6 MODEL CALIBRATION

6.1 Selection of Calibration Events

The selection of suitable historical events for calibration of computer models is largely dependent on available historical flood information. Ideally the calibration and validation process should cover a range of flood magnitudes to demonstrate the suitability of a model for the range of design event magnitudes to be considered.

Following a relatively flood free period of some 40 years, there have been two significant flood events within Woolgoolga in recent years. The June 2011 event is the larger of the two in the Woolgoolga Creek gauge record and has substantial observed flood event data available for calibration, including surveyed flood marks. Due to the availability of data, June 2011 has been selected as the primary event for model calibration.

The January 2012 event occurred during this study and provided another recent event for the model calibration process, albeit with less available observed flood data in comparison to the June 2011 event. It has therefore been used to assist the calibration of the hydrologic and hydraulic models.

The highest flood level recorded at the Woolgoolga Creek stream flow gauge was for the March 1974 event. There is little supplementary data available for this event to enable a detailed calibration. However, being the largest recorded event in the catchment, it has been selected for model validation.

The model calibration therefore is based on the historical data available for the three events. The available data, modelling approach and model results for each of these events are discussed in further detail in the following sections.

6.2 June 2011 Model Calibration

6.2.1 Rainfall Data

The distribution of rainfall gauge locations in the vicinity of Woolgoolga was shown in Figure 2-2 with their respective periods of record shown in Table 2-3. The only gauge within the study area that is currently operating is located at Clear Place, Woolgoolga, which records daily rainfall totals. It recorded a total rainfall depth of 250mm on 14th June 2011.

The June 2011 storm was localised and intense, with rainfall depths and temporal patterns exhibiting significant spatial variation. Only around 120mm rainfall depth was recorded on the same day at the nearby rainfall stations of Lower Bucca, Nana Glen, Coramba and Coffs Harbour. To supplement the available rainfall records for the June 2011 event, Council provided rainfall data collected by the local community. This typically comprised daily rainfall records from private residences, a summary of which is presented in Table 6-1. The accuracy of the rain gauges and the times at which depth reading were taken impacts on the reliability of the data. A number of readings indicated a minimum rainfall depth, as the true totals likely exceeded the capacity of the gauges. There are also a number of likely errors such as daily totals that actually represent totals for multiple days.

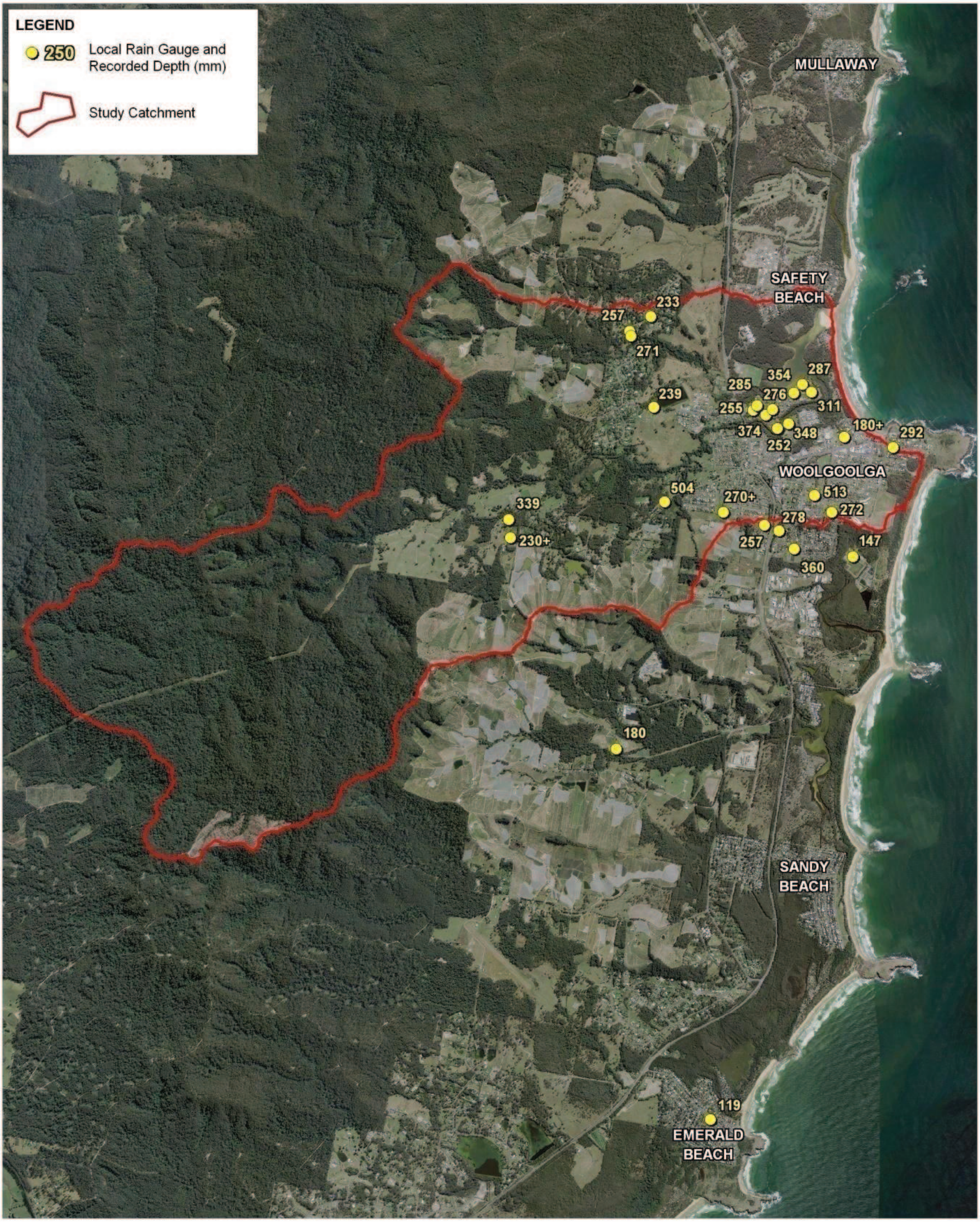
Table 6-1 Daily Rainfall Records from Local Gauges for the June 2011 Event

Gauge Location	13th June (mm)	14th June (mm)	15th June (mm)
Clear Pl (BoM)	121	250	37
Sunset Ave	128	225	30
Arkan Ave	100	230	27
High St	106	245	27
Woolgoolga Ck Rd	285	452	52
South St	96	147	-
Morgans Rd	269	126	54
Shearer Dr	126	235	22
Tomkins Ave [2]	110	347	27
Sunset Ave [1]	107	184	92
Melaleuca Ave	114	283	28
Landrigan Cl [2]	111	278	-
McCready St	113	270+	-
High School	151	-	348 (2 day)
Shearer Dr	122	249	22
Haines Cl	121	252	-
Melaleuca Ave	110	350	4
Wharf St	128	160+	20
Woolgoolga Ck Rd [1]	108	167	172
Palmer Rd	128	211	22
Sunset Ave	102	149	136
Nightingale St	108	147	213
Gordon St	-	513	-
Ocean St [1]	119	132	160
Newmans Rd	75	236	3
Woolgoolga Ck Rd	155+	155+	75
Emerald Beach	*67*	*74*	*45*

1 indicates gauge readings that are known to be taken typically before 7 a.m.

