Independent Flood Review

of ‘Novus Build to Rent’

at 39-43 Hassall Street, Parramatta

For the New South Wales Independent Planning Commission

By Professor Seth Westra

21 February 2024

1. Background

On 6th February 2024, the New South Wales Independent Planning Commission (the Commission) requested the provision of independent advice on the flood risk of a proposed development to be located at 39-43 Hassall Street, Parramatta (the Development). Specifically, the Commission sought a review of multiple flood studies and related documents that have presented differing conclusions on the flood risk of the Development.

This review provides an independent assessment of these studies and related documents, focusing on the following issues:

- the likely flood levels in a 1% AEP and PMF event at the Site;
- the likely flow velocity of the creek at the Site;
- whether the blockage factor has been appropriately calculated;
- whether a land connection can be maintained during a 1% AEP; and
- the risk rating for the Site in 1% AEP and PMF events.

In addition to the above issues, the Commission requested advice as to whether the Development, as proposed, adequately responds to flooding risk and/or whether specific changes to the physical design of the development should be required.

This review assesses the information contained in the materials summarised in Appendix A, and does not extend to a detailed technical review of the underlying data or models that supported this work. A technical review of one of the flood models (by Lyall and Associates, 2022) was conducted and forms part of the supporting materials for this review (GRC Hydro Independent Flooding Advice, 2 Nov 2023).

2. Key flood metrics relevant to the Development

This section reviews several key descriptors of flood magnitude at the site, which collectively form the basis for setting flood planning levels and enabling a broader assessment of flood risk.

The foundational studies to support this review are the Lower Parramatta River Floodplain Risk Management Study – Flood Study Review, 2005 (SKM), and a more recent flood study conducted by Lyall and Associates (2022) for the purposes of this development. It is understood that Parramatta City Council has also commissioned a revised flood study of the region, but that this flood study is not yet finalised, and can therefore not be used as the basis for evaluating flood risk at the proposed Development.

The likely flood levels in a 1% AEP and PMF event at the Site

The potential for flooding at the site of the proposed Development arises from three sources:

- Flooding from Clay Cliff Creek, with a contributing area of approximately 2.5 km^2, and with a flow direction from west to east;
- Overland flow pathways predominantly from north to south towards Clay Cliff Creek; and
- Backwater effects from Parramatta River.

The flood mechanisms that generate the highest flood levels at the site vary depending on the flood magnitude, and are therefore summarised separately for the 1% annual exceedance probability (AEP) event and the probable maximum flood (PMF) event.

1% AEP event

The flooding at this AEP is driven by a combination of overland and Clay Cliff Creek flow pathways, with different flood levels identified by the two key flood studies assessed in this review (SKM, 2005 and Lyall and Associates, 2022).

According to the SKM (2005) study, the 1% AEP flood level for mainstream flooding along Clay Cliff Creek adjacent to the proposed Development is 6.2m AHD. This was derived using the RAFTS hydrological model and the MIKE-11 one-dimensional flood model. It is understood that this model remains the official model used by Parramatta City Council[1].

Lyall and Associates (2022)[2] conducted a flood modelling study using more contemporary methods (e.g. two-dimensional hydrodynamic modelling) and following more recent flood guidance advice contained in Australian Rainfall and Runoff (2019). It is claimed that this represents an improvement over the SKM (2005) study in at least three respects[3]:

- Use of a two-dimensional hydraulic model (TUFLOW) rather than the one-dimensional model (MIKE-11) used by the SKM (2005) study;
- Incorporation of a detention basin in Ollie Webb Reserve upstream of Clay Cliff Creek, which was not included in the SKM (2005) study; and
- Improved representation of Clay Cliff Creek bridge crossings to correct their representation as culverts in the 2005 model.

The study provided a range of flood levels based on different modelling assumptions, including partial blockage of the bridges over Clay Cliff Creek and the incorporation of a climate change factor. Moreover, the two-dimensional hydraulic model enabled the provision of more spatially resolved flood levels and hazard ratings across the site and surrounding area. As summarised by Table 1 of the Molino Stewart report[4], the 1% AEP event could potentially range from 5.85m to 6.49m AHD depending on the assumptions used and the specific location within the site.

