1% AEP wave runup level for a 2100 planning horizon. Wave runup has been estimated using the empirical formulation of Stockdon et al (2006)¹⁷:

$$R_2 = 1.1 \left[0.35 B_f (H_o L_o)^{\frac{1}{2}} + 0.5 \left(H_o L_o \left(0.563 B_f^2 + 0.004 \right) \right)^{\frac{1}{2}} \right]$$

Where R_2 is the wave runup level exceeded by 2% of waves, B_f is the beach slope (taken as a nominal 1:25), Hs is the offshore wave height and L_0 deepwater wavelength. A 1% AEP wave height of Hs 6.75m. A Tp 13.77 was used, based on new extreme wave analysis being undertaken for the Sunshine Coast Shoreline Erosion Management Plan (2024). The resulting 1% AEP wave runup is 2.3m, which was added to the mean 1% AEP storm tide the open coast (2.43m AHD). The nominal 1% storm tide plus wave runup level is therefore 4.7m AHD across the LGA.

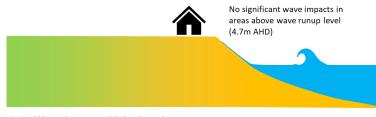


Figure 3-2: Wave impact - high elevation zone

¹⁵ SCC (2022) Sunshine Coast Coastal Hazard Adaptation Strategy, May 2021

¹⁶ QRA (2019) "Storm Tide Resilient Building Guidance for Queensland Homes", © The State of Queensland (Queensland Reconstruction Authority) 2019. Reference: QRA 2635/GD 0320

¹⁷ Stockdon, Hilary & Holman, Robert & Howd, Peter & Sallenger, Asbury. (2006). Empirical parameterization of setup, swash, and runup. Coastal Engineering. 53. 573-588. 10.1016/j.coastaleng.2005.12.005.

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3.3 Storm tide inputs for wave impact zone (Exposure W - waves)

Storm tide inputs for the wave impact zone include:

- Storm tide levels plus wave setup levels, and
- Wave forces

3.3.1 Exposure W - Storm tide and wave setup levels

The wave impact zone (Exposure W - waves) considers storm tide levels, wave setup levels and potential wave impacts.

The storm tide plus wave setup level is adopted from the existing Sunshine Coast Storm Tide Study (Aurecon 2013) for return periods up to a 1 in 1,000-year AEP. The TMST level is adopted from NDRP (GHD 2014).

When mapping storm tide plus wave setup, the wave setup is assumed to be a localised effect only. It can be applied within inundation maps as a triangular distribution, where full setup values are added at the future coastline which reduce to zero setup at a distance 200m inland (see Figure 3-3). At this point the open coast (excluding wave setup) values should be applied further inland.

The wave impact zone storm tide levels are shown in Table 3-1 and Table 3-2. They combine the open coast storm tide (either present day for emergency planning or 2100 for land use planning) with full wave setup values.

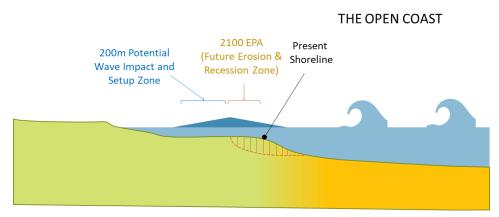


Figure 3-3: Open Coast coastal inundation beach cross-section, showing present day conditions.



Location	20-year	50-year	100-year	500-year	1000-year	PMST	
Bells / Lamerough	See ICOLLs, Section 5						
Pumicestone Passage	1.94	2.19	2.38	2.56	2.64	4.42	
Kings	1.94	2.19	2.38	2.56	2.64	4.43	
Tooway			See ICOLL	s, Section 5			
Dicky	1.93	2.17	2.37	2.55	2.61	4.43	
Bunbubah	See ICOLLs, Section 5						
Coondibah	See ICOLLs, Section 5						
Currimundi			See ICOLL	s, Section 5			
Bokarina	2.06	2.33	2.56	2.76	2.83	4.49	
Buddina	2.29	2.65	2.93	3.19	3.27	4.49	
Mooloolah River	2.27	2.62	2.91	3.19	3.27	4.45	
Mooloolaba	2.16	2.48	2.72	2.91	2.99	4.45	
Aerodrome Road	2.20	2.53	2.79	3.03	3.10	4.41	
Pincushion Island	2.27	2.62	2.89	3.14	3.22	4.44	
Cotton Tree Park	2.27	2.61	2.88	3.13	3.21	4.44	
Mudjimba Beach	2.24	2.58	2.86	3.09	3.16	4.48	
Mount Coolum	2.22	2.56	2.82	3.04	3.11	4.53	
Stumers	See ICOLLs, Section 5						

Table 3-1: PRESENT DAY storm tide estimates (mAHD), includes full wave setup

Table 3-2: FUTURE '2100' Storm tide estimates (mAHD), includes 0.8m sea level rise plus full	
wave setup	

Location	20-year	50-year	100-year	500-year	1000-year	PMST	
Bells / Lamerough	See ICOLLs, Section 5						
Pumicestone Passage	2.74	2.99	3.18	3.36	3.44	5.22	
Kings	2.74	2.99	3.18	3.36	3.44	5.23	
Tooway	See ICOLLs, Section 5						
Dicky	2.73	2.97	3.17	3.35	3.41	5.23	
Bunbubah	See ICOLLs, Section 5						
Coondibah	See ICOLLs, Section 5						
Currimundi	See ICOLLs, Section 5						
Bokarina	2.86	3.13	3.36	3.56	3.63	5.29	
Buddina	3.09	3.45	3.73	3.99	4.07	5.29	
Mooloolah River	3.07	3.42	3.71	3.99	4.07	5.25	
Mooloolaba	2.96	3.28	3.52	3.71	3.79	5.25	
Aerodrome Road	3.00	3.33	3.59	3.83	3.90	5.21	
Pincushion Island	3.07	3.42	3.69	3.94	4.02	5.24	
Cotton Tree Park	3.07	3.41	3.68	3.93	4.01	5.24	
Mudjimba Beach	3.04	3.38	3.66	3.89	3.96	5.28	
Mount Coolum	3.02	3.36	3.62	3.84	3.91	5.33	
Stumers	See ICOLLs, Section 5						



3.3.2 Exposure W - wave forces

Development within the Exposure W zone will need to consider wave impacts. Wave impact forces occur when waves crash onto a structure, which can have a significant impact on buildings located along the shoreline. The additional risk in areas exposed wave impacts is described within the Queensland Reconstruction Authority's Storm Tide Resilient Building Guidance for Queensland Homes (QRA 2019):

"Waves increase at the peak of the storm tide when the depth of water is at its highest, causing greater damage to homes". ... " Wave forces can be significant. Most wall construction is usually unable to resist waves around one metre high. Even if the load on freestanding piers or stumps is not sufficient to cause structural failure, the crest of the wave may cause entry of seawater at the floor level well before the storm tide level reaches that height. The greatest wave force will be experienced when a wave breaks against a part of the home."

The magnitude of this force depends on several factors, including the wave conditions, foreshore conditions, the presence, shape and size of any coastal defence, and the local geometry of the structure being impacted. Wave forces require detailed assessment, which will be a requirement for any significant structures. A generic wave force calculation method for design and compliance purposes has been developed for this Storm Tide Study. This calculates wave forces based on the structure's distance from the future shoreline and its elevation relative to the Australian Height Datum (AHD).

3.3.3 Residual Wave Force Calculations within 50m of the Future Shoreline

Wave forces in proximity to the future shoreline are calculated using the site-specific method detailed below. The key input parameters are:

- RL at the base of structure (yH) in mAHD (Australian Height Datum).
- The distance of the structure from the future shoreline (*xh*) in metres.
- Future 1% storm tide + wave setup level (*ySTL*) in mAHD.

The calculation process is as follows:

- Starting Wave Force (*SF*): A standard starting wave force at the future shoreline is assumed to be 300 kN/m, based on typical storm conditions, modelling, and physical testing results for vertical seawalls.
- 2. Residual Wave Force (*F%*): As the waves propagate landward or overtop the shoreline, their force diminishes. The percentage of residual wave force at the house's location depends on its distance from the shoreline (xh). The residual wave force is calculated using the following formula:

$$F_{\text{residual}} = SF \times F\%$$

Where:

- SF is the starting wave force, 300 kN/m, based on available literature.
- *F*% is the reduction factor based on the house's distance from the future shoreline. It is calculated using the following equation:

F% = (-0.019 * *xh*) +1, for *xh* ≤ 50

An example calculation for a property at a distance of 20m away from future shoreline:

$$F\%$$
 = -0.019 × 20 + 1 = 0.62
 F_{residual} = 300kN/m × 0.62 = 186kN/m

This residual wave force will act on the ocean-facing wall of a structure in the wave impact zone and should be incorporated into the structural design. This residual force value should be used within structural calculations with an appropriate factor of safety, recommended by a structural or civil engineer. This value is highly dependent on the structure geometry and should be used as a guide only.

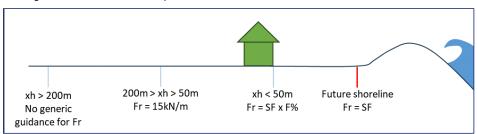


3.3.4 Residual Wave force calculations beyond 50m landward of the future shoreline

The wave impact force for broken waves typically decreases further landward from the shoreline. This is because as the waves break at the shore, their energy is dissipated, resulting in a decrease in wave energy and impact force. The rate of decrease in wave impact force with landward distance depends on various factors such as the wave characteristics, initial impact/breaking characteristics at the shoreline, and the landward topography.

For structures located between 50 to 200m landward of the future shoreline, it is recommended to undertake a sensitivity test on any structural calculations, using 15 kN/m as a generate wave impact force estimate for structural checks. This value should be incorporated into design calculations with an appropriate factor of safety, as advised by a structural or civil engineer. Where the site conditions are complex or uncertain, consultation with an experienced coastal engineer is recommended.

For areas beyond 200m from the future shoreline, there are no generic wave impact loading guidelines. Practitioners must apply professional knowledge and judgment, taking into account local site conditions, wave behaviour, ground conditions, structure's design life, and any unique project considerations to determine the appropriate wave force considerations.



See Figure 3-4 for a schematic representation of the residual wave force.

Figure 3-4: Schematic representation of residual wave force.

3.3.5 Vertical distribution of the Residual Wave force

Sections 3.3.3 and 3.3.4 provided guidance on calculating the residual wave force at any subject site. This section focuses on how to work out the vertical distribution of the residual wave force, which is then applied to relevant structural members and components.

The residual wave force, expressed in kN/m along the structure's ocean-facing frontage, must be converted into wave pressure. The future 1% storm tide + wave setup level (ySTL) is the critical design event, representing the maximum water level the structure will encounter during a significant storm. Therefore, the structure will experience the following:

 Below the storm tide level (ySTL): The structure will be subject to a combination of wave impact forces, hydrostatic pressure, and hydrodynamic forces. These forces must be considered together in the structural design.

The wave pressure distribution below the storm tide level will vary based on the depth of water at different time instances, wave characteristics, and the geometry of the structure. For simplicity in this exercise, it is assumed that the water reaches all the way up to the ySTL level, and a uniform load/pressure is assumed for the design.

