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Project title	Bega Valley Health Service Hospital Development - Review of Flooding Aspects	Job number	224753-00
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Introduction

Health Infrastructure are in the process of assessing development requirements for the South East Regional Hospital at a site in the south-east corner of the town of Bega. The site is bounded by Howard Avenue to the north, Tathra Road to the west, Boundary Road to the south and the Bega River to the east (see Figure 1).

Arup has been engaged to undertake a review of an assessment of flooding aspects prepared by WMAwater ('Bega Valley Health Service Hospital Development Flooding Aspects', WMAwater, 27th March 2012) [Reference 1]. This review has included a review of the available data, a re-assessment of the estimated flood levels at the site and provides further commentary on relevant land use planning policy and flood risk management guidance documents.

Available Data

As outlined in the WMAwater report a detailed Flood Study has not been undertaken for the Bega River. In the absence of such a study this review has sought to identify any available data which may be relevant to inform an assessment of flooding aspects

Flow and water level information has been sourced from the gauges listed in Table 1, which also includes additional information relating to the gauge and the subject site. The location of these gauges is shown in Figure 1.

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Figure 1 Site location

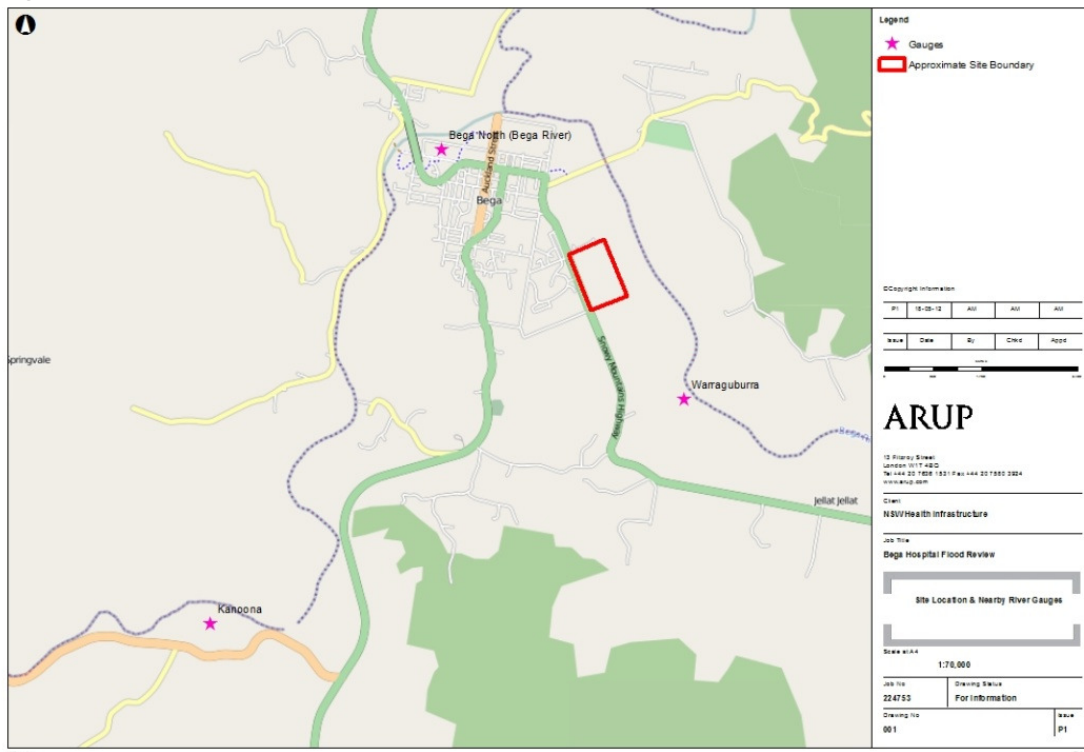


Table 1 River gauging stations

Gauge No.	Location	Catchment Area (km ²)	Distance to Site Location (m)	Data Available
219032	Bega River @ Kanoona	825	17,600 (u/s)	Flow and level
219900	Bega River @ Bega	1020	930 (u/s)	Level only
219026	Bega River @ Warraguburra	1828	500 (d/s)	Level only

Flood inundation data has been taken from a Water Resources Commission diagram which was produced in 1979 [Reference 2]. This contains predicted flood inundation extent information (see Figure 2) and predicted flood heights at the Bega gauge (see Table 2).