2 indicates gauge readings that are know to be taken typically before 8 a.m.

The June 2011 event spanned two rain days and therefore the rainfall depths for 14th and 15th June have been combined and are presented on Figure 6-1. The local records provide some additional information of the rainfall spatial variability, but are largely located in the eastern quarter of the Woolgoolga Lake catchment. There is a large degree of local spatial variability, which makes it difficult to infer any broader spatial trend. It is likely that many of the very high or low rainfall totals are data errors, although the rainfall event may have exhibited locally high spatial variability.



Title:
Local Rain Gauge Distribution and Recorded Rainfall

Figure: 6-1

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BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 1 2km
Approx. Scale

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The average two day rainfall depth from the available gauges is around 300mm, which is close to that recorded at the BoM gauge at Clear Place (287mm). The daily rainfall totals at Clear Place have therefore been selected as providing the best representation of rainfall depths within the Woolgoolga Lake catchment. The total depths recorded there are typical of the depths recorded elsewhere and the BoM gauge readings are likely to be less susceptible to errors than some of the privately operated rain gauges.

The nearest local gauge with available temporal data is located at Emerald Beach and recorded a total rainfall depth of 74mm on 14th June. It also recorded 45mm on 15th June, which is largely part of the same rainfall burst of the June 2011 event. The main rainfall burst started at around 07:00 on 14th June and had passed through the area by around 10:00. This time period spans two separate rainfall recording days, as daily rainfall readings are traditionally taken at 09:00. This can be observed in the BoM radar rainfall data presented in Figure 6-2.

The radar data shows the progression of the main rainfall burst from the June 2011 event. It can be seen that the storm progresses in a southerly direction and has largely passed the Woolgoolga Lake catchment by the end of the 14th June daily rainfall record period, but is still moving through Emerald Beach in the 15th June daily rainfall record period, as evidenced by the 14/06/11 10:00 image. There is a one to two hour delay between the storm passing over the Woolgoolga Lake catchment and through Emerald Beach.

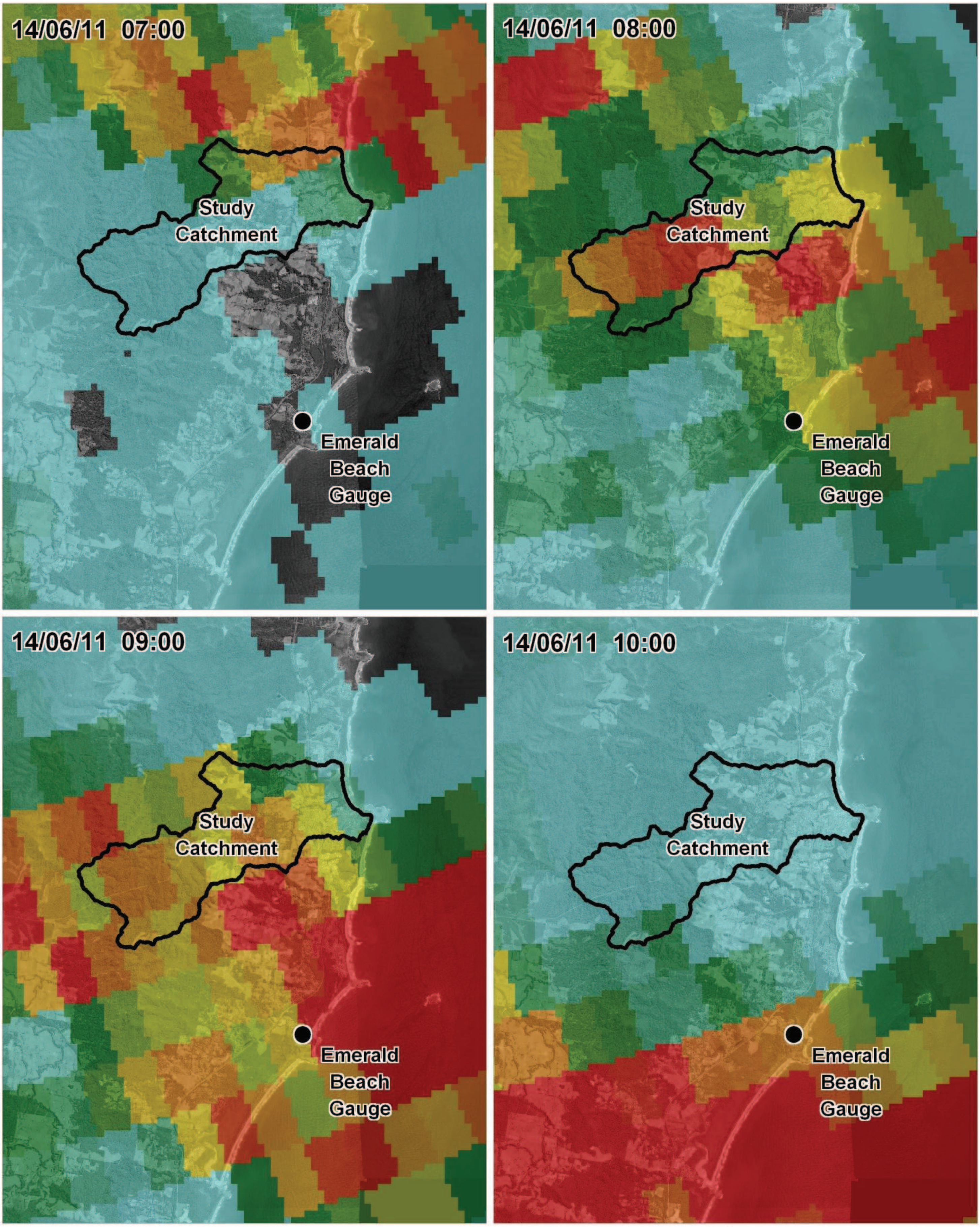
The rainfall radar data can be used to provide reasonable temporal patterns for use in modelling calibration events. However, it does contain a lot of ‘noise’, particularly when only a relatively small number of radar grid cells cover the area of interest, such as in the case of the Woolgoolga Lake catchment. Therefore, the record captured by the local gauge at Emerald Beach is the most reliable data source available for the provision of a temporal pattern of the June 2011 storm.

The gauge at Emerald Beach recorded rainfall depths at a one minute interval. These were converted to a ten minute interval and adopted as the temporal pattern for the Woolgoolga Lake catchment. The total rainfall depth of 287mm recorded at Woolgoolga on 14th and 15th June was fitted to the temporal pattern for the same period to derive the rainfall distribution for the June 2011 calibration. The resultant rainfall hyetograph at Woolgoolga for the 14th to 15th June 2011 is presented in Figure 6-3.