 Above the storm tide level (ySTL): The structure will primarily experience wave impact forces, which will taper off as the height increases, particularly as the elevation approaches 4.7m AHD. The impact forces diminish with height as the energy of the waves dissipates.

Vertical Distribution Considerations:

- Below the storm tide level, combined wave pressure is applied uniformly for simplicity, acknowledging that, in reality, hydrostatic pressure will vary with depth. The uniform load assumption provides a conservative design approach.
- Above the storm tide level, wave impact pressure diminishes progressively, with no significant forces acting above 4.7m AHD.



The pressure diagram below illustrates the uniform wave pressure distribution below the ySTL and the tapering off of wave forces above this level, approaching 4.7m AHD.

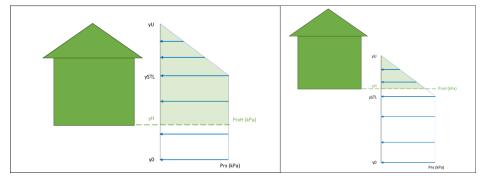


Figure 3-5: Wave pressure schematic for a house below ySTL (left) and above ySTL (right). Where:

- SF is the starting wave force, 300 kN/m, based on available literature.
- Fresidual is the residual wave force at structure •
- yU is the upper wave action cutoff level 4.7m AHD (where wave force = 0) •
- ySTL is the future 1% storm tide + wave setup level
- yH is RL of the base of the structure .
- **y0** is 0m AHD
- Prx is the maximum residual wave pressure
- \pmb{P}_{rxH} is the maximum residual wave pressure base on yH

For yH < ySTL

$$Prx = \frac{2 \times Fresidual}{ySTL + yU}$$
$$PrxH = Prx$$

For yH ≥ ySTL

$$Prx = \frac{2 \times Fresidual}{ySTL + yU}$$
$$PrxH = -Prx\left(\frac{yH - yU}{yU - ySTL}\right)$$

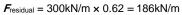


3.3.6 Worked examples

Example 1: Future 100-year wave pressure for house 1 situated 20m from the future shoreline, with a base RL of 1.5m AHD.

- Step 1: Key inputs.
 - Given: xh = 20m
 - Given: yH = 1.5m AHD
 - $\circ~$ From Table 3-2, the future 100-year storm tide level (ySTL) at the location of the dwelling is 3.18m AHD
 - From Section 3.3.5, yU = 4.7m AHD and y0 = 0m AHD.
- Step 2: Residual wave force (horizontal). At 20m from the future shoreline, the residual wave force is calculated as follows and shown in Figure 3-6:

 $F\% = -0.019 \times 20 + 1 = 0.62$



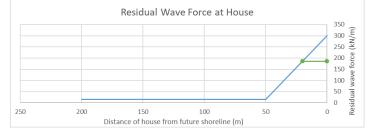


Figure 3-6: Residual wave force diagram for the house 1.

Step 3: Vertical distribution of residual wave force. Since yH (1.5m AHD) is less than ySTL (3.18m AHD), we use the formula for PrxH when yH < ySTL.:

$$Prx = \frac{2 \times 186}{3.18 + 4.7} = 47.21$$
kPa
PrxH = 47.21kPa

Therefore, the future 100-year wave pressure acting on the house 1 is 47.21kPa, as shown in Figure 3-7.

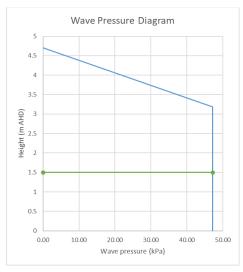


Figure 3-7: Wave pressure diagram for house 1.



Example 2: Future 100-year wave pressure for house 2 situated 35m from the future shoreline, with a base RL of 4.0m AHD.

- Step 1: Key inputs.
 - Given: xh = 35m
 - Given: yH = 4m AHD
 - $\circ~$ From Table 3-2, the future 100-year storm tide level (ySTL) at the location of the dwelling is 3.66m AHD
 - From Section 3.3.5, yU = 4.7m AHD and y0 = 0m AHD.
- Step 2: Residual wave force (horizontal). At 35m from the future shoreline, the residual wave force is calculated as follows and shown in Figure 3-8:

$$F\% = -0.019 \times 35 + 1 = 0.335$$

 $F_{\text{residual}} = 300 \text{kN/m} \times 0.335 = 100.5 \text{kN/m}$

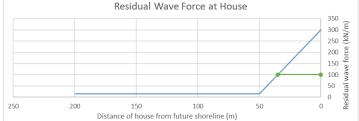


Figure 3-8: Residual wave force diagram for house 2.

Step 3: Vertical distribution of residual wave force. Since yH (4m AHD) is greater than ySTL (3.66m AHD), we use the formula for PrxH when yH > ySTL.:

$$Prx = \frac{2 \times 100.5}{3.66 + 4.7} = 24.04 \text{kPa}$$
$$PrxH = -24.04 \left(\frac{4 - 4.7}{4.7 - 3.66}\right) = 16.18 \text{kPa}$$

Therefore, the future 100-year wave pressure acting on house 2 is 16.18kPa, as shown in Figure 3-9.

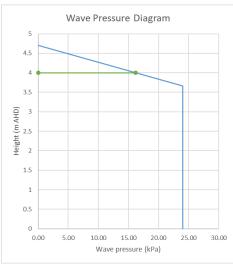


Figure 3-9: Wave pressure diagram for house 2.



4 Storm tide inundation zone (Exposure I)

4.1 Defining the coastal inundation zone (Exposure I - inundation)

The coastal inundation zone (Exposure I - inundation) has been mapped to the extent of future 1% AEP storm tide conditions in 2100. This extends across the coastal floodplain and estuaries.

4.2 Storm tide inputs for coastal inundation zone (Exposure I - inundation) Storm tide inputs for the coastal inundation zone include:

Storm tide levels without wave setup levels

Storm tide levels, without wave setup components, are relevant for areas within the mapped coastal inundation zone beyond the 200m wave impact zone, for medium to large estuaries (based on the review of literature in Section 2.3) and beyond 55m of a coastal creek (see Section 5). For these areas the storm tide excluding wave setup level is adopted from the existing Sunshine Coast Storm Tide Study (Aurecon 2013) for return periods up to a 1 in 1,000-year AEP. The TMST level is adopted from NDRP (GHD 2014) minus the average wave setup value from Aurecon (2013), which is 1.3m for the Sunshine Coast region between Kings Beach and Stumers Creek. Levels are available for present day in Table 4-1 which are increased by 0.8m to reflect sea level rise under a 2100 planning scenario in Table 4-2.



Location	20-year	50-year	100-year	500-year	1000-year	PMST	
Bells / Lamerough		See ICOLLs, Section 5					
Pumicestone Passage	1.47	1.57	1.65	1.71	1.75	3.13	
Kings	1.47	1.57	1.65	1.71	1.75	3.14	
Tooway			See ICOLL	s, Section 5			
Dicky	1.42	1.50	1.58	1.63	1.66	3.14	
Bunbubah	See ICOLLs, Section 5						
Coondibah	See ICOLLs, Section 5						
Currimundi	See ICOLLs, Section 5						
Bokarina	1.45	1.54	1.62	1.68	1.72	3.20	
Buddina	1.45	1.55	1.63	1.69	1.73	3.20	
Mooloolah River	1.42	1.51	1.60	1.67	1.71	3.16	
Mooloolaba	1.41	1.50	1.57	1.62	1.65	3.16	
Aerodrome Road	1.45	1.55	1.63	1.70	1.73	3.12	
Pincushion Island	1.47	1.57	1.65	1.72	1.76	3.15	
Cotton Tree Park	1.47	1.57	1.65	1.72	1.76	3.15	
Mudjimba Beach	1.46	1.56	1.65	1.71	1.74	3.19	
Mount Coolum	1.46	1.56	1.65	1.71	1.74	3.24	
Stumers	See ICOLLs, Section 5						

Table 4-1.	PRESENT DAY	Storm tide	estimates	(mAHD)	excludes wave effects
		Storn lide	estimates		

Table 4-2: FUTURE Storm tide estimates (mAHD), includes 0.8m sea level rise, excludes wave effects

Location	20-year	50-year	100-year	500-year	1000-year	PMST	
Bells / Lamerough	See ICOLLs, Section 5						
Pumicestone Passage	2.27	2.37	2.45	2.51	2.55	3.93	
Kings	2.27	2.37	2.45	2.51	2.55	3.94	
Tooway	See ICOLLs, Section 5						
Dicky	2.22	2.30	2.38	2.43	2.46	3.94	
Bunbubah	See ICOLLs, Section 5						
Coondibah	See ICOLLs, Section 5						
Currimundi	See ICOLLs, Section 5						
Bokarina	2.25	2.34	2.42	2.48	2.52	4.00	
Buddina	2.25	2.35	2.43	2.49	2.53	4.00	
Mooloolah River	2.22	2.31	2.40	2.47	2.51	3.96	
Mooloolaba	2.21	2.30	2.37	2.42	2.45	3.96	
Aerodrome Road	2.25	2.35	2.43	2.50	2.53	3.92	
Pincushion Island	2.27	2.37	2.45	2.52	2.56	3.95	
Cotton Tree Park	2.27	2.37	2.45	2.52	2.56	3.95	
Mudjimba Beach	2.26	2.36	2.45	2.51	2.54	3.99	
Mount Coolum	2.26	2.36	2.45	2.51	2.54	4.04	
Stumers	See ICOLLs, Section 5						



5 Small creeks and ICOLLs

Many of the smaller Sunshine Coast creeks act as Intermittently Closed and Open Lake or Lagoons (ICOLLs). Peak water levels within an ICOLL are dependent on rainfall and runoff processes, the coastal berm / estuary mouth geometry, coastal processes and infragravity waves. Examples include Stumers Creek (Figure 5-1), Currimundi Lake, Coondibah and Tooway.



Figure 5-1: Aerial picture of Stumers Creek

5.1 ICOLL processes

The dynamics of ICOLL entrances (i.e. the proportion of time that systems remain closed and the frequency with which they may open and close) are determined by the interactions between the opposing forces of catchment and ocean processes on the movement and accumulation of sand at the flood-tide delta, entrance berm and nearshore¹⁸.

After a breach, the typically small tidal prism is usually insufficient to maintain an open entrance. In these instances, while the initial closure is driven by processes that occur below high tide level (e.g. Ranasinghe and Pattiaratchi, 2003¹⁹), the longer term variation in barrier elevation is strongly correlated with run-up elevation and swash processes (Takeda and Sunamura, 1982²⁰; Weir et al., 2006²¹). Vertical barrier growth is usually wave driven and requires wave run-up to overtop the

¹⁸ DPIE (2021) Form and function of NSW intermittently closed and open lakes and lagoons. State of NSW and Department of Planning, Industry and Environment. ISBN 978-1-922558-52-7

¹⁹ Ranasinghe, R., Pattiaratchi, C., 2003. The seasonal closure of tidal inlets: causes and effects. Coastal Engineering Journal 45 (4), 601–627.

