MOLINO STEWART

ENVIRONMENT & NATURAL HAZARDS

Powerhouse Museum Alliance

Stage 1 Assessment for the Proposed new Parramatta Powerhouse Museum

Flood Risk and Review Assessment

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FLOOD RISK AND REVIEW ASSESSMENT

for

Powerhouse Museum Alliance

by

Molino Stewart Pty Ltd
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MAY 2020

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DOCUMENT CONTROL

Document Reference	1194 Phillip St Parramatta Powerhouse Museum Flood Study Report Stage 1_v2
Project	Stage 1 Assessment for the Proposed new Parramatta Powerhouse Museum
Document Type	Flood Risk and Review Assessment
Author	Filippo Dall'Osso

REVISION HISTORY

Date	**Version**	**Name**	**Comments**
12/05/2020	1.0	Filippo Dall'Osso	Draft for client comment
19/05/2020	1.1	Filippo Dall'Osso	Final draft
21/05/2020	2	Steven Molino	Final report

DOCUMENT APPROVAL

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1 INTRODUCTION

1.1 CONTEXT

In 2014, the NSW State Government announced the Powerhouse Museum would be moved from its location in Ultimo to Parramatta. A site was selected for the proposed Powerhouse District on the southern bank of the Parramatta River on Phillip Street, between Church Street and Wilde Avenue. The proposed new cultural precinct in Parramatta is expected to attract about one million people per year.

As it is located directly on the bank of the Parramatta River, the site is exposed to flooding from the both the river and local overland flooding in events as frequent as the 20 year ARI (Average Recurrence Interval) flood, but it is likely that minor flooding would occur even in more frequent events.

The Powerhouse Museum Alliance, as well as a number of community members, have raised concerns regarding the overall appropriateness of choosing to construct a major community development at this location.

Flooding can affect the proposed museum in many ways and carries a number of risks. These include:

- The risk posed to museum visitors and staff inside the building;
- The risk posed to people outside of the building, particularly in the public outdoor areas throughout the precinct;
- The risk posed to the museum collections from direct contact with flood waters
- The risk posed to museum collections which do not come in direct contact with floodwaters but which may suffer damage from increased humidity within a flooded building;
- The extent to which the proposed development will impact local flood behaviour, and potentially result in increased flood risk for the neighbouring properties;
- The risk posed by flooding to the proposed building, in terms of damage to property.

While the final design details of the proposed Powerhouse Precinct and Museum have not been released yet, there are concerns regarding how the above flood risks will be addressed.

1.2 SCOPE OF THIS REPORT

This report reviewed the available documentation regarding the relocation of the Powerhouse Museum from its current address in Ultimo, to the designated site in Phillip Street, Parramatta. The review focused on the factors relating to the first four points of concern outlined above. The last two points will require to be assessed by a flood modeller and as such are excluded from the scope of this report.

The remainder of this report provides:

- A description of the subject site and flood affectation;
- A description of the most recent architectural concepts of the proposed development;
- A summary of the documents that were reviewed, with a focus on any references to flood risk. These include all the documents provided or mentioned by the client. It should be noted that most of these documents refer to previous iterations of the development concept and architectural design;
- An analysis of how flood risk was addressed, or proposed to be addressed, in each document. This included our comments on any issues, omissions, and potential consequences in relation to public safety and damage to the museum collections;
- An analysis of the extent to which the Stage 2 Design Competition Brief and the current concept design fulfil what we believe are appropriate requirements to suitable address flood risks to people and to the museum collections; and
- A summary of our findings.

1.3 SUBJECT SITE

As displayed in the NSW Planning Portal as of April 2020, the proposed site for the

Parramatta Powerhouse Museum district is on the southern bank of the Parramatta River, on Phillip Street between Church Street and Wilde Avenue.

As shown in Figure 1, the precinct boundary follows the southern bank of the Parramatta River for approximately 260 m. The western extent of the precinct site comprises a strip of riverfront area approximately 100 m long and 20 m wide (approximately 200m^2), situated between the Meriton Suites developments and the river. The total area of the total proposed precinct, as calculated by our spatial analysis software, is about 19,900 m^2, and the proposed footprint of the buildings is 7,700 m^2.

The terrain elevation across the site is between 2 and 8 m AHD (Australian Height Datum). The high point of the lot is in its southeast corner. The land surface generally slopes gently northward towards the Parramatta River.

The site is exposed to flooding from the adjacent Parramatta River, as well as local overland flooding through the streets south of the site towards the river.

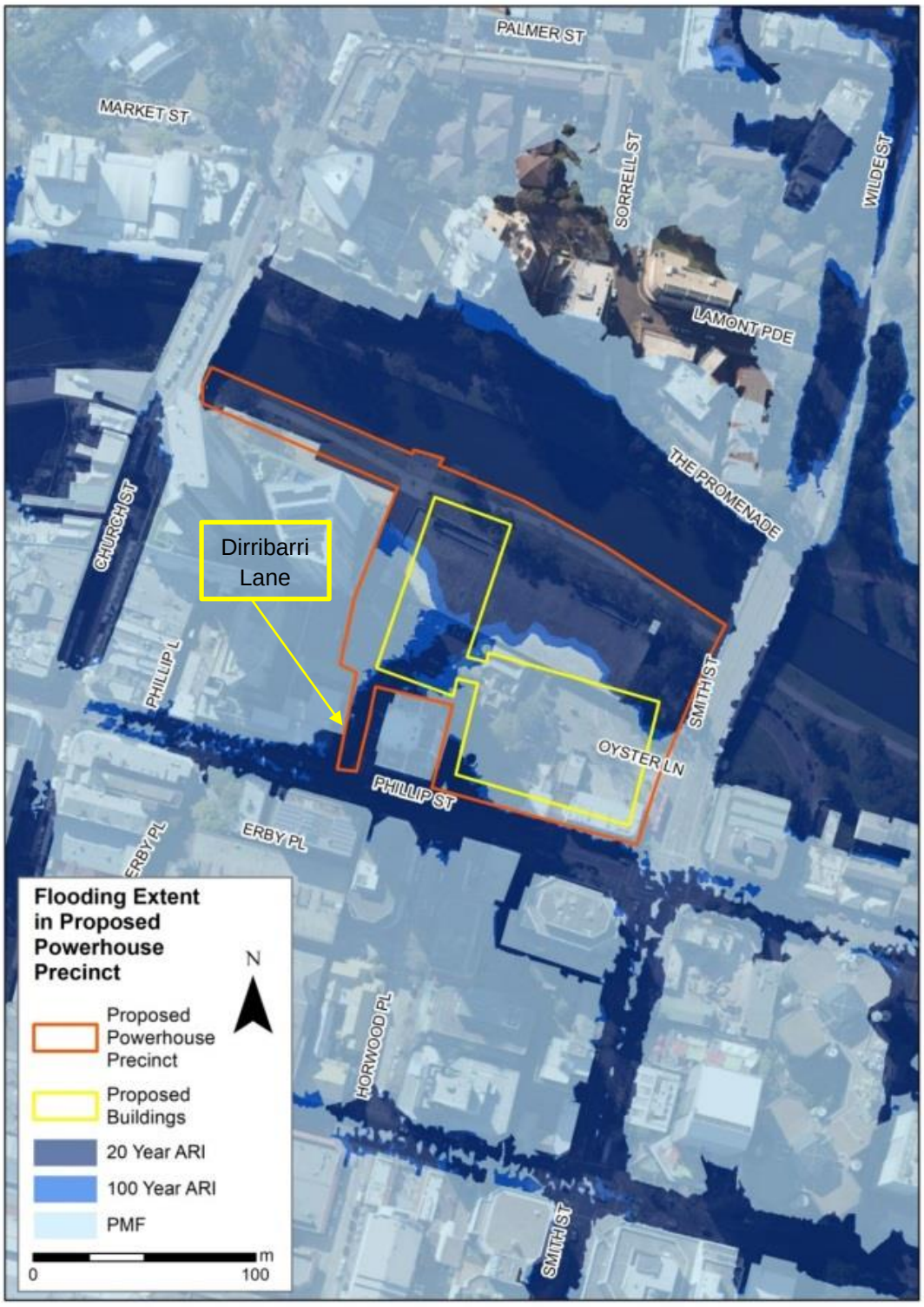

Figure 1. Proposed Powerhouse Precinct in relation to flooding.

Sources: Site extent and building footprints - NSW Planning Portal April 2020.
Flooding extents - Upper Parramatta River Catchment Trust flood model.

2 FLOOD AFFECTATION

2.1 FLOOD HAZARD

The flood extents of the 20 year ARI flood , 100 year ARI flood and Probable Maximum Flood (PMF), extracted from the Upper Parramatta River Catchment Trust (UPRCT) Flood Model (Bewsher Consulting, 2003), are shown in Figure 1. This considers both overland and riverine flooding. Figure 1 shows an overland flow path running from Phillip Street to the river, and bisecting the site along Dirrabarri Lane.

The on-site peak flood levels are:

Riverine (Regional) Flooding:

- 20 year ARI flood level : 5.41 m AHD
- 100 year ARI flood level: 5.95 m AHD
- PMF flood level: 10.39 m AHD

Overland (Local) Flooding:

- 20 year ARI flood level: 6.90 m AHD
- 100 year ARI flood level: 6.95m AHD
- PMF flood level: 11.32 m AHD

The levels above were obtained from the UPRCT model and provided by Council to Taylor Thomson Whitting, for the preparation of the site Flood Study.

The UPRCT Model provides predictions for increased levels due to climate change only for the 100 year ARI flood events (riverine and overland), namely:

- 100 year ARI riverine flood level (climate change): 6.22m AHD; and
- 100 year ARI overland flood level (climate change): 6.99m AHD.

The climate change increased levels were obtained by assuming a 15% increase in rainfall intensity and no contribution from sea level rise because this would be negligible at this location.

It should be emphasized that there are known issues with the accuracy of the UPRCT flood model. The model was developed in the 90s using a one dimensional software model, which is best suited to simulate flood behaviour within the river but it is limited in its accuracy when extrapolated to obtain flood levels across the floodplain. The accuracy of such model is even lower when used to simulate overland flooding, because it cannot resolve the interactions between floodwaters and urban landscape appropriately.

Notwithstanding its limitations, the UPRCT flood model is currently the official flood model adopted by the City of Parramatta Council, although a new two dimensional riverine flood model is currently being prepared. Given the age and limitations of the UPRCT model, it is expected that the new flood model will show

Figure 2. 1 year ARI overland flood depths at the subject site

Source: BG&E (2016) as part of the flood studies informing the redevelopment of Parramatta Square.

different peak levels and extents throughout the floodplain and at the proposed Powerhouse Museum location.

