Metocean Data Provision - Location Nearshore Disaster Bay, NSW.

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Contents

1 Introduction

1.1 Background and Location of Interest

BMT have been commissioned by AusKelp to undertake an initial desktop assessment of coastal processes in Disaster Bay to provide baseline metocean data required to address several components of Item 5 (*Coastal Processes and Suitability of Infrastructure)* of the Planning Secretary's Environmental Assessment Requirements (SEARs).

The Location of Interest (LOI) in this desktop study is in Disaster Bay, near the southern border of New South Wales (NSW). The proposed Eden 1 Marine Seaweed Aquaculture Lease is a 200-hectare region inside Disaster Bay that reaches a maximum depth of approximately 25 m (see Figure 1.1).

Table 1.1 Location of Interest (LOI)

Location	Longitude	Latitude	Depth (m)
Proposed Disaster Bay Lease Site	153°15'0.00"E	27°15'0.00"S	25m

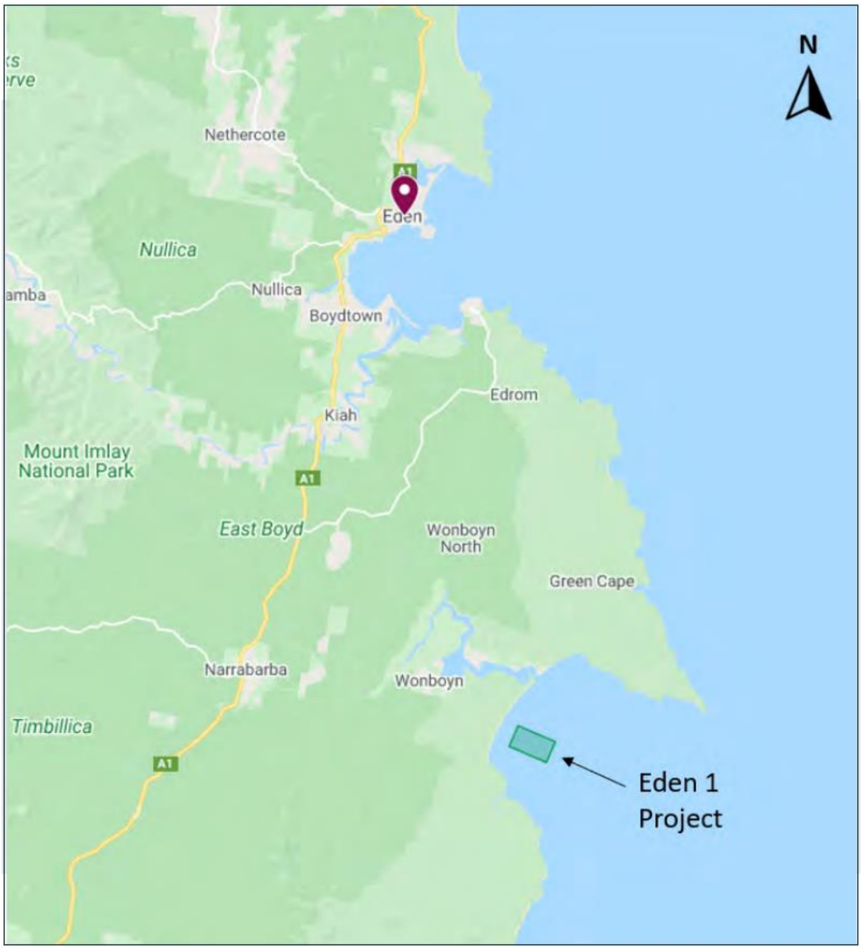

Figure 1.1 Proposed location of the Eden 1 Project (Source: *AusKelp (2022) Scoping Report Ver 2.5*)

1.2 Compliance and Fitness for Purpose

The data provided by BMT will be suitable for use in support of:

Preliminary Design and Environmental Assessments

Wherever possible, the data and methods proposed in this study shall comply with the relevant standards and guidelines (e.g., ISO 19901-1, the ISO standard governing metocean activities for the offshore industry).

Where the work proposed is to be applied for purposes other than those stated above, it is the responsibility of the user to check whether the approach is appropriate for those purposes. Although always important, this is particularly relevant where human safety may be at stake, large investments depend on the data or potential environmental impacts could result. Further information on the data validation processes can be found elsewhere in this proposal. BMT will be happy to advise the client on whether the work proposed is suitable for a particular application or on how it can be made so.

1.3 Frame and References

1.3.1 General conventions

Units are expressed using the SI (Système International d'unités) convention unless otherwise stated.

Wave and Wind direction is expressed as 'FROM' which the wind and waves are approaching (meteorological convention) and in nautical degrees, i.e., degrees relative to true north (°T), positive clockwise, e.g., direction of 45º represents wind or wave FROM the northeast.

1.3.2 Definition and Notations

Wave Terms	
Significant Wave Height, **Hs (H_{m0})**	Is a purely statistical term, like the average or mean, that describes a sea state (or roughness of the sea) associated with a given sample duration (typically 3 hours). Unlike the mean it has a distinct positive bias and historically this term was approximated to the mean height of the highest one third of the individual (real observable) waves. The significant wave height is nowadays determined from the 'zeroth' spectral moment as $H_{m0} = 4.(m_0)^{0.5}$. The term Hs used throughout this report refers to this spectral definition.
Mean Wave Direction, **Hsd**	Mean wave direction of total wave spectrum (degrees clockwise from True North – direction **FROM**).
Spectral Mean Wave Period, **Tm (T_{m01})**	The spectral mean wave period is estimated from the 'zeroth' and first spectral moments as $T_{m01} = (m_0/m_1)^{0.5}$.
Spectral Peak Wave Period, **Tp**	The wave period associated with the peak in wave spectral energy. Derived as the reciprocal of the frequency associated with the peak energy of the wave spectrum.

