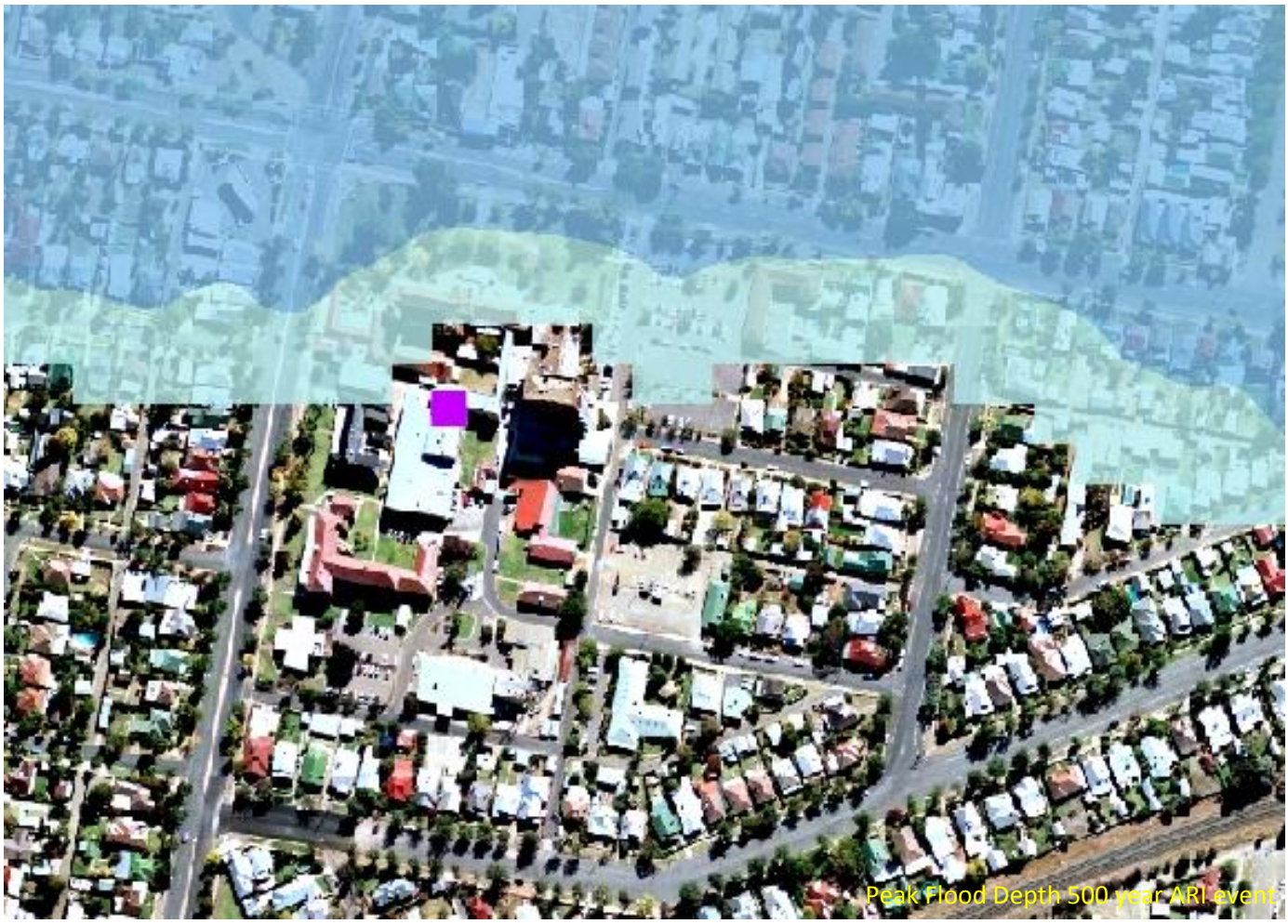
APPENDIX E

Flood Impact Assessment

HEALTH INFRASTRUCTURE

WAGGA WAGGA BASE HOSPITAL REVIEW OF FLOODING ASPECTS

FINAL REPORT



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MARCH 2011

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WAGGA WAGGA BASE HOSPITAL
REVIEW OF FLOODING ASPECTS

FINAL

MARCH 2011

Project Wagga Wagga Base Hospital Review of Flooding Aspects	**Project Number** 110071
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Date 8 March 2011	**Verified by**

Revision	Description	Date
3		
2	Final	MAR 10
1	Draft for Client Review	DEC 10

WAGGA WAGGA BASE HOSPITAL
FLOOD IMPACT ASSESSMENT

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EXECUTIVE SUMMARY

The Greater Southern Area Health Service are currently evaluating redevelopment of the Wagga Wagga Base Hospital located at a site bounded by Docker and Edward Streets.