The ten minute interval rainfall data for the main storm burst, as input to the hydrological model is presented in Figure 6-4.

The hyetograph indicates over 100mm of rainfall in the two hour period from 08:30 and 10:30. An analysis of the daily rainfall readings in Woolgoolga at the gauges read at 7 a.m. (as indicated in Table 6-1) compared to those read at 9 a.m. suggests that around 100mm of rain fell in the two hour period from 07:00 to 09:00. This matches well with the hyetograph, when considering the one to two hour time lag that has been discussed.

To gain an appreciation of the relative intensity of the June 2011 event, the derived rainfall depths for various storm durations is compared with the design IFD data for the Woolgoolga Lake catchment as shown in Figure 6-5. The derived depth vs. duration profile for the June 2011 event from the scaled Emerald Beach recorded data shows it generally tracking just below the design 5% AEP (20-year ARI) rainfall for durations up to 24 hours, with the 3-hour rainfall burst peaking over the 5% AEP level.



Title:

Storm Progression of the June 2011 Event

Figure: 6-2

Rev: A

N

0 2.5 5km

Approx. Scale

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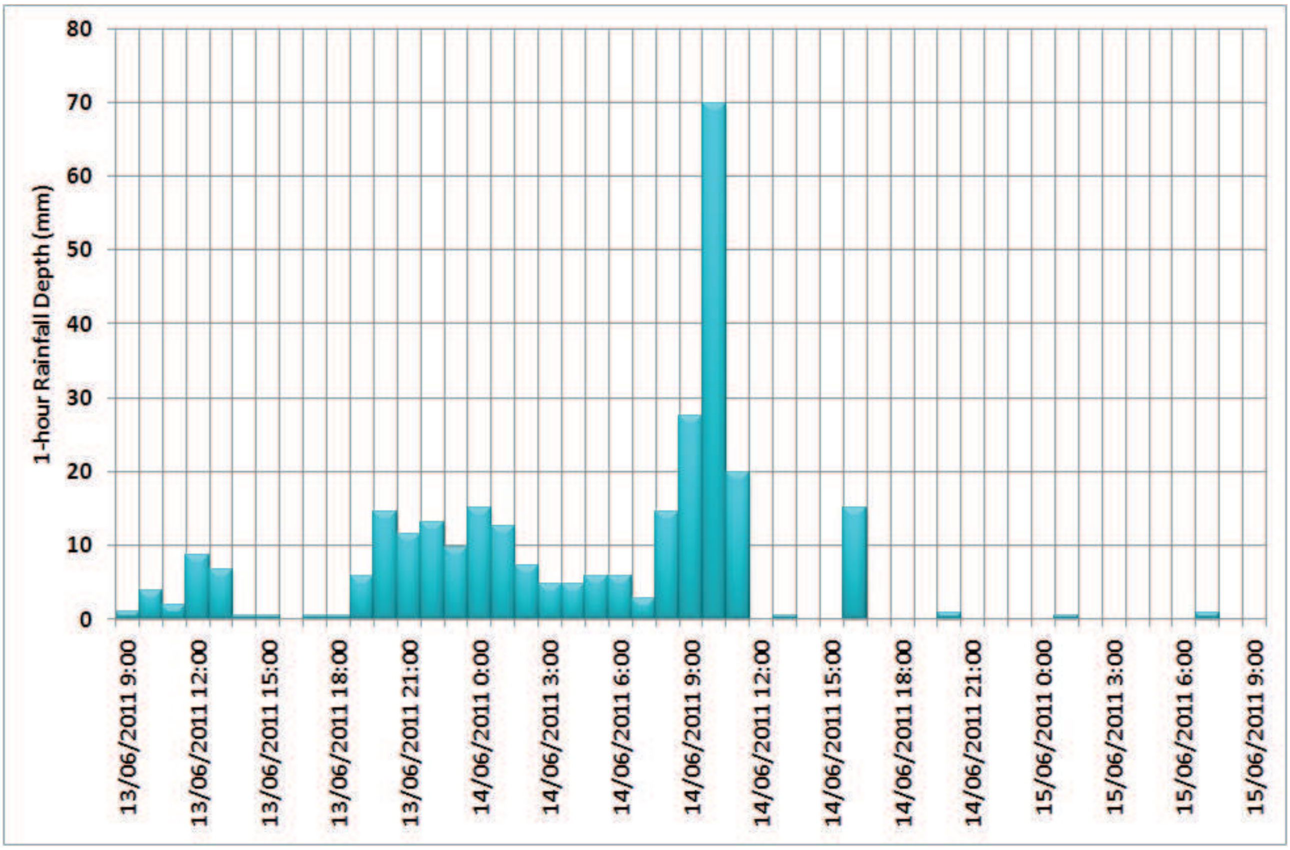