Current Terms	
Residual Current	Refers to currents that are related to any non-tidal phenomena, for example wind-driven currents.
Tidal Current	Currents caused as a result of astronomical tides.
Total Current Speed, **w**	Current speed of considering the combination of residual and tidal current.

Water Level Terms	
Residual water-levels	Meteorological and baroclinic contribution to sea level.
Tidal water-levels	Astronomical tidal component of the water level.
Total water-level, **H**	Total water-level considering both residual and tidal contributions.

2 Data Sources

2.1 Waves

2.1.1 BMT Hindcast Waves

BMT runs a series of third-generation wave prediction models based on the WaveWatch III ™ (WW III) code on a global grid and several regional grids, for hindcast and forecast purposes.

WaveWatch III is a third-generation wave model developed at NOAA/NCEP in the spirit of the WAM model (Komen, Hasselmann, & Hasselmann, 1984). It is a further development of the model WW I, as developed at Delft University of Technology (Tolman 1989, 1991) and WW II, developed at NASA, Goddard Space Flight Center (e.g., Tolman 1992). WWIII however, differs from its predecessors in many important points such as the governing equations, the model structure, the numerical methods and the physical parameterisations. The model is written in ANSI standard FORTRAN 90; it is fully modular and uses dynamic memory allocation. For a generic validation of the model, see the document (Tolman H. L., Testing of WAVEWATCH III version 2.22 in NCEP's NWW3 ocean wave model suite, 2002).

In this investigation we have used the latest version of BMT's global hindcast (v361). This hindcast has a spatial resolution of 0.25º and covers the time period January 1979 to October 2018 at a temporal resolution of 3 hours. The latest version of the model is driven entirely by the most up to date Climate Forecast System Reanalysis (CFSR) wind fields. The output locations for the BMT wave model are displayed in Figure 3.1.

2.1.2 In-Situ Wave Data

Manly Hydraulics Laboratory maintains a series of Waverider buoys in NSW coastal waters. Data from the Eden Waverider Buoy was used in the study to provide in-situ wave measurements for calibration/validation of the SWRT model. The Eden Waverider Buoy is located at approximately 150°11'36.00"E and 37°15'57.00"S (see Figure 3.1).

2.2 BMT Tidal Model

The global tidal information is based on the integration of approximately 5000 tidal stations and 17 years of satellite radar altimeter measurements into depth average global and regional tidal models (2DH model). The Australasian tidal model has a resolution of approximately 1/15 degrees. The tidal model provides tidal current harmonics (u, v components) as well as harmonics of surface elevation, from which predicted time series of levels and currents can be generated. The model includes the M2, S2, N2, K2, K1, O1, P1 and Q1 harmonic constituents, from which 12 more minor constituents are inferred.

2.3 Bluelink Reanalysis (Ocean Currents and Water-levels)

The Bluelink ReANalysis (BRAN) is a near-global ocean general circulation model produced by CSIRO and BoM. The model includes a data assimilation process to incorporate historical ocean observations in order to reduce model bias. BRAN aims to provide a realistic quantitative description of ocean circulation of key physical variables (i.e., temperature, salinity, sea-level and velocity) in four dimensions (spatially throughout the water-column and in time). A technical description of the model and validation is provided by Chamberlain et al., (2021).

3 Key Methodologies

3.1 General Approach

BMT maintains a 38-year (1979-2018) global wave hindcast at approximate ~25km resolution (and accompanying wind hindcast) suitable for developing offshore wave criteria. Data has been extracted from this database for use in this project.

Figure 3.1 shows the LOI at Disaster Bay, NSW. Spectral Wave Ray Tracing (SWRT) has been undertaken to transform deep offshore waves to the LOI in shallow waters. BMT's wave and wind hindcast has been used to supply boundary conditions the SWRT model.

The nearshore wave results have been calibrated against in-situ wave measurements from the Eden Waverider Buoy), which is located in approximately 100m of water depth offshore of Disaster Bay (also shown in Figure 3.1).

Representative current speed and water-levels has been derived based on the Bluelink ReANalysis (BRAN) ocean model (residual / ocean water-levels and currents) and BMT's global tide model (tidal water-levels and currents).

Full details on the data sources used in this project are provided in Section 2.

