7 DESIGN FLOOD CONDITIONS

Design floods are hypothetical floods used for planning and floodplain management investigations. They are based on having a probability of occurrence specified as Annual Exceedance Probability (AEP) expressed as a percentage.

Refer to Table 7-1 for a definition of AEP.

Table 7-1 Design Flood Terminology

AEP	Comments
0.2%	A hypothetical flood or combination of floods which represent the worst case scenario with a 0.2% chance of occurring in any given year.
1%	As for the 0.2% AEP flood but with a 1% probability.
2%	As for the 0.2% AEP flood but with a 2% probability.
5%	As for the 0.2% AEP flood but with a 5% probability.
20%	As for the 0.2% AEP flood but with a 20% probability.
Extreme Flood / PMF[1]	A hypothetical flood or combination of floods which represent an extreme scenario.

1 A PMF (Probable Maximum Flood) is not necessarily the same as an Extreme Flood.

In accordance with Council's brief, the design events to be simulated include the 20% AEP, 5% AEP, 2% AEP, 1% AEP, 0.2% AEP and PMF event. The 1% AEP flood is generally used as a reference flood for development planning and control.

In determining the design floods it is necessary to take into account:

- Design rainfall parameters (rainfall depth, temporal pattern and spatial distribution). These inputs drive the hydrological model from which design flow hydrographs will be extracted as inputs to the hydraulic model;
- Design entrance channel geometry. As discussed, the entrance condition is a significant feature in terms of flood water level controls in Woolgoolga. As outlined in the Department of Environment, Climate Change and Water's (DECCW's) Draft Flood Risk Management Guide: Incorporating sea level rise benchmarks in flood risk assessments (2009), both closed and open entrance scenarios are to be modelled;
- Design downstream ocean boundary levels. A fully scoured entrance condition will provide for the critical case for ocean flooding, whilst for closed condition and intermediate scouring, coincident fluvial and tidal conditions may dictate flooding;
- The impact of future climate change on berm heights, ocean levels and catchment inflows.

7.1 Changes to the Model Configuration

The hydrologic and hydraulic models were developed through the model calibration process. However, there were a number of changes to the model required for design purposes, including:

- The construction of the Woolgoolga bypass was underway during the undertaking of this study. Design information relating to the road elevations and bridge crossings of Woolgoolga Creek and Poundyard Creek were provided by Council and incorporated into the design model geometry;
- A number of locations zoned for future development in Councils LEP were considered as developed when determining runoff from the hydrological model; and
- Recent stormwater drainage works have been undertaken by Council to improve local drainage on Trafalgar Street and provide some local flood relief. Details of these works were provided by Council and incorporated into the design model.

A map showing the locations of these model developments is provided in Figure 7-1.

7.2 Simulated Design Events

In consultation with Council a suite of design event scenarios was defined that is most suitable for future floodplain management planning in Woolgoolga. Consideration was given to flood events driven by both catchment and ocean processes. The potential impact of climate change on flood behaviour within Woolgoolga has also been considered.

7.2.1 Catchment Derived Flood Events

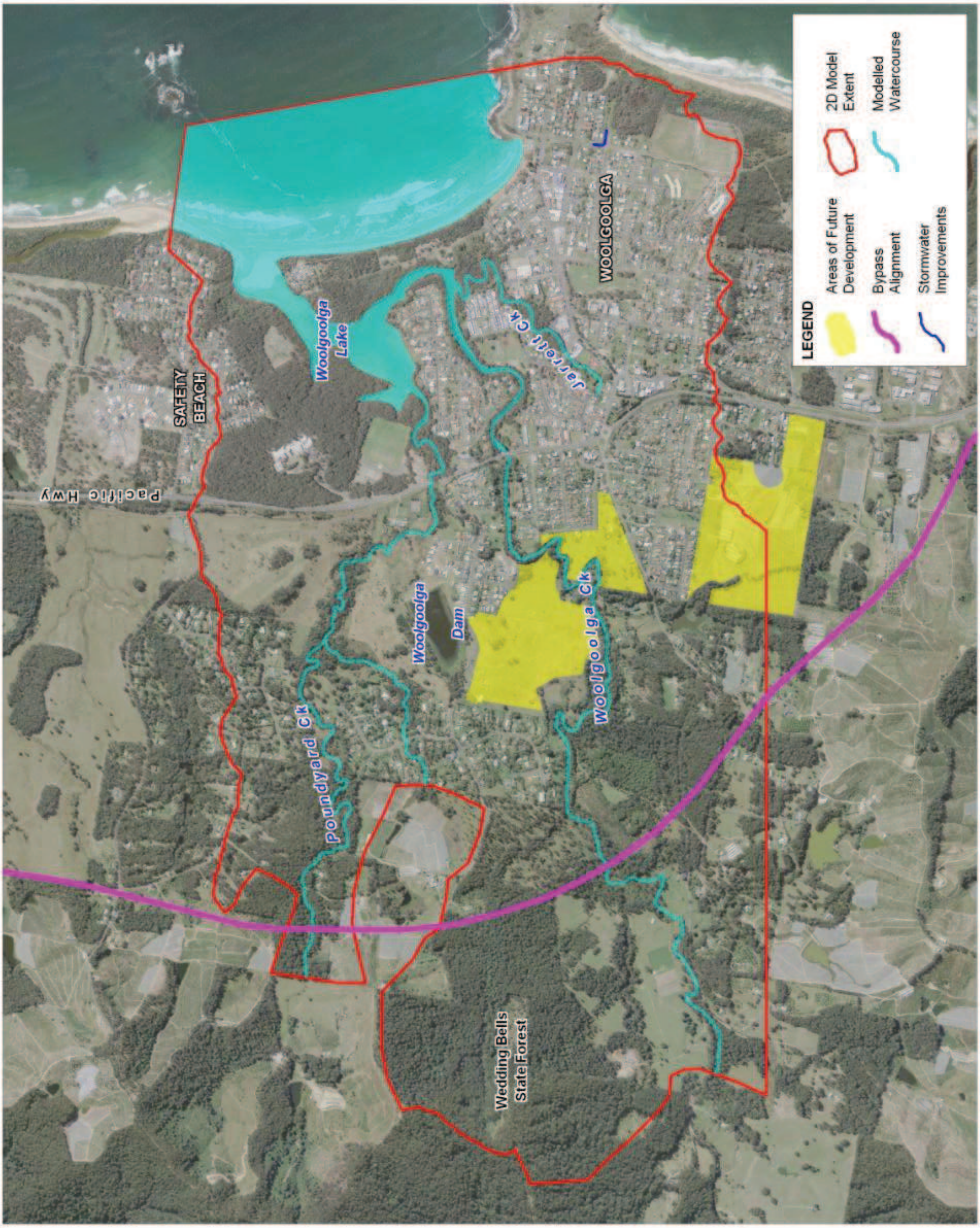
A range of design events was defined to model the behaviour of catchment derived flooding within Woolgoolga including the 20% AEP, 5% AEP, 2% AEP, 1% AEP, 0.2% AEP and PMF events. An overview of adopted model conditions for these design events is presented in Table 7-2. The adopted storm durations are discussed in Section 7.3.4. The adopted ocean boundary conditions are discussed in Section 7.4.1.