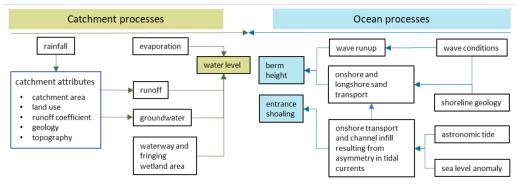
²⁰ Takeda, I., Sunamura, T., 1982. Formation and height of berms. Transactions Japanese Geomorphological Union 3, 145–157 21 Weir, F.M., Hughes, M.G., Baldock, T.E., 2006. Beach face and berm morphodynamics fronting a coastal lagoon. Geomorphology 82 (3–4), 331–346.

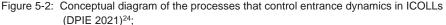
²⁰²²s1141-JBAP-00-00-RP-MO-0001-A1-P01-Storm Tide Study.docx



barrier, depositing sediment beyond the existing crest (Hine, 1979²²; Strahler, 1966²³). Whilst closed, an ICOLL can become disconnected from the ocean tides, and act as a lake. Lake water levels can rise due to overtopped wave energy or from catchment runoff. If water levels initiate a breach, the entrance can scour out which will restore tidal processes and can allow waves to enter the creek mouth. Section 2.6 of this report includes an example of IG waves propagating into the Stumers Creek ICOLL whilst it had an open berm during Ex TC Seth in 2022.

This study considers an open berm scenario only. Peak water levels open coast storm tide levels plus an allowance for IG waves and future sea level rise. It does not consider closed ICOLL scenarios, where peak water levels will be dependent on elevated berm levels and catchment processes illustrated below in Figure 5-2.





5.2 Estimation of IG wave allowance

The gauge records and analysis of videos presented In Section 2.6 identified surge from IG waves to be a primary cause for elevated water levels in small creeks. An extreme 1% AEP water level has been calculated that includes IG surge allowance. This follows three steps:

- 1. Calibration of an IG wave model at Stumers Creek and estimation of an extreme 1% AEP IG surge magnitude
- 2. Estimation of 1% AEP IG surge magnitude for all creeks using simulated and recorded data.
- 3. Addition of the 1% AEP Open Coast storm tides plus IG surge magnitude

Step 1: Calibration of an IG wave model at Stumers Creek and estimation of an extreme 1% AEP IG surge magnitude

The magnitude of extreme IG waves has been estimated using an XBeach wave model. This is an open-source 1D cross-shore model that has been increasingly used in recent years for the purpose of wave runup and overtopping assessment (Roelvink et al, 2010)²⁵ and has been validated with a series of analytical, laboratory and field test cases using a standard set of parameter settings. The model includes:

- Short wave transformation (refraction, shoaling and breaking).
- Long wave (infragravity wave) transformation (generation, propagation, and dissipation).

²² Hine, A.C., 1979. Mechanics of berm development and resulting beach growth along a barrier spit complex. Sedimentology 26, 333–351.

²³ Strahler, A.N., 1966. Tidal cycle of changes on an equilibrium beach. Journal of Geology 74, 247-268

²⁴ Ferguson, A., Wiecek, D., Hughes, M., Hanslow, D., Wainwright, D., & Scanes, P. (2021). Form and function of NSW intermittently closed and open lakes and lagoons Implications for entrance management. Department of Planning. Industry & Environment, Sydney. 25 Roelvink, D., Reniers, A., Van Dongeren, A., Van Thiel de Vries, J., Lescinski, J. and McCall, R. 2010. XBeach model description and manual. Delft University of Technology, User Manual, Delft, The Netherlands



- Non-hydrostatic wave diffraction.
- Wave-induced setup and unsteady currents.
- Over wash and inundation

The model was calibrated against the elevated water level record captured within Stumers in January 2022 (Ex TC Seth). A cross section was cut through the nearshore bathymetry and a partially open berm introduced at 1m AHD. The underlying tide signature for the event was based on the recorded Mooloolaba gauge, which is sheltered from waves and peaked at 1.49m AHD. Offshore waves were input into the model based on the Mooloolaba waverider buoy records, which recorded a significant wave height (Hs) of 2.7m and peak period (Tp) of 12.7s. The model was simulated and water levels extracted inside the estuary mouth. Figure 5-3 shows a comparison of the recorded water levels and simulated water levels. There are challenges in a direct comparison as the Stumers Creek water level record is based on 15 min instantaneous values where the peak values may be during a IG wave crests or trough) and Xbeach simulated water levels have a high frequency output that include short wave crests. An approximate match between both sources was found by taking the average XBeach water levels over 10 minutes, where:

- The Stumers Creek gauge peaked at 1.88m AHD.
- 10 minute average water levels from XBeach peaked at 1.83m AHD.

The model was rerun to test the influence of larger design waves. Offshore wave conditions were increased to reflect a 1% AEP wave event, and a 10-minute average water levels extracted from the model within the estuary mouth. Figure 5-4 shows a comparison of the average water levels using 1% AEP design wave conditions, January 2022 simulated waves and 2022 recorded water levels. Whilst the observed January 2022 surge was 0.41m, the re-simulated event with 1% AEP waves increased the surge to 0.75m.

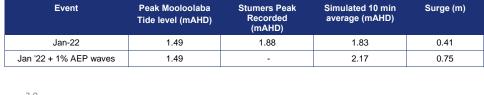


Table 5-1: Peak storm surge for January 2022 and design wave conditions (1% AEP)

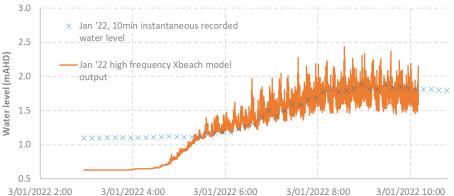


Figure 5-3: January 2022, recorded water levels (10 min instantaneous) and Xbeach simulated water levels (high frequency output).

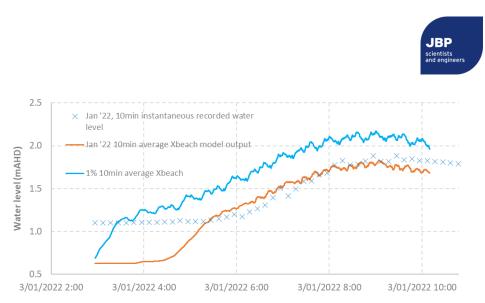


Figure 5-4: 10-minute average water levels using design wave conditions (1% AEP), January 2022 simulated waves and 2022 recorded water levels.

Step 2: Estimation of 1% AEP IG surge magnitude for all creeks using simulated and recorded data

The average water level increases for each coastal creek have been calculated over three historic events in June 2016, December 2020 and January 2022. Over this period Currimundi has long term data spanning all three events, Tooway Creek two events, and Coondibah and Stumers only a single event.

The largest average observed storm surge values are at Coondibah, which had water levels 0.6m higher than Mooloolaba records. Tooway and Stumers were elevated by 0.5 and 0.4m respectively, and Currimundi by 0.2m. The differences in average observed water level increase were used to adjust the simulated 1% AEP IG surge at Stumers Creek to other locations.

Bells Creek and Lamerough Canal do not experience significant wave effects due to the presence of Bribie Island. The future 2100 scenario assumes complete loss of the island, returning the Golden Beach area into the open coastline. For this scenario, a wave allowance has been included for the creek and canal, based on the average value of the four small coastal creeks of 0.78m.

Location	Location H		ts	Average surge	Variation to
	Jun-16	Dec-20	Jan-22	above Mooloolaba	Stumers average surge (m)
Stumers Creek	N/A	N/A	1.88	0.4	0.0
Currimundi Creek	1.50	1.75	1.56	0.2	-0.2
Coondibah Creek	N/A	N/A	2.06	0.6	0.2
Tooway Creek	N/A	1.98	2.02	0.5	0.1
Mooloolaba	1.29	1.44	1.49		

Table 5-2: Average surge in storm surge for January 2022 and design wave conditions (1% AEP)



Table 5-3: Estimated 1% AEP IG surge allowances for coastal creeks

Location	Variation to Stumers average surge (m)	Simulated 1% AEP IG Surge (m) - XBeach results	1% AEP IG Surge
Stumers	0.00	0.75*	0.75
Currimundi Creek	-0.19		0.56
Coondibah Creek	0.18		0.93
Tooway Creek	0.15		0.90
*simulated levels only available	ble for Stumers Creek		

Step 3: Addition of the 1% AEP Open Coast storm tides plus IG surge magnitude

The 1% AEP storm tide values for small coastal creeks has been estimated based on:

- Open Coast storm tide (excluding wave effects) Table 4-1 and Table 4-2 Plus;
- Estimated 1% AEP IG surge allowances for coastal creeks Table 5-3

5.3 Storm tide inputs for coastal creeks

Storm tide inputs for the coastal inundation zone include:

- 1% AEP Storm tide levels without wave setup levels
- 1% AEP IG surge allowances for coastal creeks

Storm tide levels are not always available for coastal creeks within the Sunshine Coast Storm Tide Study (Aurecon 2013). Tooway and Bunbubah have been based on the Dicky Beach reporting point, Coondibah is based on an average value of Dicky Beach and Currimundi, whilst Stumers Creek uses the Stumers output point. These have been increased to reflect an IG surge allowance. Available water levels for present day and future 2100 scenarios for a 1% AEP event are shown in Table 5-4. TMST values have been adopted from the open coastline.

When mapping the storm tide around coastal creeks a 2-part approach is recommended, similar to the open coast wave impact zone. For areas within 55m of the creek banks the Small Coastal Creeks plus IG wave allowance values should be used, as shown in Table 5-4. For areas beyond 55m of the creek banks the open coast storm tide excluding wave effects should be used (Table 4-1 and Table 4-2).

Location	100-year Present day	100-year Future '2100'	TMST Present Day	TMST Future '2100''
Bells / Lamerough	1.65*	3.23	3.13	3.93
Tooway/Bunbu bah	2.48	3.28	3.14	3.94
Coondibah	2.54	3.34	3.14	3.94
Currimundi	2.18	2.98	3.14	3.94
Stumers	2.41	3.21	3.25	4.05
*Bells / Lameroug	h only includes IG	wave allowances in	a 1% AEP future '2	100' scenario.

Table 5-4:	Small	Coastal	Creeks	'present day'	and	'2100'	storm t	ide es	stimates	(mAHD),	includes
	sea	level rise	and IG	wave allowa	nces						



6 Assumptions and recommendations

A range of assumptions have been made throughout this report that have been based on limited recorded information. This includes:

- Tide and storm surge trends within Pumicestone Passage are likely to be dynamic as the new entrance breakout continues to evolve. Future conditions may not reflect current conditions.
- Water level trends within the smaller coastal creeks is based on limited data. Currimundi
 has relatively long term data spanning three significant storm surge events (since 2016),
 whilst Tooway Creek observed two events, and Coondibah and Stumers only a single
 event. This limited data has been used to adjust the IG wave allowance within individual
 estuaries.
- During extreme events the peak still water levels, including wave crest level, within the small coastal creeks cannot be resolved by the low-frequency (15 minute) water level gauge.
- The future coastline scenario assumes Bribie Island offers no protection from waves, and Bells Creek and Lamerough Canal begin to experience IG waves, similar to the northern creeks.
- Wave forces inland of the future shoreline will be influenced by future coastal protection. The 'landward' wave impact force is heavily dependent on future site-specific conditions, volume of wave overtopping (linked to the shape and characteristics of the future shoreline or defence), and slope behind the shoreline. An appropriately designed coastal seawall may remove the wave impact load for inland areas, depending on its characteristics.
- The future position of the coastline will influence the distance of the wave impact zone. This report adopted the future shoreline position as the landward extend of the mapped 2100 Erosion Prone Area.