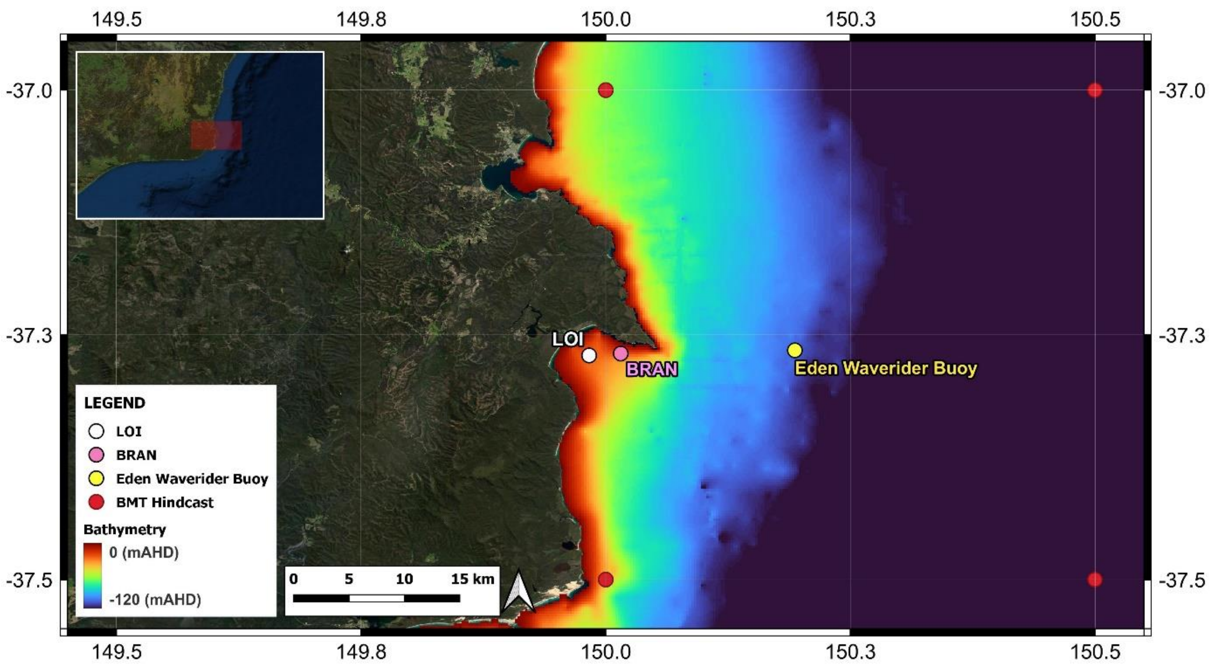

Figure 3.1 BMT Hindcast output points and In-Situ (Buoy) measurement location relative to the Location of Interest (LOI), Disaster Bay, NSW.

3.2 Wave Downscale Modelling – Spectral Wave Ray Tracing ((SWRT)

BMT's Spectral Wave Ray Tracing (SWRT) model is a wave transformation model that allows downscaling wave conditions (higher resolution), typically applied to downscale from offshore to nearshore and or coastal condition. The wave transformation takes account of the following using the calibrated offshore hindcast at one or more grid points as boundary conditions:

- Sheltering of certain wave directions by islands and capes
- Refraction of waves by varying bathymetry
- Wave shoaling due to changing water depth
- Wave breaking at the nearshore location of interest due to the limited water depth or steepness of waves
- Fetch-limited growth.

The first step in the wave transformation is to calculate the wave trajectories from the offshore boundary to the nearshore location of interest. A wave ray is the trajectory in space followed by a wave packet with a particular frequency and initial propagation direction. It is determined by the spatial variation of depth and current. The present model only accounts for the effect of depth variation; the effect of current variation is ignored. A wave ray bends (‘wave refraction’) where there is a gradient in depth perpendicular to the wave direction, which causes a gradient in propagation speed along a wave crest.

Starting from the nearshore location, ray back-tracing is used to compute the wave rays for a discrete set of frequencies and nearshore propagation directions. The frequencies are the same as those of the wave hindcast model providing the offshore wave conditions, and the wave directions are on a regular grid of 2.5 degree spacing. An Ordinary Differential Equation (ODE) solver is used to solve the coupled equations for position and propagation direction backwards, while deriving the wave number magnitude from the local depth. The depth is determined from a realistic digital bathymetry of the region of interest of sufficient resolution, based on nautical charts. The ray curvature is limited by an uncertainty principle to prevent unrealistic directional variation (oscillations). The solver adapts its step length to guarantee sufficient accuracy.

When the wave rays are computed, the near shore spectra are calculated from the offshore spectra multiplied by weights determined from the Action Balance over the ray and reduced to satisfy the breaking criteria when necessary. For paths traced back to the shore, weights are set to zero and fetch-limited growth is estimated from the local wind to account for waves from these directions. Fetch-limited growth is also added for paths traced back to the seaward boundary. Where appropriate, this depends on the wind-sea component already present at a boundary point. Fetch-limited growth is computed using a growth curve and a JONSWAP spectral shape. Finally, the propagated and fetch-limited spectra are combined to form integrated wave spectrum. Therefore, using this downscale modelling, total, sea, and swell wave spectra are made available.

3.3 Extreme Value Analysis

BMT’s primary method of deriving extreme values is the ‘Exceedance Duration Analysis’ (EDA) method. This method is considered robust and is considered to offer many advantages over alternate methods. In ocean engineering, the Weibull distribution is commonly used as a model for the tails of distribution functions of wind speed, significant wave height and current speed, and of many variables like forces or accelerations derived from sea state or wind parameters.

Our choice of the Weibull distribution is based on earlier research for the Dutch government, which demonstrated that it leads to more stable (less variable) and less biased estimates than the Generalised Pareto distribution (GPD), normally associated with the Peak Over Threshold (POT) method.

By default, the BMT compound directional analyses, used to derive the omni-directional criteria, uses a modification of the approach set out by Forristall (2004). Forristall’s approach ensures that differences in severity between directions are accounted for while preserving the overall safety level provided by the omni-directional design criterion. For some sectors the directional extremes will exceed the omni-directional value, and this is perhaps the main reason why this statistically sound, but non-intuitive, technique has been partially but not been universally accepted within the metocean community. BMT have developed a method to address this apparent inconsistency that holds the principles of Forristall's method whilst ensuring consistency between maximum directional and omni-directional criteria.

3.4 Standard Operational Statistics

Standard operational (ambient) statistics were derived from interrogation of the validated hindcast datasets using BMT's established suite of MATLAB® based analyses tools.

4 Metocean Criteria

4.1 Waves

Operational and extreme wave criteria (refer to Section 3.3 and Section 3.4) have been developed based on spectral wave ray tracing model (SWRT) and BMT's Wave and Wind hindcast dataset (refer to Section 3.2 and Section 2, respectively).

The wave dataset used in this study has been calibrated and validated against measured wave data from the Eden Waverider Buoy, discussed in Annex A.

The wave climate of NSW is characterised by persistent moderate energy, with occasional large wave events due to coastal storm events. Offshore in deeper water (e.g., ~ 100m), the median significant wave height is around 1.5m (Shand et al., 2010), while inside Disaster Bay in shallow waters is predicted to be smaller at around 0.5 to 0.75m. At Disaster Bay, there is little seasonal variation in terms of wave heights, however wave period is noted to be on average higher during the winter months.