The higher estimates for the 1% AEP flood level assume a 15% blockage of the key bridge structures, together with a 19.7% increase in extreme rainfall due to climate change. In relation to the blockage assumption:

- The 15% blockage factor was reviewed by GRC Hydro (2023) who suggested that '*a 15% blockage factor for Harris Street bridge was a conservative assumption given that the blockage factor could reasonably be calculated to be 0% as part the ARR 2019 Blockage Assessment methodology*'.
- Lyall and Associates (2022) also highlight the '*inherently unstable nature*' of the channel where '*any minor change in the bed slope of the channel or any obstruction to the flow will cause the water surface to rise rapidly towards critical depth, and under certain conditions even higher to its conjugate subcritical flow depth*'.

This suggests that although the 15% blockage factor may be conservative, the potential for '*any minor change in the bed slope of the channel or obstruction to the flow*' to cause rapid changes to surface water levels suggests that assuming some level of obstruction is prudent in this case.

[1] For example as stated in Council Advice on RtS Attachment A Engineering Advice, 12 July 2023.
[2] Included as Attachment 2 of the Molino Stewart Flood Risk Assessment, 20 June 2023.
[3] GRC Hydro Independent Flooding Advice – 2 Nov 2023
[4] Molino Stewart Flood Risk Assessment, 20 June 2023

In relation to the climate change assumption, it is noted that:

- There is compelling evidence that the climate has already changed, with increases in temperature of well over 1°C since pre-industrial times;
- Parramatta City Council recommends that '*a climate change factor of 22.9% (for the year 2100)... needs to be incorporated in the model for [the] design case'* [5]; and
- For hourly and sub-hourly storms such as those likely to be critical for the overland flow and Clay Cliff Creek pathways, current scientific understanding is that this is scaling at a rate 15%/C of global warming[6]. This would lead to potential changes in extreme rainfall much greater than the 19.7% change factor simulated by Lyall and Associates (2022), or the 22.9% factor recommended by Parramatta City Council[7]. Whilst it is noted that the Wasko *et al* reference (which is written to support the update to the climate change guidance in Australian Rainfall and Runoff) was not available at the time of the study, most of the foundational scientific evidence has been available in the published scientific literature for at least half a decade, and Australian Rainfall and Runoff (2019) highlights that '*the latest published sources should always be sought for use in future assessments and decision making'*.

It is my assessment that the SKM (2005) and Lyall and Associates (2022) studies both represent credible flood studies, that used rigorous methods that were available at the time. However, I do not support using the lower end of the estimates by Lyall and Associates (2022) as the basis for design, as this appears to make a set of assumptions that collectively appear overly optimistic.

Based on an overall assessment of the material, it would be prudent to adopt 1% AEP flood levels based on the Lyall and Associates (2022) scenario with 15% blockage together with climate change (e.g. as summarised in Table 1 of Molino Stewart, 2022), which is higher than the SKM (2005) level given that it did not factor in climate change. This level provides a balance across a range of uncertainties, including arguments that inclusion of 15% blockage may be a conservative representation of potential blockage at the site, and recent published evidence that suggests climate change factors are likely to exceed the 19.7% adopted by Lyall and Associates (2022).

<u>PMF event</u>

According to the SKM (2005) study, the PMF is 9.5m AHD. Unlike for the 1% AEP event, the maximum PMF level is driven by backwater effects from Parramatta River.

The Lyall and Associates (2022) analysis included additional model results for the PMF, focusing on flooding resulting from overland and creek flooding. Based on this, PMF levels based on overland and creek flood pathways were estimated to range from 6.91-7.39m AHD. However, this report also recognised that the key flood pathway for the PMF is from Parramatta River, and accepts the 9.5m level provided by SKM (2005).

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[5] Parramatta City Council advice dated 29/03/2023

[6] Wasko, C., Westra, S., Nathan, R., Pepler, A., Raupach, T., Dowdy, A, Johnson, F., Ho, M., McInness, K., Jakob, D., Evans, J., Villarini, G. & Fowler, H, 2024, A systematic review of climate change science relevant to Australian design flood estimation, Hydrology and Earth Systems Science (pre-print available here https://hess.copernicus.org/preprints/hess-2023-232/)

[7] For example, using SSP2-4.5 and SSP3-7.0 as mid-range climate change scenarios for 2081-2100 indicates a warming of between 2.7°C and 3.6°C relative to a 1961-1990 baseline. For hourly storm bursts scaling at 15%/°C, this would lead to change factors from 40.5% and 54%--much higher than the scaling assumed either by Lyall and Associates (2022) or Parramatta City Council.

