Nowra Riverfront Precinct Flood Impact and Risk Assessment

Final Report

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Executive Summary

The Nowra Riverfront Precinct (the Precinct) Flood Impact and Risk Assessment (FIRA) has been prepared for Shoalhaven City Council (Council) to define the existing flood behaviour in the catchment and to assess, and address, if necessary, the potential impacts arising from the proposed future development of the Precinct.

Objectives

The purpose of this Study was to determine if:

- Changed flood behaviour associated with the concept form of the Precinct could arise and have adverse impacts on the flood risk to the existing community and development;
- The proposed development within the Precinct and its users or occupants can be enabled with an acceptable level of flood risk; and
- Effective flood emergency response is achievable without adverse impacts on the ability of the existing community to respond to floods.

The FIRA is required to establish at concept level whether the proposed Precinct works would result in impacts that are localised and / or can be readily managed. The FIRA can also be used to support/inform land-use rezoning processes, planning proposals, inform development applications against the SLEP and SDCP (in particular the safe occupation and evacuation requirements of the SLEP) and the establishment of development controls for future development in the Precinct.

Background

The Precinct is an important location that Council plan to utilise to strengthen the role of the Nowra Riverfront Precinct as a civic, community, tourism, and recreational hub for the Shoalhaven region.

Urban design consultants, Studio GL, were engaged in 2018 to prepare recommendations for planning and development controls. Studio GL made a number of recommendations for changes to existing zones, floor space ratios and height controls, and prepared preliminary masterplans.

The preliminary sub-precinct layout developed by Studio GL is shown in **Figure i**.

Figure i Proposed Sub-precincts (Source: Studio GL)

Technical Working Group

The involvement of key stakeholders has been an important part of this study. To this end, a series of four Technical Working Group (TWG) workshops have been undertaken over the course of the study.

The aim of the TWG workshops was to provide a means of engagement with key stakeholders, and to provide early and ongoing opportunities to provide feedback and comment on the progression of the FIRA.

These workshops were help throughout the project, namely:

- TWG1: Undertaken on 15 December 2021, the first TWG workshop was held to present the results of the base case flood modelling, and to invite comments and suggestions for the development of future scenarios and options for assessing in the hydraulic model. The presentation and comments received are provided in **Appendix B**.
- TWG2: Undertaken on Monday 21 February 2022. The workshop was held to present the results of the concept option flood modelling, and to invite comments and suggestions for the development of scenarios that warranted further assessment. The presentation from the workshop is provided in **Appendix C**.
- TWG3: The third TWG workshop was held on 7 June 2022. The workshop was held to present the results of the Flood Planning Level (FPL) assessment, the NSW SES evacuation modelling, site specific development controls, and the development of a set of performance criteria for the assessment of various landform options. The presentation from the workshop is provided in **Appendix D**.
- TWG4: The draft FIRA was reviewed by stakeholders, namely NSW State Emergency Service (SES), Department of Planning and Environment (DPE) and Transport for NSW (TfNSW) prior to its finalisation. As part of this review, an initial workshop with SES and DPE was held on 21 February 2023 to discuss the comments submitted. Following this, a fourth TWG workshop was convened on 3 April 2023 to further discuss comments received and how the FIRA should be revised to address them. Provided in **Appendix G** is a summary of how the report was revised in light of these comments, as well as the submissions received from stakeholders.

Existing Flood Behaviour

Flood modelling has been undertaken for the 20%, 10%, 5%, 1%, 0.5%, 0.2 and 0.05% Average Exceedance Probability (AEP) events and the Probable Maximum Flood (PMF) event in accordance with Australian Rainfall and Runoff, 2019 (Commonwealth of Australia (Geoscience Australia), 2019).

For local catchment flood events, outside of the central flood storage area (the open space area between the Mandalay sub-precinct and the Hyam Street and Scenic Drive sub-precincts), the flood affectation is minimal, and typically confined to the road reserves for all modelled events. The exception to this is that in the PMF, the portion of the Precinct east of the highway experiences inundation of developed areas as a result of backwater flooding from the Lower Shoalhaven River (assumed to occur at the same time as a local catchment flood event).

For riverine floods, the riverbank first overtops in the 5% AEP event immediately upstream of Nowra Bridge, with flows spilling into the central open space of the Precinct. Flow first breaks out of the river adjacent to the south-western embankment of the recently completed bridge across the Shoalhaven River and flows through the existing low point adjacent to the Nowra Aquatic Park. The 5% AEP levels in the central depression are 0.08m higher for a riverine flood, compared to the 5% AEP local catchment

event. This trend intensifies for larger events, with the 1% AEP being 0.5m higher in a riverine flood compared to a local flood event, and the PMF is 3.5m higher for riverine foods. As such, catchment-driven flooding governs the local flood behaviour up to the point at which the riverbank overtops (the 5% AEP), after which peak flood levels in the Precinct are governed by riverine flood levels.