4.1.1 Operational Criteria

Table 4.1 Monthly probability distribution of significant wave height (Hs)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	All
5.25	**5.50**	0	0	0	0	0	0	0	0	0	0	0	0	**0**
5.00	**5.25**	0	0	0	0	0	0.010	0	0	0	0	0	0	**0.001**
4.75	**5.00**	0	0	0	0	0	0.010	0	0	0	0.010	0	0	**0.002**
4.50	**4.75**	0	0	0	0	0	0.021	0	0	0	0.021	0	0	**0.003**
4.25	**4.50**	0	0	0	0	0	0.042	0	0	0	0.010	0.021	0	**0.006**
4.00	**4.25**	0	0	0	0.010	0	0.042	0.071	0.020	0	0.031	0.011	0	**0.016**
3.75	**4.00**	0	0	0.010	0.052	0.081	0.063	0.151	0.010	0.052	0.072	0.011	0.010	**0.043**
3.50	**3.75**	0.010	0	0.040	0.063	0.091	0.167	0.111	0.010	0.021	0.083	0.075	0.021	**0.058**
3.25	**3.50**	0.102	0.033	0.030	0.219	0.101	0.094	0.252	0.081	0.031	0.155	0.192	0.041	**0.111**
3.00	**3.25**	0.081	0.100	0.061	0.208	0.182	0.354	0.423	0.232	0.052	0.124	0.203	0.145	**0.181**
2.75	**3.00**	0.122	0.066	0.121	0.313	0.161	0.771	0.383	0.383	0.146	0.217	0.192	0.228	**0.259**
2.50	**2.75**	0.132	0.089	0.444	0.625	0.383	1.313	0.726	0.474	0.344	0.341	0.321	0.207	**0.451**
2.25	**2.50**	0.244	0.653	0.776	0.833	0.554	1.542	1.028	0.927	0.719	0.548	0.641	0.279	**0.729**
2.00	**2.25**	0.507	1.073	1.341	1.375	1.371	2.146	2.198	1.220	1.500	0.941	1.079	0.651	**1.285**
1.75	**2.00**	1.035	1.914	2.540	2.302	2.389	3.021	2.692	2.319	1.792	0.982	1.378	1.034	**1.954**
1.50	**1.75**	2.121	3.197	3.538	4.167	3.952	4.167	3.730	3.105	2.688	1.602	2.586	2.089	**3.081**
1.25	**1.50**	4.819	6.648	5.655	5.708	5.827	6.229	5.998	4.294	4.260	3.649	4.252	4.539	**5.152**
1.00	**1.25**	9.304	11.294	9.184	10.604	9.718	9.344	8.589	8.065	7.698	7.206	7.361	6.493	**8.729**
0.75	**1.00**	18.101	19.038	19.184	16.917	16.079	15.885	14.264	12.903	12.896	13.346	15.021	15.736	**15.768**
0.50	**0.75**	43.466	37.987	38.932	32.646	29.083	26.229	26.623	29.123	34.063	37.465	38.857	44.489	**34.873**
0.25	**0.50**	19.673	17.788	17.903	22.625	27.067	25.531	28.589	32.561	30.802	31.397	26.977	23.439	**25.399**
0.00	**0.25**	0.284	0.122	0.242	1.333	2.964	3.021	4.173	4.274	2.938	1.799	0.823	0.600	**1.899**
		100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 4.2 All-Year percentage of occurrence of conditions in Hs interval (Rows) and Tp interval (Columns)

		0	2	4	6	8	10	12	14	16	18	20	22	24	Total
		2	4	6	8	10	12	14	16	18	20	22	24	26	
5.25	5.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5.00	5.25	0	0	0	0	0	0.001	0	0	0	0	0	0	0	0.001
4.75	5.00	0	0	0	0	0.001	0.001	0	0	0	0	0	0	0	0.002
4.50	4.75	0	0	0	0	0.002	0.002	0	0	0	0	0	0	0	0.003
4.25	4.50	0	0	0	0	0.006	0	0	0	0	0	0	0	0	0.006
4.00	4.25	0	0	0	0	0.008	0.008	0	0	0	0	0	0	0	0.016
3.75	4.00	0	0	0	0.001	0.022	0.021	0	0	0	0	0	0	0	0.043
3.50	3.75	0	0	0	0.003	0.032	0.022	0.002	0	0	0	0	0	0	0.058
3.25	3.50	0	0	0	0.009	0.068	0.034	0.001	0	0	0	0	0	0	0.111
3.00	3.25	0	0	0	0.031	0.102	0.046	0.003	0	0	0	0	0	0	0.181
2.75	3.00	0	0	0.001	0.059	0.125	0.063	0.010	0.001	0	0	0	0	0	0.259
2.50	2.75	0	0	0.007	0.115	0.174	0.134	0.019	0.001	0.002	0	0	0	0	0.451
2.25	2.50	0	0	0.028	0.223	0.298	0.140	0.037	0.002	0.002	0	0	0	0	0.729
2.00	2.25	0	0	0.126	0.352	0.520	0.205	0.059	0.020	0.003	0	0	0	0	1.285
1.75	2.00	0	0	0.234	0.474	0.831	0.296	0.088	0.026	0.006	0	0	0	0	1.954
1.50	1.75	0	0.008	0.515	0.818	1.188	0.358	0.126	0.037	0.030	0	0	0	0	3.081
1.25	1.50	0	0.026	0.868	1.492	1.788	0.564	0.251	0.104	0.059	0.001	0	0	0	5.152
1.00	1.25	0	0.213	1.173	2.518	2.806	1.148	0.497	0.242	0.124	0.008	0.001	0	0	8.729
0.75	1.00	0	1.788	1.563	3.884	4.506	2.251	0.886	0.495	0.367	0.021	0.008	0	0	15.768
0.50	0.75	0	7.422	2.149	7.526	9.136	4.782	1.761	1.068	0.879	0.136	0.014	0.002	0	34.873
0.25	0.50	1.172	3.679	1.593	4.591	6.711	3.698	1.359	0.956	1.135	0.417	0.085	0.003	0	25.399
0.00	0.25	0.171	0.010	0.072	0.176	0.579	0.387	0.197	0.091	0.145	0.064	0.007	0.002	0	1.899
Total		1.342	13.144	8.326	22.272	28.901	14.158	5.296	3.044	2.750	0.646	0.115	0.006	0	100.000