WMAwater (formerly trading as Webb, McKeown and Associates) have been engaged to provide information relating to flood levels, time of inundation and potential impacts. The information will provide advice on the potential design and risk management measures that may exist to reduce the impact of flooding.

Results indicate that immediate access to the site is first inhibited at the northern entrance by the 500 year ARI event. The 1000 year ARI inundates approximately 50% of the site severely affecting site access.

A development such as a hospital would ideally be located above the PMF, southern portions of the site remain flood free during this event allowing flood free evacuation. Site constraints associated with the redevelopment of the existing hospital, set the proposed flood level at 182.58 mAHD. Flood risk varies slightly across the site with some areas becoming inundated in slightly more frequent events. The proposed floor level at the existing clinical services building is 182.58 mAHD which provides that location with flood protection up to approximately the 750 year ARI event with a 0.5m allowance for freeboard.

Climate Change scenario modelling indicates that flood levels may reasonably increase by between 0.2 to 0.3 m. Assumptions regarding levee failure result in flood level increases of up to 0.2 m. A 0.5m freeboard should be adopted to incorporate model uncertainty and climate change impacts.

Further, the implications of flood inundation should be documented in a flood response and evacuation plan and strategies developed to minimise impacts to essential patient care.

1. INTRODUCTION

The city of Wagga Wagga is located on the Murrumbidgee River and has been subjected to significant flooding in the past. The CBD area is protected by the main City Levee (Figure 1), which at present protects the town in most locations up to approximately the 1974 flood event (approximately 60 year ARI including an allowance for freeboard). Overtopping or failure of the levee, however, may result in flooding in the main CBD area, including in the vicinity of Wagga Wagga Base Hospital (WWBH).

The Greater Southern Area Health Service are currently evaluating redevelopment of the WWBH, located at a site bounded by Docker and Edward Streets. WWBH is an important regional health centre, servicing much of south-western New South Wales.

WMAwater (formerly trading as Webb, McKeown and Associates) have been engaged to provide sufficient information relating to flood levels, time of inundation and potential impacts to enable a clear picture of the overall risks to the proposed hospital redevelopment, and to provide advice on the potential design and risk minimisation measures that may assist in reducing the impact of flooding.

This report will form part of the submission for a Part 3A Concept Application for the WWBH Masterplan.

2. HISTORY OF FLOODING

The Murrumbidgee River is a major tributary of the Murray River system and drains some 100,000 km^2 in the southern inland area of New South Wales. Rising on the western slopes of the Snowy Mountains the Murrumbidgee River has a catchment area of some 26,400 km^2 at the city of Wagga Wagga.

Since early European settlement in the 1840's, the city of Wagga Wagga has experienced flooding on numerous occasions causing considerable damage and inconvenience. These events have shaped the past and will continue to shape the future development of the city and the region. The original settlement of North Wagga Wagga is situated on the northern floodplain but the majority of the city and recent developments are now located on the high ground of the southern bank. Industrial development has also occurred on the southern floodplain spreading east from Wagga Wagga along the Sturt Highway towards the township of Gumly Gumly and the airport. This is known as the Eastern Industrial Area.

Official records of river levels are available at Hampden Bridge from 1886 onwards, with estimated river levels available since 1838. Floods over 10 metres at the Hampden Bridge Gauge were recorded in 1891, 1925, 1950 and 1974. Flood events in 1844, 1852, 1853 and 1870 also probably exceeded this height. The flood record is extremely variable with five floods occurring in 1974 and frequent flooding experienced in the period from 1950 to 1956. There have also been long periods of no flooding, such as from 1939 to 1949, 1960 to 1970 and 1992 to 2005. More recently the town experienced flooding during December 2010 when the river peaked at 9.8m.