As part of the redevelopment of Parramatta Square, an improved overland flood model was created for BG&E (2016). While this is not an official model adopted by Council, it shows that the site, in its pre-development condition (i.e. current condition), may experience overland flood depths of up to 0.5m in events as frequent as the 1 in 1 year ARI flood (Figure 2).

2.2 THE FEBRUARY 2020 SYDNEY FLOOD

Between 7 and 10 February 2020, Sydney experienced a record rainfall which caused widespread flooding throughout the metropolitan area.

The event caused the Parramatta River level to rise and flood a significant proportion of the site. The existing car park, which is located where the outdoor area and the northern portion of the north-western building will be built, had its ground floor completely submerged by floodwaters (Figure 3 and Figure 4).

The Bureau of Meteorology (BoM) Riverside gauge, located just upstream of Lennox Bridge, recorded a peak river level of about 5.5 m AHD on 9 February. Figure 5 shows a time series (or hydrograph) of the Parramatta River level on 9 February.

According to the flood extent maps obtained from the UPRCT model and in use at the City of Parramatta Council, a level of 5.5 m AHD at the Riverside Theatre gauge would have corresponded to a level of about 4.5 m AHD at the site. The drop in level is due to the narrow opening under Lennox bridge, causing floodwaters to build up upstream of the bridge. This can be observed by looking at the levels tabulated in Figure 6 for chainage 2341.9 and 2373.3.

A level of 4.5 m AHD at the site is about 1 m below the level of the 20 year ARI flood. This means that the 9 February event represents flood significantly more frequent than the 20 year ARI.

The most recent plans of the proposed development show a ground level RL 3.5 in the outdoor area along the river, and also within the north-west building, in the undercroft area facing the river (the red-circled area in Figure 10). As such, a flood like the one observed on the 9 February 2020 would be able to flood the proposed Powerhouse Museum outdoor area with depths of about 1 m. The same depth would be observed in the undercroft area of the north-west building, assuming this area will not be built to be flood-proof (i.e. sealed so that floodwaters cannot penetrate the building).

Figure 3. Flooding of the site occurred in February 2020 showing the existing car park.

On the other hand, if the above mentioned undercroft were to be water-proofed, there could be an impact of the site's pre-development hydraulic flow and storage which would need to be assessed with dedicated local flood model. More detail on this issue can be found in our comments to the Stage 2 Design Brief Competition in the remainder of this report.

Figure 4. Flooding of the ground level of the existing car park occurred in February 2020.

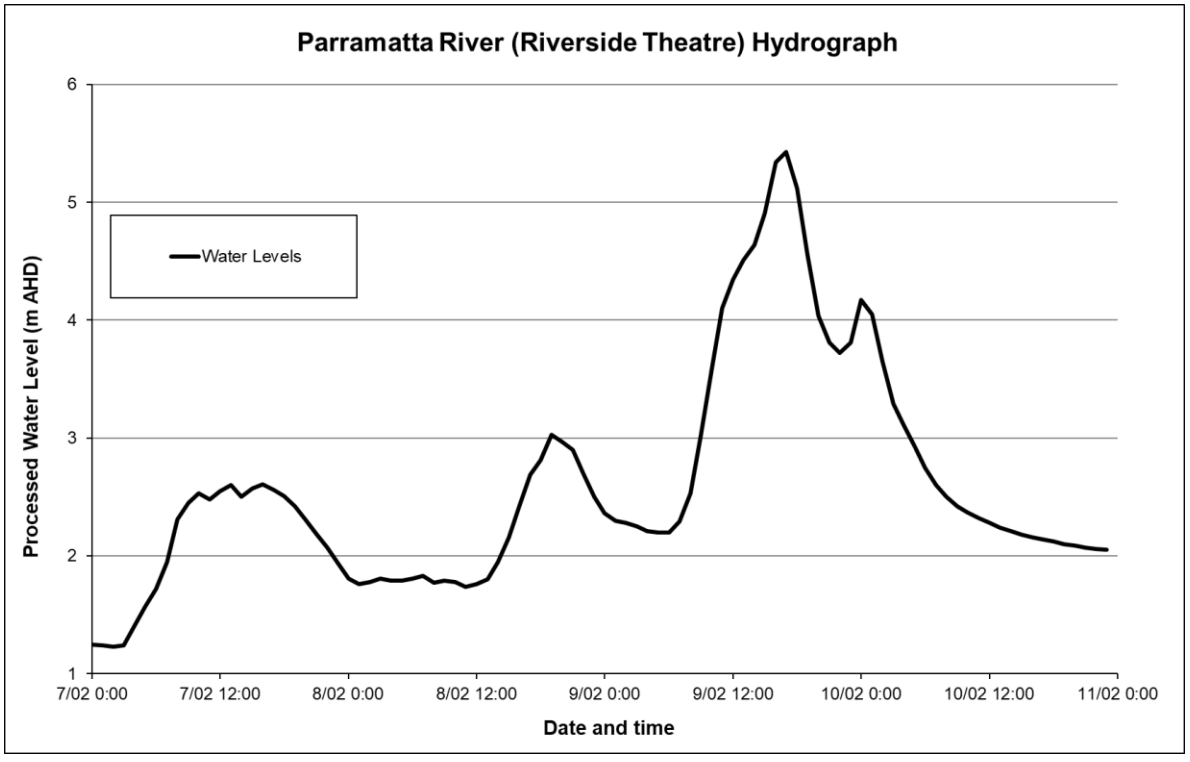

Figure 5. Time series of the Parramatta River level at the Riverside Theatre gauge on 9 February 2020 (source: Bureau of Meteorology).

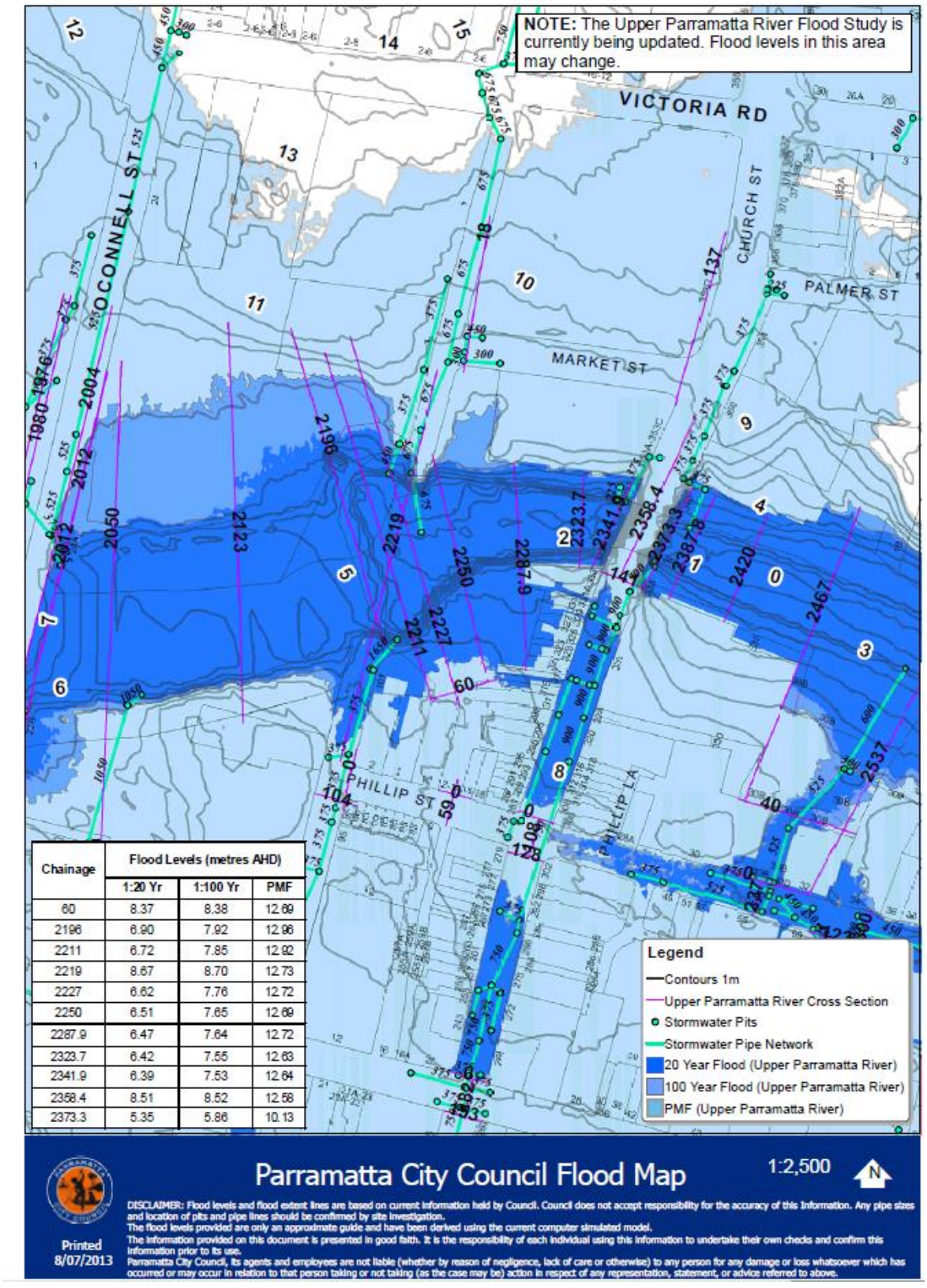

Figure 6. Flood extent and level map based on the UPRCT flood model (source: City of Parramatta Council).

3 CURRENT ARCHITECTURAL PLANS

Several design concepts of the proposed new Powerhouse Museum have circulated since its relocation to Parramatta was announced. The most recent version is available through the NSW Planning Portal, and is attached to the Request for SEARs.

The plans include two multi-storey buildings, connected by a pedestrian bridge (Figure 7). The south-eastern building (Figure 9) has three presentation spaces, located on three different levels, with Presentation Space #1 located at the ground floor (RL 7.5 m). From the plans it would appear that this space will contain the largest and heaviest items of the museum collection.

The north-western building (Figure 8) shows seven storeys, with the ground level (RL 7.5 m) hosting a concierge/retail area, cloak room and loading bay. It is noted that at the northern end of the building, facing the river, there is an additional level below the ground floor, which appears to be used for a bar/café.