The following recommendations are made to improve the understanding of local conditions and support future revisions of storm tide levels, IG wave allowances, wave forces and the width of the mapped wave impact zone. This includes:

- Installation of high-frequency wave level recorders in small coastal creeks that have the ability to capture wave crest information.
- Identification of areas that will be offered coastal protected due to existing or future seawalls.
- Ongoing coastline monitoring to track the occurrence and speed of any coastal recession to identify any differences from the adopted 2100 coastal EPA.

JBP scientists and engineers

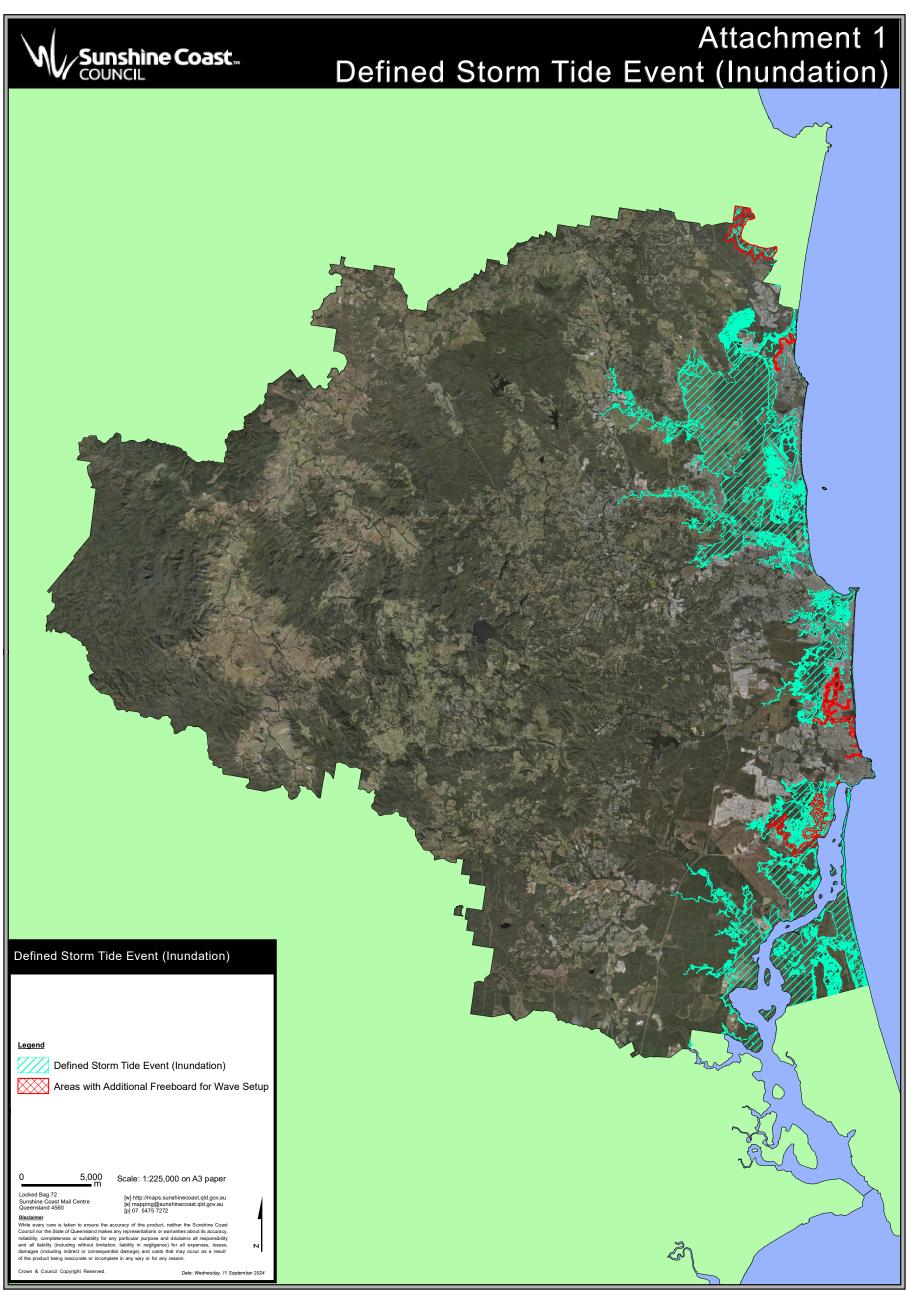
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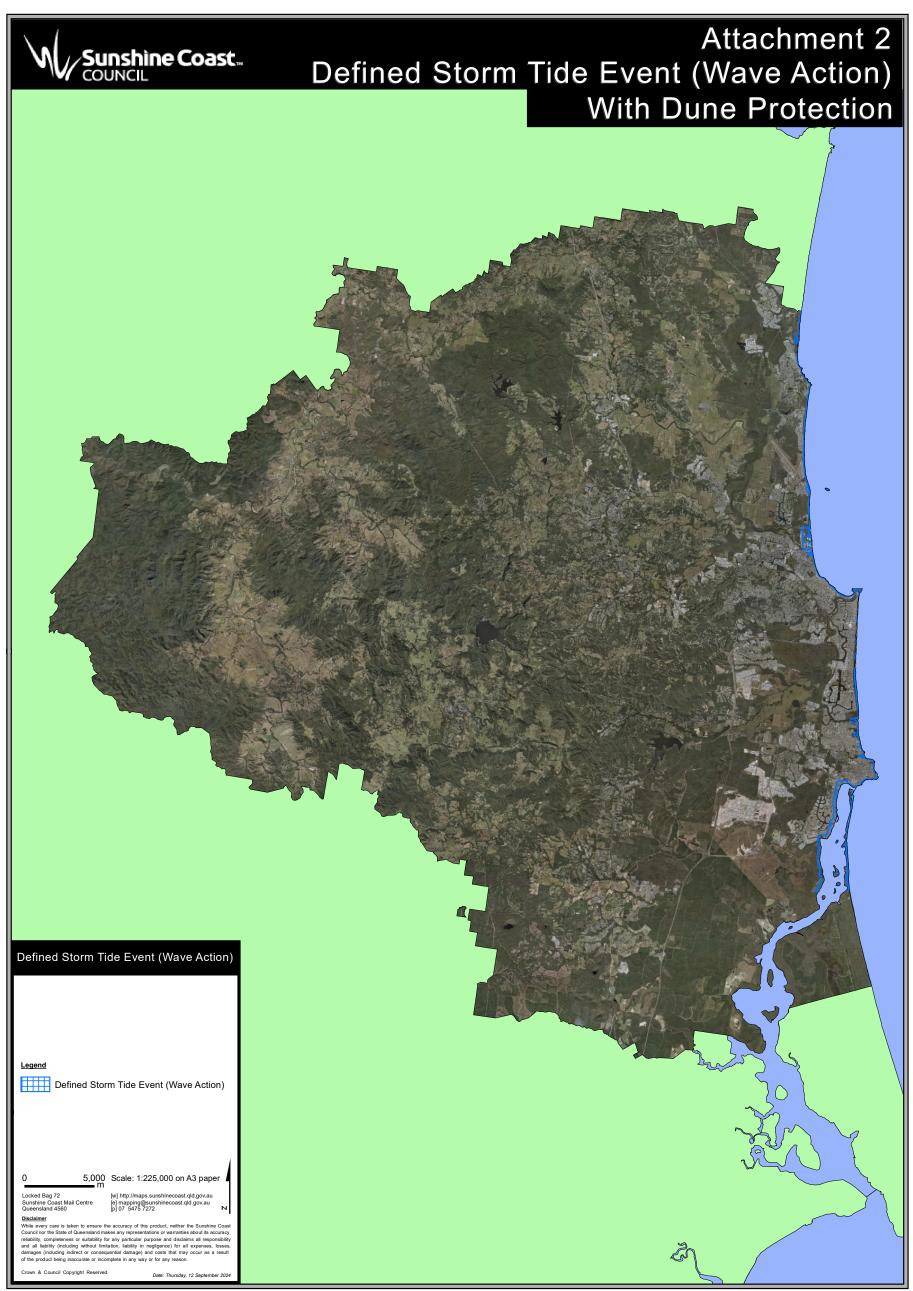
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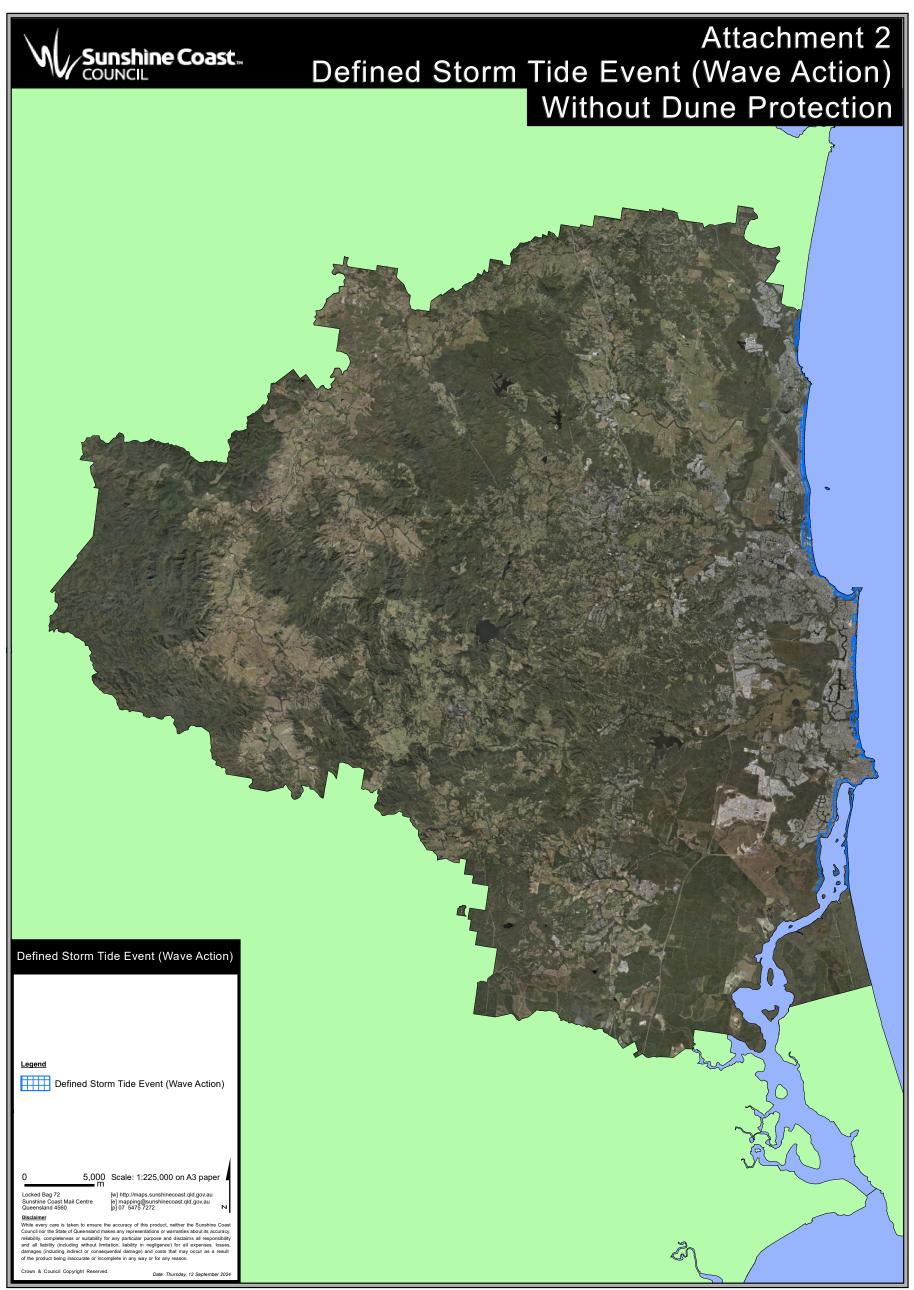
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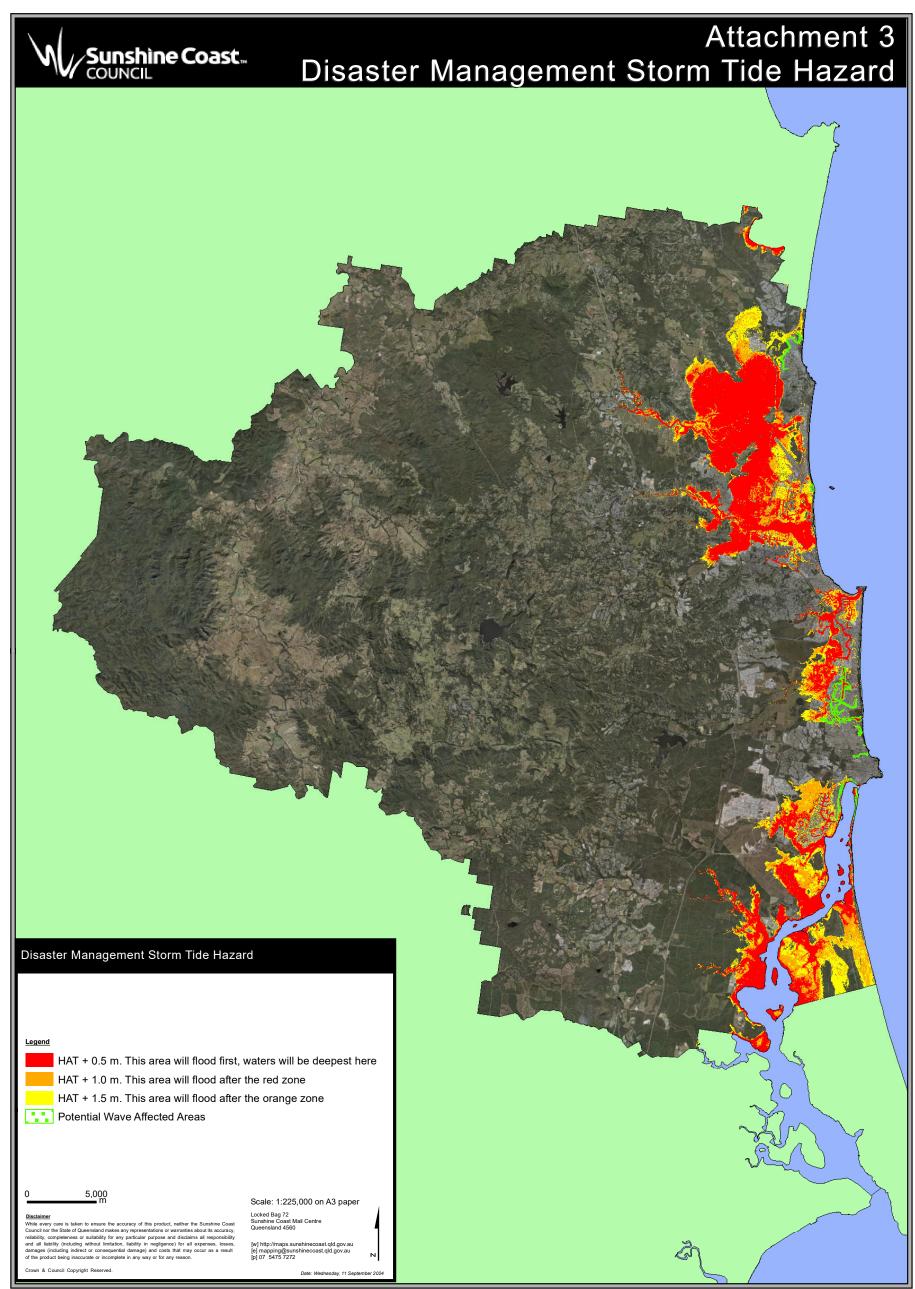
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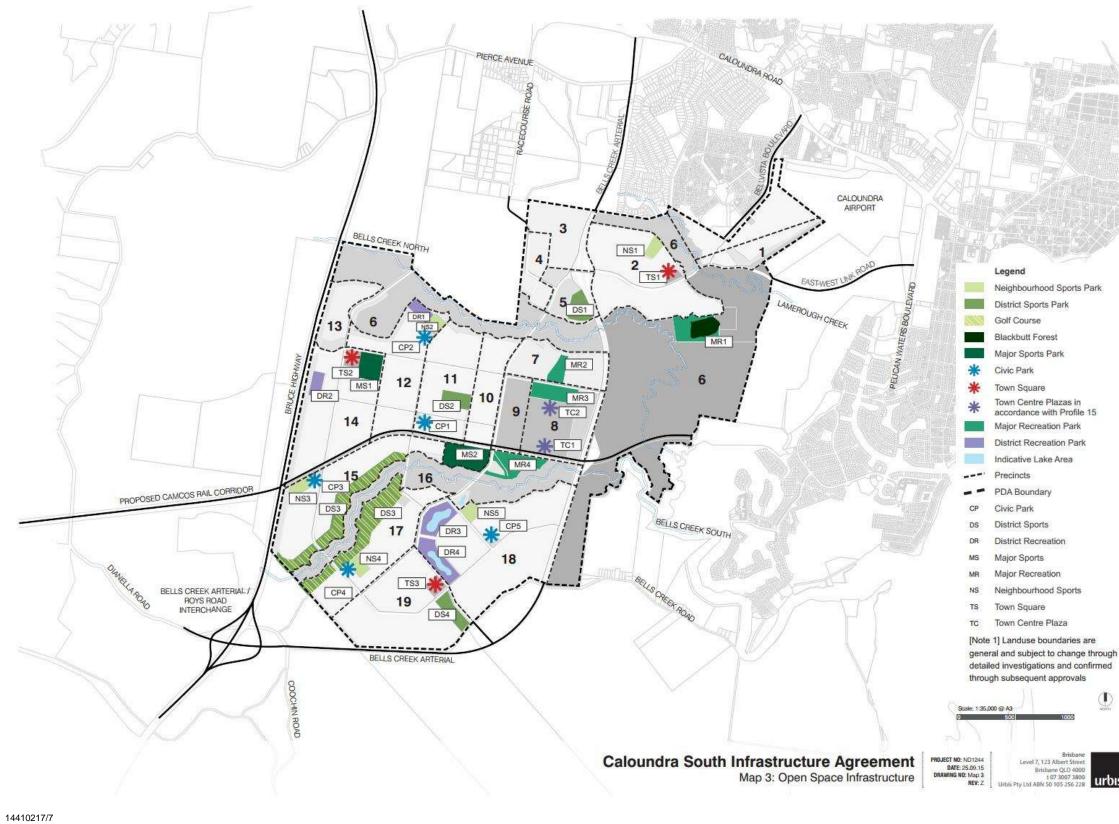
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Risk Hazard Management Plan – People's Place Lagoon – Phase 1 – Design and Construction