It is also important to identify that the Wagga and North Wagga levees, as well as other infrastructure that has been built over the past 50 years, have raised flood levels on the surrounding floodplain. As a results, the floods that occurred in the 1800's and the early 1900's would be potentially higher if they occurred under current conditions.

3. BACKGROUND

3.1 Survey

Spot height levels were collected around the perimeter of the Hospital as well as in key areas within the property, including essential services, ambulance and emergency areas and floor levels of major buildings.

3.2 Light Detection and Ranging (LIDAR) Data

LIDAR data was collected along the Murrumbidgee River and Floodplain in 2008. This data once processed was provided to Council. WMAwater have utilised this data to update various aspects of Councils hydraulic modelling. The data has an accuracy of +/- 0.15m at 67% confidence (1 standard deviation) and covers the site of WWBH.

3.3 Murrumbidgee River Wagga Wagga Flood Study (September 2004)

The Murrumbidgee River Wagga Wagga Flood Study was completed by Webb, McKeown and Associates in September 2004. The Flood Study reviewed the previous work undertaken, updated topographical information and expanded upon the flood modelling results using updated techniques. A rigorous flood frequency analysis of all past flood records was undertaken to determine the magnitude of the design events. A 1D RUBICON hydraulic (computer) model was established, calibrated to historical data and used to determine design flood levels. The modelling and results incorporated many significant changes to the floodplain which have occurred since the previous 1988 Flood Study was undertaken.

The Flood Study also included an examination of the location and extent of overtopping of the Main City Levee. Following a detailed analysis of the historic flood record, it was determined that the August 1974 flood is now considered to be a 60 year ARI event and not a 90 year ARI event as previously thought. The Main City Levee was designed to the 1974 event plus freeboard. That is, the Main City levee currently provides protection to Wagga Wagga up to approximately 60 year ARI event.

3.3.1 Flood Study Update - April 2005 and October 2006

Following the completion of Wagga Wagga Flood Study in September 2004, a discrepancy in the levels of a section of the Main City Levee, upstream of the Hampden Bridge, were identified. A new survey was commissioned for this area and the update levee heights incorporated into the RUBICON hydraulic model. The updated model results had minimal impact across the floodplain except in the vicinity of the updated survey. The primary impact of the updated levels on the levee performance is that the levee provides greater protection at this location than previous identified.

Following a review of the Flood Study and Floodplain Risk Management Study (FRMS), two guidelines were prepared for the assessment of flood levels and impacts associated with leveed towns and assumed levee failure mechanisms. The previous modelling assumed the unrealistic case that the levee would not fail if overtopped. The design flood levels were subsequently reviewed inline with an assumed levee failure mechanism.

Design flood behaviour was established for the 10, 20, 50, 100, 200, 500 year ARI events and the Probable Maximum Flood (PMF) event. The Flood Study and FRMS provide detailed peak height profiles, design flood contours and flow and velocity information (based on the October 2006 update). Selected peak design levels in the river and in the vicinity of the hospital are shown in Table 1.

Table 1: Selected Design Flood Levels [(1)] (mAHD) - RUBICON

Flood (ARI) / Location	10y[(2)]	20y[(2)]	50y[(2)]	100y	200y	500y	PMF
Cnr Edward & Docker St (approx)	(3)	(3)	(3)	177.4	181.3	182.2	186.0
Gobbagombalin Bridge	177.8	178.5	179.3	179.9	180.9	181.8	185.7
Hampden Bridge	179.3	180.0	180.8	181.2	181.8	182.5	186.0
Railway Bridge	179.9	180.5	181.3	181.8	182.4	183.2	186.3

(1) Estimate of the order of accuracy of the design flood levels is ±0.5 m.
(2) Levee not overtopped
(3) Not flooded

3.4 Murrumbidgee River Model Conversion Project - January 2010

Prior to the completion of this study all hydraulic modelling of the Murrumbidgee River in the Wagga Wagga area had been completed with 1D or pseudo 2D (RUBICON) modelling packages. As computation methods improve, best practice dictates that 2D modelling packages should be used to determine flood behaviour for areas such as Wagga Wagga.

The primary aim of this study was to generate a fully 2D (TUFLOW) hydraulic model of riverine flood behaviour of the Murrumbidgee River for Wagga Wagga City Council. This included validating model performance against the historic events of 1974, 1975, and 1976.