The proposed ground floor level of 7.5 m AHD provides a freeboard of 505 mm above the peak level of the 100 year ARI overland flood, and about 1.5m above the 100 ARI riverine flood. This is consistent with the requirements of the City of Parramatta Development Control Plan (DCP) 2011.

It is acknowledged that the new Powerhouse Museum is a State-Significant Development and as such it does not need to obtain Council's approval; hence it does not formally have to fulfil the DCP requirements. However these are based on national and NSW State guidelines, including the NSW Flood Manual (2005), and represent the best practice for development in flood prone areas. As such, it is expected that the Land and Environment Court will consider the extent to which the proposed developed is consistent with the DCP requirements.

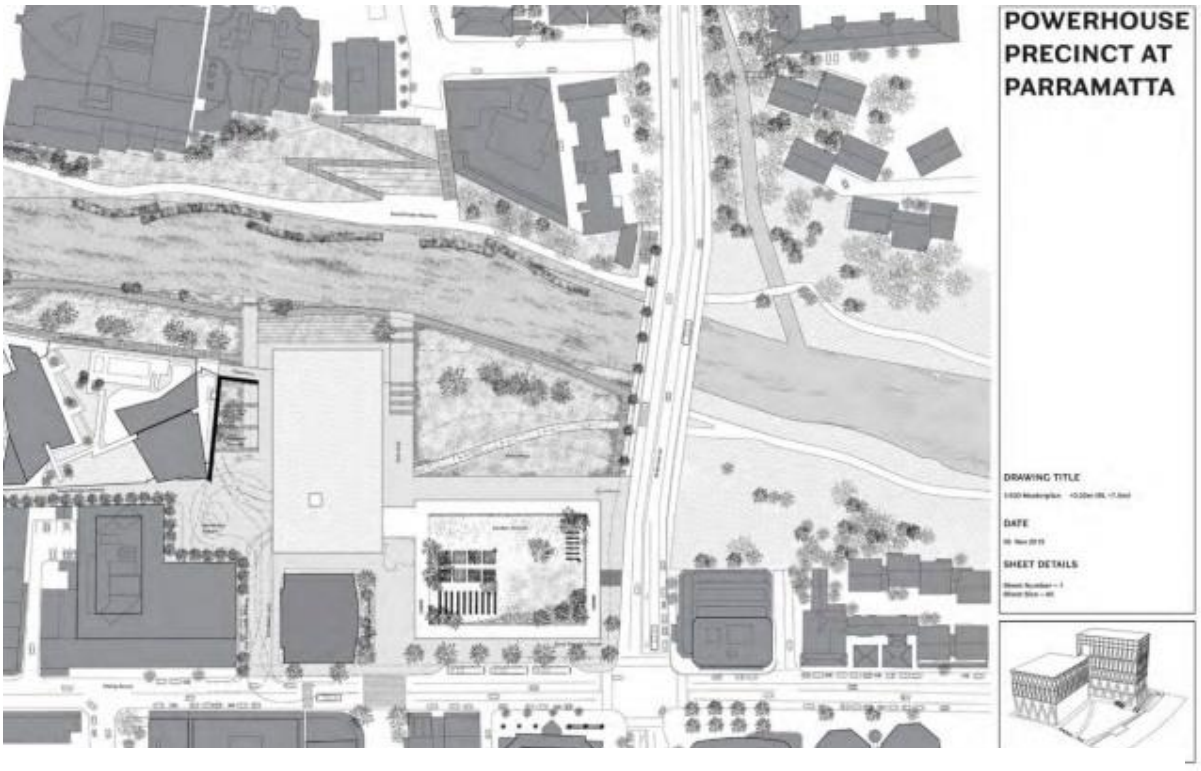

Figure 7. Current architectural plan of the proposed site and buildings

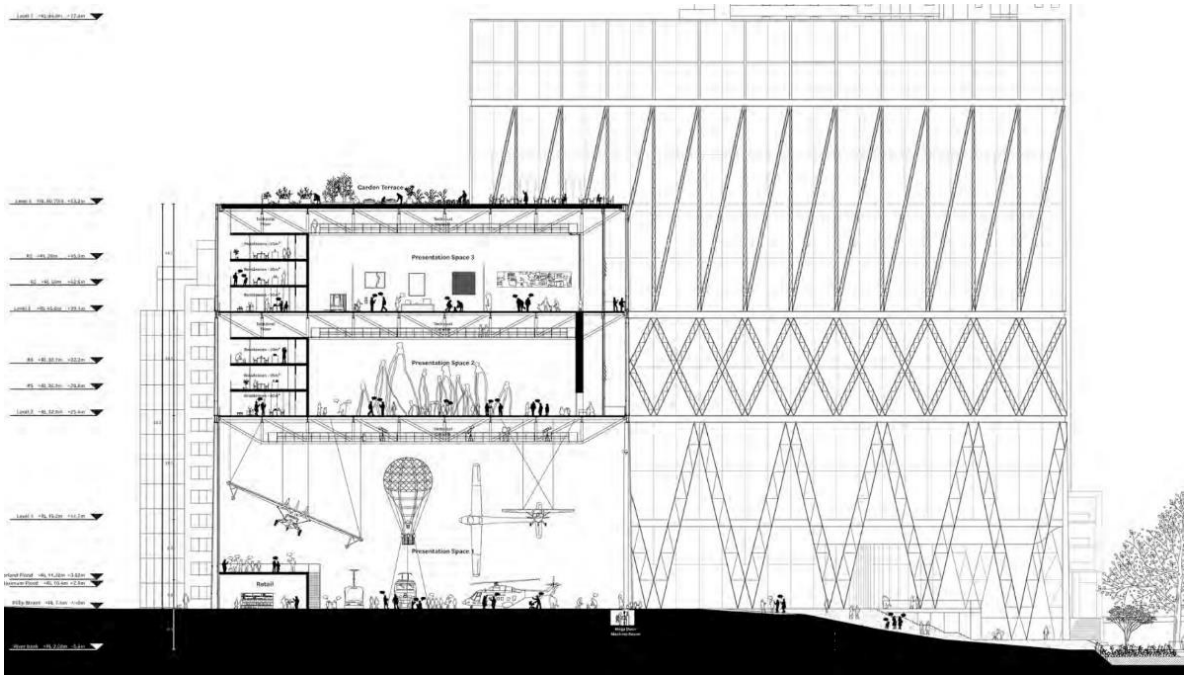

Figure 9. Section of the proposed South-East building.

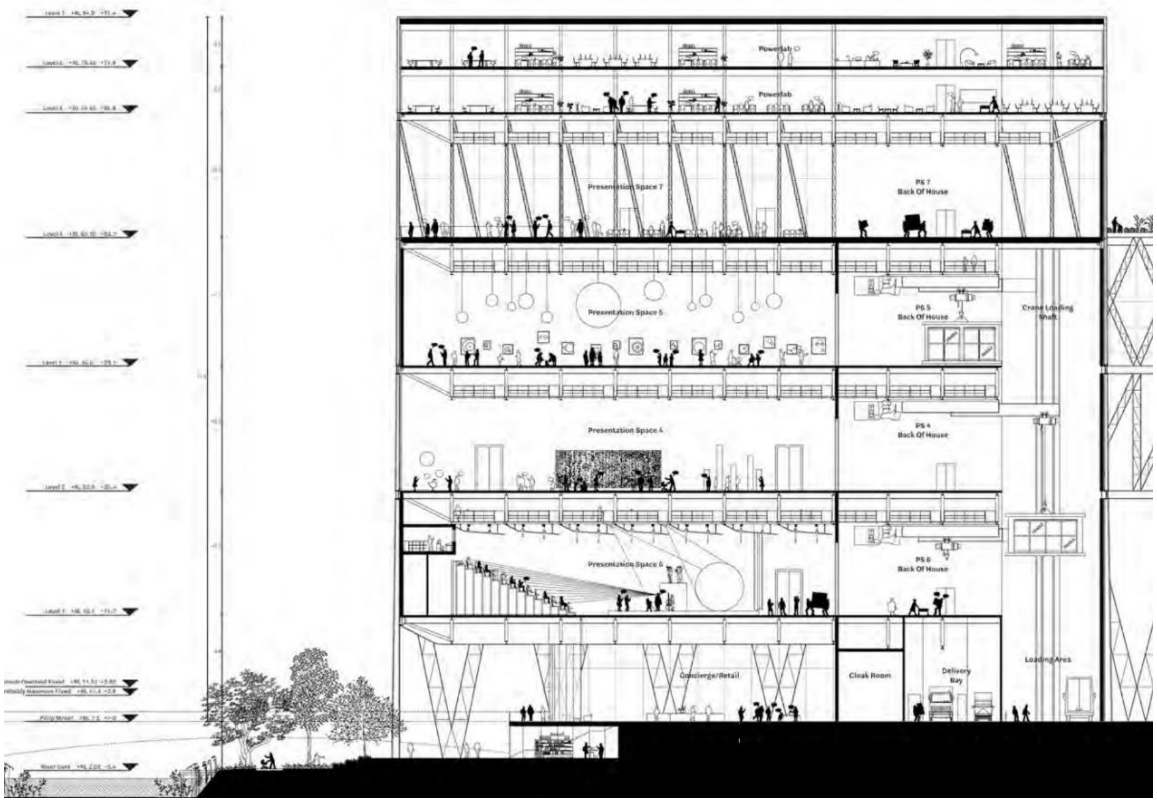

Figure 8. Section of the proposed North-West building.

4 REVIEW OF AVAILABLE DOCUMENTATION

The key documents reviewed or considered in this study are discussed in this section in chronological order.

4.1 SITE ASSESSMENT REPORT (URBIS AND COX PARTNERS FOR INFRASTRUCTURE NSW, 2016)

Following the NSW Government announcement to relocate the Powerhouse Museum from Ultimo to Parramatta, a site selection assessment was undertaken by Urbis and Cox Partners for Infrastructure NSW. The report is not publicly available, but the Powerhouse Museum Alliance communicated that only two potential sites were considered: Mays Hill Golf Club, in Parramatta Park, and the Riverbank site in Phillip Street. The assessment concluded that the Riverbank site in Parramatta was the preferred site for the museum relocation, however we are unable to comment on the appropriateness of such decision without accessing the relevant report. It is noted however that Mays Hills is not affected by riverine flooding, according to the Upper Parramatta River Catchment Flood Study.