As such, the PMF flood level relevant to the site is deemed to be 9.5m, as suggested by the SKM (2005) report. However, it is important to note that although the PMF event from overland and creek flooding has a lower overall level, it would be associated with a much faster rate-of-rise (of 0.7m every 10 minutes)[8], leading to highly hazardous conditions albeit it at a lower overall flood level. This is particularly relevant in considering the potential efficacy of measures contained in the Flood Emergency Response Plan, recognising that floods from combined creek/overland flow pathways are still capable of exceeding the basement entry crest levels, with the potential for very little time between the initiation of any emergency response actions and the emergence of dangerous water levels.

The likely flow velocity of the creek at the Site

Depending on the flood study and assumptions adopted, the following flow rates and velocities were identified in Clay Cliff Creek adjacent to the Development site for the 1% AEP event:

- Flow rate of 30m^3/s and velocity of 2.9m/s (Appendix B of SKM, 2005)
- Flow rate of 34.2m^3/s under historical climate assumptions (Table 3 of Lyall and Associates, 2022) [9]
- Flow rate of 41.6m^3/s under climate change assumption (Table 3 of Lyall and Associates, 2022)

Detailed velocity vectors were not provided, although hazard information (which combines depth with velocity) was presented by Lyall and Associates (2022). This is discussed further in the context of the Development's overall risk rating below. Consistent with the above recommendations for the design 1% AEP flood level, it is recommended that the greater of these flow rates be adopted for design.

For rarer flood events up to and including the PMF, it is possible that the greatest velocities are associated with the PMF arising from creek and/or overland flow pathways, even though these lead to lower flood levels compared to the PMF arising from backwater effects from Parramatta River. Limited quantitative information was available to provide further detail on likely flow velocities at the site for events rarer than the 1% AEP event.

Whether the blockage factor has been appropriately calculated

It is understood that the Lyall and Associates (2022) report assumed 100% blockage of the 'underground drainage network'; namely that the existing stormwater drainage system is 100% blocked. As a result, details of the local stormwater drainage network were not incorporated in the TUFLOW model used. This represents a conservative assumption and is considered appropriate.

A blockage factor of 15% was used for a sensitivity analysis for the bridge crossings over Clay Cliff Creek, and the application of this factor was subject to peer review by GRC Hydro (2023). GRC Hydro concluded that the '*15% blockage factor for Harris Street bridge was a conservative assumption given that the blockage factor could reasonably be calculated to be 0% as per the ARR 2019 Blockage Assessment methodology*'. However, tempering this, Lyall and Associates (2022) highlight the '*inherently unstable nature*' of the channel where '*any minor change in the bed slope of the channel or any obstruction to the flow will cause the water surface to rise rapidly towards critical depth, and*

[8] Figure 12 of Molino Stewart Flood Risk Assessment, 20 June 2023

[9] This estimate, presented in Table 1 of Lyall and Associates (2022), was also attributed to the SKM (2005) study but appears to have been taken directly from the output of the MIKE 11 model developed within the SKM (2005) study.

under certain conditions even higher to its conjugate subcritical flow depth'. This suggests that it is prudent to maintain the 15% blockage factor as calculated by Lyall and Associates (2022).

Whether a land connection can be maintained during a 1% AEP

No vehicular land connection is possible during the 1% AEP event (15% bridge blockage plus climate change scenario).

The primary land connection for pedestrian access is the elevated jetty/walkway on the south of the site. The RLs for this were not fully clear from the documentation, with the DA schematic provided in Lyall and Associates (2022) showing this walkway reduces to a level of RL 6.1m on the southeast site boundary, and the survey by SDG Pty Ltd showing levels of approximately 5.95m on Harris Street immediately adjacent to the site exit, before rising again moving southwards down Harris Street. On the other hand, Molino and Stewart suggest that the footbridge '*will be raised to tie in with the Harris Street footpath at 6.2m AHD*'[10].