Sunshine Coast Our region. COUNCIL

Issued By: Version: Last review: Risk Identification Working Group 1 Oct 2024

Shari Fisher – Coordinator Corporate Risk and Insurance e: <u>shari.fisher@sunshinecoast.qld.gov.au</u>

Version	Reason/Trigger	Change (Y/N)	Endorsed/Reviewed by:	Date
1	New Document	Yes	Risk & Insurance	July 2024

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Risk Hazard Management Plan – Phase 1 – Design and Construction

Introduction

The People's Place is a major community destination located at the heart of the 2,360Ha Caloundra South Priority. Development Area (PDA). The wider PDA is to be developed by Stockland and delivered to the community over a 30-40 year period, accommodating an ultimate population of 50,000 residents in 20,000 dwellings. The People's Place Parkland is to be a significant community asset with an overall estimated value of \$45 million. The parkland is to be co-located alongside the Major Civic Centre (library, community, and cultural spaces) and Town Centre uses (stage one intended to be delivered alongside the People's Place and comprising approximately 20,000m² GFA retail centre uses, with an ultimate size of 90,000m² GFA plus 50,000m² GFA of commercial uses).

The People's Place Lagoon will ultimately form part of a major recreation park accommodating a variety of formal and informal uses, activities and events, with plans for development of a 2100m² recreational lagoon with associated facilities including amenities and a kiosk.



Figure 1. People's Place

What is Risk Management?

Risk management is a fundamental and integral element of contemporary business practice, effective corporate governance and decision-making. Risk management provides a method of determining which risks present opportunities and those risks that can have a negative impact on an organisation and form a basis for considering risk responses. Risk management offers an insight into activities or events that may have a negative impact on councils operational, project or strategic objectives. It assists management in making informed decisions.

By taking active steps to prevent harm and complying with laws and regulations, the community is kept safe, impacts are lessened and there is potential for the organisation to save resources. While all risks can never be fully avoided or mitigated, Council have to be prepared to accept some level of residual risk.

The process of risk identification in the People's Place project includes a consideration of the following factors:

- · Past events that have had a negative impact on councils operations, business outputs or reputation
- Information gathered from events that have occurred at other Lagoons
- Reports and advice given by external experts
- Scenario analysis
- S.W.O.T (strengths, weaknesses, opportunities and threats) analysis

Risk Hazard Management Plan - Phase 1 - Design and Construction

- Financial impacts on Council
- Audits and on site inspections when construction begins
- Emerging social or community issues
- Climate change impacts
- Impacts from critical high risk WHS activities

After identification has taken place, the risk needs to be analysed for urgency and criticality and then treated to be controlled within councils tolerance levels where possible.

- What is the likelihood of this risk happening?
- What would the consequence be if this risk occurred?
- Developing a mitigation strategy to control the risk
- Implementing controls to ensure the risk would not have a great adverse effect on operational outputs
- Monitoring and reporting on the risk

Purpose of this Manual

This Risk Hazard Management Plan (RHMP) sets out the requirements for implementing Risk Management throughout the People's Place Lagoon Project. The initial Phase 1 risk assessment for the project is to be the Design and Construct Phase of the People's Place Lagoon, Phase 2 is to be the handover of the constructed Lagoon and Phase 3 is to be the operational takeover of the Lagoon and ongoing water safety. Council has committed to an approach that includes how risks and opportunities will be identified and managed, monitored and reviewed throughout the life of the project.