7.2.2 Ocean Derived Flood Events

A range of design events was defined to model the behaviour of ocean derived flooding within Woolgoolga including the 20% AEP, 5% AEP, 2% AEP, 1% AEP and 0.2% AEP events. An overview of adopted model conditions for these design events is presented in Table 7-3. The adopted ocean boundary conditions are discussed in Section 7.4.2.

7.2.3 Coincident Flood Events

A range of design events was defined to model the behaviour of coincident flooding from both catchment and ocean sources within Woolgoolga including the 20% AEP, 5% AEP, 2% AEP, 1% AEP and 0.2% AEP events. An overview of adopted model conditions for these design events is presented in Table 7-4. The adopted ocean boundary conditions are discussed in Section 7.4.2.



Title:

Location of Model Developments for Design Scenarios

Figure: **7-1**

Rev: **A**

N

0 750m

Approx. Scale

BMT WBM

www.bmtwbm.com.au

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Table 7-2 Design Model Runs for Catchment Derived Flood Events

Design Flood	Rainfall	Berm Geometry	Ocean Boundary Peak Water Level (m AHD)
20% AEP	• 20% AEP 2h duration • 20% AEP 6h duration • 20% AEP 48h duration	Closed (1.5m AHD Berm Saddle)	0.60 (Regular Neap Tide)
5% AEP	• 5% AEP 2h duration • 5% AEP 6h duration • 5% AEP 48h duration	Closed (1.5m AHD Berm Saddle)	0.60 (Regular Neap Tide)
2% AEP	• 2% AEP 2h duration • 2% AEP 6h duration • 2% AEP 48h duration	Closed (1.5m AHD Berm Saddle)	0.60 (Regular Neap Tide)
1% AEP	• 1% AEP 2h duration • 1% AEP 6h duration • 1% AEP 48h duration	Closed (1.5m AHD Berm Saddle)	0.60 (Regular Neap Tide)
0.2% AEP	• 0.2% AEP 2h duration • 0.2% AEP 6h duration • 0.2% AEP 48h duration	Closed (1.5m AHD Berm Saddle)	0.60 (Regular Neap Tide)
PMF	• PMP 1.5h duration • PMP 3h duration	Closed (1.5m AHD Berm Saddle)	2.70 (0.2% AEP)

Table 7-3 Design Model Runs for Ocean Derived Flood Events

Design Flood	Rainfall	Berm Geometry	Ocean Boundary Peak Water Level (m AHD)
20% AEP	No Flow	Open (-0.5m AHD)	1.85 (20% AEP)
5% AEP	No Flow	Open (-0.5m AHD)	2.10 (5% AEP)
2% AEP	No Flow	Open (-0.5m AHD)	2.27 (2% AEP)
1% AEP	No Flow	Open (-0.5m AHD)	2.40 (1% AEP)
0.2% AEP	No Flow	Open (-0.5m AHD)	2.70 (0.2% AEP)

Table 7-4 Design Model Runs for Coincident Flood Events

Design Flood	Rainfall	Berm Geometry	Ocean Boundary Peak Water Level (m AHD)
20% AEP	20% AEP 6h duration	Closed (1.5m AHD Berm Saddle)	1.85 (20% AEP)
20% AEP	20% AEP 6h duration	Open (-0.5m AHD)	1.85 (20% AEP)
5% AEP	5% AEP 6h duration	Closed (1.5m AHD Berm Saddle)	1.85 (20% AEP)
5% AEP	20% AEP 6h duration	Open (-0.5m AHD)	2.10 (5% AEP)
2% AEP	2% AEP 6h duration	Closed (1.5m AHD Berm Saddle)	1.85 (20% AEP)
2% AEP	20% AEP 6h duration	Open (-0.5m AHD)	2.27 (2% AEP)
1% AEP	1% AEP 6h duration	Closed (1.5m AHD Berm Saddle)	2.10 (5% AEP)
1% AEP	5% AEP 6h duration	Open (-0.5m AHD)	2.40 (1% AEP)
0.2% AEP	0.2% AEP 6h duration	Closed (1.5m AHD Berm Saddle)	2.40 (1% AEP)
0.2% AEP	1% AEP 6h duration	Open (-0.5m AHD)	2.70 (0.2% AEP)