Table 2 Flood Heights at North Bega (taken from Reference 2)

Recurrence Interval	Gauge Height (m)	R.L. Metres (A.H. Datum)
100	9.6	15.3
50	9.25	14.95
20	8.5	14.2
10	7.7	13.4
5	6.7	12.4

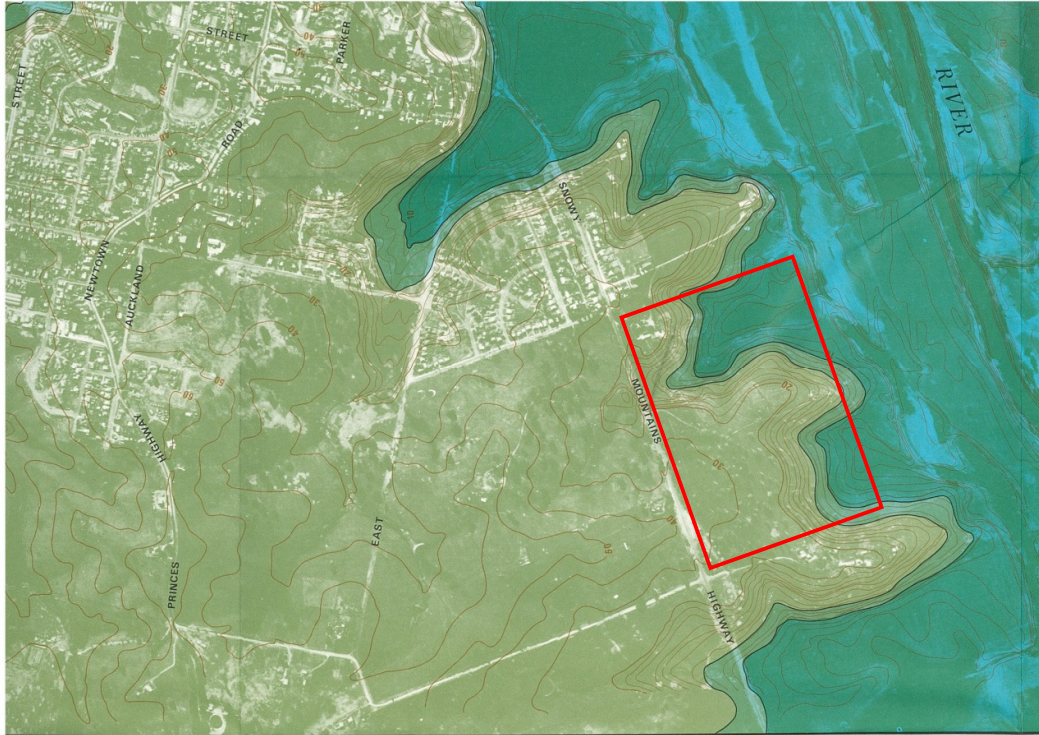
Topographic survey was available for the proposed site, as well as two cross-sections through the Bega River and floodplain. These sections have been annotated with peak levels for 1971 and 2011 flood events, provided by a local landowner. The peak levels are 14.1 mAHD and 11.2 mAHD, respectively.

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Figure 2 WRC Bega Flood Inundation Map (1979)



Estimated Flood Levels at the Site

Historic Flood Data

As shown in Table 1 the total catchment area at the Warraguburra gauge, approximately 500m downstream of the site, is 1828 km². The catchment area to the site is therefore likely to be in the range 1700-1800 km². The Bega River, adjacent to the site, should be considered as a relatively major river.

An account of historic flooding in Bega along with assignment of return periods to two flood events is provided in [Reference 1]. Due to a lack of relevant flow data it has not been possible for Arup to independently confirm these return periods. However, a qualitative assessment of the peak flood levels and return periods did not identify any major concerns, so that the historic flood levels at the site may be regarded as:

- 1971 event @ 14.1 mAHD = 138 year ARI event
- 2011 event @ 11.2 mAHD = 20 year ARI event

Reference 1 identifies the 100 year ARI event peak level, at the site, to be approximately 14.0 mAHD. This is based on the Water Resources Commission flood inundation plan and correlates reasonably well with the two observed events above. This review confirms this to be the most appropriate 100 year ARI event peak level, based on the presently available data.