The model was then used to develop design flood information for the 10, 20, 50, and 100 year ARI events as well as the PMF. Note that hydrology was consistent with that used for the original RUBICON Flood Study (with minor scaling to match Flood Frequency Analysis expected levels at Hampden bridge gauge).

Table 2 shows the results of the 2D modelling (at the same locations as Table 1). As shown the 100 year ARI flood levels are very similar. The 1D RUBICON model indicated that the hospital site would be inundated during the 100 year ARI event while the 2D TUFLOW model shows the hospital as flood free during the same event. This discrepancy is due to the broadscale representation of the CBD in the RUBICON model by one result node applied to an area over 10km^2 while the 2D TUFLOW model uses a more detailed representation of the ground topography within the CBD.

Floods smaller that the 100 year ARI event are typically higher for the revised modelling. The PMF event produces much lower flood levels in the revised TUFLOW modelling. The lower PMF values are due to the greater representation of floodplain storage in the 2D model. The values shown below in Table 2 represent the best available design flood levels and have been adopted by Council. The assessment at the hospital site is based on these results.

Table 2: Selected Design Flood Levels (mAHD) - TUFLOW

Flood (ARI) / Location	10yr	20yr	50yr	100yr	PMF
Cnr Edward & Docker St	(1)	(1)	(1)	(1)	183.5
Gobbagombalin Bridge	178.3	178.7	179.3	179.8	183.0
Hampden Bridge	179.5	180.0	180.7	181.3	184.5
Railway Bridge	180.2	180.5	181.2	181.8	185.3

(1) Not flooded

Modelling for this project assumed that if river levels rose to the 1974 flood level, the levee would fail over a 5 minute period to half its original height. The modelled assumed failure points are near Tarcutta Street and Flowerdale Lagoon as shown in Figure 1. This is a potential failure mechanism though it is possible that during a real event the levee may fail at other locations.

3.5 Wagga Wagga Major Overland Flow Flood Study (Draft) - October 2010

Flooding mechanisms in the local government area of Wagga Wagga can be from riverine flooding in the Murrumbidgee River which has been extensively modelled but also local rainfall initiated overland flooding. WMAwater have been commissioned by Wagga Wagga City Council to conduct a Major Overland Flow Study for North and South Wagga Wagga.

The study has shown flood levels in the vicinity of the Hospital are not overly sensitive to ARI. Only a minor flow path along the roads adjacent to the hospital exists.

This indicates that floor level planning should be primarily concerned with riverine flooding which is the dominate flood mechanism for the hospital. Standard design philosophy for local flooding should however be adopted such as setting floor levels a minimum level above surrounding ground levels (irrespective of whether the flood planning level for overland flooding is below ground level).

3.6 Wagga Wagga Floodplain Risk Management Study - April 2009

The FRMS was completed in April 2009. The FRMS examines flooding issues relating to the floodplain area associated with the Murrumbidgee River in the vicinity of the city of Wagga Wagga and surrounds. The FRMS was initiated by Wagga Wagga City Council to address the management of the flood problems of the Murrumbidgee River floodplain area around Wagga Wagga. The primary objectives were to define the nature and extent of the hazard, to identify, assess and optimise measures aimed at reducing the impact of flooding on both existing and future development and to make recommendations for the future management of the study area.

This Floodplain Risk Management Study builds on the Wagga Wagga Flood Study and has been formalised into an overall Floodplain Risk Management Plan. The Floodplain Management Plan contains many controls relating to appropriate development and flood planning levels within flood prone land.

3.7 Main City Levee

Flooding of the CBD will occur when the Murrumbidgee River overtops the Main City Levee. The most recent TUFLOW hydraulic modelling assumes levee failure mechanisms at Tarcutta Street and Flowerdale Lagoon. Based on prior modelling other potential locations for levee overtopping include Copeland Street, Hammond Avenue, sections downstream of Hampden bridge and some sections of Narrung Street. The location where the levee first overtops will depend on the actual flood gradient in the Murrumbidgee River. Not all floods are the same and the gradient for a historical event can vary significantly from that of the design events.