7.2.4 Climate Change

The NSW Government has published guidelines on the practical consideration of climate change (DECCW, 2007). For Woolgoolga a range of design events was defined to model the potential impacts of future climatic change within the study catchment. There are three outcomes of current climate change predictions which may have a significant impact of flood behaviour within Woolgoolga:

- Future sea-level rise;
- Elevated berm heights, themselves a function of sea-level rise;
- Increased extreme rainfall intensities.

These three factors were considered in combination with each other for two future horizons, 2050 and 2100. The outcomes of these climate change considerations will help understand the potential changes in future flood behaviour and how to best plan for future development within the catchment. The design events for which climate change impacts were considered were therefore focussed on the main planning event – 1% AEP event. An overview of adopted model conditions for these climate change events is presented in Table 7-5.

Table 7-5 Design Model Runs for Climate Change Flood Events

Design Flood	Rainfall	Berm Geometry	Ocean Boundary Peak Water Level (m AHD)
1% AEP 2050	• 1% AEP 2h duration +10% • 1% AEP 6h duration +10%	Closed (1.9m AHD Berm Saddle)	1.00 (Regular Neap Tide +0.4m to 2050)
1% AEP 2050	No Flow	Open (-0.1m AHD)	2.90 (1% AEP +0.5m to 2050)
1% AEP 2050	1% AEP 6h duration +10%	Closed (1.9m AHD Berm Saddle)	2.60 (5% AEP +0.5m to 2050)
1% AEP 2050	5% AEP 6h duration +10%	Open (-0.1m AHD)	2.90 (1% AEP +0.5m to 2050)
1% AEP 2100	1% AEP 6h duration +10%	Closed (2.4m AHD Berm Saddle)	1.50 (Regular Neap Tide +0.9m to 2100)
1% AEP 2100	No Flow	Open (0.4m AHD)	3.60 (1% AEP +1.2m to 2100)
1% AEP 2100	1% AEP 6h duration +10%	Closed (2.4m AHD Berm Saddle)	3.30 (5% AEP +1.2m to 2100)
1% AEP 2100	5% AEP 6h duration +10%	Open (0.4m AHD)	3.60 (1% AEP +1.2m to 2100)

7.3 Design Rainfall

Design rainfall parameters are derived from standard procedures defined in AR&R (2001) which are based on statistical analysis of recorded rainfall data across Australia. The derivation of location specific design rainfall parameters (e.g. rainfall depth and temporal pattern) for the study catchment is presented below.

7.3.1 Rainfall Depths

Design rainfall depth is based on the generation of intensity-frequency-duration (IFD) design rainfall curves utilising the procedures outlined in AR&R (2001). These curves provide rainfall depths for various design magnitudes (up to the 1% AEP) and for durations from 5 minutes to 72 hours.

The Probable Maximum Precipitation (PMP) is used in deriving the Probable Maximum Flood (PMF) event. The theoretical definition of the PMP is “the greatest depth of precipitation for a given duration that is physically possible over a given storm area at a particular geographical location at a certain time of year” (AR&R, 2001). The ARI of a PMP/PMF event ranges between 10^4 and 10^7 years and is beyond the “credible limit of extrapolation”. That is, it is not possible to use rainfall depths determined for the more frequent events (1% AEP and less) to extrapolate the PMP. The PMP has been estimated using the Generalised Short Duration Method (GSDM) derived by the Bureau of Meteorology.

A range of storm durations were modelled in order to identify the critical storm duration for design event flooding in the catchment. Design durations considered included the 1-hour, 2-hour, 3-hour, 4.5-hour, 6-hour, 9-hour, 12-hour, 18-hour, 24-hour, 48-hour and 72-hour durations.

Table 7-6 shows the average design rainfall intensities based on AR&R adopted for the modelled events.

Table 7-6 Average Design Rainfall Intensities (mm/hr)

Duration (hours)	Design Event Frequency				
	20% AEP	5% AEP	2% AEP	1% AEP	0.2% AEP
1	58	76	90	100	126
2	38.5	51	60	67	83
3	29.8	39.1	46.2	52	65
4.5	23.2	30.4	35.9	40.1	50
6	19.1	25.2	29.7	33.2	42.1
9	15.0	19.7	23.3	26.1	32.8
12	12.6	16.7	19.8	22.1	27.5
18	10.2	13.6	16.2	18.2	23.1
24	8.62	11.7	14.0	15.7	20.4
48	5.98	8.33	10.1	11.5	14.9
72	4.65	6.57	8.06	9.23	12.2

7.3.2 Temporal Patterns

The IFD data presented in Table 7-6 provides for the average intensity (or total depth) that occurs over a given storm duration. Temporal patterns are required to define what percentage of the total rainfall depth occurs over a given time interval throughout the storm duration. The temporal patterns adopted in the current study are based on the standard patterns presented in AR&R (2001).