4.2 THE NEW MUSEUM: FLOOD STUDY (TAYLOR THOMSON WHITTING FOR JOHNSTAFF, NOV 2016) AND SUBSEQUENT AMENDMENTS (I.E. ATTACHMENT 4 TO THE EFBC)

4.2.1 Review

As part of the preparation of the technical documentation forming the business case for the proposed Powerhouse Museum move to the river bank site in Parramatta, a preliminary Flood Study was drafted by Taylor Thomson Whitting for Johnstaff in November 2016. This study was later included in the 2018 Business Case as Attachment I (subsequently revised to Attachment Y).

The purpose of the study was to identify flood risk, levels and hazards and to provide recommendations in relation to floor levels, drainage and possible flood mitigation measures. At the time the Flood Study was undertaken, there was only a preliminary set of building design alternatives. These were included in Appendix B of the Flood Study, however we were unable to assess these as the document appendices were not provided.

The Flood Study states that all the design options that were considered consist of a new six level building with non-habitable basement with car parking. The idea of a basement with car park was abandoned at a later stage.

Section 3.1 of the Flood Study summarises flood behaviour at the site. Figure 4 of the Flood Study shows flood extents of the 20 year ARI event, 100 year ARI event and the Probable Maximum Flood.

The Flood Study highlights the presence of an overland flow path running north across the site, from Phillip Street towards the river, running through Dirrabarri Lane. The report highlights how such a flow path does not seem to build up against the existing car park building (as it would be expected), revealing an apparent shortcoming of the UPRCT overland model at this location.

A preliminary assessment of the impact of the proposed building on local flood behaviour was undertaken as part of the Flood Study, which developed a new two dimensional flood model for the 100 year ARI event only. The model was calibrated to generate the same overland and riverine on-site 100 year ARI peak level of the UPRCT model and concluded that:

- The building design options available at the time the Flood Study was undertaken would not cause a significant change in riverine flood behaviour (i.e. flow and storage), with respect to the pre-development condition.
- The overland flow path running through the site along Dirrabarri Lane does in fact

build up against the existing car park, causing higher peak levels (in pre-development conditions) than what the UPRCT model shows. The report continues by stating that such a flow path will have to be managed by providing a minimum building offset of 12m from the western site boundary, and/or a larger stormwater pipe (currently there is a 600 mm pipe which is proposed to be diverted to the west of the new building). These arrangements will be required to avoid an increased flood affectation of the adjacent sites.

- The model will need to be updated once a final building design is available which includes the outdoor areas, particularly along the overland flow path. Such a model will also need to consider the impacts of the proposed diversion of the existing 600mm pipe to the west of the new building.

The remainder of the Flood Study discusses the impacts of flooding on the proposed non habitable basement level, however this part is not addressed here as the basement is not featured in the current version of the building plans.

After the original Flood Study was released, the proposed building design options were amended. In response to these changes, the Flood Study recommendations were updated and included in the Extended Final Business Case (EFBC), Attachment F – Site Analysis Updates (Taylor Thomson Whitting, Nov-2017).

While the plans of the new design options were not available for us to review, the text of Attachment F implies that these included a smaller set-back from the Parramatta River compared to the design assessed in the original flood study. In Attachment F, Taylor Thomson Whitting express concerns on the impact on flood levels and extents due to a potentially larger ground floor encroaching on the 100 year ARI flood extent, which would reduce flood storage and obstruct flood flow. Attachment F concludes that this change in footprint area will require to reassess the impacts of the proposed development on local flood behaviour via an updated flood model, unless the extended ground floor:

- Did not overlap with the extent of the 100 year ARI flood, or
- Was suspended on columns and elevated above the peak level of the 100 year ARI plus 500mm freeboard.

With regard to the risks associated with the overland flow path running along Dirrabarri Lane, Attachment F outlines that the updated design options allow for a sufficient set-back from the boundary with the western site (i.e. 12m) and as such fulfil the requirements of the original Flood Study.

Finally, Attachment F clarifies that the ground floor level is to allow a 500mm freeboard above the peak of the 100 year ARI, which at the site is 6.95m AHD (overland flooding), and that provision must be made for safe internal access and refuge to a floor above the PMF level, presumably to allow the building occupants to take Shelter in Place (SIP) during an extreme flood.

4.2.2 Comments

Without access to the building design options assessed in the original Flood Study and to the subsequent updates, it is difficult to comment on the relevance of the proposed flood mitigation measures (e.g.12m offset from western site and/or pipe capacity upgrade) to the current building plans. If the red-hatched polygon in Figure 8 of the Flood Study represents the proposed building footprint at the time the Flood Study was undertaken, this is significantly different from the building footprint currently being proposed in the Request for SEARs and a new flood model to assess the impacts on local flood behaviour may be required.

Similarly, the updated design options that Attachment F of the EFBC refers to were not available for us to review, but are also likely to be different from the concept plans supporting the Request for SEARs. In such plans, the most northern part of the ground floor of the north-western building, which extends the footprint of the original building design assessed in the Flood Study within the 100 year ARI flood extent, appears to be suspended as requested in Attachment F to the EFBC. However it is not clear from the drawings whether:

- The portion of suspended floor (Figure 10) is sufficient to preserve the pre-development available flood storage.
- The area under the suspended floor is an open design (i.e. without walls) or if it is enclosed by glass walls. In the former case, it is possible that the updated design will not alter local flood behaviour and afflux on neighbouring properties with respect to the design used in the original Flood Study, however we expect that this would have to be ascertained by a qualified hydraulic engineer. On the other hand, if this area is enclosed by glass walls, it would definitely have an impact on local flood behaviour regardless of it being suspended, and a new flood model to assess such impact would be required to ascertain if this would cause higher flood levels within the neighbouring properties.
- Should the undercroft area highlighted by the red circle in Figure 10 be an open design, while it may preserve the overall site flood storage, it would contain a non-flood -proof habitable area below the level of the 100 year ARI plus 500 mm freeboard (i.e. RL 7.5 m). This would be inconsistent with the requirements of the Parramatta DCP, the updated Flood Study, the Stage 2 Design Competition Brief, and advice that Molino Stewart provided to the City of Parramatta Council as part of the development of the River Strategy (Molino Stewart, 2014). According to such advice, permanent cafes and food outlets in the river banks and below the 100 year ARI level plus freeboard would be permissible, provided that these are *fitted with special flood doors or similar which secure the businesses and protect them against direct flooding. Such doors and their supporting structures are required to be specifically designed to take hydrostatic pressures and potential debris strike into account. They must be designed for flood impacts up to the 1 in 100 chance per year flood.*

With regard to the Flood Study requirement of the building to provide access to an area of refuge above the reach of the PMF, we note that while this is of critical importance, it is not the only requirement to address flood risks to public safety.

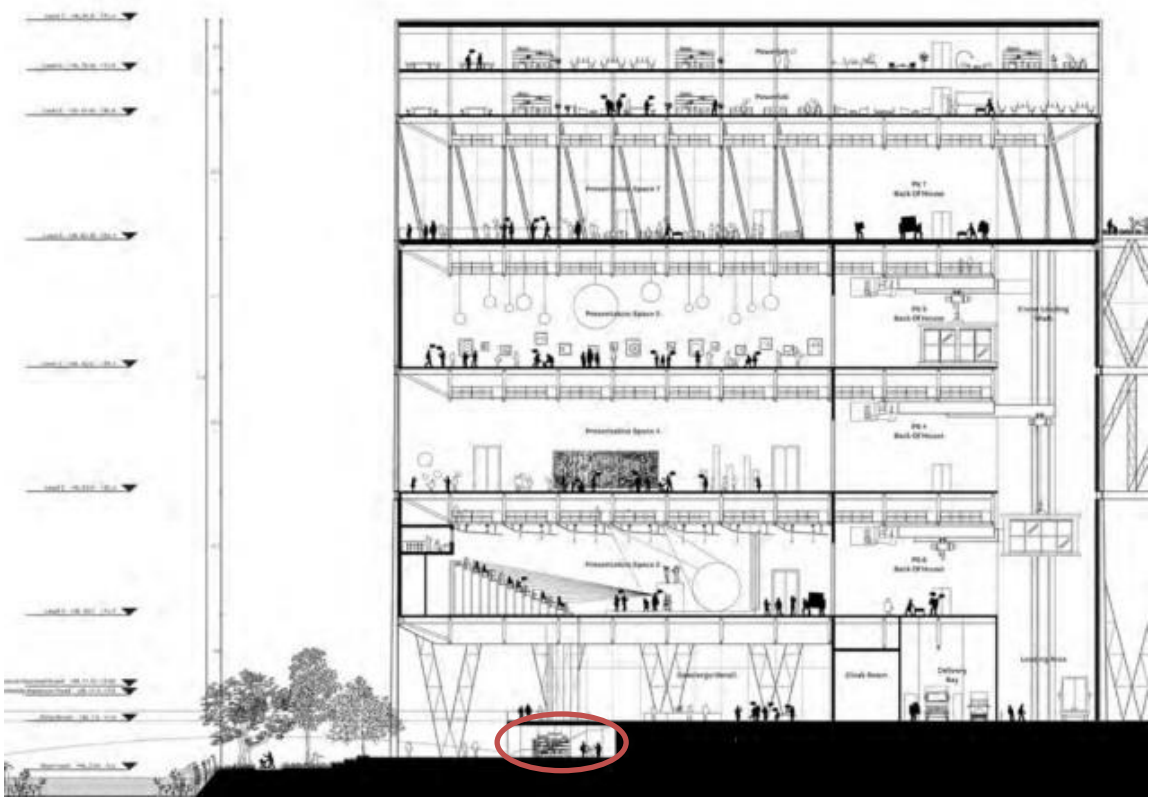

Figure 10. Section of the north-western building showing portion of suspended ground floor, and the habitable space underneath it.

The NSW SES preferred flood emergency response strategy is to evacuate people in flood prone areas to flood-free land outside the extent of the PMF (i.e. horizontal evacuation). According to the NSW SES, this is to be preferred to vertical evacuation (i.e. taking Shelter in Place) because it significantly reduces risks to evacuees and the burden on emergency responders. However, the NSW SES accepts that horizontal evacuation may not be possible in circumstances where evacuation routes are cut by floodwaters early. In these cases, the risks of horizontal evacuation are deemed to be excessive, and the NSW SES recognises that SIP becomes the safest alternative, provided that the associated risks are adequately managed.