Figure 6-3 1-hour Rainfall Hyetograph for the June 2011 Calibration Event

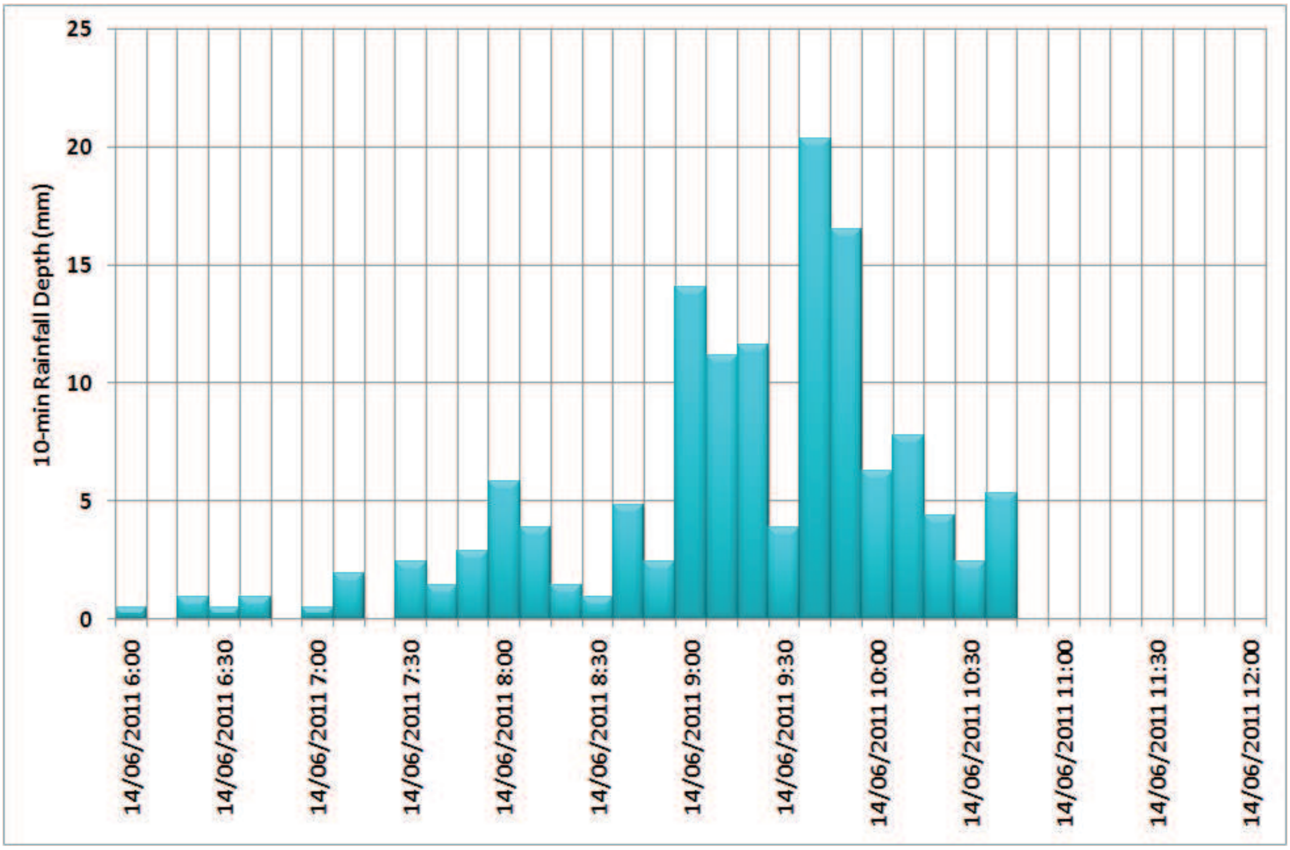


Figure 6-4 10-min Rainfall Hyetograph for the June 2011 Calibration Event

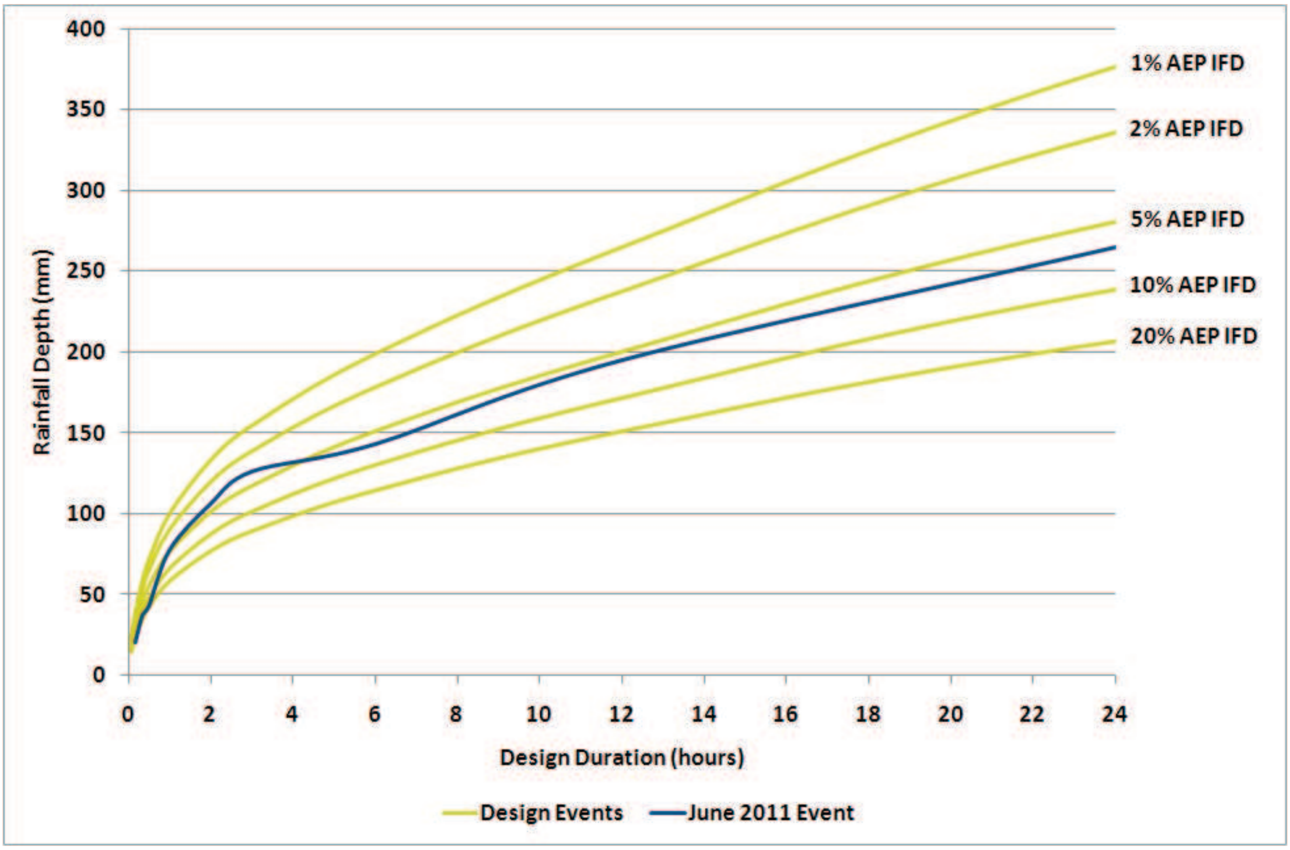


Figure 6-5 Comparison of Derived June 2011 Rainfall with IFD Relationships

6.2.2 Initial Conditions

Establishing appropriate initial conditions at the onset of a calibration event is integral to ensuring that the observed catchment response can be simulated adequately by the computer models. For this study the key initial conditions that were considered included:

- The storage level within Woolgoolga Lake;
- The storage level within Woolgoolga Dam;
- The antecedent catchment conditions.

The water level in Woolgoolga Lake is monitored by the MHL gauge and is presented for the June 2011 event in Figure 6-6, alongside the water level at the stream flow gauge on Woolgoolga Creek and the tide level at Coffs Harbour. The tide and lake levels are to Australian Height Datum and the creek levels are to gauge datum. Both the creek and the lake levels show a response to rainfall after 16:00 on 12th June. To assist in the calibration of the lake entrance dynamics, the entire period of lake response has been modelled, rather than just the main storm burst. The modelled period is effectively three rain days from 09:00 on June 12th to 09:00 on June 15th. For modelling purposes the initial water level in the lake has been set to 0.75m AHD, corresponding to the gauged level at that moment in time.

Woolgoolga Dam has a surface area of around 5ha and a catchment area only three times as large. It is therefore not critical for model calibration. However, there is the potential for overtopping of the spillway to contribute to flooding downstream and so it was incorporated into the TUFLOW model.

Weekly water level records for the dam were provided by Council. These show that in the period before the onset of the June 2011 event, the dam was close to the operating level of 17.86m AHD. This level was therefore applied as the initial condition in the model.