The same temporal pattern has been applied across the whole catchment. This assumes that the design rainfall occurs simultaneously across each of the modelled sub-catchments. The direction of a storm and relative timing of rainfall across the catchment may be determined for historical events if sufficient data exists, however, from a design perspective the same pattern across the catchment is generally adopted.

7.3.3 Rainfall Losses

The hydrologic model parameters adopted for the design floods were based on the initial and continuing loss model, with a continuing loss of 2.5mm/h as recommended in AR&R (2001). For the initial loss AR&R recommends values between 10mm and 35mm for eastern NSW. However, testing of the hydrologic model indicated that adopting initial loss values within this range resulted in a critical duration of 6-9 hours at the Woolgoolga Creek gauge. This was contradictory to the observations made during the model calibration process.

The three flood events considered during model calibration showed a 1-3 hour storm burst, within an extended period of rainfall. For each event the catchment was saturated long before the onset of the main storm burst. It was decided to adopt an initial loss value of 0mm for design purposes. This provided a critical duration of 2-3 hours at the Woolgoolga Creek gauge and is more representative of the previous significant flood events in the catchment. The peak flood flows modelled at the Woolgoolga Creek gauge with an adopted initial loss of 0mm are also supported by the flood frequency analysis presented in Section 8.2.1.

7.3.4 Critical Durations

The critical duration is the storm duration for a given event magnitude that provides for the peak flood conditions at the location of interest. For example, small catchments are more prone to flooding during short duration storms, while for large catchments longer durations will be more critical.

The 1% AEP flood event was run for all durations to determine the critical duration for each location in the study area. The critical duration for Woolgoolga Creek was found to be the 6-hour storm, whereas for Poundyard Creek and Jarrett Creek the 2-hour storm was the critical duration. Adopting both the 2-hour and 6-hour storm durations provided the critical condition across most of the modelled area. In locations where the 2-hour or 6-hour storm was not the critical duration, the peak flood level of the critical duration was typically less than 10mm greater than that of the peak flood level for the 2-hour or 6-hour storm duration.

There are two locations within the modelled area for which the 2-hour and 6-hour storm durations do not provide an adequate representation of the critical conditions:

- Within the swamp located at the eastern end of Trafalgar Street; and
- Within Woolgoolga Dam.

At the Trafalgar Street swamp the 48-hour duration provided the critical condition within the swamp and through the properties to the north-west. Within Woolgoolga Dam the 48-hour duration also provided the critical condition. Assumptions were made regarding the available swamp storage and initial conditions in the swamp. Further investigation of the swamp would be required to confirm the detention capacity and assist in the verification of the critical duration.

The PMP has been estimated using the Generalised Short Duration Method (GSDM) derived by the Bureau of Meteorology. The critical storms using this method were found to be the 1.5-hour and the 3-hour durations.

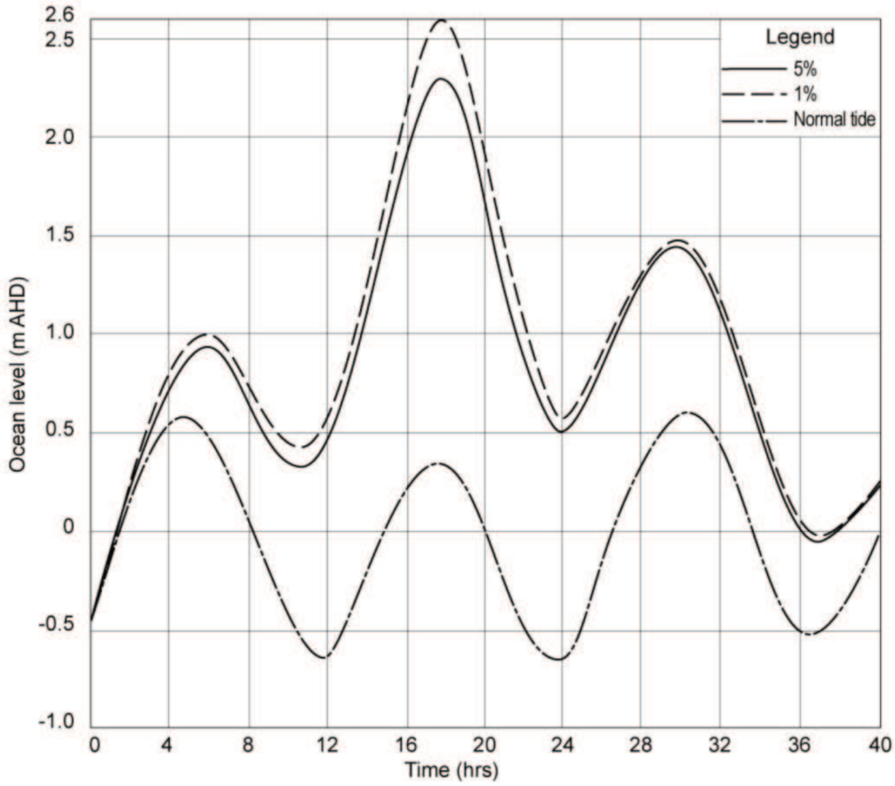
7.3.5 Climate Change Impact on Design Rainfall

Current guidelines predict that a likely outcome of future climatic change will be an increase in extreme rainfall intensities. Climate Change in New South Wales (CSIRO, 2004) provides projected increases in annual extreme rainfall intensities for north-east NSW of 5% for both the years 2030 and 2070. The spring extreme rainfall intensities are projected to increase by 10% for the year 2070. These figures are based on a 2.5% AEP 24h duration rainfall event. Based on these guidelines a design rainfall intensity increase of 10% was selected as being appropriate for assessing the potential impact of climate change on design rainfall in the study catchment.