4. FLOOD BEHAVIOUR

4.1 Overtopping of Main City Levee

The CBD of Wagga Wagga will be inundated from riverine flooding when the Murrumbidgee River overtops the levee. The overtopping behaviour of the levee and subsequent flooding is considerably variable and will depend on a number of factors including levee failure locations and the gradient of the event. For example, a 100 year ARI event without levee failure although unlikely would result in generally minor inflows to the CBD area, ponding mostly in low lying areas. While the same event with levee failure would results in large amounts of water rushing into the CBD, causing serious damage and devastation. The maximum rate of water entering the CBD could be over 1000 m^3/s which is well over a hundred times greater than the maximum combined pumping rate available from the pumps inside the levee. The pumps would therefore be quickly overwhelmed resulting in flooding of the CBD. Even during events with less overtopping the rate of water overtopping the levee would still be greater than the maximum pumping capacity.

Any flood waters overtopping the levee would quickly fill up the lowest lying areas of town such as the western areas near Olympic Highway and Flowerdale Lagoon. To reach these areas the flood waters would generally take the most convenient flowpaths such as (but not necessarily) along the roads. Slightly larger events would results in considerable increases in depth and extent of inundation. The approximate extent of inundation for the 100 and 200 year ARI design events based on current 2D modelling are shown on Figures 2 and 3.

4.2 Flood Impacts at Wagga Wagga Base Hospital

4.2.1 Flood Depths

The flood risk varies across the hospital site. Levels taken from the latest 2D TUFLOW hydraulic model results across key locations on the present Hospital site are detailed graphically on Figure 4.

The results indicate that once the Main City Levee overtops, inundation of the Hospital will occur to varying extents across the property. The northern part of the property will flood first, blocking access to the existing main entrances. Access is first inhibited at the 500 year ARI event. During the 1000 year ARI event approximately 50% of the property and buildings would be inundated. During the PMF event the entire site bar the south east corner (near Yathong Street) would be inundated.

The new development is proposed to tie into the existing Clinical Services floor level of 182.58mAHD. The flood level at this location in the 1000 year ARI event is 182.2mAHD. Assuming a 0.5m freeboard to account for model uncertainty and climate change impacts, the proposed floor level would provides the hospital with protection from inundation in events up to approximately the 750 year ARI event. Adopting the PMF level for setting floor levels would reasonably mean the hospital would remain flood free and could continue to function in large events. The consequences of adopting the 750 year ARI level implies that at some point the hospital would become inundated and would likely not be able to function albeit the frequency of this is quite rare.

It should be noted that the TUFLOW model utilised a 10m grid cell to represent ground topography. Modelled flood extents are useful as a guide. Flood extents should be confirmed by reviewing the closest flood level and comparing it to ground level and proposed floor level.

The flood levels presented in Figure 4 are based on the assumption that the main city levee would fail at Tarcutta Street and Flowerdale Lagoon. The location of the hospital means that this failure mechanism is beneficial to flood levels at the site. In reality the levee may fail at other locations. Hydraulic modelling has shown that alternative overtopping scenarios could increase flood levels at the site by up to 0.2m. It is therefore essential that an appropriate freeboard is adopted for setting floor levels.

4.2.2 Duration of Inundation

Once the Main City Levee is overtopped, the amount of water within the CBD is contained by the levee systems and will take some time to drain away. Hydraulic modelling of design events suggests that the CBD area would be inundated at peak levels for up to 48 hours, with inundation remaining and slowly decreasing over some days.

It is likely that the Hospital site will drain relatively quickly, since it is located on the fringe of the flood extent. The long inundation period of the CBD itself, however, will have significant impact on the hospital, with high ground areas isolated for days.

4.2.3 Climate Change

Research into the potential impacts of climate change has been rapidly evolving over recent years. Current reports indicate that climate change is likely to result in more frequent and intense storms as well as sea level rises. Changes in flood behaviour due to climate change have the potential to increase the risk of inundation for the redevelopment of the Wagga Wagga Base Hospital.

The study area is prone to inundation from riverine flooding in rare events (greater than 500 year ARI). The impacts of climate change and associated ramifications on development decisions can be significant and an assessment of the potential impacts on flood behaviour is therefore essential.

Studies undertaken by the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) in conjunction with the Bureau of Meteorology (BOM) in 2007 investigated past and likely future changes to climate in NSW. The outcomes estimate that extreme rainfall (defined as a 1 in 40 year 1 day total rainfall event) would be likely to increase by up to 7% for the Murrumbidgee River catchments by 2030.