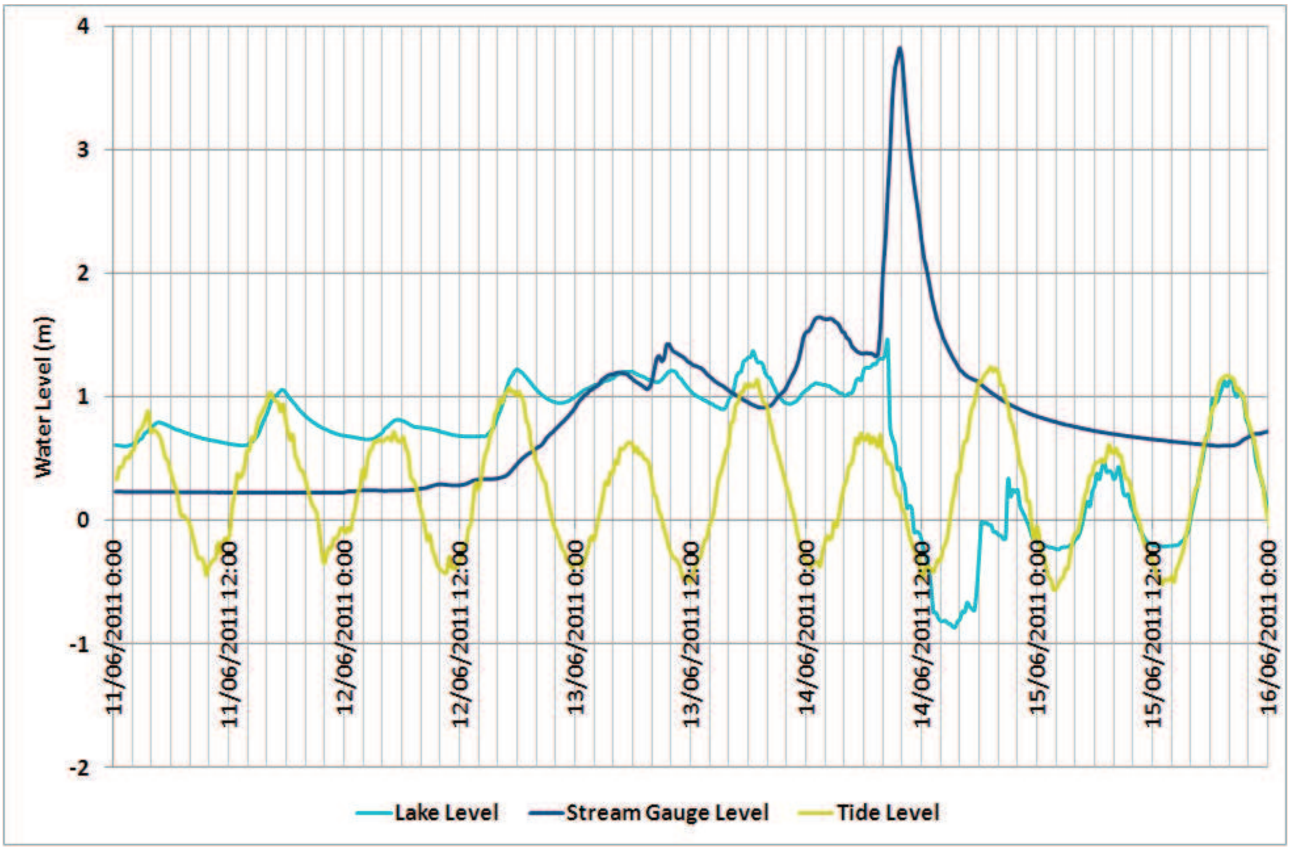


Figure 6-6 Woolgoolga Gauge Levels for the June 2011 Event

The antecedent catchment condition reflecting the degree of wetness of the catchment prior to a major rainfall event directly influences the magnitude and rate of runoff. This is represented through the initial loss component of the hydrological model, which has been set to a typical value of 20mm. The modelled period is three days in length from 09:00 on June 12th 2011. The main storm burst of the event was almost 48 hours after this, with some 260mm of rainfall in the intervening period. At the onset of the main storm burst the initial loss will already have been fully depleted, representing a fully wet catchment. This is appropriate given the large amount of rainfall before the event.

6.2.3 Entrance Berm Geometry

The modelled geometry of the lake entrance berm can significantly impact on the response of modelled lake levels to catchment inflows and tides. Ideally, for full calibration of the entrance dynamics, survey data of the berm heights before and after the event would be available. However, this data was not available for the June 2011 event.

Inspection of the available aerial images for the Woolgoolga Lake entrance (which date back to 1943) shows that the entrance is typically shoaled, with a shallow channel running across the berm. This condition is also suggested by the recorded lake levels in the period preceding the June 2011 event. Figure 6-6 shows that before 13th June the lake levels responded to the high tides but did not drop below 0.6m AHD on the low tides. This suggests an open but restricted entrance condition.

In the absence of event specific survey data, a typical berm condition has been represented. The available entrance elevations from the LiDAR data and hydrographic survey indicate that the entrance berm was generally elevated between 1.2m AHD to 1.5m AHD at the time of the surveys. This topographic representation of the berm was initially adopted and subsequently lowered by 0.6m, to provide the best match between the recorded and modelled water levels in Woolgoolga Lake. A 20m wide channel with a bed elevation of 0.5m AHD was also incorporated, in an attempt to recreate the entrance conditions that were indicated by the gauge records.

6.2.4 Adopted Model Parameters

The model calibration centred around the adjustment of the sub-catchment PERN values and Bx storage routing factor (hydrological model parameters) and the Manning's 'n' values for the floodplain and channel (hydraulic model parameter). The median grain size of the beach berm material also influenced the modelled peak water levels in Woolgoolga Lake and so was also varied during the calibration process.

The final values adopted, as shown in Table 6-2 were found to give a good result in representing the recorded water level hydrographs at the Woolgoolga Creek and Woolgoolga Lake gauges. The adopted parameters also provided a good match to the surveyed flood marks.

Table 6-2 June 2011 Model Calibration Parameters

Parameter	Value	Comment
Initial Loss (mm)	20	Initial loss was not a significant influence on the model results, given the lengthy modelled period and large rainfall depth preceding the main storm burst.
Continuing Loss (mm/hr)	2.5	Similar to adopted design continuing loss rate as recommended in AR&R (2001).
PERN Forested Cleared Urban (pervious) Urban (impervious)	 0.12 0.06 0.04 0.015	The PERN factors are used to adjust the catchment routing factor to allow for catchment roughness. Catchment average values were estimated based on representative land use/ground coverage.
Bx (storage routing parameter)	1.0	The adopted value was applied globally for the entire catchment and provided the best fit of catchment response in terms of flow magnitude and timing.
Manning's n (channel)	0.03 – 0.08	Variable adjusted locally (within reasonable bounds) to provide best fit for peak water level profiles. Variability largely reflects degree of channel vegetation, channel size and sinuosity.
Manning's n (floodplain)	0.02 – 0.12	Variable adjusted locally (within reasonable bounds) to provide best fit for peak water level profiles. Variability largely reflects land use on the floodplain (cleared, forested, roads, urban lots)
Entrance berm median grain size (mm)	0.25	Available data suggests that a median grain size of 0.25mm is appropriate for Woolgoolga.