In most of Parramatta CBD, the floodwater's rate of rise in a PMF (Figure 11) is such that the available notice provided by Council's flood warning system is relatively short, ranging between 45 minutes and 2 hours. By the time an evacuation order is issued and communicated to the population, most roads would already be cut by local flooding. Molino Stewart (2017) has undertaken a detailed analysis of flood emergency response strategies for the CBD on behalf of the City of Parramatta Council, and this work indicated SIP is the safest option, because most roads would be cut by local flooding before

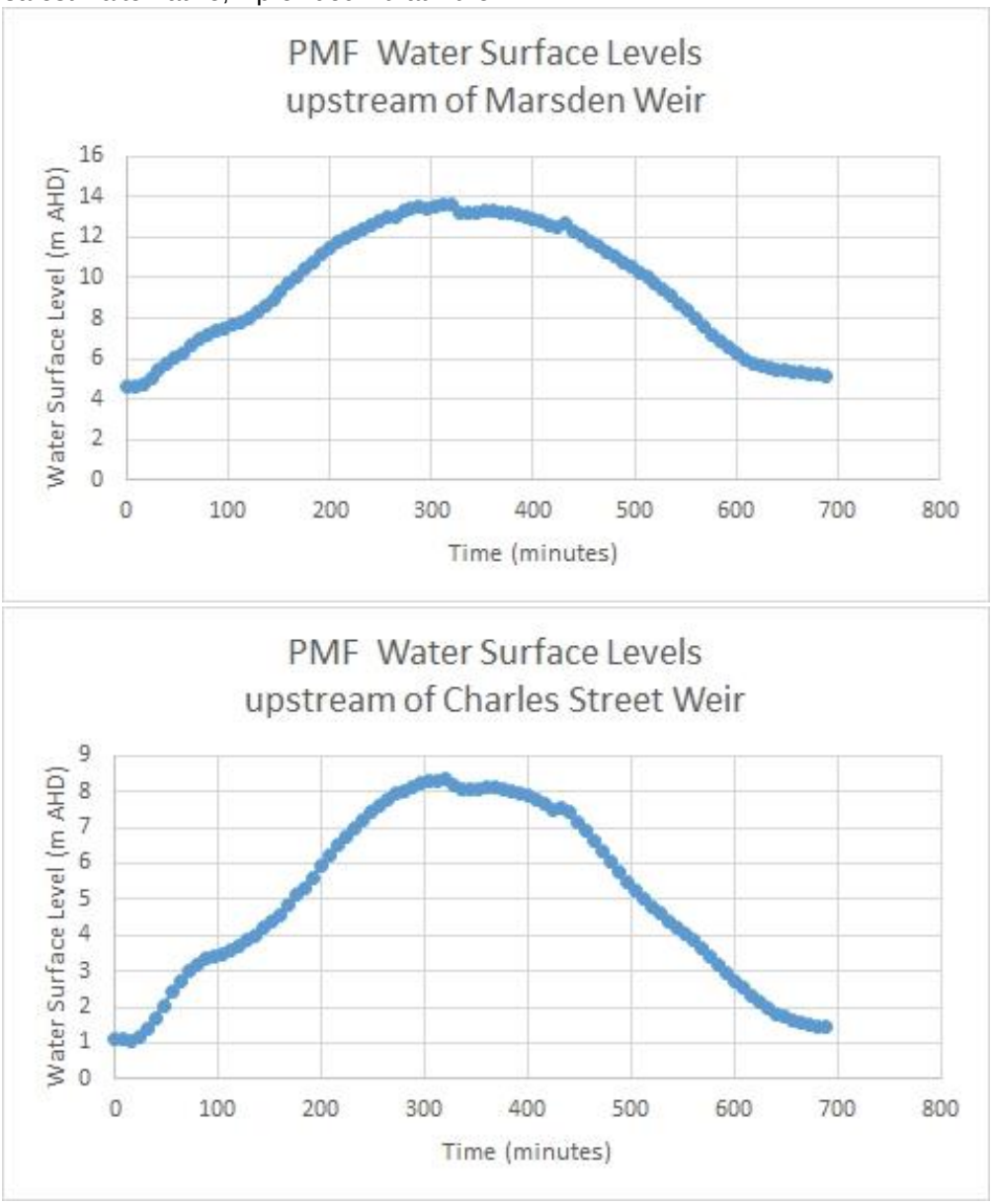

Figure 11. PMF rate of rise upstream of Marsden Weir and Charles Street Weir (from the UPRCT flood model). The subject site is located in between the two weirs.

evacuation can commence.

For the same reason, SIP is also likely to be the only option available to the new museum visitors and staff, should an extreme flood occur when the site is occupied. As such, as correctly stated in Attachment F to the EFBC, the new Powerhouse Museum building would need to provide adequate access to an area of refuge within the building above the reach of the PMF. However, in addition to this, the building would need to develop and implement a Flood Emergency Management Plan (FEMP). The FEMP may require:

- Closure of the museum (or at least cancellation of any major functions) when a Severe Weather Warning for the area of Parramatta or a Flood Watch is issued for the Parramatta River by the Bureau of Meteorology to minimise the risk of people being trapped on site during a flood. This means that the museum may preventatively close several days in some years due to flood risks. There are currently no other, less frequent triggers that could possibly be used to provide sufficient warning time to evacuate the building ahead of a flood which could isolate people in the building; or
- Visitors and staff to Shelter in Place (SIP) in a designated refuge above the reach of the PMF, within the building. Molino Stewart's database indicates that the site may be isolated for up to 8 hours in a PMF caused by riverine flooding.

The FEMP would also need to set out actions to be undertaken before, during and after a flood by the museum staff and visitors, and it would define roles and responsibilities for each of these actions. As part of the preventive set of measures, the FEMP would require that appropriate design solutions are implemented and that the necessary arrangements are put in place to ensure that the risks associated with taking Shelter in Place are adequately managed. The main risks of SIP, and the relevant risk reduction measures, are listed below:

- The designated refuge is not sufficiently safe. This may happen because: (a) the building is not structurally stable in the PMF; (b) the building does not offer a refuge above the level of floodwaters; (c) some of the building occupants are unable to reach the building higher levels; (d) the designated refuge does not have sufficient capacity. These risks are to be addressed by ensuring that the building is structurally stable in a flood up to the PMF, the designated refuge sits at a level above the PMF level, and the refuge is accessible to all building occupants, including mothers with prams or people with mobility impairments (e.g. wheelchair users). The refuge should be able to accommodate all the visitors and staff members expected to be on site at any one time, including in the outdoor areas. While the Stage 2 Design Brief Competition suggests that people outside the building should evacuate to neighbouring areas, we believe this would not be sufficiently safe (please refer to our comments on the Stage 2 Design Competition Brief for further details).
  A minimum floor surface area of 2m2 per person should be available, in addition to adequate availability of toilets. It is our understanding from what is indicated in the Stage 2 Design Competition Brief (page 128) that functions with up to 10,000 people may be occasionally be held on the premises. While such functions should be cancelled in advance, there is still a risk that a large flood occurs during the function if the BoM warnings fail to be issued, or if is it an overland flooding for which there may be no warning at all. As such, the area of refuge would need to provide a total floor surface area in excess of 20,000 m2. Alternatively, the size of the functions should be capped to match the capacity the flood refuge can provide.
- Risk of fire within the building while people are taking shelter. This risk will be reduced by an automated fire suppression system.
- Lack of power, food or water. If the isolation lasts for several hours, some of the building occupants may feel uncomfortable without access to power, food or water and may decide to leave the site and walk though floodwaters. In the PMF, the proposed building can be isolated for up to 8 hours. To address this risk, the FEMP will require that an independent alternative power generator is in place and located above the reach of the PMF. The refuge will need access to stock of food and water general medicines for a minimum of 1 day is kept in the designated refuge at all times. This could be arranged through the pre

existing food outlets, assuming these are above the PMF level and have flood free access from the designated refuge. Alternatively, a kitchenette powered by the independent generator would be required.

- Medical emergencies may occur while the site is isolated. This risk will be reduced by having first-aid kits and defribulators onsite and by ensuring that sufficient staff are trained in first aid. All visitors relying on regular medication or life assisting devices should be informed that they may become isolated for up to 8 hours within the museum should an extreme flood occur.
- Communication failure. As power outages can easily happen during a flood, the telecommunications network may stop working as battery backups within those systems generally do not last more than a day. Any risks arising from these circumstances will be reduced by keeping a satellite phone and spare batteries in each designated refuge at all times.
- Human behaviour. People that are isolated by floodwaters may panic and take actions which may increase risk to their lives and the lives of others. For instance, some visitors may decide to evacuate the building when this is still surrounded by floodwaters. Most of these risks will be reduced by the measures already discussed in this section however any dangerous human behaviours will be further discouraged by: (a) annual training in flood response; (b) periodical drills of evacuation and SIP; and (c) the use of temporary signage placed at each pedestrian and vehicular egress point.

The FEMP would need to set as a condition that that the power generator and the building fire suppression system would be able to work in any flood event up to the PMF.

4.3 PLANNING DUE DILIGENCE REPORT FOR BUSINESS CASE (JBA ON BEHALF OF JOHNSTAFF, NOV. 2016)

A due diligence report was prepared by JBA on behalf on Johnstaff to guide the preparation of the Business Case. This report provides recommendations on the items that need to be addressed by the Business Case, based on the preliminary technical analysis (including the 2016 Flood Study by Taylor Thomson Whitting).

With regard to flooding, the Due Diligence report states that: *A flooding model of the site and surrounds has been prepared as part of the final business case process, information with respect to flooding should be ascertained from this report. A Flood Impact Statement will need to be provided for future development of the site.*

As such the Due Diligence Report does not add anything to the way flood risks will need to be addressed that was not already mentioned in the Flood Study.

4.4 INTERIM REPORT - FIRST REPORT (NSW LEGISLATIVE COUNCIL - MUSEUMS AND GALLERIES, DEC 2017)

4.4.1 Review

This is the Interim Report generated by the NSW Legislative Council under the Inquiry for Museums and Galleries, in response to the announcement of the NSW Government of documentation regarding the intention to move the Powerhouse Museum to Parramatta.

It includes a set of recommendations for the NSW Government to be considered alongside the request to develop and share a business case to support the transfer of the Powerhouse Museum to Parramatta. From the Foreword:

This poorly informed decision was made before a preliminary business case had even been prepared, details regarding the cost or rationale being released, or a final business case even being completed.

We have therefore recommended that the NSW Government release the full business case for the Powerhouse Museum and all assessed proposals to the committee and the

community for full public consultation before making its final decision.

Regarding flooding, this report mentions and summarises all the submissions made by the community expressing concerns on flood risk (Section 2.47 to 2.53). Most of these highlight the risk of flooding generally, however some are more specific and recommend against the inclusion of a basement in the proposed building to minimise flood risks to property (and the cost of addressing such risks) (paragraph 2.50), or mention the requirement that all habitable floor levels would need to be above the 100 year ARI peak level (paragraph 2.51).