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PMF Analysis

The PMF peak flood level for the site has been re-assessed using the methodology outlined in [Reference 3], where an initial indication of the peak flow is provided by the equation:

- $Q = 129.1 \text{ Area}^{0.616}$

For the subject site the catchment area has been linearly interpolated between the upstream and downstream gauge catchment areas, to produce a value of 1545 km². It is acknowledged that this approach may not truly reflect the Brogo River inflow immediately downstream of the Bega gauge but the higher weighting assigned to the Warraguburra gauge is considered to smooth this out somewhat.

Substituting this area value into the equation above produces a peak PMF flow at the site of approximately 12,000 m³/s.

The channel cross-section information in Figure 3 and Figure 4 (Section B-B) has been used to derive cross-sectional area and wetted perimeter information for varying elevations. These have then been input to the Mannings equation to calculate the resultant peak flow at each elevation. The results from this assessment are sensitive to the roughness (Mannings 'n') value assumed within the calculation.

Table 3 provides a summary of the elevation at which a flow of 12,000 m³/s is attained, for a range of Mannings 'n' values.

Table 3 PMF Peak Flows at Varying Mannings 'n' Roughness Values

Mannings 'n'	Peak Flow (m ³ /s)	Elevation (mAHD)
0.04	12,464	15.0
0.05	12,487	16.0
0.06	12,882	17.0
0.07	12,167	17.5
0.08	12,178	18.25

From internet-based digital imagery and mapping the Bega River is relatively sinuous and is characterised by significant stones and boulders. The text reference 'Understanding Hydraulics' (Hamill, 2011) [Reference 4] provides typical values of Mannings 'n' for different types of surface, including:

- Rivers, with stones 75-150 mm diameter & poor alignment = 0.040 – 0.080

The results in Table 3 reflect this range in roughness values. An elevation of 15 mAHD constitutes a rise of only 1m above the 100 year ARI event peak level and this is considered to be an unrealistically small increase in peak level between these two events. It would be reasonable to expect a rise of at least 2m between the 100 year ARI event and the PMF, although it should be highlighted that this rise can be considerably greater.

Based on the initial PMF peak flow estimate and guidance on appropriate range of roughness values, the PMF peak level at the site can be expected to lie between 16.0 and 18.25 mAHD. This range takes no account of any back-water effects arising from the impact of structures or constrictions in the channel, nor from any effects of elevated sea levels at the mouth of the Bega River Estuary.

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Due to the high-level nature of this PMF analysis, coupled with the assumptions documented above, a conservative approach is highly recommended. Therefore, a PMF peak level of 18.25 mAHD should be utilised within any subsequent land-use planning and/or early design phases. This compares with a level of 20.5 mAHD within the WMAwater study [Reference 1]. It is also stressed that further, more detailed assessment of the actual PMF flow and level should be undertaken to confirm this level.