6.2.5 Observed and Simulated Flood Behaviour

The recorded water level hydrograph at the Woolgoolga Creek gauging station provides the principal calibration data of the hydrological model for this event. A comparison of the simulated and recorded water level hydrographs at the gauge for the June 2011 event is shown in Figure 6-7. The recorded stage has been converted to Australian Height Datum using a surveyed level from the gauge board. The hourly rainfall distribution used in the hydrological model has been included for reference.

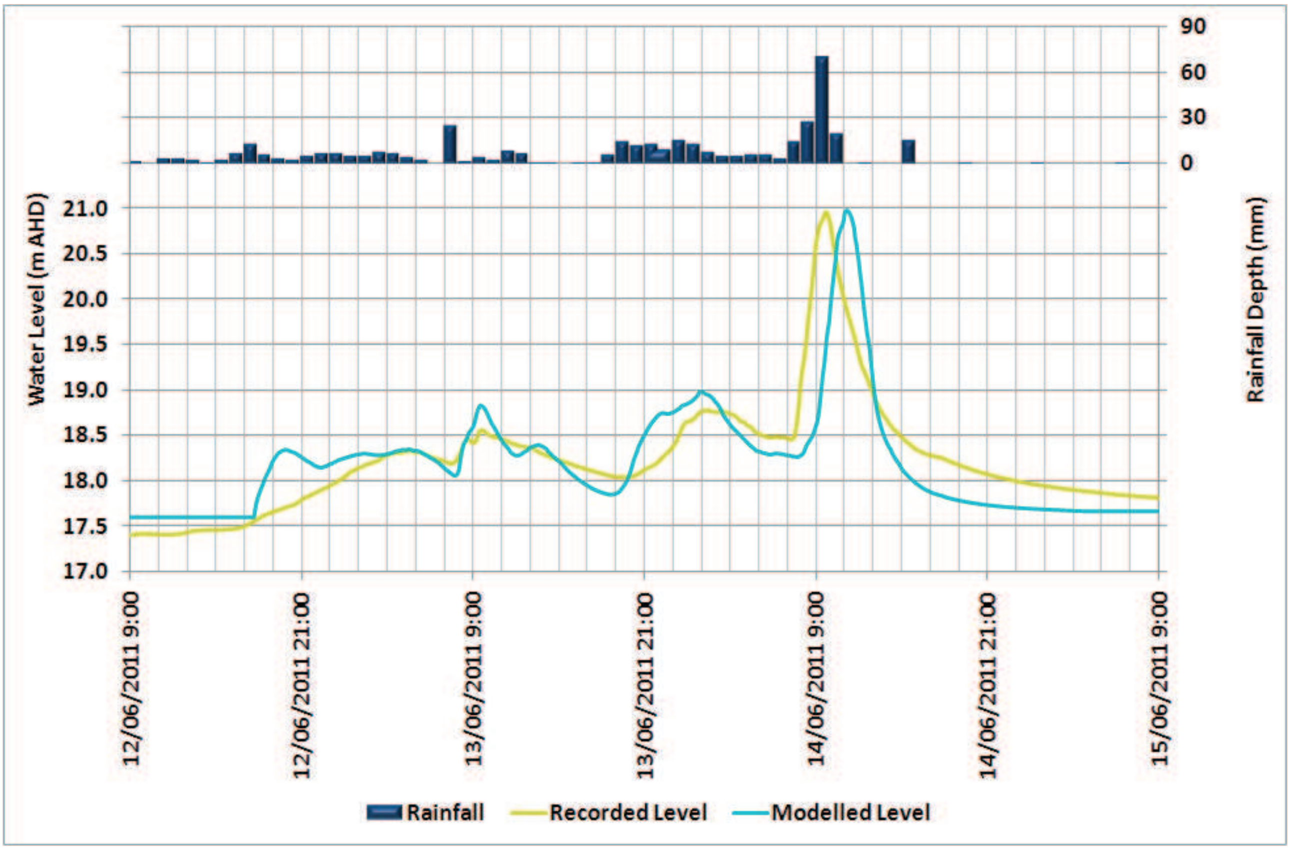


Figure 6-7 Comparison of Observed and Simulated Stage at Woolgoolga Creek for the June 2011 Event

The results indicate a relatively good agreement between observed and simulated conditions. The timing and shape of the hydrograph conform to the observed conditions with some expected minor discrepancy in the rainfall response prior to the main storm burst. As was discussed in Section 6.2.1, the temporal pattern adopted for the rainfall was known to show a one to two hour lag for the time at which the main storm burst passed over the Woolgoolga Creek catchment. This is evident in the timings of the modelled and recorded hydrographs, where the modelled peak occurs around one and a half hours after the recorded peak. The simulated peak flood level is less than 0.1m higher than the recorded peak and the modelled hydrograph shape is also a good representation of the recorded data.

There are a number of uncertainties in the simulated hydrological conditions, not in the least the assumed spatial and temporal distribution of rainfall which may have a significant influence on the catchment generated runoff. Overall the simulated catchment response is considered a good representation of the observed conditions. The deviations in the timing, shape and peak levels of simulated hydrographs from observed conditions are within acceptable bounds considering uncertainties in the data such as spatial and temporal variations in rainfall across the catchment.

The other location within the catchment that has recorded water level data available is Woolgoolga Lake. A comparison of the simulated and recorded water level hydrographs at the gauge for the June 2011 event is shown in Figure 6-8. The hourly rainfall distribution used in the hydrological model and the sea level recorded at Coffs Harbour have been included for reference.