The Former NSW Department of Environment and Climate Change now Department of Environment, Climate Change and Water (DECCW) Draft Floodplain Risk Management Guideline – Practical Consideration of Climate Change recommends a sensitivity analysis for increases in rainfall of between 10% and 30% based on consideration of the 100 year ARI event. However, given the research undertaken by CSIRO/BOM and the frequency of inundation of the site (in events greater than 500 year ARI), it is considered that a rainfall increase of 10% based on consideration of the 1000 year ARI event would provide a reasonable upper bound for assessment of the effects of increases in rainfall due to climate change within the study area.

Results show flood levels as a result of climate change could potentially increase by between 0.2 and 0.3 m. The most significant potential increase occurs at the corner of Lewis Drive and Yabtree Street (0.3 m). A potential increase in rainfall of 10% also increases the extent of inundation, resulting in a small portion of the site now being inundated during the 1000 year ARI, that was previous flood free during that event.

The outcomes of these sensitivity analyses are presented on Figure 5.

4.2.4 Essential Services

There are a number of key infrastructure locations within the Wagga Wagga CBD area, including the Hospital, that will be seriously impacted by a major flood, particularly if the Main City Levee fails.

A number of essential services, including water supply pumping stations, electricity substations and sewage treatment would be affected in floods which overtop the levee. During extended inundation periods, the isolation of these services could also lead to further evacuations due to public health concerns. It is unlikely that these services to key infrastructure (including the hospital) would be restored in less than a week following a major flood event and it is possible that it would take several weeks before services are restored.

4.2.5 Emergency Access

Local access roads and evacuation routes are likely to be cut off for some time in a major flood event.

In a major flood event, such as a 100 year ARI, it is also likely that major inundation will occur in floodplain areas along the length of the Murrumbidgee River. Other villages and major towns in the area, such as Hay, Gundagai and Narrandera, would also be experiencing similar flooding, further limiting access to other emergency centres. Access to alternative facilities would have to be by air, placing significant stress on helicopter services.

5. RECOMMENDATIONS

5.1 Floodplain Management

The Floodplain Management Plan prepared by WMAwater for Wagga Wagga City Council in accordance with the NSW Floodplain Development Manual 2005 has new guidelines relating to the development of essential services in the floodplain.

The Plan states that existing essential community facilities (such as a Hospital) should be moved to a location above the PMF design flood level. The PMF extent is shown on Figures 2 and 3. It would be expected that the new development would be elevated above the design PMF flood level. While this guideline is considered to be good floodplain management practice, it is also appreciated that economic and practical considerations need to be factored into the decision making process.

If it is impractical and cost prohibitive to elevate the Hospital above the PMF design flood level, it is important that every opportunity is taken to incorporate in the design, mitigation measures that will reduce the flood risk to the Hospital. Such mitigation measures are briefly included below.

5.2 Conclusions & Recommendations

- Critical electrical infrastructure such as the electrical switchboard and backup generators, should be relocated to above the 500y ARI design flood level (preferably the PMF). Backup generators should also be designed to operate for up to several weeks (ie sufficient fuel etc).

- The Wagga Wagga Base Hospital Emergency Management (Response and Evacuation) Plan needs to be reviewed to ensure that it accounts for several possible scenarios during a flood, including restricted or cut-off access due to flood waters, inundation of low lying parts of the site and extended periods of isolation. It will also need to consider the transfer of equipment and patients to other hospitals. It should also consider the flood free access to the south east corner of the hospital.

- The minimum floor level of any new building on the present site must be evaluated taking into account the floor level of any surrounding existing buildings and the intended use of the building. For example, essential services (eg generator housing) should be raised to the PMF, and non-essential services/areas, such as carparks and recreation areas, should be located in the lower lying areas of the property.

- Ideally the PMF should be adopted as the flood planning level for the site. Economic and practical considerations prohibit this in some locations. The proposed floor level (182.58 mAHD) provides the site with approximately 750 year ARI protection including an allowance for 0.5m frerboard.

- The adoption of any event bar the PMF level for setting floor levels should include a freeboard of 0.5m to account for model uncertainty and climate change.

Figures