Figure 3 Site topographic survey

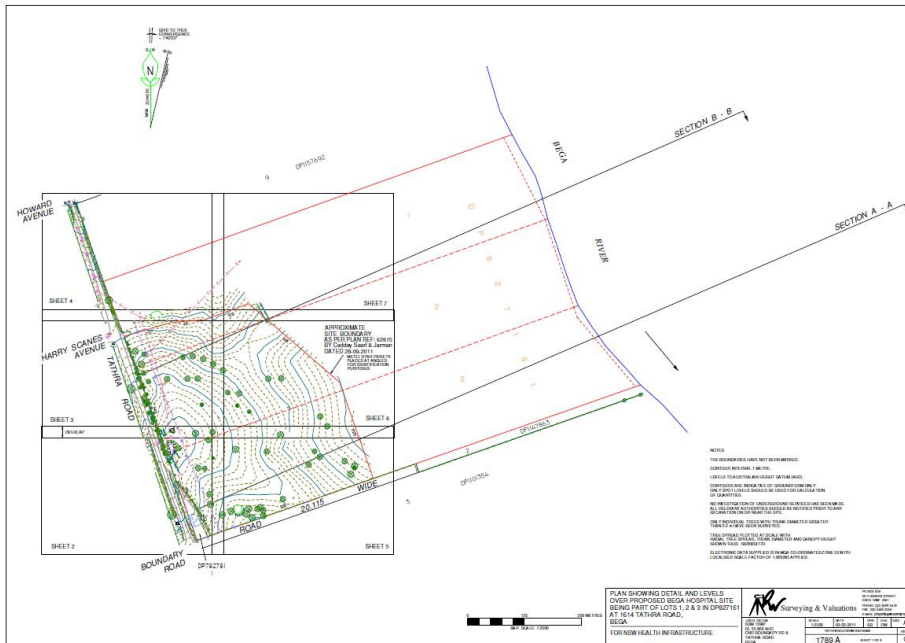
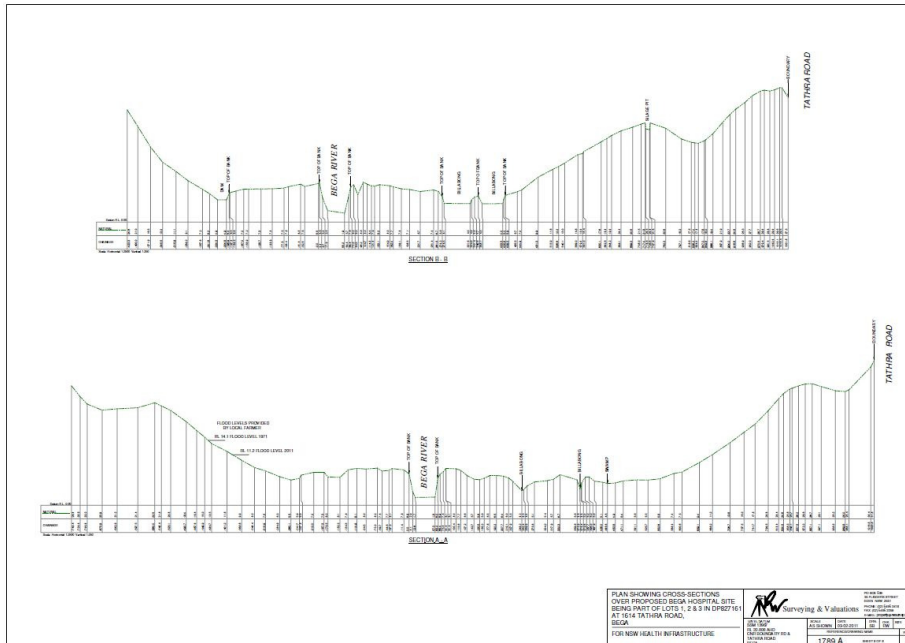


Figure 4 Cross-sections through site

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Flood Levels Below PMF

A method outlined in Australian Rainfall and Runoff (Book 6) [Reference 5] has been used to estimate flow rates for 500 and 1000 year ARI events. These were then converted to peak levels using the same methodology as applied to the PMF analysis, again applying a precautionary principle. These peak level results are shown in Table 4.

Summary Flood Levels

Table 4 provides a summary of the estimated peak flood levels for the proposed site, at varying recurrence intervals, and also includes the peak levels as outlined in the WMAwater study [Reference 1]. These levels are based on a high-level, desktop assessment only. The levels should be confirmed by the completion of a comprehensive and detailed flood study of flood behaviour in the Bega area.

Table 4 Estimated Peak Flood Levels at the Proposed Site

ARI Event	Arup Peak Flood Level Estimate (m AHD)	WMAwater Peak Flood Level Estimate (m AHD)
100 year	14.0	14.0
500 year	15.0	15.4
1000 year	16.75	16.0
PMF	18.25	20.5

The degree of flood risk varies considerably across the site. Approximately half the site would be inundated during a PMF event with depths in excess of 10m. The spatial extent of flooding only reduces by a relatively small amount in the 1000 year ARI event so that a significant proportion of the site would be inundated by such an event. It should be highlighted that the Tathra Road would be become inundated during both a PMF and 1000 year ARI event. This may present issues associated with access to the site.

Climate Change

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The NSW Floodplain Development Manual (OEH, 2005) requires that a flood study should address the possible implications of climate change on flooding behaviour, including sea level rise and increased rainfall intensity.

The site levels are such that sea level rise will not impact upon flood levels.