This Plan provides information about how the Project Team manage risks, including examples of how medium to high risks are managed using a four-step process.

It also provides a framework for the project, outlining roles, responsibilities and an overall reference guide for undertaking risk assessment.

In the formation of this Plan, the Project Team have had regard to the following resources:

- Consultation and guidance from the Corporate Risk & Insurance Team;
- Council Master Risk Management Manual;
- Australian Standard AS ISO 31000:2018 Risk management Guidelines (Australian Standard) (the Standard); and
- Liquid Blu consultation reports
- Royal Life Saving Australia Risk Assessment Report (Settlement Cove)
- Local Government Mutual Services Signs (Public Places) 2019 (LGMS)
- Standards Australia International, (2010). Water Safety Signs and Beach Safety Flags Specifications for Water Safety Signs in Workplaces and Public Area. AS2416.1 – 2010. Standards Australia International Ltd. Sydney, Australia.
- Standards Australia International, (1986). Public Information Symbol Signs Water Safety Signs. AS2899.2 1986. Standards Australia International Ltd. Sydney, Australia.
- Standards Australia International, (1996). Playground surfacing Specifications, Requirements and Test Methods. AS4422 1996. Standards Australia International Ltd. Sydney, Australia.
- Standards Australia International, (2014). Guide to the Specification and Testing of Slip Resistance of Pedestrian Surfaces. SA HB 198. Standards Australia International Ltd. Sydney, Australia

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Risk Management Framework

How to manage risks

As an organisation, it is councils responsibility to understand and manage the risks of harm from its operational activities. In many situations, managing risks involves thinking through your operational activities and taking simple steps to avoid the risk of harm.

The Risk Management Framework below outlines the process by which risk management is carried out throughout Council. Each step of the Framework flows from one step to another to show the dependencies from each area to the next

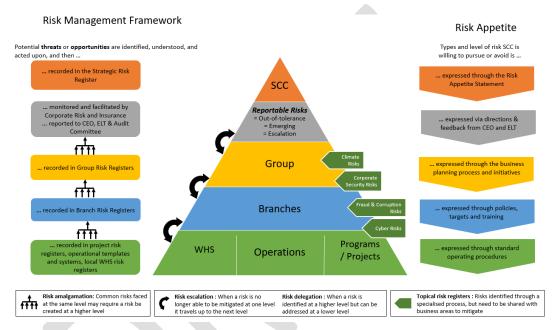


Figure 2. Risk Management Framework

Responding to risks requires ongoing and active risk management. The benefits of practising good risk management are not limited to merely reducing liability exposure. Effective risk management can also assist in identifying, assessing, managing and controlling other categories of risk such as financial, asset management, reputational or public image impacts.

The People's Place Lagoon Project Team utilises the following four steps to help manage risks:

- 1. Identify the hazard from your business activities that could cause harm.
- 2. Assess the risk, based on the likelihood of the hazard causing harm and the consequence of that harm.
- 3. **Implement** suitable control measures based on what is reasonably practicable for the operational team and Council, with the aim of choosing the greatest level of protection and reliability.
- 4. **Monitor** controls regularly to make sure they are functional, well maintained and remain the most appropriate option. This process includes monitoring control measures and identifying any changes that may need to be made to improve their overall effectiveness.

Risk Hazard Management Plan - Phase 1 - Design and Construction

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This four-step process along with councils Risk Management Framework is illustrated in Figures 3.



Figure 3. Risk Management Process

Roles and Responsibilities

The People's Place Project Team have in place clear roles and responsibilities for the effective management of risks experienced within the project. It is critical the risk management framework and structures adopted facilitate effective and appropriate dialogue within Council, including internal and external stakeholders.

Role	Responsibility
Council	 Provide leadership for the effective governance of councils business and high level monitoring of the management of risk Raise emerging risks and opportunities with the CEO for action Review strategic risks each calendar quarter
CEO	Establish a culture of risk and opportunity awarenessEnsure that governance arrangements are in place to monitor and manage risks
Group Executives	 Ensure that risks and opportunities are managed and regularly reviewed within their group – including strategic, operational and project risks Review strategic risks at least annually
Manager – Property Management Branch	 Phase 1, 2 & 3 Identify associated project risks Integrate risk management practices into project activities Report on identified risks
Project Manager – Urban Growth Projects	 Phase 1 Identify associated project risks Integrate risk management practices into project activities Report on identified risks
Team Leader – Sports and Community Venues	 Phase 1 & Phase 3 Identify associated project risks Integrate risk management practices into project activities Report on identified risks Advise Project Manager of any risk and opportunity issues
Coordinator Commercial Analysis	 Phase 1 & Phase 3 Identify associated project risks Integrate risk management practices into project activities

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	Report on identified risksAdvise Project Manager of any risk and opportunity issues
Coordinator Smart City Framework	 Phase 1 & Phase 3 Identify associated project risks Integrate risk management practices into project activities Report on identified risks Advise Project Manager of any risk and opportunity issues

Stakeholder Engagement

The below stakeholders are the key subject matter experts that have been or will be consulted throughout this project:

- Stockland
- CUSP Landscape Architecture and Urban Design
- Liquid Blu Specialist Architects for Aquatic Environments
- Royal Life Saving Society Australia
- Existing Lagoon Operators
 - Streets Beach Southbank Brisbane
 - Orion Lagoon Ipswich
 - Yeppoon Lagoon
 - Bluewater Lagoon Mackay
 - Airlie Beach Lagoon
 - Riverway Lagoon Thuringowa
 - Cairns Lagoon
 - Executive Leadership Team & CEO
- Mayor and Councillors
- Council Branches impacted by the maintenance of the Lagoon and surrounding area

Risk Management Process

The risk management process is set out below and applies to operational risks within the project. The process framework is used to improve accountability, responsibility, transparency and governance in relation to decision making and outcomes.

The risk management process undertaken in the project is the systematic application of corporate management and Council policies, processes, procedures and practices to the tasks of:

- establishing the context that risk exists in;
- identifying and capturing risks;
- analysing to understand risk nature and scope;
- evaluating risk to prioritise risk treatment;
- treating risk to reduce the associated likelihood or consequences; and
- monitoring and reviewing risks on a continuous basis.

The risk management process is applied by Management as part of project planning and operational decision making, as well as all staff and stakeholders associated with the project as part of their day-to-day operational activities and the delivery of People's Place.

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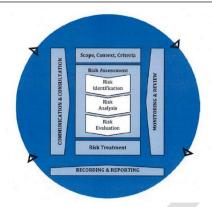


Figure 4. Risk Assessment Process

Once the risks are established the urgency and criticality of each risk needs to be analysed. Mitigations and controls can then be put into place to keep the risk within a tolerance that is acceptable to Council. Factors to consider in this analysis include:

- What is the likelihood of this risk happening?
- What would the consequences be if this risk occurred?
- Working out a mitigation strategy to control the risk
- Putting controls in place that work with the mitigation strategy to ensure the risk would not have a great adverse effect on the operational outputs
- · Creating action plans to bring any risks with a residual of high back into a medium or low residual
- Continual monitoring and reporting on the risk

What is the difference between a risk and an issue?

- As pointed out above a risk is the identification of activities or events that may have a negative impact on the People's Place project. A risk may turn into an issue should it eventuate after being identified.
- An issue is an event that has already taken place and is required to be dealt with in real time. An issue could be described as an unforeseeable event that occurs and affects the deliverables of the Project

Categorising the Risk



Theft, Fraud & Crime



Political

Environmental Management / climate change

Asset Management (Property & Infrastructure)

Risk Hazard Management Plan – Phase 1 – Design and Construction

Risk Hazard Management Plan – People's Place Lagoon – Phase 1 Sunshine Coast. COUNCIL Natural Catastrophes and Disasters - Business Continuity Technology (IT infrastructure and Cyber)

Compliance

Ineffective Governance



Service Delivery

Risk Evaluation

Risk evaluation involves assessing the risks and determining which risks are granted priority for treatment.

The prioritisation is based on the risk rating which is a function of the likelihood and consequence of the risk. The least acceptable risks would no doubt attract the highest priorities. The risk rating is determined using the Risk Assessment Calculators noted in councils Risk Management Manual.

The risk rating determined by the Project Team is the inherent risk rating – that is, the risk rating score in the absence of controls.

The Project Sponsor will set the risk tolerance for People Place Lagoon project based on the information provided by the Project Team as the project progresses.

Risk Treatment

After evaluating a risk, the Project Team undertake a risk treatment process to select and implement measures to modify the risk.

This process involves:

- Accepting the risk for various reasons including the possibility of the cost of the treatment being considerably higher than the potential result of the risk or benefit of accepting the risk outweighing the likelihood of damage.
- Risk sharing or transferring the risk through insurance or outsourcing of the activity.
- Avoiding the risk completely by stopping the activity or making the decision that the activity carries for too much risk to perform.

In cases where risks are identified for necessary works, the Project Team will implement a mitigation strategy and controls to reduce the likelihood and/or consequence of the risk occurring. The mitigation strategy and controls are noted in the People's Place risk register and used in the determination of the residual risk rating.

Risk Control and Risk Mitigation

Risk control actions implemented in the Project Team are taken to eliminate, prevent or reduce the occurrence of an identified risk.

Controls include any policy, procedure, practice, process, technology, technique, method, or device that modifies or manages the risk. Risk treatments become controls or modify existing controls once they have been implemented and put into practice.

Examples of this are:

• The correct use of a maintenance procedure reduces the likelihood of failure; and

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• The implementation of budget guideline procedures decrease the likelihood of budget blow outs and inflations.

Risk mitigation action(s) within the project are taken to reduce or increase the impact or consequence of a risk. By adopting risk mitigation measures, the project aims to reduce (risk treat or hazard) or increase (risk opportunity) the effect once a risk event has occurred.

Risk Tolerance and Appetite

Council strives to understand, meet and appropriately balance the expectations of all its stakeholders to ensure the achievement of business strategies, outcomes and goals to deliver value for the community and a sustainable environment to meet the long-term plan.

The set of levels and their definitions below has been used effectively across multiple Councils and provides a robust basis for a Risk Appetite discussion. See Appendix 2 for councils set tolerance levels.

Appetite level	Meaning	Description
Avoid	Little to no appetite	Avoidance of adverse exposure to risks even when potential outcome benefits are higher
Averse	Small appetite	A general preference for safer options with only small amounts of adverse exposure
Accept	Medium appetite	Options selected based on outcome delivery with reasonable a degree of protection
Receptive	Larger appetite	Engagement with risks is based more on outcome benefits than potential exposure

Figure 5. Risk Appetite – JLT Consulting's Position and Methods

Risk Monitoring

The Project Team monitor its overall risk exposure and report on the effectiveness of controls when required unless in the circumstances of an unforeseeable event occurring before a report has been requested. The People's Place Risk Register is a living document that requires regular monitoring and review. Effective risk monitoring provides confidence that the operational needs of Council are being met, including objectives and deliverables.

Legal Framework and Regulatory Compliance

Legal Liability Risks

Risks associated with this project exist within a comparatively complex legal framework in Queensland and this framework extends significantly beyond the concepts of legal liability and duties of care. Council and the Project Team will be in a better position to manage legal liability associated with risks if the duties that are owed and the standard of care that is required having regard to the circumstances and facts of a situation are easily explained. Some significant duties relevant to the conduct of the project in general include the common law duty of care (noting a strong interrelationship between the common law and the Civil Liability Act 2003 (Qld)) and health and safety duties under the Work Health and Safety Act 2011 (Qld) (WHS Act).