Flood Planning Level Assessment

To inform the setting of Precinct Flood Planning Levels (FPLs) an assessment was undertaken for three FPL options:

- The 1% AEP + Sea Level Rise (SLR) + Rainfall Increase (RI) + Freeboard
- The 0.5% AEP + Sea Level Rise (SLR) + Freeboard
- The 0.5% AEP + Sea Level Rise (SLR) + Rainfall Increase (RI) + Freeboard.

Each scenario was assessed for:

- Benefits to flood warning and evacuation
- Benefits to risk in likelihood of flooding
- Impact on developable area
- Integration with adjacent infrastructure
- Aesthetic and open space integration considerations.

Following this assessment, for investigations as part of this study, it was elected to set the level of the Precinct building pads at the 0.5% AEP +SLR +0.5m freeboard. This outcome was consistent with the recommendations from the Lower Shoalhaven River Flood Study (Cardno, 2022).

Options Development

To allow the assessment and comparison of the various options to be assessed, and to determine which options could be considered feasible, a set of performance criteria were developed. The adopted criteria evolved from discussion at the second TWG meeting (on 15/12/2021) concerning what a “successful” option would deliver, as well as consultation with Council and DPE technical personnel.

A raised building pad was determined to be the primary means by which flood risk could be managed on site as this design approach seeks to provide a level of flood protection for the proposed buildings for both local catchment and riverine flood events, and to assist with flood evacuation though the provision of additional evacuation time.

Various landform options for the Precinct were assessed using flood modelling to determine the maximum extent the raised building pad levels could take up without adversely affecting flood behaviour.

Through an iterative approach, a pad arrangement was determined that maximised the developable area of each sub-precinct, whilst not resulting in adverse flood behaviour.

The assessment found that the proposed building pads would result in a water level increase over Hyam Street and adjacent properties for the local catchment 1% AEP. Further testing showed that this impact could be mitigated by either constructing a second stormwater outlet to the Lower Shoalhaven River, or by reducing the Mandalay, Hyam Street and Scenic Drive pads by 7.5m, adjacent to the central open space.

Flood Emergency Response

Flood warning time and evacuation potential were both assessed for the Precinct. The assessment found that a warning time of 8 to 10 hours was available, and that rising road access to flood free land was achievable for the Mandalay Avenue, Scenic Drive and Hyam Street sub-precincts. The Wharf Road, Pleasant Way and Bridge Road sub-precincts were determined to be low flood islands.

The NSW SES undertook evacuation modelling for three population estimates for each of the sub-precinct areas.

The assessment found that all sub-precincts had sufficient time to evacuate, subject to the population and SES resourcing (number of door knocking teams) assumptions:

- Scenic Drive and Bridge Road had sufficient time to evacuate under all population and SES team assumptions;
- Mandalay Avenue had sufficient time to evacuate under the low population scenario, or if two or more teams were deployed, the medium population scenario;
- Hyam Street had sufficient time to evacuate under the medium population scenario, or if three SES teams were deployed, the high population scenario;
- Pleasant way was sensitive to the SES team assumptions. Evacuation was feasible only for the low population scenario with one team, up to the medium population scenario with two teams, or up to the high population scenario with three teams;
- Wharf road had sufficient time to evacuate for all population scenarios if two or more SES teams were deployed. If only one team was deployed, Wharf Road could only be evacuated under the low population scenario.

Following the assessment, the SES provided the following comments:

- The SES do not recommend residential or tourist development in places where people may be trapped in a low flood island (i.e., the Wharf Road Sub-precinct).
- In large flood events SES resources will be required to be deployed across much of the South Coast and regional access routes are likely to be cut due to flooding. As such, while the assessment indicated that evacuation is feasible within the available warning time, it needs to be recognised that the ability of the SES to respond in a large flood event will be constrained by regional flooding and that occupants should be provided with the information necessary to self-evacuate.
- Flooding in the Nowra Riverfront Precinct offers significant risks to those that choose not to evacuate or become trapped by flood waters. PMF flood depths and velocities are such that rescue and/or resupply may be too risky for emergency personal to attempt.
- There is never a complete uptake of evacuation commands. A portion of occupants will always elect to remain, and their eventual rescue puts SES personnel at risk.

However, they noted that the tool used to determine this estimate was developed for the Hawkesbury Nepean floodplain where properties are much more dispersed, and evacuation distances are much greater than that for the Precinct.