Paragraph 2.52 and 2.53 include a response to the above concerns from Mr Shine, the former President of the Board of Trustees with the Museum of Applied Arts and Sciences, stating that the new museum would be designed *'to mitigate any risk of flooding and with all exhibitions and collections being located above the flood line'.* Minister Harwin also informed the committee that *'engineering studies were being undertaken to examine the potential for flooding on the riverbank site'.*

4.4.2 Comments

The submission mentioned in the report express a generalised concern about flood risks, which are inherent in the proposed location of the new museum. It is noted that the submissions refer to superseded design options and that the current plans included in the Request for SEARs do not include a basement.

The comments from Minister Harwin is most likely referencing the Flood Study from Taylor Thomson Whitting (and subsequent updates), as no other engineering studies addressing flood risk were identified in our literature review. The "flood line" referred to is probably the flood planning level of 0.5m above the 1% AEP flood level as the current design shows collections above this level but not all collections being above the PMF level.

4.5 SUBMISSION TO THE INQUIRY ON MUSEUMS AND GALLERIES (JOHN MACINTOSH, JANUARY 2018).

4.5.1 Review

Dr John Macintosh, a civil engineer specialising in hydraulic modelling and floodplain risk management, prepared this submission to provide his view on the recommendations included in the Interim Report to deal with flooding. Specifically, this submission questions whether a Business Case, which is requested by the Interim Report, will be sufficient to fully appreciate and address flood risks at the proposed new Powerhouse Museum site.

Dr Macintosh is mostly concerned about risk to life and risk to the collection. To support his concerns, he attached flood depth and hazard maps from Molino Stewart's Update of Parramatta Floodplain Risk Management Plans for Parramatta City Council (Molino Stewart, 2019). The maps show that the site is affected by high and medium flood hazards, and that it floods with an annual probability of at least 5% (this is the equivalent of a 20 year ARI flood). Dr Macintosh adds that flood hazard would be even higher along external walkways and lanes, where the water flow concentrates and results in higher depths and velocities. Based on these considerations, Dr Macintosh concludes that risk to life is in his opinion incompatible with the proposed development.

In relation to risk for the collections, Dr Macintosh notes that the PMF peak depth at the site is over 4m. It acknowledges that the building can be constructed to be flood proof even with such a large flood, however this would be costly and may fail at least once over the life of the structure.

4.5.2 Comments

In relation to public safety, as correctly stated by Dr Macintosh, the UPRCT flood model clearly shows that the building site would be

affected by medium to high hazard floodwaters in the PMF, according to the flood hazard classification used in Molino Stewart's Update of Parramatta Floodplain Risk Management Plans for Parramatta City Council (2016).

The rate of rise of floodwaters, in a flood rising as fast as the PMF, would be such that there would not be sufficient time to safely evacuate the building horizontally. This implies that the only viable flood emergency response strategy for the proposed museum's visitors and staff would be to close the museum (or at least cancel any major functions) when a Severe Weather Warning is issued for the Parramatta area, or a Flood Watch is issued for the Parramatta River to provide sufficient time to evacuate. The alternative is to SIP within the building should a flood occur when the museum is open.

While it is acknowledged that the risks of such a large number of people taking SIP within the building for up to 8 hours are significant, in our opinion these may potentially be reduced to acceptable levels by a suitable Flood Emergency Management Plan (FEMP), provided that the required SIP risk reduction measures are integrated in the building design and daily management.

Regarding the risk of damage to the museum collections, we agree with what was pointed out by Dr Macintosh. The risk that the museum collection may incur extensive damage from an extreme flooding is relatively high for two reasons:

- The collections include several unique items which could not be replaced and as such have a relatively high commercial, artistic and cultural value;
- The current building design has a significant presentation space (Presentation Space 1) at the ground level of the south-eastern building (RL 7.5m), which may flood in events as frequent as the 100 year ARI. Such space has been provisionally allocated to hosting the largest items of the collection, which will not be able to be relocated to higher levels if a flood were to be forecasted, especially considering that the notice before an extreme flood may be as little as 45 minutes.

We believe that the only way to reduce the risk of damage to the museum collection, aside from relocating the museum to a flood free area, would be to either:

Ensure that the building is flood-proof up to the PMF event, even if its ground floor sits below the PMF level, or

- Ensure that the lowest level at which the museum collection items are located is above the PMF level.

Even if the above conditions were to be fulfilled, and we note that the current building architectural concepts suggest this is not the case, there would still be a residual risk that:

The building flood-proofing fails; or

- Floodwaters enter the ground floor of the building and cause spikes in dampness/humidity which would likely damage collections, even if these are stored at the upper levels.

4.6 EXTENDED FINAL BUSINESS CASE (EFBC) FOR THE POWERHOUSE MUSEUM IN WESTERN SYDNEY PROJECT, VERSION 4 (JOHNSTAFF FOR THE CULTURAL INFRASTRUCTURE PROGRAM MANAGEMENT OFFICE, JANUARY 2018).

4.6.1 Review

The EFBC is an extensive report whose main aim is to document the rationale for the proposed museum relocation to the Phillip Street site, and assess the associated implications. It includes a cost to benefit analysis of the proposed relocation options. The EFBC deals with flood impacts in section 4.2.6. This section summarises the outcomes and recommendations of the Flood Study by Taylor Thomson Whitting (2016) and the relevant 2017 updates. These are included in

full in the EFBC in attachment Y and F respectively.

4.6.2 Comments

The content of the EFBC relating to flood risks has already been addressed in the review of the Flood Study (and updates) from Taylor Thomson Whitting.

Regarding the cost to benefit analysis, we would like to bring to the client's attention that we have not seen in the EFBC evidence that the following costs related to flooding were considered:

- Recurring flood damages and clean-up costs to the museum's indoor and outdoor spaces;
- Flood damages to the art collection, particularly the items stored at the ground floor of the south-eastern building, due to direct contact with floodwaters or due to increased dampness and humidity;
- Cost of having to close the museum in advance when there is a risk of a flood. As discussed earlier in this document at this stage we recommend that the museum should close every time a Severe Weather Warning or a Flood Watch for the Parramatta River are issued by the Bureau of Meteorology as the best means of managing risk to life;
- Costs of flood emergency planning, including the arrangement of a suitable refuge area above the PMF level and the associated SIP risk reduction measures listed earlier in this report.

Flood damages, at a location such as the banks of the Parramatta River, are likely to be a significant recurring expense that the museum will need to factor in. The cost benefit analysis of flood damages is a standard step undertaken in each Floodplain Risk Management Study to assess the economic soundness of possible flood risk reduction options, as per the guidelines of the NSW Flood Manual (2005) and the NSW Department of Primary Industry and Environment. As such, there are well validated financial tools that allow assessing costs of flooding through extended time horizons (e.g. Annual Average Damages). It is our view that these should be used to:

Assess the museum expected flood damages and plan resources accordingly;

- Assess the economic viability of any building design options whose scope is to reduce the frequency of flooding at the site;
- Inform the EFBC overall benefit to cost ratio for the proposed museum relocation.

4.7 FINAL REPORT (REPORT 40) (NSW LEGISLATIVE COUNCIL - MUSEUMS AND GALLERIES, FEBRUARY 2019).

4.7.1 Review

This is the Final Report issued by the NSW Legislative Council – Museum and Galleries, upon completion of the Inquiry for Museums and Galleries and in response to the published Business Case for the Powerhouse Museum in Western Sydney Project.

The authors strongly disagree with the methodology used in the Business Case. The following is an extract from the report foreword:

After much evidence, it seems that the decision to relocate the Powerhouse Museum has been based on poor planning and advice, a flawed business case and insufficient community consultation. Nothing so far has demonstrated the necessity or purpose for relocating this world renowned cultural institution, an institution that is much loved and internationally well regarded. Given the significance of this project, the lack of detail, analysis and evidence regarding costs and logistics associated with the relocation has been staggering. Add to that a total disregard for Treasury guidelines regarding a cost benefit analysis for the project, and what remains is simply an expensive and unnecessary project built on poor foundations. Given these issues, the committee has recommended that the NSW Government not proceed with the relocation of the Powerhouse Museum from Ultimo to Parramatta.

The report makes the following references to flooding:

- Paragraph 1.42: Dr Sharp explained that the final business case did not emphasise, among other costs, the cost of flood mitigation.
- A subsequent comment from the Committee, at paragraph 1.81, states that *as noted in the committee's first report, there has also been a lack of genuine community consultation about the project in both Ultimo and Parramatta, and serious questions raised as to the appropriateness of the Parramatta riverbank site for a museum, given its size, accessibility and risk of flooding.*

4.7.2 Comments

This publication from the NSW Legislative Council reiterates the concerns about flood risks that have been discussed throughout this report, and points the attention to the lack of consideration of flood damages and flood mitigation in the Business Case's cost to benefit analysis.

4.8 INTERNATIONAL COMPETITION STAGE 2 DESIGN BRIEF (NSW GOVERNMENT, JANUARY 2020).

This document is the brief released by the NSW Government to inform the international tendering process for the proposed museum's architectural design. It is our understanding that the current site concept design supporting the request for SEARs and publicly available through the NSW Planning Portal were obtained from the architectural firm who won the tender.

Flood risks are dealt with throughout the brief, and are discussed more in detail in Appendix 3 (Stormwater and Flooding, page 248), which explains in some detail how the design is expected to address impacts from flooding (overland and riverine), as well as the associated risk to life. A SIP refuge is requested within the building and above the PMF level, although there are no specific requirements about its capacity, access or structural soundness in a PMF.

There is a statement confirming that the basements were excluded from the design brief due to the cost of flood proofing. The references to flooding are summarised below in the order these appear in the brief.

The Design Brief is discussed in detail in the following subsections.

Part 2 – Design Brief

Section 4.3 (Presentation Spaces #3, #4 and #5, page 132) states that *These spaces should be highly flexible and adaptable, to cater for a range of layouts and media, and function appropriately to display, in rotation, the Collection of the Museum as well as international collections and exhibitions. These spaces will incorporate the highest level of climatic control (rated as AA) suitable for the display of the Museum's Collection and the loan of international collection objects and exhibitions. The floor height and level of all these spaces should be positioned to above the PMF (Probable Maximum Flood level, as defined in the technical appendices) to ensure the security of the Collection.*

Comment on part 2 - 4.3

The concern on the protection of the museum collection from flood damages and dampness is addressed in this section, and it translates into specific brief requirements. However such requirement does not apply to Presentation Space #1 and #2. The reasons for this exclusion are not clear. Furthermore, it is noted that AA class climate control for museums, art galleries, libraries and archives require a 50% average relative humidity with 5% short term fluctuations. Temperatures are to be maintained between 5oC and 25oC in humidity with 2oC short term fluctuations and 5oC seasonal fluctuation.