This legal framework has implications in a number of contexts, including:

- Council as a regulated entity (particularly related to the requirement to workplace health and safety); and
- More generally, Council (including the Project Team) as an entity undertaking the provision of services at People's Place.

Ensuring Regulatory Compliance

The operation of a lagoon is subject to significant levels of regulation.

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Risk Hazard Management Plan – People's Place Lagoon – Phase 1

The Project Team are committed to meeting its legislative and regulatory obligations to ensure a safe work environment for all patrons and staff.

This is demonstrated by:

COUNCIL

- Ensuring facilities or equipment are suitable for the intended use and purpose;
- Providing information about safety features and systems and instructions on their use;
- Ensuring facilities or equipment have the appropriate signage;
- Ensuring employees hold appropriate licences, certificates or competencies as relevant to their roles and responsibilities;
- Work scheduling that considers facility use;
- Providing appropriate monitoring and supervision;
- Implementing and maintaining appropriate reporting and record keeping systems, procedures and processes for work; and
- Ensuring equipment is inspected and maintained in accordance with manufacturer and design specifications and relevant operating standards.

It is important to recognise that obligations exist for employees within People's Place. These include or can be demonstrated by:

- Taking reasonable care of their own health and safety or the health and safety of others;
- · Complying so far as reasonably possible with reasonable instructions given by management;
- Following or complying with reasonable policies and procedures relating to health and safety at the workplace that have been notified;
- Holding necessary licenses, certificates or competencies for equipment or plant being used in the course of performing roles;
- Carrying out specified routine facility, plant or equipment checks in accordance with relevant policies, procedures and processes; and
- Reporting risks, incidents or accidents in accordance with the law or Council policies.

Workplace Health & Safety

The WHS Act imposes a number of obligations on the project in the provision of its operations. Obligations are imposed on persons conducting a business or undertaking (PCBU) to ensure that the health and safety of workers and other persons are not put at risk from work that is being carried out.

Council is a PCBU for the purposes of the WHS Act and this includes services associated with lagoon facilities.

Section 19 of the WHS Act imposes a duty on Council to ensure the health and safety of workers at work in the business or undertaking and that the health and safety of other persons is not put at risk from the business or undertaking, as far as reasonably practicable.

Relevantly and specifically for the Project Team, this includes:

- Providing and maintaining a work environment without risks to health and safety;
- · Providing and maintaining safe buildings, structures and plant;
- · Providing and maintaining safe systems and practices of work;
- Ensuring the safe use, storage and transport of plant, structures, materials and substances;
- Providing information, instruction, training and supervision to relevant staff; and
- Monitoring staff health and workplace conditions.

In the context of this People's Place, practical measures may include:

- Swimming pool barriers locked at night to prevent unauthorised and unsupervised access to the site;
 - Compliance with Guidelines for Safe Pool Operations including:
 - Direct supervision

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- A Supervision Plan tailored to People's Place
- Appropriate lifeguard qualifications
- · Appropriate rescue and emergency response equipment
- Appropriate lighting
- · Appropriate water safety signage in compliance with GSPO
- Appropriate minimisation of line-of-sight barriers and management of line-of-sight barriers
- An appropriate Emergency Response Plan and associated activities (training, planning, committee, evacuation demonstrations) as outlined in GSPO Emergency Planning.

Phase 1 Design and Construction Risk Assessment

Consultation

This phase of the risk identification is based on the research and reports that have been performed by councils specialist advisors, Liquid Blu. Liquid Blu are specialist architects for aquatic environments in Australia who are nationally renowned for their expertise is the construction of aquatic facilities. They have worked with over 25 councils across Australia assisting with the design and construct of various recreational water facilities. Their range of expertise includes design for splash parks, surf aquatics, lagoons, aquatic centres and sporting facilities. Below are a few examples of the designs that Liquid Blu have created:



Image 1 - Darwin Waterfront Master Plan and Aquatic Precinct



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Sunshine Coast Regional Council

Image 2 – Gympie ARC



Image 3 - Yeppoon Foreshore Revitalisation Project



Image 4 – Pimpama Sports Hub

Liquid Blu Risk Identification

Within the reports Liquid Blue have provided to Council, they have identified four areas of key risks that relate to the development of the wider People's Place Lagoon Project. These key risk areas are:

- Design and Environment
- Engineering and Materials
- Social & Political
- Economic and Operations

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- Lagoon demands exceed filter and sanitation capacities, resulting in retroactive strategies to control bather loads. As the design progresses, it fails to consider future facility
- The final shading strategy is inadequate, results in long term public health risks.
- Poor integration and balance with wider site elements
 results in use conflicts.
- Large areas of parkland are disproportionate to the ultimate population, resulting in underutilised facilities.
- Large, dense areas of vegetation could create result in opportunities for criminal activity.
- Design fails to meet operational requirements (e.g lack of storage space or service vehicle access).
- Design fails to provide adequate facilities, resulting in an under serviced Precinct (e.g. lack of seating or BBQs). Design results in public discrimination (e.g. excessive use of terraced steps into the Lagoon).
- Design is not fully optimised, resulting in additional security, cleaning and lifeguarding requirements.
- The design does not meet the expectations/needs of all user groups, resulting in under serviced populations.
- Public injury or death due to mis-design (e.g. blind spots, climbable ledges, or movement in pavements).
- Relationship of site elements results in user clashes (e.g. people short cutting through the Children's Waterplay)
- Mismatched design expectations between Council and the developer/design team.
- Absence of flexibility/responsiveness of the design team to allow for changes.
- Inappropriate selection of planting species or location results in additional maintenance/cleaning costs, as well as potential damage to sub-structure.
- Noise and artificial light is not appropriately attenuated, impacting the amenity of adjacent uses.
- New/emerging technologies do not operate as expected.
 CEPTD is not fully considered, increasing crime rates.

· Not all standards and/or guidelines are followed.

- Excessive site settlement results in damage to Lagoon structure and finishes (e.g. de-lamination or uncontrolled cracking).
- Incompatibility between structural and non-structural elements.
- Premature failure of finishes as a result of UV exposure, chemicals, accelerated wear or inadequate design/ construction methods.
- Filtration and other plant equipment is undersized and without enough redundancy, resulting in partial or full closure of the Lagoon.
- Pipe run distances are excessive, creating inefficiencies in the design.
- Unknown bedrock depths or water table results in additional construction costs.
- Complex design (e.g. excessive use of curves) results in complex construction methods, increasing risk of failure.
- Mismanagement or pool design of the site stormwater strategy and drainage results in increased sediments and nutrient loads in the Lagoon.
- nutrient loads in the Lagoon. Under-suppoyl of car parking may over-stress adjacent uses. Further, lack of public transport routes (particularly during early phases) may result in an underutilised facility. Under supply of infrastructure results in higher than expected power, water, and waste demands.
- Inadequate sub-surface drainage system results in excessive pressures on structure.
- Non-durable, high maintenance materials specified.

- Unequal sharing of project risks between the developer and Council, resulting in long term funding and operational issues.
- Lack of communication and/or reluctance of parties to share intellectual property.
- Acceptance of inadequate design resulting from a lack of due diligence during all stages of development.
- Population growth of the Greater Caloundra South PDA does not meet projections.
- Risk of political interference/conflicts, changes to policy and/or government, and approval delays.
- Limited Australian tier one contractors able to complete works.
- If the Precinct is unable to be fully delivered, the community would remain without a desirable asset.

- Lack of funding for capital maintenance, renewal, and operations due to inaccuracies in sinking fund model.
- Unforeseen external economic forces and general rise of 'uninsurable risks' such as the pandemic or climate change undermine project delivery.
- Long term mismanagement of facility elements results in unnecessary dilapidation.
- Lack of routine inspections results in Lagoon shut downs during peak season (e.g. structural or pipework inspections).
- Mismanaged lagoon drainage (e.g. for extensive periods) results in material and/or structural failure.
- Ongoing supply chain issues results in further price escalations of building materials and labour, causing project delays and/or inflated costs.
- Scope creep and cost overruns due to project scale and complexity.
- Project is not correctly staged, resulting in untimely delivery of community assets.
- Further investigations or latent conditions render the project infeasible.
- Level of service scope is not appropriately defined and does not capture all on-going operational requirements (e.g. security, cleaning, and lifeguarding level of service).
- Appropriate misk management plans are not implemented, increasing public facility risk (e.g. mis-management of lifeguarding).

Figure 6 Liquid Blu High Level Risk Assessment

The above identified risks will form the basis for the initial risk assessment we will carry out to identify the risks we feel are the ones that will have the most impact on the Project. We will be using the risk analysis framework that has been described throughout this Manual to perform this analysis.

- 1. Identify any further risks that the project team feel could impact on the Project that are not in the Liquid Blu reports:
- 2. Assess the risks, based on the likelihood of the hazard causing harm and the consequence of that harm. In this assessment the project team may find that some of the risks that have been identified are so low that we will not be assessing them further. Our aim is to identify the highest rated risks and concentrate on mitigating those:
- 3. Implement suitable control measures based on what is reasonably practicable for council, with the aim of choosing the greatest level of protection and reliability available.
- Monitor controls regularly to make sure they are functional, well maintained and remain the most 4. appropriate option. This process includes monitoring control measures and identifying any changes that may need to be made to improve their overall effectiveness. As we progress through the project some controls will no longer be needed while new controls will be put into place.

Risk Hazard Management Plan - Phase 1 - Design and Construction

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Insurance Requirements

As with undertaking any local government activity or function, it is critically important that appropriate and sufficient coverage for liability, professional indemnity, assets and property, workers compensation and other related risks in relation to the People's Place project. With this in mind, the Project Team have provided councils insurance provider (LGM) with regular updates on the project. The Team has also used the recommended Guides that were provided by LGM to assist with the governance of the project.

Best practice indicates a risk assessment is undertaken to determine appropriate types of cover, arrangements, contractor insurance, liability limits, and coverage amounts. When undertaking a risk assessment, the Project Team considers the potential risks associated with a project to try to determine what kinds of problems could arise and the consequences of those problems. In other words, determining the extent of any liability cap or minimum sum insured will depend on the level of exposure, the nature of the site, works or the activities being performed, any related contracting issues and the activity to be performed, or the goods supplied under contract.

When undertaking a risk assessment, it is recommended that assessments are conducted in consultation with the Corporate Risk & Insurance Team and completed in accordance with Australian Standard AS ISO 31000:2018 Risk management - Guidelines (Australian Standard) (the Standard).

Such insurable losses where Council may be eligible to receive cover under councils Insurance Policies for categories of financial loss may include:

- Reinstatement of Council assets;
- Business interruption expenses;
- Financial loss sustained as the result of a criminal act, including cybercrime or data breach;
- Increased costs of working to maintain normal operations; and
- Reduction in gross revenue.

As with all insurance policies, cover will be subject to meeting the relevant policies terms and conditions which may impose exclusions or limits for certain situations.