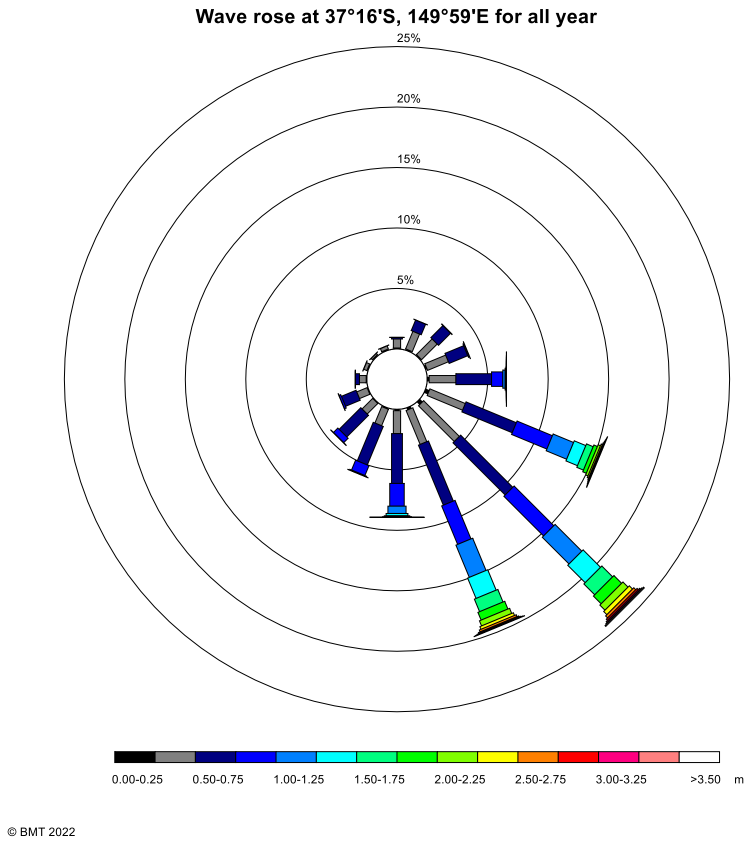

Figure 4.1 All-year Rose (Hs-Hsd)

4.1.2 Extreme Criteria

Extreme wave criteria have been developed based on the nearshore SWRT dataset, representative of an approximately 25m water-depth. The developed extreme omni-directional significant wave height is shown in Table 4.3 and associated peak and mean wave periods in Table 4.4 and Table 4.5 respectively.

For comparative purposes, Shand et al., (2010) developed extreme wave conditions based on data from the Eden Waverider Buoy, representative of deep-water wave extremes. This report presents a 1- and 100-year ARI extreme significant wave heights of 5.4m and 8.5m respectively.

Table 4.3 Extreme omni-directional significant wave height, Hs (m). Source: BMT Hindcast / SWRT

Hs (m)	Return Period (years)			
Percentile	1	10	50	100
Median	4.00	5.58	6.68	7.15

Table 4.4 Extreme omni-directional peak wave period, Tp (s). Source: BMT Hindcast / SWRT

Tp (s)	Return Period (years)			
Percentile	1	10	50	100
Median	9.16	10.81	11.82	12.22
10%	8.18	9.34	9.81	9.93
90%	10.38	12.54	14.19	15.04

Table 4.5 Extreme omni-directional mean wave period, Tm (s). Source: BMT Hindcast / SWRT

Tm (s)	Return Period (years)			
Percentile	1	10	50	100
Median	8.09	9.54	10.43	10.79
10%	7.28	8.30	8.70	8.81
90%	8.84	10.77	12.27	13.05

4.2 Currents

Total currents just offshore of Disaster Bay in approximately 30m of water-depth have been developed based on the following data sources:

- Tidal currents from BMT's Global Tide Model
- Residual / Ocean currents from CSIRO's BRAN2020

It is noted that the major component of total current at this location is the residual / ocean current, represented by CSIRO's BRAN2020, which shows maximum surface current speeds in excess of 1m/s, while tidal currents do not exceed 0.16m/s.

This total current timeseries is representative of currents offshore of Disaster Bay and are likely to be greater than speeds inside Disaster Bay at the proposed AusKelp development site. Estimation of local current speeds inside the bay requires the use of a hydrodynamic model to simulate the hydrodynamic processes inside and outside of the bay. Nonetheless, the total current speeds presented in this report provide a (likely) conservative indication of current speed to inform design.

This region is known to be influenced by the East Australia Current (EAC), a warm southward flowing boundary current that extends from Fraser Island in Queensland down to the East Coast of Tasmania. However, the BRAN dataset shows that currents may flow in either a northerly or southerly direction, hence suggesting that currents can be driven also by the occurrence of strong coastal weather systems (e.g., strong winds) and/or meso-scale eddies spinning off the EAC.

Occasional strong current events occur year-round with velocities in excess of 1 m/s. These events are also noted to be either northerly or southerly flowing.