It is beyond our expertise to assess whether it is possible to maintain these specifications within the upper levels of the building when flood waters enter the lower levels of the building, taking into account that there is likely to be failure of power supply in such a flood. We also do not have sufficient information to know whether the costs of the backup power supply and the air conditioning system

required to meet these requirements have been included in the EFBC.

Part 3 – Urban Design Guidelines

Section 1.7 (Site Content) describes the site topography and flood affectation. It requests that the design considers the riverine and overland PMF flood levels. Section 2.9 (Flooding and Stormwater: the Site) provides additional details on flood behaviour at the site and includes the peak levels of the 100 year ARI (overland only) and PMF (riverine and overland). It specifies that the site is affected by an overland flow path currently building up against the southern wall of the existing undercover car park. It also requires that the existing stormwater pipes are diverted to suit the future museum design.

Comment on Part 3 - 2.9

It is not clear why only these specific peak levels were listed. It makes sense, for the 100 year ARI, to list the overland flood level because this is higher than the equivalent riverine level, however this does not explain why the same approach was not adopted for the PMF levels. In addition to this, the 20 year ARI levels were omitted, while we believe it would have been useful for design purposes to have the full picture of flood affectation. The more frequent floods are relevant to the design of the outdoor spaces which need to be resilient to more frequent inundation.

The considerations on the existing overland flow path in Section 2.9 are taken from the Flood Study, however the 12m set back from the western site is not mentioned in this section (it is only mentioned in Part 3 – Section 3.7).

Section 3.4 (Public Domain and Open Space) states that *The public domain will need to consider the flood-prone nature of the site and fully integrate flood resilience principles into its design. Flood mitigation and egress infrastructure should not be single-use but part of the use of the site day-to-day.*

Comment on Part 3 - 3.4

The current concept plans do not allow to appreciate the extent to which this requirement was fulfilled in the design of the public domain.

Section 3.5 (Access and Movement)

The second paragraph states that *Topographic level changes across the site will be a significant challenge to delivering universal accessibility (compliant to AS1428), routes for vehicular servicing, emergency vehicle access and flood/emergency egress.*

This is picked up again under the guidelines subsection: *Ensure any flood egress routes are fully integrated into the daily use of the site and serve a purpose day-to-day.*

The guidelines also add that *Basement servicing solutions will not be considered due to the flood-prone nature of the site.*

Comment on Part 3 - 3.5

The current concept plans do not allow to appreciate the extent to which this requirement was fulfilled in the design of the flood/emergency egress. If the strategy is to take shelter in place, it is assumed that the egress routes mentioned are to reach the refuge area within the building from all parts of the site exposed to flooding. This assumption is confirmed in Part 2- Section 3.7 of the brief.

Section 3.6 (Built Form and Architectural Expression), recommends to *Engage with the unique challenges and opportunities presented by the flood-affected nature and topography of the site.*

Comment on Part 3 - 3.6

The current concept plans do not allow appreciating the extent to which this requirement was fulfilled in the architectural design.

Section 3.7 (Flooding)

This is a key section of the brief as it contains several important requirements to deal with flood risk. For simplicity, this are summarised and comment on in Table 1.

Table 1. Section 3.7 (Flooding) summary.

Extract from Section 3.7 (Flooding)	Comment
Subsection "FLOODING"	
The site is affected by the 5 to 100 year Average Recurrence Interval (ARI) flood events and the Probable Maximum Flood (PMF) level.	It is unclear where the information on flood affectation in the 5 year ARI was taken from. Other sources (i.e. Parramatta Square Flood Study) indicate that, in current conditions, the site floods in the 1 in 1 year ARI overland event with peak depths of about 0.5 m.
It is crucial that a flood resilience approach is embedded throughout the project to ensure that there is no adverse impact of flooding to the site and to adjacent properties	This refers to the need of remodelling the impact of the proposed development on local flood behaviour to ensure it does not increase flood levels on neighbouring sites. This was discussed in our comments to the Flood Study.
The development will provide accessible routes to points of refuge	We interpret the word "accessible" in this statement as a reference to people with mobility impairments and note that the current design does not appear to have included ramps to reach the building levels above the PMF. It may be that the design is relying on elevators associated with emergency power supply. If not, this is an omission. It will also be important that outdoor areas be designed to have continuously rising access routes to Phillip Street which avoid overland flow paths so that people can evacuate away from a rising river flood without getting trapped by floodwaters.
Mechanical flood mitigation solutions including flood gates should be utilised in a targeted manner to address specific scenarios with the project. The avoidance of mechanical flood mitigation solutions within the site will reduce the site's operation and maintenance requirements as well as potential points of failure should the site experience a flood event.	The available concept plans do not allow to appreciate the extent to which this recommendation was implemented. If mechanical solutions are to be relied upon they need to be fail safe and not utilise manual handling to install as there may be insufficient time available and should not rely upon mains power supply as it may fail.
The existing multi-storey car park has been designed to allow for water ingress in the case of flood. A key constraint for the project will be to ensure that there is no adverse flood affectation associated with reducing this hydraulic flood capacity, as a result of the development.	The available concept plans do not allow to appreciate the extent to which this recommendation was implemented. The cross section provided in Figure 4 of our report suggests that parts of the development may be encroaching into flood storage areas

The development must ensure that the existing overland flow to the west of the site is maintained, with a minimum 12m width. This sits predominantly within the existing easement on the west of the site	The proposed design appears to have allowed as 12m set back from the western site as required.
Subsection "PRINCIPLES"	
— Integrate flood resilience principles throughout the project. — Locate building and design topography in order to not increase flood affectation elsewhere having regard to: – loss of storage. – changes in flood levels, flows and velocities caused by alterations to flood flows. – the cumulate impact of multiple potential development in the vicinity	This section reiterates some of the requirements listed under "Flooding" and, as state above, Figure 4 raises questions as to whether the existing concept properly does this.
Subsection "GUIDELINES"	
Design all habitable spaces to 1:100 year ARI flood plus freeboard - at RL+7.5 and above.	This requirement is consistent with the DCP, confirming that the DCP may be used as guidance even if this is State-Significant Development. The current concept design placed the ground floor of both buildings at RL 7.5m, however there appears to be a habitable undercroft level in the north-western building below the ground floor, facing the river bank and hosting a bar/café. This is the area circled in red in Figure 10. The RL of this area is 3.5m which means that it may flood in the 20 year overland ARI event with depths up to about 3.5m (the level of the 20 year ARI overland flood is 6.9m, and the main site overland flow runs along the western wall of this building). Regardless of how frequently it would flood, this area lies below the level of the 100 year ARI flood plus freeboard, and as such it is incompatible with the requirements of the City of Parramatta DCP, the Flood Study from Taylor Thomson Whitting the Stage 2 Design Competition Brief. With that said, as part of a consultancy to the City of Parramatta Council in regard to the development of the City River Strategy, Molino Stewart (2014) suggested that some commercial activities within the river banks could be located below the flood planning level (i.e. the level of the 100 year ARI flood plus freeboard), provided that certain conditions were fulfilled. In case of permanent cafes, the conditions were that these had to be fitted *with*

	special flood doors or similar which secure the businesses and protect them against direct flooding. Such doors and their supporting structures are required to be specifically designed to take hydrostatic pressures and potential debris strike into account. They must be designed for flood impacts up to the 1 in 100 chance per year flood. (from Molino Stewart, 2014). The current concept plans do not allow to appreciate if this café in the north-western building is protected by this type of doors, however if this were the case there would be an impact on flood storage within the extent of the 100 year ARI flood, which would be incompatible with the requirements set in updated Flood Study and Part 3- Section 3.7 of the Stage 2 Design Competition Brief (see next requirement in this table).
Consider the impact of northern extent of the precinct to ensure hydraulic storage capacity is maintained on the site. *Any development within the storage capacity zone would be required to withstand forces of floodwater, debris and buoyancy up to the 1:100 year ARI, whilst not impeding hydraulic storage capacity*	This refers to the recommendations in the updated Flood Study that any increase of the building footprint (with respect to the smaller building footprint used to assess flood afflux in the Flood Study) within the 100 year ARI flood extent would need to be suspended on columns to preserve storage. As comment in the Flood Study section, it appears that the current design has made use of suspended floors, however it is unclear whether the ground floor of the north-western building is enclosed by glass walls. If this were the case, it would defeat the purpose of having a suspended floor to preserve storage, and this brief requirement would not be fulfilled.
Design the public domain to fully integrate flood mitigation, egress routes to points of refuge. Elements should be designed to be multi-functional and part of the site's day-to-day use. *Seek innovative design solutions and appropriate material and landscaping selection which increase the site's capacity to recover after a flood event.*	The available concept plans do not allow to appreciate the extent to which this recommendation was implemented. The outdoor areas should also be designed to have continuously rising access routes to Phillip Street which avoid overland flow paths so that people can evacuate away from a rising river flood without getting trapped by floodwaters.
Consider innovative solutions to create activation at levels below the 1:100 year ARI flood plus freeboard where habitable spaces cannot be located at RL+7.5 and below	The available concept plans do not allow to appreciate the extent to which this recommendation was implemented.
Consider water sensitive urban design (WSUD) principles public domain design to	The available concept plans do not allow to appreciate the extent to which this