Irrespective of the precise level, any of these levels are below the 1% AEP event recommended here (15% bridge blockage plus climate change scenario). As such, the site would be isolated during a 1% AEP event. This was also the conclusion provided in Table 1 of Molino Stewart for that scenario[11].

The risk rating for the Site in 1% AEP and PMF events

It is assumed that this refers to a 'hazard rating' rather than a risk rating, as an evaluation of risk requires a more detailed assessment of potential consequences across a range of different flood exceedance probabilities, including an evaluation of residual risk. Such an assessment is not standard practice for this type of development, and has not been conducted.

The concept of flood 'hazard' (represented on a six-point scale from H1 to H6 based on a combination of the depth and velocity of flood waters) is often used as a proxy for risk, and describes risks in the event that people or property become situated within the flood waters. This does not account for factors such as rate of rise, which influences capacity to evacuate, and human factors, which determine the likelihood that people or vehicles enter the flood waters.

As the water levels and velocities vary throughout the site and surrounding land, there isn't a single hazard rating but rather several depending on the purpose:

- The hazard rating within the building footprint itself. Although a significant portion of the building are located well below the 1% flood level, it is argued by Molino Stewart that the hazard is zero within large parts of the building's lower elevations (e.g. basement car parks) as a result of hydraulic flood gates that are designed to provide protection up to and including the riverine PMF. As discussed in Section 3 below, there is a non-zero probability that the flood gates will fail either because of mechanical and/or human factors, and in the event of such a failure the consequences in the basement levels of the building could be severe.
- The hazard rating on egress from the property. As shown in Figure 10 of Molino Stewart (2023), at the 1% AEP event using the 15% blockage plus climate change scenario, the site is surrounded by at least an H3 hazard rating, with hazard categories up to H5 in the southeast portion of the site where the jetty/walkway enters the road network. It is noted that hazard

[10] Molino Stewart Letter in Response to Submissions Number 1 – 20 June 2023
[11] Molino Stewart Flod Risk Assessment – 20 June 2023

categories of H3 and above are unsafe for people (children and the elderly for H3 and people in general for H4 and above) or vehicles.

3. Whether the Development Adequately Responds to Flood Risk

Much of the documentation reviewed focuses on the theoretical differences between alternative flood modelling studies, most notably the Lower Parramatta River Floodplain Risk Management Study – Flood Study Review (2005) by SKM, and the site-specific flood study by Lyall and Associates (2022). In addition, a new model by Council, which was not available for this review and is still in draft, was used as evidence for some of the submissions.

The differences in flood model levels from the different studies are in the order of several tenths of a meter, are caused by different modelling assumptions, and are broadly within the uncertainty range that might be expected when modelling flood events with exceedance probabilities of 1% or rarer. Notwithstanding these uncertainties, the following appears to be reasonably clear:

- The site of the Development would be surrounded by flood waters with hydraulic hazard ratings of H3 or above with an annual exceedance probability of around 1% (either slightly above or slightly below a 1% AEP, depending on the modelling assumptions). An equivalent way of stating this information is that the site has a greater than 50% chance of being surrounded by at least H3 hazard flood waters at least once during the building's effective service life (assuming the service life at least 70 years). During an H3 flood, as indicated by the SES response[12], it would be unsafe for people or vehicles to exit the building footprint.
- Floor levels of the residential habitable parts of the building are set above the PMF, and it is understood that the building structure is to be built to withstand a flood of this magnitude. Floods are generally but not exclusively expected to be of six-hour duration or less, and emergency provisions of power, water and sewage appear to be incorporated within the design. There is therefore a limited risk to life assuming people remain within the residential habitable parts of the building during the flood event.
- A 'shelter-in-place' or 'vertical evacuation' strategy is proposed. Whilst the intent (and assumptions contained in the applicant documents) is that all occupants conform to this strategy, human behaviour can be unpredictable during flood events and may lead to individuals seeking to evacuate when it is not safe to do so. The ability to enforce key controls during the Development's effective service life, such as is described in the proposed Flood Emergency Response Plan[13], is also unclear. Therefore, although these risks can to some extent be mitigated, they cannot be eliminated, and it is unavoidable that a development of this nature will cause more people to be located in the flood plain and thus exposed to associated flood risks.
- Flood protection to the basement carpark and other below-ground facilities are to be achieved through mechanical flood gates. There is a non-zero probability of failure due to mechanical and/or human factors, noting that flood events are inherently rare but could occur with very little notice (particularly Clay Cliff Creek and overland flow pathways, that can trigger events that occur with very little notice but would exceed the crest levels of key entry points). Failure of any of the flood gates would lead to a rapid rise of water in any basement areas, and could have catastrophic impacts for any occupants of the affected areas if they are not evacuated in time. Although it is argued that '*a riverine flood large enough to reach the top of the basement ramp crest would have an Annual Exceedance Probability of 1*