4.2.1 Operational Criteria

Table 4.6 Monthly probability distribution of total current speed – near surface

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	All
1.8	**2.0**	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1.6	**1.8**	0	0	0	0	0	0	0	0.034	0	0	0	0	**0.003**
1.4	**1.6**	0	0	0.019	0.087	0	0	0.089	0.103	0.213	0	0.030	0.031	**0.048**
1.2	**1.4**	0	0.224	0.074	0.251	0.077	0.144	0.665	0.427	0.414	0.048	0.290	0.168	**0.232**
1.0	**1.2**	0.896	1.615	0.674	0.427	0.569	0.992	2.724	2.995	1.952	0.679	0.945	0.960	**1.287**
0.8	**1.0**	5.481	6.284	3.802	2.746	3.564	5.221	6.440	7.117	6.446	4.275	4.755	4.402	**5.036**
0.6	**0.8**	13.296	15.476	11.626	7.302	8.737	12.349	10.873	13.388	11.379	12.022	12.235	13.006	**11.786**
0.4	**0.6**	23.158	21.639	21.985	17.483	18.328	18.155	18.136	19.016	18.455	19.105	19.435	23.834	**19.888**
0.2	**0.4**	28.922	29.588	31.303	32.517	29.968	28.874	25.790	26.265	27.832	28.394	29.640	29.599	**29.047**
0.0	**0.2**	28.248	25.174	30.516	39.189	38.758	34.266	35.285	30.655	33.309	35.477	32.671	28.000	**32.674**
		100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 4.7 All-year percentage of occurrence of conditions in total current speed interval (Rows) and direction interval (Columns) – near surface

		345	15	45	75	105	135	165	195	225	255	285	315	Total
		15	45	75	105	135	165	195	225	255	285	315	345	
1.8	**2.0**	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1.6	**1.8**	0	0.003	0	0	0	0	0	0	0	0	0	0	**0.003**
1.4	**1.6**	0	0.036	0	0	0	0	0.002	0.010	0	0	0	0	**0.048**
1.2	**1.4**	0	0.171	0	0	0	0	0.030	0.031	0	0	0	0	**0.232**
1.0	**1.2**	0.001	0.880	0	0	0	0	0.220	0.186	0	0	0	0	**1.287**
0.8	**1.0**	0.036	2.909	0	0	0	0	1.189	0.901	0	0	0	0	**5.036**
0.6	**0.8**	0.460	5.420	0	0	0	0	3.518	2.388	0	0	0	0	**11.786**
0.4	**0.6**	2.056	7.035	0.012	0	0	0.002	6.353	4.424	0.006	0	0	0	**19.887**
0.2	**0.4**	4.468	7.995	0.253	0.018	0.027	0.380	8.164	7.276	0.333	0.012	0.010	0.110	**29.047**
0.0	**0.2**	4.643	5.336	2.023	1.164	1.191	2.236	5.193	5.184	2.024	1.019	0.981	1.680	**32.674**
Total		**11.665**	**29.785**	**2.288**	**1.182**	**1.218**	**2.618**	**24.668**	**20.400**	**2.364**	**1.032**	**0.991**	**1.790**	**100.000**

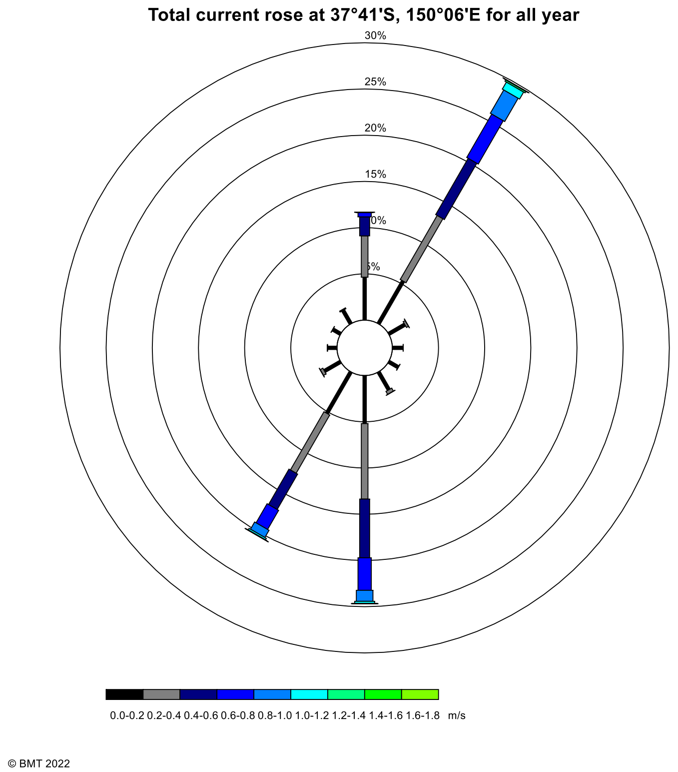

Figure 4.2 All-year total current speed rose – near surface

Table 4.8 Monthly probability distribution of total current speed – near seabed (approx. -30m)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	All
1.6	**1.8**	0	0	0	0	0	0	0	0	0	0	0	0	**0**
1.4	**1.6**	0	0	0	0	0	0	0	0.031	0	0	0	0	**0.003**
1.2	**1.4**	0	0	0	0.129	0	0	0.142	0.149	0.273	0	0.040	0.031	**0.064**
1.0	**1.2**	0	0.042	0.065	0.265	0.266	0.332	1.315	1.203	0.781	0.202	0.313	0.233	**0.422**
0.8	**1.0**	0.709	1.420	1.042	1.436	1.627	2.897	5.088	5.684	3.881	1.697	1.116	1.210	**2.329**
0.6	**0.8**	7.151	8.415	6.142	5.141	6.965	11.811	10.729	12.260	10.501	8.161	7.751	6.567	**8.467**
0.4	**0.6**	19.432	22.082	20.125	15.466	16.655	18.110	17.862	19.463	17.741	18.380	18.822	21.577	**18.797**
0.2	**0.4**	34.117	31.508	33.641	31.954	31.471	28.554	27.568	27.628	30.280	28.992	30.868	34.075	**30.879**
0.0	**0.2**	38.592	36.533	38.986	45.608	43.016	38.296	37.296	33.583	36.543	42.569	41.091	36.307	**39.040**
		100	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 4.9 All-year percentage of occurrence of conditions total current speed interval (Rows) and direction interval (Columns) – near seabed (approx. -30m)