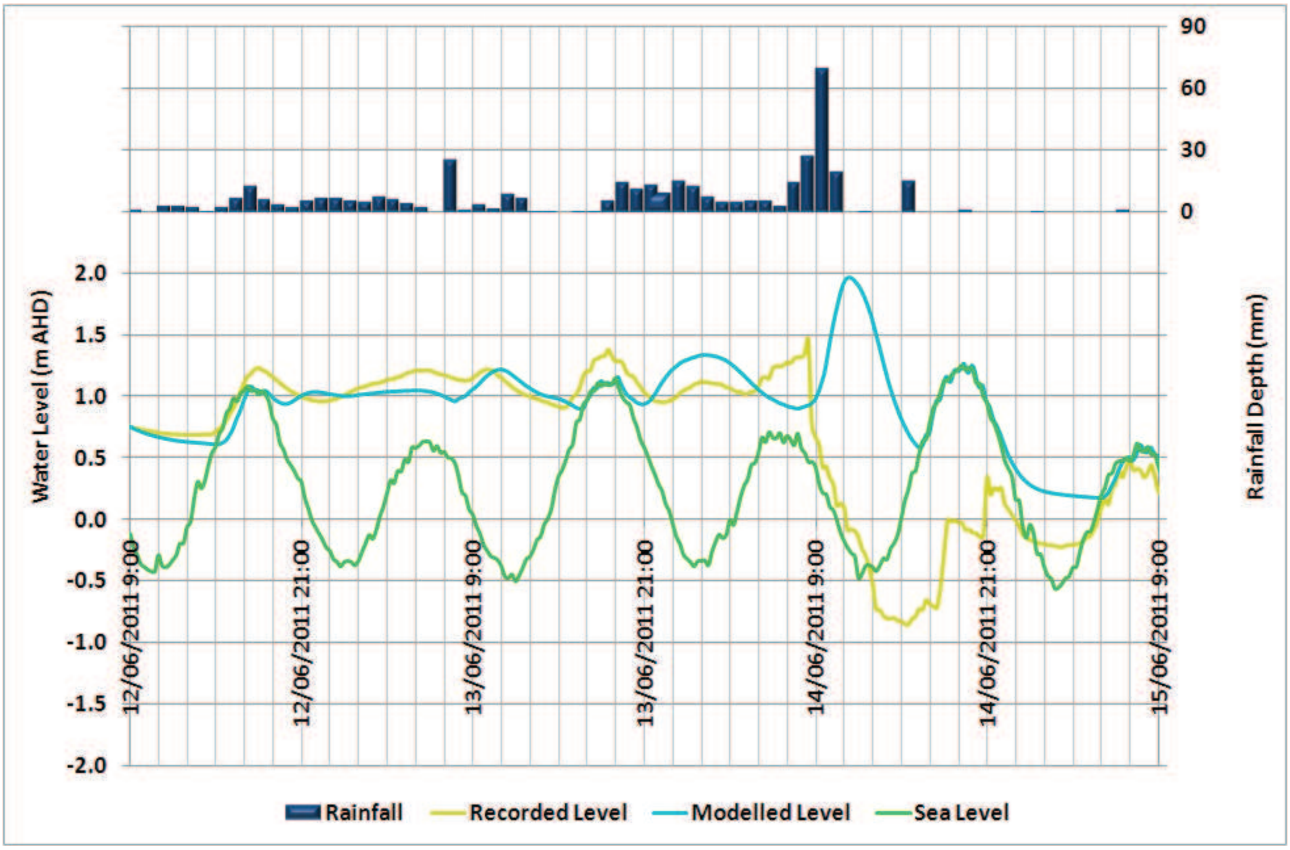


Figure 6-8 Comparison of Observed and Simulated Stage at Woolgoolga Lake for the June 2011 Event

The results indicate a relatively good agreement between observed and simulated conditions preceding the main storm burst. This indicates that the adopted entrance berm conditions provide a similar conveyance of water in and out of the lake. There is a tendency for the high tides to produce an increased water level in the lake within the recorded data, which is not replicated by the model. This may be due to the adopted sea level boundary from Coffs Harbour, which is a more sheltered location than the open coast at Woolgoolga. There may have been a small amount of wave setup or other water level anomaly not captured by the Coffs Harbour gauge.

Unfortunately, the Woolgoolga Lake gauge did not capture the event. It is evident from the comparison of recorded levels at Coffs Harbour that the Woolgoolga Lake gauge was not recording correct water levels during the peak of the event. The recorded gauge data at Woolgoolga Lake can therefore not be used to assess the accuracy of the modelled peak lake level.

There were also a number of surveyed flood marks available for the June 2011 event. Almost 30 flood marks were surveyed across the study area, largely relating to flooding on Woolgoolga Creek and in local urban sub-catchments. There are also a couple located on Poundyard Creek and Jarrett Creek. Figure 6-9 presents a long section of modelled peak water levels on Woolgoolga Creek for the June 2011 event, against the available flood marks relating to Woolgoolga Creek flooding. The modelled bed elevation is also included for reference.