assist in managing water flows and treatment of stormwater.	recommendation was implemented.
Extract from Appendices	**Comment**
Appendix 1	
Power Supply *Substations, main switchboards, backup power UPS and generator systems shall be designed to withstand floods and ensure operation of the facility on the upper levels during 1:100-year flood level at RL7.5. and where possible the Probable Maximum Flood (PMF).*	In order for the building to be used as a refuge during extreme floods and for the AA Climate Control to be maintained to protect collections, the back-up power supply should be fully functioning up to the PMF, not only in the 100 year ARI.
Appendix 3 – Stormwater and Flooding	
2. Stormwater Management *Stormwater management, on site detention (OSD) and water sensitive urban design (WSUD) will need to be to be in accordance with the following: — City of Parramatta Stormwater Disposal Policy, — City of Parramatta Development Control Plan, — City of Parramatta Development Engineering Design Guidelines — Upper Parramatta River Catchment Trust on site detention Handbook*	The available concept plans do not allow to appreciate the extent to which this recommendation was implemented.
3. Flood Levels and Floor Levels *The Flooding Study Final V6 outlines three key flood levels: — The 1:100 year ARI overland flood level of RL7.00m — The Probable Maximum Flood River level of RL10.40m — Probable Maximum Overland Flood Level of RL11.30m Parramatta Development Control Plan 2011 (DCP) sets out the requirements for developments in flood prone areas and requires that all habitable spaces must be designed to 1:100 year ARI plus freeboard (500mm) – i.e. habitable spaces must be at RL7.50m or above.* *Non-habitable basements are not anticipated for the Precinct, as they are considered to be cost-prohibitive due to the significant flood mitigation measures required*	It is requested that habitable spaces are at RL 7.5m or above, however as previously discussed this condition is not fulfilled by the area highlighted in Figure 6. The current concept plans are consistent with the requirement of not having non habitable basements.
3. Flood Levels and Floor Levels *The majority of Presentation Spaces should be designed to be above the overland PMF (RL11.3) to ensure they are suitable for*	This applies to all presentation spaces except Presentation Space #1, which is at RL 7.5m and appears to be the only one containing items which could not be relocated to higher

display of some Museum Collection items.	levels during a flood emergency, because of their size and weight. It is our opinion that this arrangement should be revisited to ensure that all presentation spaces hosting items of the museum collections are above the overland PMF level.
3. Flood Levels and Floor Levels *Careful consideration is required at the northern extent of the Precinct to ensure hydraulic flows and flood storage capacity are maintained on the site. Any development within the flood storage capacity zone would be required to withstand forces of floodwater, debris and buoyancy up to the 1:100 year ARI, whilst not impeding hydraulic storage capacity.*	The plans that were available at the time this report was prepared did not allow to assess whether the current design preserved the pre-development hydraulic flows and storage capacity. It is understood that the current plans are proposing a building footprint larger than the one that was used in the Flood Study to model any impacts on overland flows and hydraulic storage. As such, as per the updated Flood Study (summarised in Attachment F to the EFBC), an extension of the building footprint within the extent of the 100 year ARI flood would only be possible if the ground floor was above the flood planning level, and suspended over columns, with an open design underneath to allow free flow of floodwaters. This requirement may be fulfilled by the north-western building assuming that the ground floor will have an open design (i.e. not enclosed in glass walls). It is recommended that overland flows and hydraulic storage are reassessed by a qualified hydraulic engineer once the final building design is available.
4. Overland Flow Consideration *The site is impacted by overland flows from the south. The current flow is via Phillip Street and Dirrabarri Lane through to the River Foreshore. Design Concepts must include:* *— Clear overland flow paths through the site to ensure that upstream overland flood levels do not increase.* *— On site detention may need to be considered to ensure no exacerbation of overland flow to downstream areas.* *— Consideration of permeable surfaces throughout the public domain to manage stormwater flow and allow infiltration.* *— Consideration of Water Sensitive Urban Design (WSUD) principles in landscape design to assist in managing water flows and*	The current concept design provides a 12 m set back from the western site boundary, along the main overland flow path that runs through the site. This fulfils the requirements of the Flood Study. The remaining requirements cannot be assessed against the currently available plans.

treatment of stormwater.	
5. Public Domain River Flood Considerations *The site is impacted by river flooding on the northern boundary. In addition to the 1:100 year events outlined in an earlier section, consideration should be given to ensuring the public domain is designed to withstand inundation in smaller, more frequent river flood events.*	The available concept plans do not allow to appreciate the extent to which this recommendation was implemented.
6. Flood Evacuation *The design for the Precinct must be capable of providing a clear and reliable access for pedestrians to an area of refuge above the PMF level. This can be achieved either on the site (i.e. a second storey) or off the site. Note that much of Parramatta CBD will be inundated to a significant depth during the PMF.* ***Guidance Note: The general expectation is that pedestrian evacuation for people within Powerhouse buildings can be accommodated within the building on levels above the PMF, whereas pedestrian evacuation from the public domain would be through clear and accessible routes to areas external to the Precinct***	This section indicates that the preferred flood emergency response strategy for visitors outside the building is horizontal evacuation, while only people that are located within the building are assumed to take shelter at the higher levels. Given the flood extent of the PMF, the relatively quick rate of rise (Figure 11) and the fact that Phillip Street, as well as most streets in the CBD, would likely be cut by local flooding by the time an evacuation order is issued (Figure 1), we think that horizontal evacuation is not a safe option for any of the people within the premises. Horizontal evacuation of the people in the outdoor areas would likely require these to walk through floodwaters in Phillip Street, or having to walk along the river edge toward Church Street. In both cases, the risks of having to walk through high hazard floodwaters would be excessive. As such it is our opinion that all the people in the premises would need to take shelter within the museum buildings, in a designated refuge above the reach of the PMF. For such refuge to be a safe shelter in a PMF, it would have to satisfy the previously mentioned requirements to reduce the risks of SIP. Of these requirements, the most basic and important are that: • the building where the refuge is located would need to be structurally sound in a PMF event. We have not seen this requirement in the Stage 2 Design Competition Brief. • The refuge would need to provide a minimum of $2m^2$ of floor surface area for each evacuee, and have capacity for all visitors and staff that are on the premises at any one time. The brief suggests that the site may be used to

	host functions with up to 10,000 people. Additional requirements are listed at page 12 of this report, and we note that none of these was a condition requested in the brief. The outdoor areas should be designed to have continuously rising access routes to the flood refuge within the building and to Phillip Street which avoid overland flow paths so that people can evacuate away from a rising river flood without getting trapped by floodwaters. This was one of the principle design criteria for any outdoor developments along the river frontage. As stated above, evacuating to the building refuge may be the only option as Phillip Street may flood before the river rises, however there may be instances in which the river would flood the outdoor public areas when the building is closed.

5 CONCLUSIONS

Although the non-availability of some documents has limited our ability to more thoroughly comment on the planning and design of the proposed museum in Phillip Street we can confidently draw the following conclusions:

- The site itself is at risk of flooding from floods more frequent than the 20 year ARI design flood in the Parramatta River and flooding as frequent as the 1 year ARI overland flows in Phillip Street and Dirrabarri Lane.
- The focus of the designs to date has been on the 100 year ARI and PMF flood events with:
  - The objective of providing most exhibition spaces above the PMF but for large items to be displayed at the ground floor level 0.5m above the 100 year ARI design flood level;
  - Provision of a PMF safe refuge for building occupants within the building;
  - A footprint which does not increase flooding on adjoining premises.
- The designs to date have failed to demonstrate:
  - How those in outdoor spaces will be provided appropriate access to flood free refuge;
  - How those taking shelter above the PMF within the building will have their needs catered for in such a way to reduce the residual risks associated with sheltering within a non-residential building for up to 8 hours;
  - That all habitable spaces have been designed either above the flood planning level or in such a way to exclude the 100 year ARI flood from entering those spaces;
  - That the building footprint does not encroach on floodways and flood storage areas and therefore does not increase flood levels on neighbouring properties;
  - That consideration be given to how AA International Museum Standard Environmental Conditions will be maintained within the exhibition spaces to protect sensitive collections (owned and on loan) if floodwaters enter the building and/or there is an extended power outage due to flooding.
- The economic evaluations to date have failed to demonstrate they have considered the costs of:
  - Cancelling events and shutting the museum in response to frequent flood alerts (a few times per year) as a means of minimising risk to life;
  - Designing the air conditioning system and backup power supply needed to maintain a AA Climate Rating to protect collections;
  - The cost of protecting assets below the flood planning level from flood damage;
  - The cost of providing support features and services to those sheltering within a building in a flood;
  - The annual average flood damages to built assets;
  - The annual average flood damages to collections.

6 REFERENCES

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NSW SES, 2020: About Us NSW State Emergency Service. <https://www.ses.nsw.gov.au/about-us/>

APPENDIX A – GLOSSARY

This report utilises the terminology used in the NSW *Floodplain Development Manual* (2005). The following Glossary is drawn from that Manual and additional sources.

Acronym	Full Name	Description
AEP	Annual Exceedance Probability	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (i.e., a one-in-20 chance) of a 500 m^3/s or larger events occurring in any one year (see ARI) (NSW Department of Infrastructure, Planning and Resources, 2005).
AHD	Australian Height Datum	A common national surface level datum approximately corresponding to mean sea level (NSW Department of Infrastructure, Planning and Resources, 2005).
ARI	Average Recurrence Interval	The long-term average number of years between the occurrence of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event (NSW Department of Infrastructure, Planning and Resources, 2005).
BoM	Bureau of Meteorology	The Bureau of Meteorology is Australia's national weather, climate and water agency (BoM, 2020).
DCP	Development Control Plan	A Development Control Plan provides detailed planning and design guidelines to support the planning controls in the Local Environmental Plan developed by a council (NSW Planning Portal, 2020).
EFBC	Extended Final Business Case	See report for specific context.
FEMP	Flood Emergency Management Plan	A formal plan to reduce the risk to people and property from flooding through planning, preparedness, response and recovery.
NSW SES	New South Wales State Emergency Service	NSW State Emergency Service (SES) is an emergency and rescue service dedicated to assisting the community (NSW SES, 2020).
OSD	On Site Detention	Means of detaining stormwater on site. Can be achieved with dams, detention basins, water storage tanks.
PMF	Probable Maximum Flood	The PMF is the largest flood that could conceivably occur at a particular location,

		usually estimated from probable maximum precipitation coupled with the worst flood producing catchment conditions. The PMF defines the extent of the flood prone land, or floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event, should be addressed in a floodplain risk management study (NSW Department of Infrastructure, Planning and Resources, 2005).
RL	Reduced Level	Relative level of the building feature above the accepted height datum.
SEARs	Secretary's Environmental Assessment Requirements	Critical State significant infrastructure (CSSI) projects are high priority infrastructure projects that are essential to the State for economic, social or environmental reasons. When an application for approval of a declared CSSI project is made, the Secretary of the Department of Planning and Environment is required to issue environmental assessment requirements (SEARs) that cover environmental impact assessment (NSW Planning and Environment, 2015).
SIP	Shelter in Place	Taking shelter within a building or a structure above the reach of floodwaters (also referred to as vertical evacuation)
UPRCT	Upper Parramatta River Catchment Trust	See Bewsher Consulting, 2003
WSUD	Water Sensitive Urban Design	An approach that integrates the urban water cycle into urban design to improve environmental impacts and aesthetics.