The flood levels in **Table 4** are not based on detailed hydrological and hydraulic calculations. It is therefore not possible to undertake a quantitative sensitivity analysis of the impact of increased rainfall intensity and/or volume. Rather, a qualitative approach is required to provide an indication of the potential impact of climate change on peak flood levels. One such method is to apply a 300 mm allowance on top of the estimated peak flood level. However, the extreme and uncertain nature of the large magnitude events such as the 1000 year ARI and PMF draws into question the need for a climate change allowance for these events.

The actual impact of climate change on flood levels should be quantified as part of a detailed hydrological and hydraulic analysis, and the subsequent management requirements discussed with OEH (as per the guidance within the Floodplain Development Manual). The flood risk management conclusions and recommendations below relate to the 1000 year ARI and PMF event levels and therefore no allowance has been applied to the lower return period events within this assessment.

Flood Risk Management

Reference 1 provides a summary of the relevant sections from a number of planning policy and flood risk management guidance documents. The conclusion drawn from these documents was that, due to the highly vulnerable nature of a hospital, the development should be sited above the PMF level. The documents referred to are:

- Draft Bega Valley Local Environment Plan (2010) (LEP) [Reference 6];
- Draft Bega Valley Shire Development Control Plan (2010) (DCP) [Reference 7];
- NSW Floodplain Development Manual (2005) [Reference 8];
- 'Guidance on Land Use Planning in Flood Prone Areas' by the Hawkesbury Nepean Floodplain Management Steering Committee (2007) [Reference 9].

In addition to the above, the following documents were also reviewed as part of this assessment:

- Floodplain Management in Australia: best practice guidelines, SCRAM Report 73 [Reference 10];
- Managing the Floodplain, Emergency Management Australia, Manual 19 [Reference 11].

As outlined in Reference 1, the draft Bega Valley Shire LEP and DCP do not contain specific controls relating to the development of new hospitals. These documents also do not contain any specific requirements relating to off-site flood impacts during events larger than the 100 year ARI event. This generally reflects the situation on a wider basis, where it is not typically considered a requirement to consider off-site effects above the 100 year ARI event.

Each of the floodplain risk management guidance documents [Reference 6 to Reference 11] outlines a preference for vulnerable new developments, such as hospitals, to be located above the PMF level and therefore outside the zone of flood risk.

However, several of these guidance documents also concede that locating a development at this level may not always be practicable. For example, Figure 5 (taken from Reference 10) shows that a

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hospital may be considered as an appropriate land use within the ‘low’ flood hazard zone. The definition of the ‘low’ flood hazard zone, as defined by the same document, is shown as Figure 6. Reference 10 also summarises that:

“Best practice principles with regard to urban infrastructure design include:

- *Essential facilities such as telephone exchanges, police stations, hospitals and flood management coordination centres should be sited in flood-free locations or above PMF level, or failing this, these facilities need to be protected with permanent or temporary banks;”*

Figure 5 Appropriate land uses from Reference 10

Land use	Degree of hazard			
	Low	Medium	High	Extreme
Open space/recreation	✓	✓	✓	✓
Residential	✓	✓		
Commercial/Industrial	✓	✓	✓ ^A	
Public Institutions	✓	✓		
Hospitals	✓			
Homes for the elderly	✓			
Caravan parks	✓	✓		
Museums/libraries	✓			
Clubs	✓	✓	✓ ^B	✓ ^B
Schools	✓	✓		
Police	✓			
Council	✓	✓		
Telephone exchanges	✓			
Emergency services	✓			