It is therefore essential that any potential insurance claims relating to the above examples are coordinated and prepared in accordance with the applicable wording and in collaboration with the relevant insurer.

To ensure Council does not conduct itself in a manner which may prejudice cover, all situations which involve a potential insurable loss must in the first instance be promptly notified to the Coordinator Risk & Insurance, Shari Fisher and the insurance mailbox, <u>insurance@sunshinecoast.gld.gov.au</u> as soon as practicable after the loss is discovered.

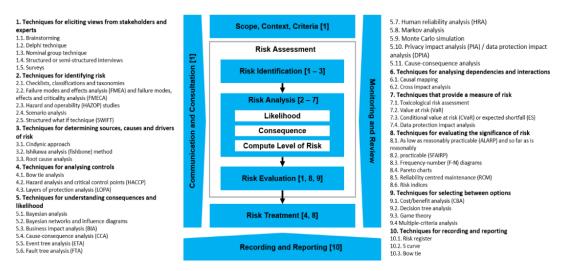
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Appendix

Appendix 1: ISO 31010 Risk Assessment Tool

Some of the techniques described in the standard can be applied during activities of the ISO risk management process in addition to their usage in risk assessment. Application of the techniques to the risk management process is illustrated in the figure below.



ISO 31010 Risk assessment

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Appendix 2: Risk Assessment Calculators

Risk Ratings are applied in accordance with councils Corporate Risk Management risk matrix to indicate to management the level of attention that is required to reduce the probability and/or impact of a risk

Risk Rating	Strategy Category
Major	Immediate detailed planning and action required at senior levels to determine how to reduce the risk and regular monitoring of progress by senior management.
Moderate	Senior management attention and monitoring of progress with risk management action is required.
Minor	Management responsibility to be specified, monitor and review response action as necessary.
Low	Manage through existing processes and procedures.

In determining the Risk Rating for a risk, it is important to consider:

- 1. The impact of the event which is not covered by existing controls, and
- 2. The probability / likelihood of the event occurring.

Ge	neric calculator			Consequence		
		Insignificant	Minor	Moderate	Major	Catastrophic
	GENERAL	None to minimal impact or inconvenience, managed by routine procedures	Inconvenience to a group in one sector or locally within the SCRC region, short term effect, managed by altered operational routine	Disruption to a number of operational areas within a location or region, managed by directors & senior officers	All or most operational areas of a location or region compromised, other locations may be affected, long term effects, managed by CEO & senior management	Total system dysfunction & shut down of operations, extensive long term impacts, state/federal gov't intervention & oversight
	Almost Certain is expected to occur at most times (e.g several times a year	M-28	M-40	H-60	E-88	E-100
L i k	Likely will probably occur at most times (e.g. about once or twice per year)	L-16	M-36	H-56	E-84	E-96
e I i h o	Possible might occur at some time (eg once every 2 to 5 years)	L-12	M-32	M-52	H-72	E-92
o d	Unlikely could occur at some time (e.g once every 5 to 15 years)	L-8	L-24	M-48	H-68	H-80
	Rare may occur in rare circumstances (e.g. unlikely during the next 15 years)	L-4	L-20	M-44	H-64	H-76

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Fina	ancial calculator			Consequence		
		Insignificant	Minor	Moderate	Major	Catastrophic
	Financial		Corporate Focus: Low to Medium \$ loss (i.e. \$100K-\$1M) Economic: Inconvenience to a group of businesses in one sector or locally within the SCC region	Corporate Focus: Medium to High \$ loss (i.e. \$1M-\$10M) Economic: Group of businesses in one sector or locally within the SCC region put at risk	Corporate Focus: Major \$ loss (i.e. \$10M-\$25M) Economic: A minor industry or whole sector of the SCC region put at risk	Corporate Focus: Huge \$ loss (i.e. >\$25M) Economic: One or more major industries (eg Tourism, Agriculture, Education, Construction, Manufacturing, Retail, Fishing) within the SCC region threatened
	Almost Certain is expected to occur at most times (e.g several times a year)	M-28	M-40	H-60	E-88	E-100
L i k	Likely will probably occur at most times (e.g about once or twice per year)	L-16	M-36	H-56	E-84	E-96
e I i h	Possible might occur at some time (e.g once every 2 to 5 years)	L-12	M-32	M-52	H-72	E-92
o o d	Unlikely could occur at some time (e.g once every 5 to 15 years)	L-8	L-24	M-48	H-68	H-80
	Rare may occur in rare circumstances (e.g. unlikely during the next 15 years)	L-4	L-20	M-44	H-64	H-76

Compliance calculator		Consequence						
		Insignificant	Minor	Moderate	Major	Catastrophic		
C	Compliance	None or minimal breaches of contractual or legislative obligations	Breach of contractual or legislative obligations identified – request to comply but no fine imposed	Significant breach of contractual or legislative obligations leading to imposed fine		Complete contractual failure or massive legislative breach leading to large fines and possible imprisonment for council's elected members and/or officers		
L	Almost Certain is expected to occur at most times (e.g several times a year	M-28	M-40	H-60	E-88	E-100		
i k e	Likely will probably occur at most times (e.g. about once or twice per year)	L-16	M-36	H-56	E-84	E-96		
l i	Possible might occur at some time (e.g once every 2 to 5 years)	L-12	M-32	M-52	H-72	E-92		
h o d	Unlikely could occur at some time (e.g once every 5 to 15 years)	L-8	L-24	M-48	H-68	H-80		
	Rare may occur in rare circumstances (e.g. unlikely during the next 15 years)	L-4	L-20	M-44	H-64	H-76		

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Service Delivery calculator		Consequence					
		Insignificant	Minor	Moderate	Major	Catastrophic	
S	ervice Delivery	Business: None or minimal disruption to business activities Assets: None or minimal impact on assets. Maybe dealt with routine maintenance Operational: No loss of capability or negative disruption to service levels	Business: Minor disruption to business activities Assetts: Minor impact on assets managed with minimal efforts. Some restrictions in capability Operational: toss of capability in some areas and some disruption to service levels	Business: Moderate to significant to business activities Assetts Some impact on assets managed with programmed response. Isolated loss of capability Operational: Serious loss of capability cover 1 week and disruption to service levels	Business: Major disruption to business activities Assetts: Major impact on assets requiring a programmed repair/ repiacement response. Limited capability Operational: Serious loss of capability for over 2 weeks and major disruption to service levels	Business: Extensive severe disruption to business activitie and essentia services across ti Sunshine Coast Assets: Extensive impact on ass requiring a massive (total) replacement or complete reconstruction of an asset. Tota loss of capability Operational: Serious loss of capability for over 4 weeks and service levels	
L i k e l h o d	Almost Certain is expected to occur at most times (e.g several times a year	M-28	M-40	H-60	E-88	E-100	
	Likely will probably occur at most times (e.g about once or twice per year)	L-16	M-36	H-56	E-84	E-96	
	Possible might occur at some time (e.g once every 2 to 5 years)	L-12	M-32	M-52	H-72	E-92	
	Unlikely could occur at some time (e.g once every 5 to 15 years)	L-8	L-24	M-48	H-68	H-80	
	Rare may occur in rare circumstances (e.g unlikely during the next 15 years)	L-4	L-20	M-44	H-64	H-76	

Repu	tation calculator	Consequence					
nepu		Insignificant	Minor	Moderate	Major	Catastrophic	
F	Reputation	Community: None to minimal complaints about project – primarily acceptance & approval Political: Concerns expressed but not acted upon Media: Negative regional multi- media coverage for up to 2 days	Community: Some inconvenience to community Political: Little impact beyond individual Councillor Media: Negative multi-media nation wide coverage for 2 days	Community: Considerable disruption or inconvenience to sectors of the community and negative press coverage Political: Strained relations at Councillor level. No change to normal democratic process. Internal Councillor disharmony Media: Negative multi-media nation wide coverage for several days	Community: Public protestation and dislocation. Potential for significant psychological or physical harm to sectors of the community, damage to relationships and loss of support Political: High levels of dysfunctional operations at Councillor level. Fragmented, divisive and indecisive decision making. Loss of an elected member Media: Negative multi-media nation- vide coverage for up to 2 weeks	Community / Social: Major Civil commotion and riot Political: Loss of multiple elected members from office - CCC investigation. Severed relationship with other partners and agencies Wedia: Negative multi-media nation wide and or international coverage for 2 weeks+	
	Almost Certain is expected to occur at most times (e.g several times a year	M-28	M-40	H-60	E-88	E-100	
i k	Likely will probably occur at most times (e.g about once or twice per year)	L-16	M-36	H-56	E-84	E-96	
e I i	Possible might occur at some time (e.g once every 2 to 5 years)	L-12	M-32	M-52	H-72	E-92	
h o d	Unlikely could occur at some time (e.g once every 5 to 15 years)	L-8	L-24	M-48	H-68	H-80	
	Rare may occur in rare circumstances (e.g. unlikely during the next 15 years)	L-4	L-20	M-44	H-64	H-76	

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Natura	I Environment calculator			Consequence		
		Insignificant	Minor	Moderate	Major	Catastrophic
Natural Environment		Localised short term reversible damage to aquatic and/or terrestrial ecosystems. No noticeable species reduction None or minimal impact on the environment and/or preferred elements of place	Localised minor reversible damage to aquatic and/or terrestrial ecosystems. Temporary reduction in one species Consequences can be readily absorbed but management effort is still required to minimise impacts. Minor impact on preferred elements of place	reduction in one or more species Significant event which can be managed under normal procedures. Significant impact on some	Widespread, long-term reversible or local irreversible, damage to aquatic and/or terrestrial ecosystems. Significant reduction in one or more species or permanent loss of one or more species Critical event that, with proper management, will be endured. Critical impacts on multiple preferred elements of place	aquatic and/ or terrestrial ecosystems. Permanent loss of
	Almost Certain is expected to occur at most times (e.g several times a year	M-28	M-40	H-60	E-88	E-100
L i k e l i h o o d	Likely will probably occur at most times (e.g about once or twice per year)	L-16	M-36	H-56	E-84	E-96
	Possible might occur at some time (eg once every 2 to 5 years)	L-12	M-32	M-52	H-72	E-92
	Unlikely could occur at some time (eg once every S to 15 years)	L-8	L-24	M-48	H-68	H-80
	Rare may occur in rare circumstances (e.g. unlikely during the next 15 years)	L-4	L-20	M-44	H-64	H-76

WHS calculator		Consequence					
		Insignificant	Minor	Moderate	Major	Catastrophic	
WHS			Minor injuries resulting in first aid treatment only	treatment required	employee, contractor or Sunshine	Life threatening injuries or death to multiple employees, contractors or Sunshine Coast Residents from Council activities	
	Almost Certain is expected to occur at most times (e.g several times a year	M-28	M-40	H-60	E-88	E-100	
i k	Likely will probably occur at most times (e.g about once or twice per year)	L-16	M-36	H-56	E-84	E-96	
e I i	Possible might occur at some time (e.g. once every 2 to 5 years)	L-12	M-32	M-52	H-72	E-92	
h o d	Unlikely could occur at some time (e.g once every 5 to 15 years)	L-8	L-24	M-48	H-68	H-80	
	Rare may occur in rare circumstances (e.g. unlikely during the next 15 years)	L-4	L-20	M-44	H-64	H-76	

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