		345	15	45	75	105	135	165	195	225	255	285	315	Total
		15	45	75	105	135	165	195	225	255	285	315	345	
1.6	1.8	0	0	0	0	0	0	0	0	0	0	0	0	0
1.4	1.6	0	0.003	0	0	0	0	0	0	0	0	0	0	0.003
1.2	1.4	0	0.050	0	0	0	0	0	0.013	0	0	0	0	0.064
1.0	1.2	0	0.375	0	0	0	0	0.020	0.028	0	0	0	0	0.422
0.8	1.0	0.015	1.911	0	0	0	0	0.055	0.347	0	0	0	0	2.329
0.6	0.8	0.233	5.044	0	0	0	0	0.504	2.686	0	0	0	0	8.467
0.4	0.6	1.358	7.884	0	0	0	0	2.825	6.731	0	0	0	0	18.797
0.2	0.4	3.205	10.728	0.142	0.003	0.002	0.051	7.312	9.366	0.071	0	0	0	30.879
0.0	0.2	5.029	8.017	2.401	1.147	1.159	1.935	7.660	7.647	1.596	0.679	0.646	1.124	39.040
Total		9.839	34.012	2.543	1.150	1.161	1.986	18.375	26.818	1.667	0.679	0.646	1.124	100.000

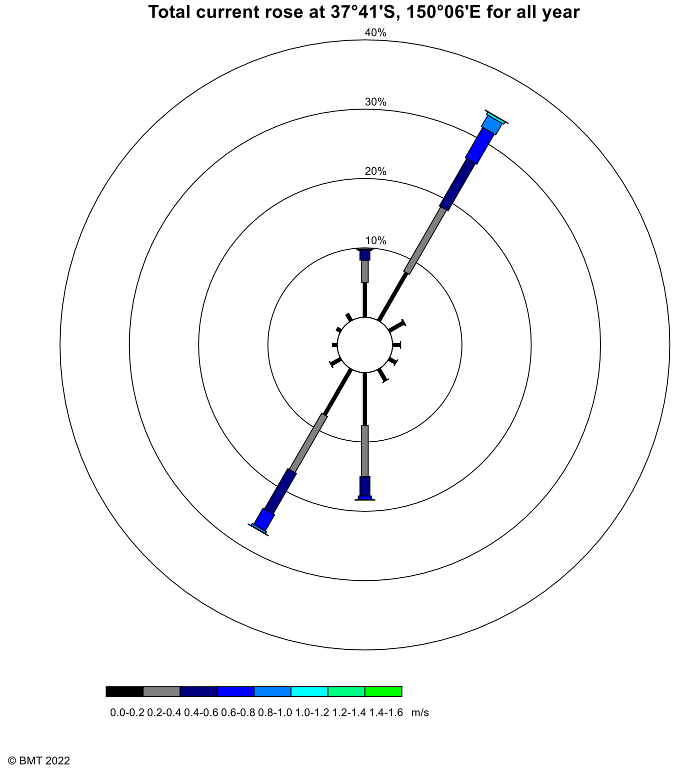

Figure 4.3 All-year total current speed rose – near seabed

4.2.2 Extreme Criteria

Table 4.10 Extreme omni-directional total current speed, W (m/s). Source: CSIRO BRAN2020 / BMT Tide Model

W (m/s)	Return Period (years)			
	1	10	50	100
Surface	1.27	1.54	1.71	1.77
Near-seabed	1.11	1.32	1.44	1.49

4.3 Water Levels

4.3.1 Operational criteria

Tidal water-level planes at the site in Disaster Bay are presented based on levels published by NSW OEH (2020) at the Eden Boat Harbour tide gauge.

Table 4.11 Tidal planes (m relative to AHD)

Tidal Plane	Level (m rel. AHD) *(2019-06 to 2020-06)*
Highest Astronomical Tide, HAT	*1.00 (1995-2014)*
Mean High Water Springs, MHWS	0.513
Mean High Water Neaps, MHWN	0.312
Mean Sea Level, MSL	-0.046 / *-0.08 (1995 – 2014)*
Mean Low Water Neaps, MLWN	-0.404
Mean Low Water Springs, MLWS	-0.605
Lowest Astronomical Tide, LAT	*-1.03 (1995-2014)*

4.3.2 Extreme criteria

Extreme water-levels have been developed based on two datasets:

- Residual water-levels from CSIRO's BRAN2020 Global Ocean Model Reanalysis and Tidal water-levels from BMT's Global Tide Model
- Daily maxima of tide + surge from Deltares' Global Tide Surge Reanalysis model.

These two datasets consider both tidal and residual water-levels, where residual includes the effects of seasonal variations, low atmospheric pressure, and wind setup.

MHL (2018) presents extreme water-levels at Eden based on locally deployed tide gauge. The extreme 20- and 100-year water-levels from this study at Eden are 1.25mAHD and 1.30mAHD respectively.

Table 4.12 Extreme still water-level, H (m). Sources: BMT Tide Model
The values are shown relative to AHD, based on an offset from MSL of -0.08m (1995 – 2014)

H (m)	Return Period (years)			
Source	1	10	50	100
BRAN2020 + BMT Tide Model	0.95	1.03	1.09	1.12
Deltares' GTSR	0.98	1.14	1.26	1.31

5 Deliverables

Operational criteria for several key parameter combinations have been developed for the LOI. Statistics were calculated for monthly and all-year conditions as well as individual months for various combinations of parameters describing waves and currents.