7.4 Design Ocean Boundary

Design ocean boundaries for use in flood risk assessments are recommended by Appendix A of the Draft Flood Risk Management Guide (DECCW, 2009). This appendix was formerly Guideline 5 of Ocean Boundary Conditions for Hydraulic Flood Modelling. The design ocean boundaries from Figure

3 of this document are presented in Figure 7-2. The recommended normal ocean boundary has been adopted for the catchment derived flood events. However, a different approach was used to determine the ocean flood event boundaries, as discussed in Section 7.4.2.



Source: Figure3, Appendix A, Draft Flood Risk Management Guide (DECCW, 2009)

Figure 7-2 OEH Recommended Design Ocean Boundaries

7.4.1 Catchment Derived Flood Events

The adopted tidal boundary for catchment derived flood events was based on the normal tide recommendation and is shown in Figure 7-3. The timing of the 0.6m AHD peak water level was adjusted to coincide with the peak catchment inflow, which occurs at between T=4 and T=5 hours.

7.4.2 Ocean Derived Flood Events

The design peak water levels to be adopted for the assessment of ocean derived flood events were agreed with Council and OEH, to be consistent with previous studies in the region. The adopted flood levels were 2.1m AHD for the 5% AEP event and 2.4m AHD for the 1% AEP event. These levels include the following considerations:

- Barometric pressure set up of the ocean surface due to the low atmospheric pressure of the storm;
- Wind set up due to strong winds during the storm “piling” water upon the coastline;
- Astronomical tide, particularly the HHWSS; and

- Wave set up.

The appropriate design peak water levels to be used for the remaining design events were then derived through use of a log graph, presented in Figure 7-4. The peak flood levels are also provided in Table 7-7.

The temporal pattern of the design boundaries for ocean derived flood events was based on the recommended ocean design events for 5% AEP, as shown in Figure 7-2. The timing of the peak water level was adjusted to coincide with the peak catchment inflow, which occurs at between T=4 and T=5 hours. The water levels were then scaled accordingly to match those from Table 7-7. The design ocean boundaries used in this study are presented in Figure 7-5.

Table 7-7 Design Peak Ocean Water Levels

Event Magnitude	Gauge Level (m)
20% AEP	1.85
5% AEP	2.10
2% AEP	2.27
1% AEP	2.40
0.2% AEP	2.70