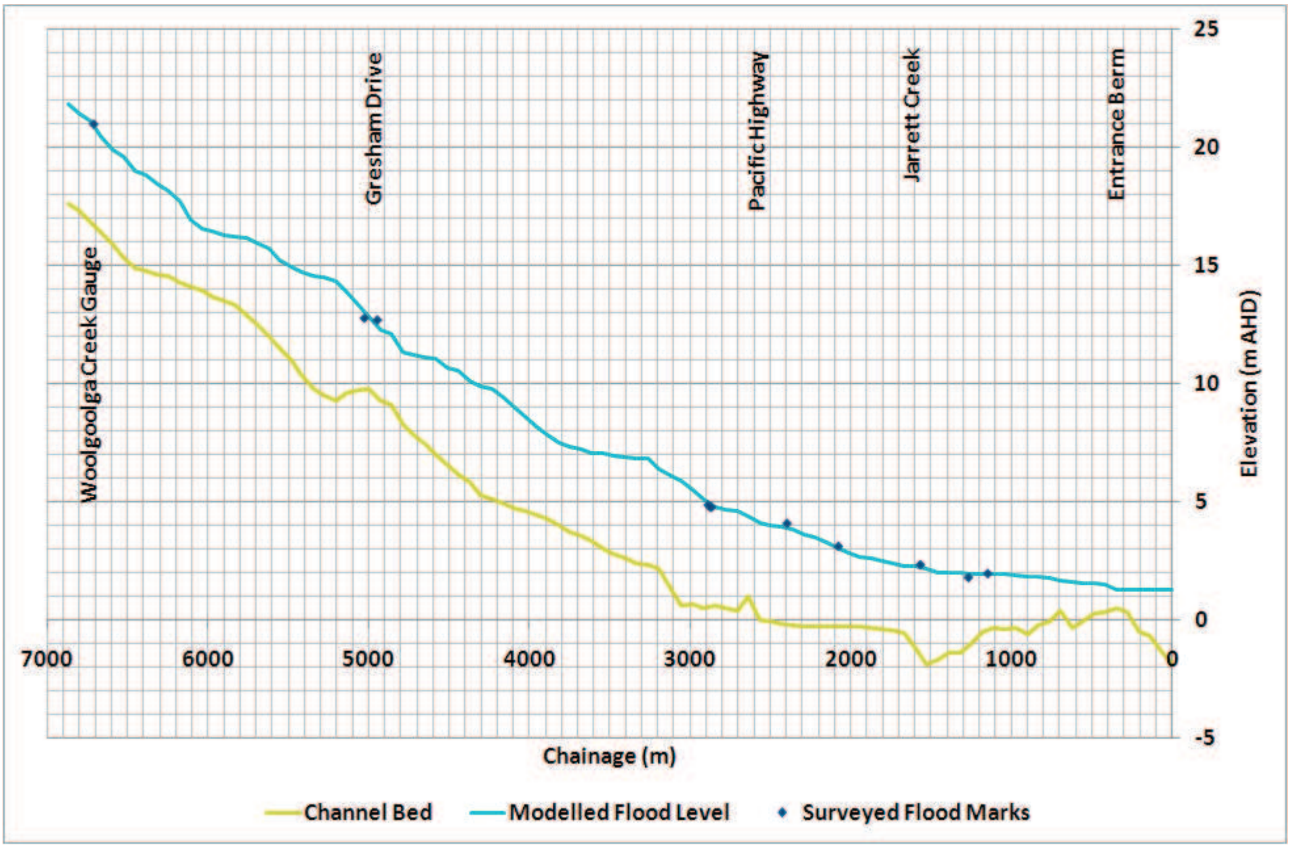


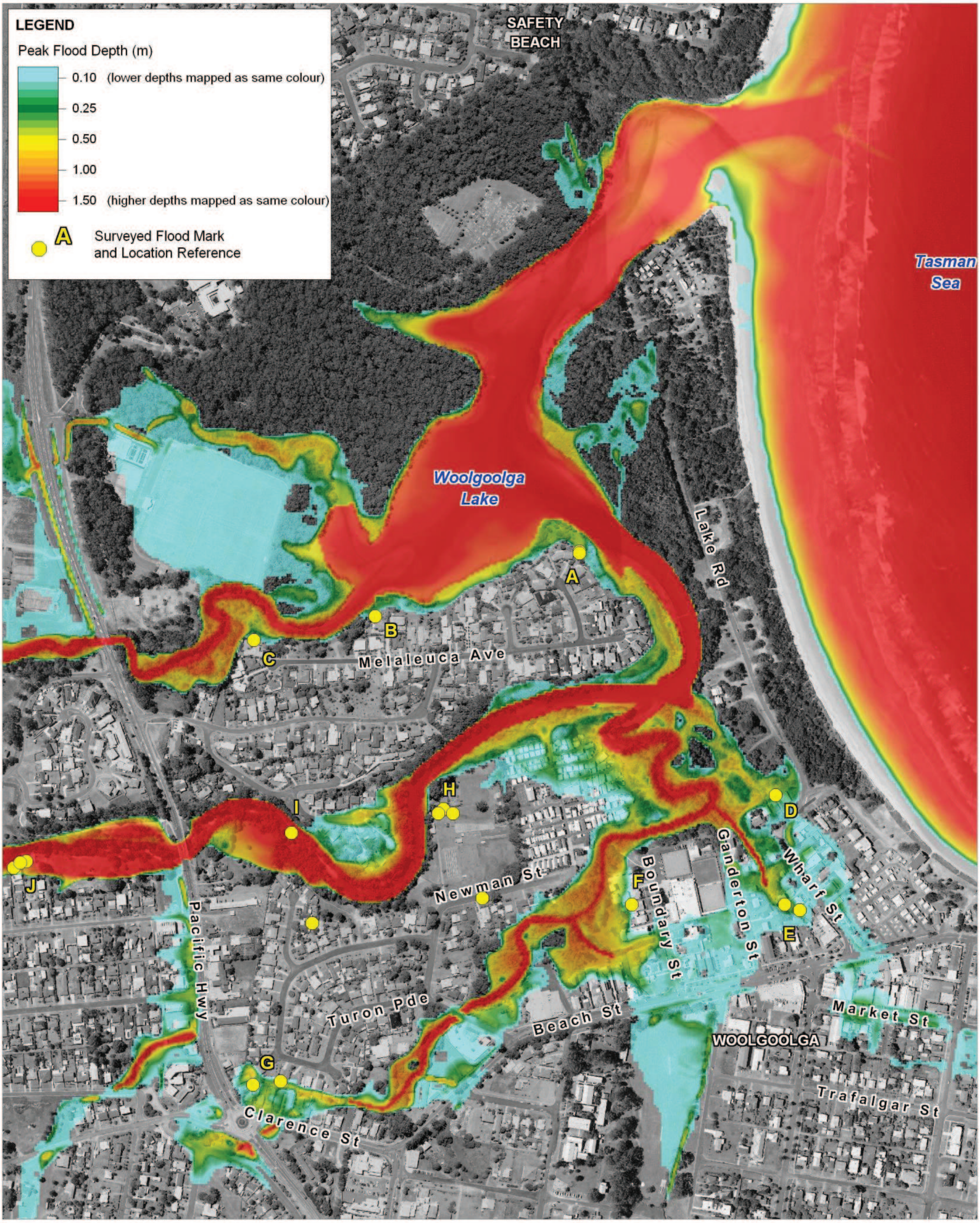
Figure 6-9 Long Section of Modelled Peak Flood Levels on Woolgoolga Creek for the June 2011 Event

The results show a good match to the surveyed flood marks, with the majority of modelled peak water levels being within 0.2m of the survey data. There is some inherent uncertainty related to the surveyed levels of flood marks. Local conditions can often indicate flood levels that are above or below the general representative flood level of the broader area. However, the overall predicted flood peak is considered a good representation of the observed conditions.

Figure 6-10 shows the modelled flood depths in Woolgoolga, where most of the surveyed flood marks are located. The flood mark locations have been marked on the map and include specific location references, which are discussed in further detail.

Woolgoolga Lake

The surveyed flood marks at Location A and Location B are indicative of the peak flood level in Woolgoolga Lake. They are both situated on the open water body, downstream of the significant hydraulic gradients associated with Woolgoolga Creek and Poundyard Creek. Three survey points were taken at Location A, two of which provide a flood level of around 1.6m AHD and another which provides a level of around 1.8m AHD. The survey point at Location B indicates a peak flood level of just under 2m AHD. The model provides a consistent flood level at the two sites of just over 1.9m



Title:

Model Calibration for the June 2011 Event

Figure: 6-10

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AHD. This matches well with the surveyed levels of 1.8m AHD and 2m AHD, given the level of uncertainty in estimating peak levels from flood marks. It is most likely that the two survey points at 1.6m AHD are not representative of the peak flood level.

Poundyard Creek

The surveyed flood mark at Location C is one of only two available on Poundyard Creek. It indicates a flood level of around 2.4m AHD, compared with a modelled level of 2.3m AHD. Again, the model provides a good match with the observed data. There is a steep flood gradient modelled at the site, ranging between 2.5m AHD to 2.1m AHD 30m upstream and downstream respectively. Therefore the local flood conditions at the location of the flood mark may have a significant impact on the flood level. A flood photo taken at the site is presented in Figure 6-11.

The only other flood mark on Poundyard Creek was located upstream of Shearer Drive, indicating a peak flood level of 20.9m AHD. The flood gradient is particularly steep here, varying by around 1m in a 40m reach. This makes interpretting the flood mark for calibration largely impractical, however, the modelled flood levels at this location are similar to that which has been surveyed.

Figure 6-11 Flood Photo at Location C

Wharf Street

There are three surveyed flood marks located in the Wharf Street area. The flood level indicated at Location D is around 2.3m AHD. At Location E there are two flood marks surveyed at 2.3m AHD and 2.4m AHD. The flood level of 2.3m AHD is indicative of the backwater level along woolgoolga Creek and Jarrett Creek and a similar level has been produced by the model. The 2.4m AHD flood mark is located slightly further upstream and may have included a small flood gradient or local hydraulic