[12] SES Advice on RtS – 21 July 2023
[13] Molino Stwart Flood Emergency Response Plan – June 2023

in 5000'[14], it is likely that the inclusion of realistic climate change factors as described in Section 2 would lead to a significantly higher probability of occurrence than assumed by Molino Stewart.

It is also noted that the proposed Development is inconsistent with Recommendation 20 of the NSW Flood Inquiry (2022) for treating '*floodplains as an asset, specialising in uses that are productive and minimise risk to life during major weather events*'.

Based on these considerations, the development as proposed contains notable residual flood risks, the likelihood of which cannot be determined from the available documentation given that:

- much of the supporting assessments are based on flood levels that are lower than the flood levels recommended herein (i.e. the combined 15% blockage and climate change scenario);
- the risks arise largely due to the possible failure of the primary mitigants (i.e. the combination of 'shelter-in-place' and flood gates), with the analysis provided by Molino Stewart not sufficiently cognisant of the possibility that key controls may not operate as intended; and
- some elements of risk mitigation, such as the reliance on a Flood Emergency Response Plan, would be difficult to consistently enforce throughout the effective service life of the development, and should not receive the same weighting compared to risk mitigants that can be enforced during the planning and design stages.

These considerations suggest that the residual risks remain significant. At minimum, there is merit in reviewing the design levels to preserve a Flood Planning Level of at least 0.5m above the 1% AEP design flood event considering the 15% blockage and climate change scenario simulated by Lyall and Associates (2022). This would include reviewing basement crest levels and levels for other sources of water ingress based on this scenario, ideally maintaining a passive protection into the site at the 1 in 2,300 AEP level as recommended in the Flood Emergency Response Plan[15]. This will likely require increasing several design levels for the Development, which may have further consequences that cannot be evaluated based on the information provided. Ultimately, however, it needs to be recognised that this Development is situated in a floodplain with the potential to be surrounded by high hazard waters (H3 or above) during a 1% AEP flood event, and much deeper and more hazardous waters for rarer events. Whilst modifying key levels will assist in reducing flood risk in several respects, in the absence of fundamentally changing key aspects of the Development, it is unclear that there are further mitigants available that would substantively reduce risks beyond those already proposed.

[14] Applicant Response to EHG – 14 September 2023
[15] Molino Stwart Flood Emergency Response Plan – June 2023

Appendix A – List of Documents

Original Flood Study
1. SKM Lower Parramatta River Floodplain Risk Management Study – Flood Study Review, 2005

Department of Planning, Housing and Infrastructure documents
1. GRC Hydro Independent Flooding Advice – 2 Nov 2023

Applicant documents
1. Molino Stewart Flood Emergency Response Plan – June 2023
2. Molino Stewart Flood Risk Assessment – 20 June 2023
    - Attachment 1 – Council Flood Certificate – 13 December 2021
    - Attachment 2 – Lyall and Associates 39-43 Hassall Street Flooding Investigation – 21 December 2022
3. Molino Stewart Letter in Response to Submissions Number 1 – 20 June 2023
4. Molino Stewart Letter in Response to Submissions Number 2 – 11 August 2023
    - Pages 51 – 54 - Lyall and Associates Letter in Response to Department Request for Info – 18 August 2023
5. Applicant Response to EHG – 14 September 2023

Agency Advice
1. SES Advice – 3 April 2023
2. SES Advice on RtS – 21 July 2023
3. EHG Advice – 31 March 2023
4. EHG Advice on RtS – 18 July 2023
5. Council Advice – Pages 19-25 – 29 March 2023
6. Council Advice on RtS Attachment A Engineering Advice – 12 July 2023