The MS Excel Spreadsheet including the following tabs accompany this report:

- 01_Monthly_Hs ➔ Monthly probability distribution of significant wave height (Hs).
- 02_Scatter_Hs-Hsd ➔ Percentage of occurrence of conditions in significant wave height (Hs) interval and direction (Hsd) interval.
- 03_Scatter_Hs-Tp ➔ Percentage of occurrence of conditions in significant wave height (Hs) interval and peak wave period (Tp) interval.
- 04_Monthly_Surface_Current ➔ Monthly probability distribution of current speed (w) near the surface.
- 05_Scatter_Surface_Current ➔ Percentage of occurrence of condition in current speed (wd) and direction intervals (wdir) near the surface.
- 06_Monthly_Seabed_Current ➔ Monthly probability distribution of current speed (w) near the seabed.
- 07_Scatter_Seabed_Current ➔ Percentage of occurrence of condition in current speed (w) and direction intervals (wdir) near the seabed.

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Annex A Wave Dataset Validation

The SWRT wave model used in this study transforms offshore waves into nearshore locations following the methodology discussed in Section 3.2.

The dataset produced by this approach has been validated against measurements from the Eden Waverider Buoy (located in approximately 100m water depth, shown in Figure 3.1 and discussed in Section 2.1.2).

The SWRT model results have been calibrated and validated against this measured dataset, by running the SWRT model for the location of the Eden Waverider Buoy location, in addition to the Disaster Bay LOI. A positive scale factor of 5% (i.e., 1.05) has been applied to waves above 4m to increase wave heights of the SWRT results during storm events, to better align with the waverider buoy observations. This same calibration scaling has been applied to the SWRT results of the Disaster Bay LOI.

A statistical comparison showing the final calibration of the SWRT dataset and the Eden Waverider Buoy dataset is shown below in Figure A.1.

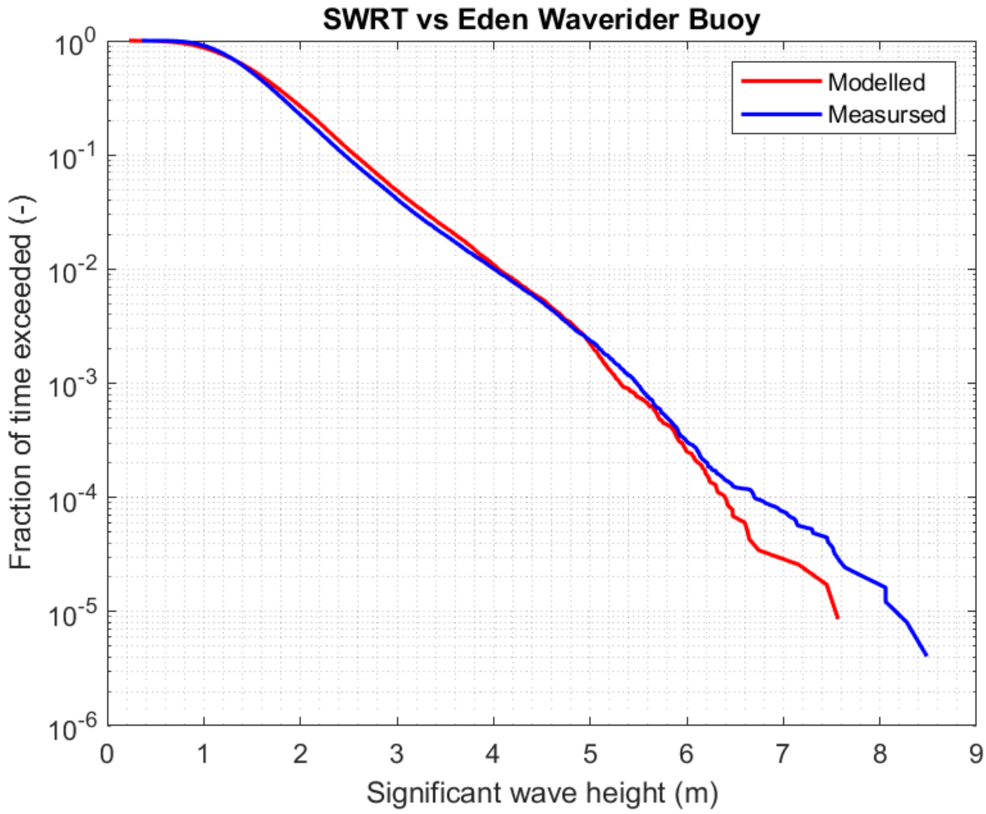
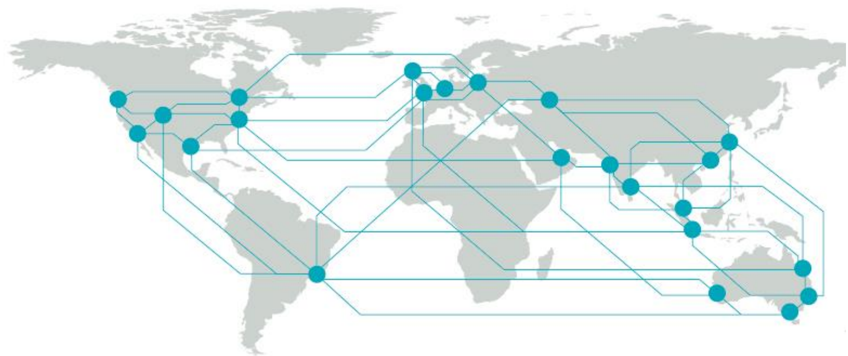


Figure A.1 Comparison between SWRT modelled waves and the Eden Waverider Buoy at an approximate depth of 100m



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