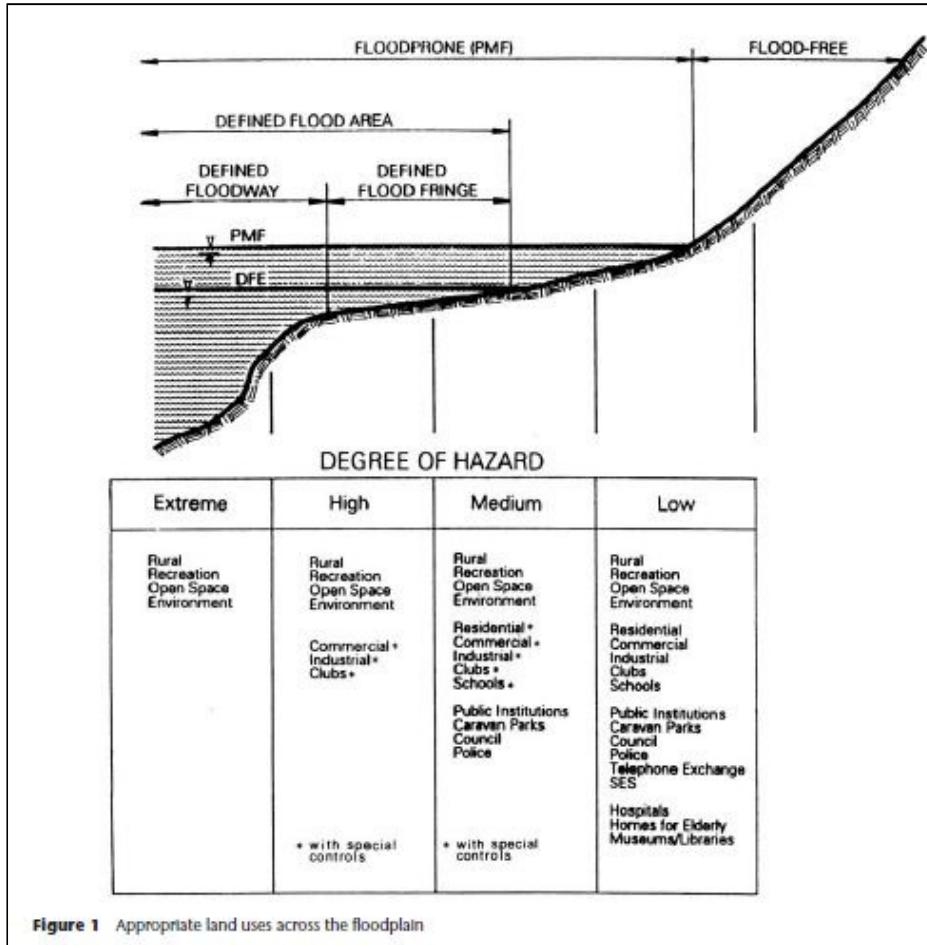
^ACommercial/Industrial operations can treat the cost of flood damage as a “business cost” and include it in their budgets.
^BClub houses may be appropriate to high hazard areas or even extreme hazard areas, provided they are appropriately floodproofed.

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Figure 6 Appropriate land uses by degree of hazard (from Reference 10)



The Hawkesbury Nepean Floodplain Management Steering Committee document [Reference 9] includes hospitals within the grouping ‘community infrastructure’, and highlights that:

“Preferably, they should not be located below the PMF but it is recognised that new community infrastructure may need to be located on flood prone land to service flood prone towns and villages. In such cases the main considerations would be the safe evacuation of occupants and protection of critical components to facilitate post-flood recovery.”

The overarching message from the relevant guidance documents is that, if at all possible, any new hospital development should be above the PMF level. However, there is also an acceptance that this may not be possible at each and every location. In such instances, protection should be afforded to the hospital up to the level of the PMF and/or the development should be planned so that those facilities of highest risk, as well as an access/evacuation route, are located above the PMF level.

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Conclusions and Recommendations

The following are a summary of the key flood risk management conclusions and recommendations which should be followed in order to provide a safe and operational hospital:

- A comprehensive analysis of flood risk to the site should be undertaken to confirm the most appropriate flood levels, for a range of return periods, and including an assessment of climate change impacts;
- The proposed hospital development should adopt the PMF level as the flood planning level;
- If this is not possible, the development should be located at as high an elevation as possible, with a minimum requirement to be above the 1000 year ARI maximum flood level. In such circumstances the hospital should be protected up to the PMF level. Initial review of the site contours suggests that such protection would be achievable;
- A further allowance on top of the 1000 year ARI or PMF event flood levels for climate change is not considered necessary at this stage, due to the extreme and uncertain nature of these events. However, this approach should be discussed with relevant representatives from OEH and re-visited following a detailed flood risk analysis;
- An access route should be available to the hospital which will remain free of flooding, including during a PMF event;
- There are no current flood risk management requirements relating to off-site impacts for land above the 100 year ARI maximum flood level

DOCUMENT CHECKING (not mandatory for File Note)

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