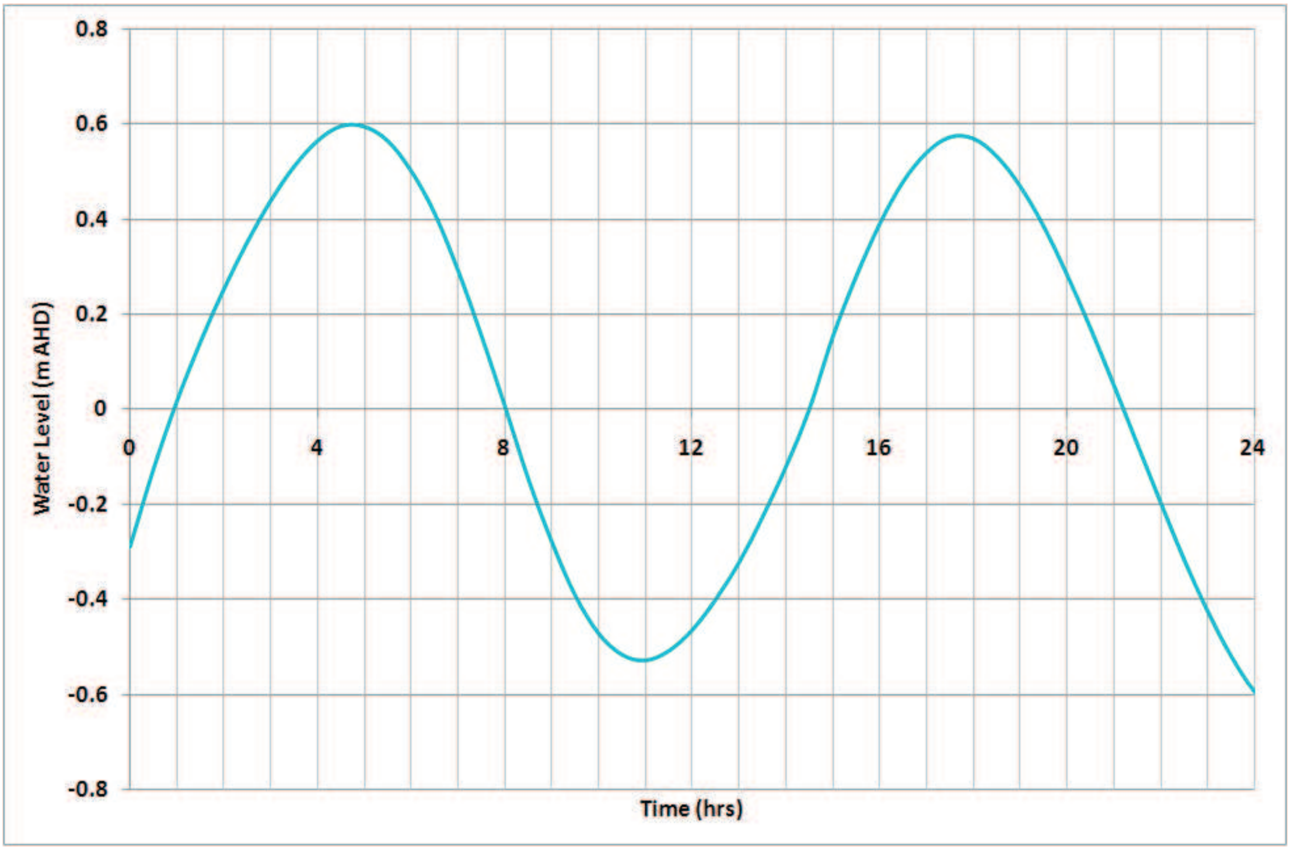


Figure 7-3 Design Ocean Boundary – Regular Neap Tide

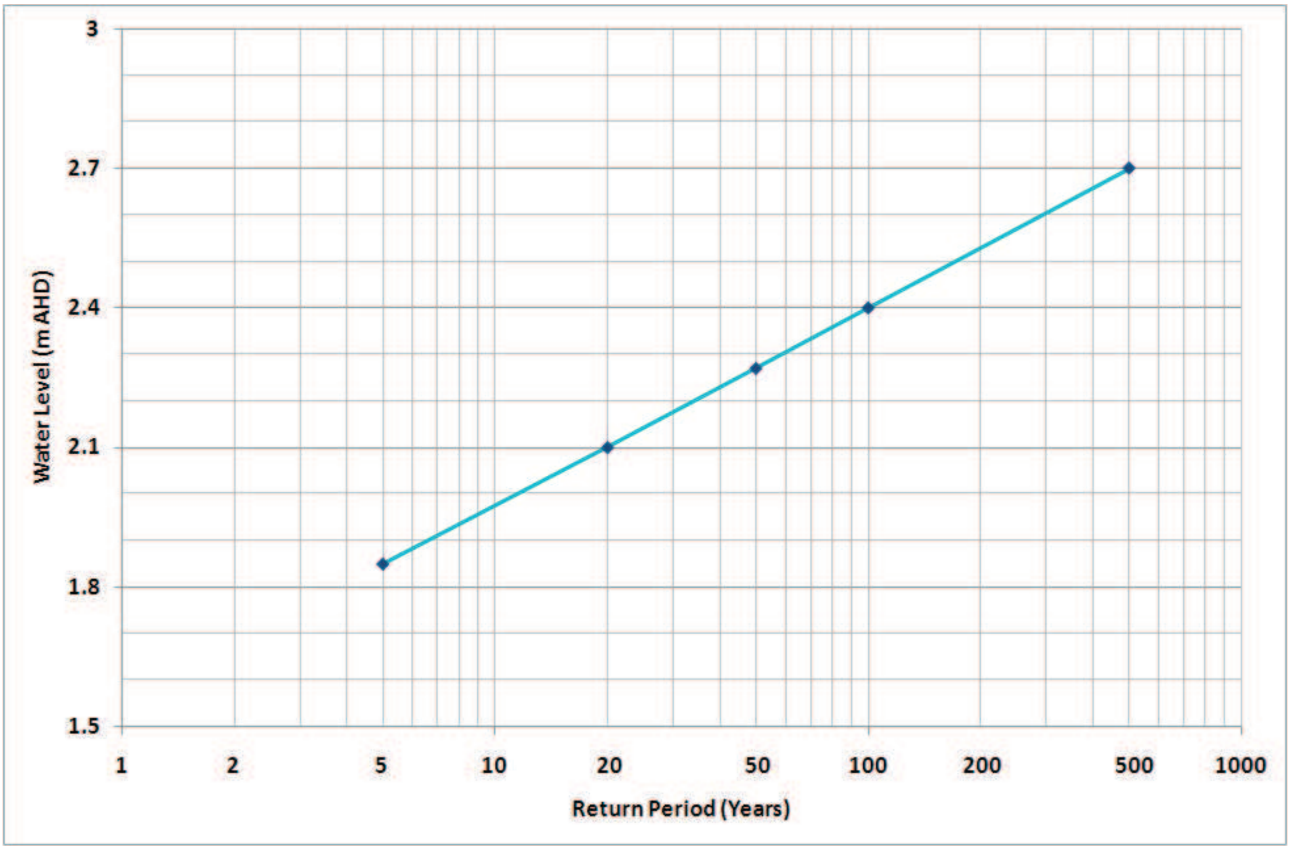


Figure 7-4 Design Peak Ocean Water Level Derivation

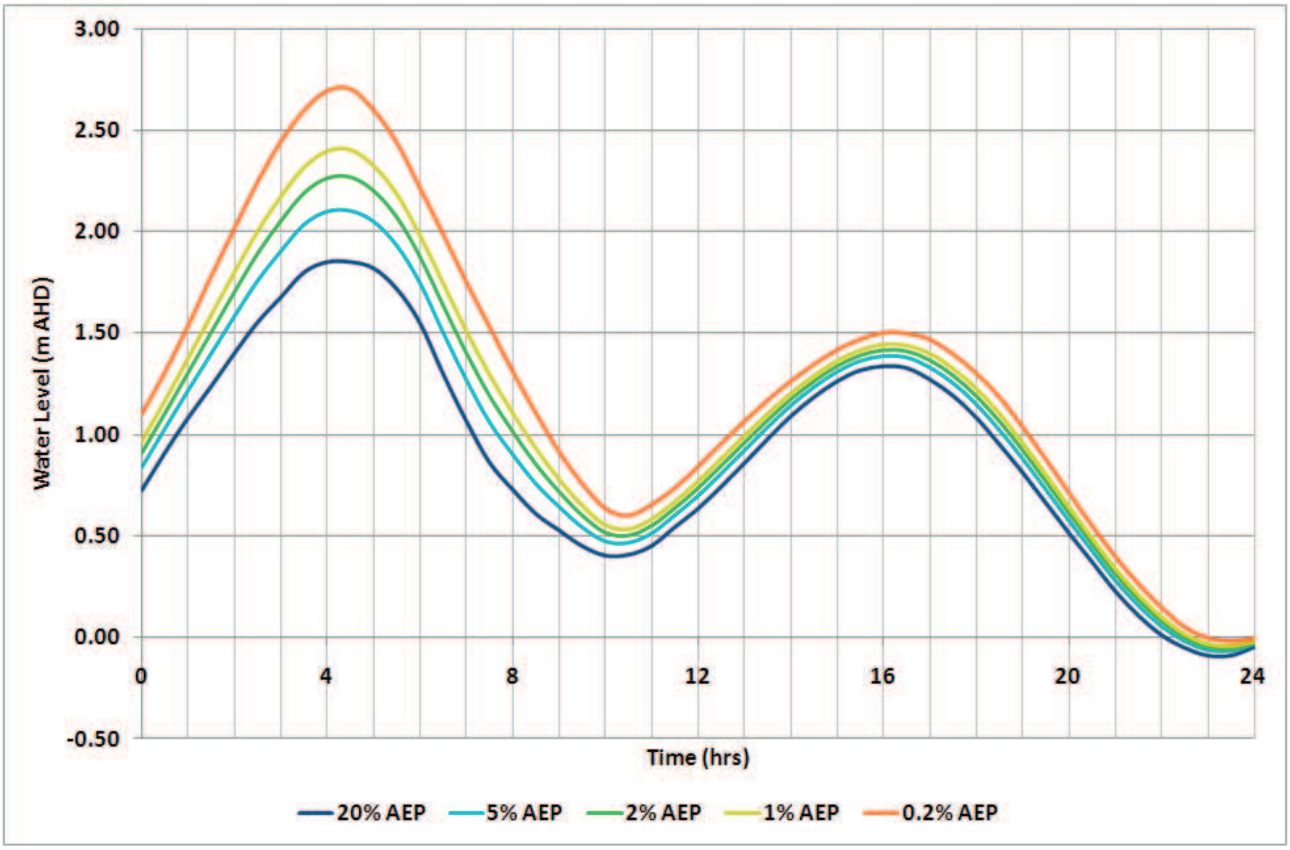


Figure 7-5 Design Boundaries for Ocean Derived Flood Events

7.4.3 Climate Change

Current guidelines predict that a likely outcome of future climatic change will be an increase in mean sea level. NSW Sea Level Rise Policy Statement (DECCW, 2009) provides projected increases in mean sea level for NSW of 0.4m and 0.9m, for the years 2050 and 2100 respectively. Based on these guidelines the design ocean boundaries have been raised by 0.4m and 0.9m to assess the potential impact of climate change on flood behaviour in the study catchment.

Climate change may also result in an increase in the frequency and intensity of storms, further exacerbating the effects of sea level rise on coastal flood behaviour. The data provided in Projected Changes in Climatological Forcing for Coastal Erosion in NSW (CSIRO, 2007) indicates that a conservative approach would be to adopt around a 10% increase in significant wave heights for the 50 year planning horizon and around a 30% increase for the 100 year planning horizon. An increase in significant wave heights for ocean events would result in an increased wave set up.

Wave data for Coffs Harbour was provided by Manly Hydraulics Laboratory (MHL), with data collection funded by the Office of Environment and Heritage. The wave rider buoys are moored in around 85 m water depth, around 10 km offshore. The analysis of storm wave height ARI for different durations is based upon a data recording period at Coffs Harbour of 33 years from May 1976 to December 2009.

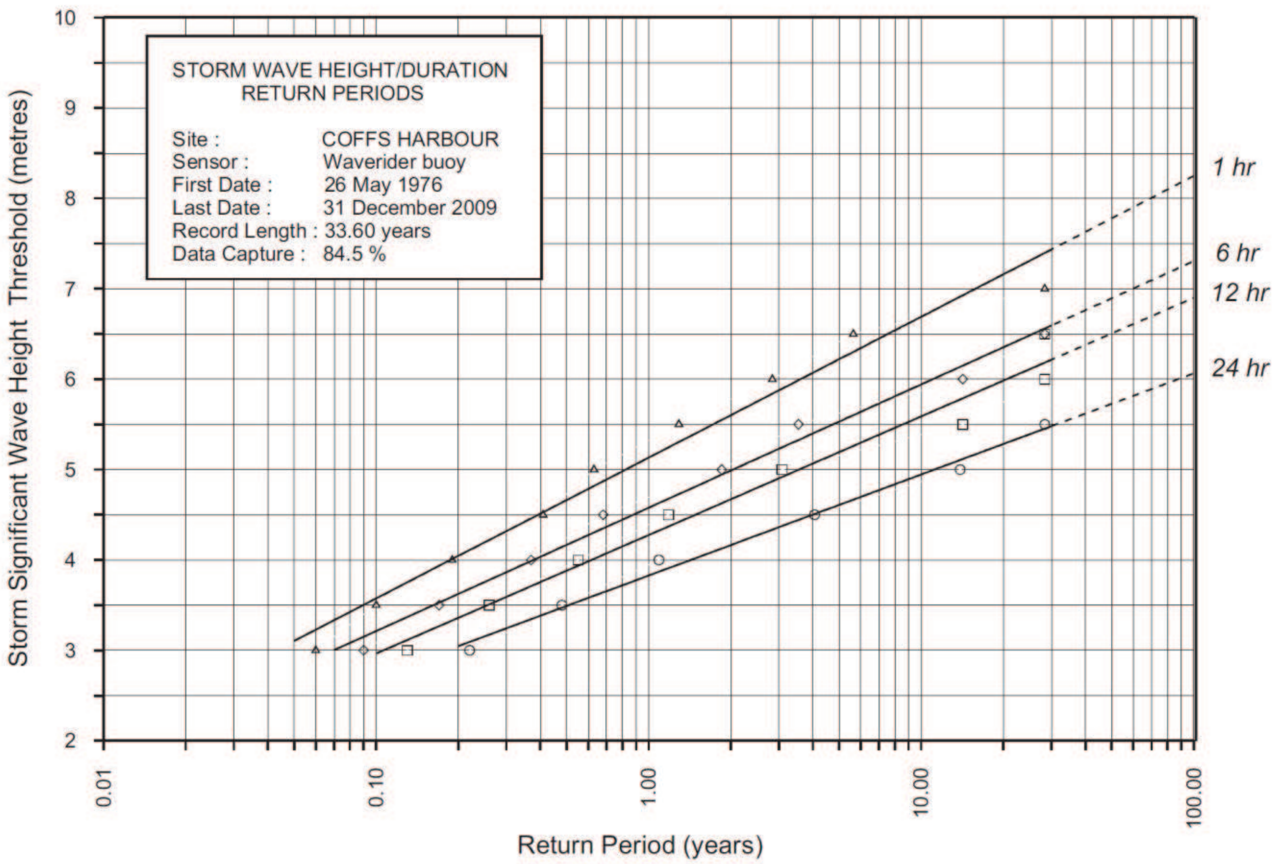


Figure 7-6 MHL Chart for Coffs Harbour Storm Wave Return Periods

Figure 7-6 shows the storm wave return periods from the Coffs Harbour wave rider buoy. It can be seen that for the 1% AEP event the significant wave height is around 6.9m for the 12-hour duration.

Wave setup is typically taken as 15% of the offshore wave height, which in this case is around 1m. A 10% increase by 2050 and 30% increase by 2100 would therefore provide an increased flood level of 0.1m and 0.3m respectively. These increases have been incorporated within the climate change assessment, on top of the 0.4m and 0.9m sea level rise allowances.

7.5 Design Berm Geometry

The design berm geometry has a significant influence on modelled flood levels in Woolgoolga Lake. In defining the entrance condition for the design flood analysis, consideration is given to the geometry of the berm for open and closed conditions, for existing and future scenarios considering potential sea level rise influences.

7.5.1 Catchment Derived Flood Events

The berm saddle height adopted for the catchment derived flooding design events is 1.5m AHD, which was agreed through consultation with Council. The design berm geometry was based on the LiDAR survey data, in which the berm crest elevation was around 1.2m AHD. The model elevations in the Woolgoolga Lake entrance have been raised by 0.3m to provide a crest elevation of 1.5m. For the 5% AEP and 1% AEP events additional model scenarios have been undertaken adopting both a 1m berm saddle height and an open entrance condition, in order to assess the impact of the lake entrance conditions on peak design flood levels.

7.5.2 Ocean Derived Flood Events

For the ocean derived flood events Appendix A of the Draft Flood Risk Management Guide (DECCW, 2009) calls for a largely unrestricted entrance condition. This has been represented through the lowering of the model elevations in the Woolgoolga Lake entrance have by 1.7m, providing an open entrance with a bed elevation of -0.5m AHD.

7.5.3 Climate Change

There are no government guidelines concerning the impact of future climatic change of entrance berm geometries. A change in entrance berm processes is likely to result from the predicted sea level rise and changes to coastal storm intensity. From this change, a net upward shift in typical berm heights at the entrance may be expected commensurate with sea level rise estimates.

For the purposes of this study a berm height increase of 0.4m and 0.9m has been adopted for the 2050 and 2100 horizons respectively. This gives a berm saddle height for catchment derived flood events of 1.9m AHD for the 2050 planning horizon and 2.4m AHD for the 2100 planning horizon. For the open entrance condition adopted for ocean derived flood events the bed elevation has been raised to -0.1m AHD and 0.4m AHD for 2050 and 2100 respectively.

The Coffs Harbour Coastal Processes and Hazards Definition Study (BMT WBM, 2011) included an assessment of shoreline recession due to sea level rise, which was found to be 45m by 2050 and 100m by 2100. This coastal recession has been represented in the climate change scenarios by shifting the berm position westwards by these distances.

7.6 Initial Water Levels

Initial water levels in Woolgoolga Lake have been set to the same level at the berm saddle height for the closed entrance condition scenarios. For open entrance conditions, the initial water levels have been set to a level similar to the sea level at the onset of the event. There is little flood storage capacity available in the lake, which peaks at a similar level to the peak sea level and is not sensitive to the initial water level. For the climate change scenarios, initial water levels in Woolgoolga Lake have been raised by 0.4m at 2050 and by 0.9m at 2100.

The initial water level in Woolgoolga Dam has been set to the normal operating level of 17.86m AHD. The initial water level in the Trafalgar Street swamp has been set to the invert level of the outlet structure, which is 3.7m AHD.