The proposed development controls identified in this report (**Section 14**) have been prepared on the basis that the Precinct development does proceed. On that basis, the controls have been prepared to minimise, as much as possible, the SES management requirements.

With respect to the development controls and emergency evacuation, it is noted that the Wharf Road, Pleasant Way, and Bridge Road sub-precincts are classed as low flood islands and become isolated prior to inundation of the sub-precinct.

This is particularly the case for Wharf Road, where access is lost prior to the full pad becoming inundated. For Pleasant Way and Bridge Road, overland escape routes remain available when the lower portion of the sub-precincts become inundated, but this overland access is lost prior to the full sub-precinct becoming inundated, hence the low-flood island classification.

At the Probable Maximum Flood (PMF) flood peak, the Wharf Road sub-precinct is covered by H6 hazard flooding and velocities in excess of 4m/s. Such flooding conditions are likely to prevent any SES rescue by boat, in the event that occupants refused or where unable to evacuate. The higher points within the Bridge Road and Pleasant Way sub-precincts have a hazard class of H1, although H6 hazard is present along all surrounding roadways. While velocities between these two highpoints exceeds 4m/s along the highway, the surrounding velocities are lower, in the order of 1-2m/s. These lower hazard and velocities may enable access via boat during the course of the flood, although this should not be relied upon.

From a flood risk perspective, constructing high density residential development on a low flood island where flood inundation could be expected to be longer than 36 hours in the PMF event is inconsistent with the SES requirements for evacuation, and the Wharf Road sub-precinct is not considered suitable under the isolated, raised pad scenario assessed in this report. To permit development on the Wharf Road sub-precinct, some form of pedestrian, if not vehicle, access must be provided to connect the sub-precinct to land above the PMF. It is noted that the SES do not support pedestrian evacuation as the primary evacuation strategy.

The Pleasant Way and Bridge Road sub-precincts have this overland connection at the FPL (and at higher events up to and including the 0.05% AEP event). When the pads first overtop, there is overland access across the Princes Highway from the Pleasant Way sub-precinct to the Bridge Road sub-precinct, and from there to flood free land and flood refuges in Nowra CBD. These access routes are lost approximately 6 hours prior to the full sub-precinct becoming inundated in the PMF event.

The Wharf Road pad has a more adverse flood behaviour. Access along surrounding roads, and to the adjacent Pleasant Way sub-precinct are lost prior to the pad being inundated. This occurs in the 0.05% AEP when flows overtop the highway from the west and flow down Pleasant Way. At this point, the pad remains dry, but all access is lost.

While this would ultimately be up to any future development to address, it is suggested that possible strategies may be:

- Raising some portion of the western end of Pleasant Way to allow for pedestrian access at the FPL from the Wharf Road sub-precinct across the highway to flood free land west of the Bridge Road sub-precinct.
- Raising the western end of Pleasant Way to allow vehicular access from Pleasant Way to the Princes Highway at the FPL as a minimum. This would improve the evacuation potential of both Wharf Road and Pleasant Way sub-precincts.
- Filling of the western depression between the Wharf Road pad and the Princes Highway to the FPL to allow pedestrian access onto the Highway, and from there to the Pleasant Way sub-precinct

from which overland access is available to flood free land in Nowra CBD. It is noted that this land is owned by TfNSW.

- Construction of a pedestrian bridge or similar over Pleasant Way to allow for overland evacuation from the Wharf Road sub-precinct to the Pleasant Way sub-precinct from which overland access is available to flood free land in the Nowra CBD.

Flood Communication System

Given the differences between the study area and the regions for which the evacuation timeline methodology was developed, there are potential additional measures to assist in the evacuation of the Riverfront Precinct that would be feasible, most notably a flood communication system capable of manual alerts. The purpose of this communication system is to reduce the time required for the mobilisation and warning stages of the evacuation timeline above.

Providing a means by which occupants are able to assist in their own evacuation is desirable. While the SES has undertaken this assessment assuming up to three teams may be available, the reality is that a flood of greater than the 0.5% AEP (which would threaten to inundate the proposed pads) would see widespread flooding and road closures across potentially numerous areas on the south coast and the Greater Sydney region, placing substantial numbers of people at risk, and stretching the ability of the SES to respond in all locations. Warnings that can be issued automatically or remotely, will assist in allowing the study area to evacuate, without the physical presence of SES teams, and could potentially reduce the SES door knocking timeframe by encouraging and assisting occupants to evacuate early. It is noted that the SES would still door knock each property, but if occupants have already evacuated, the time needed for communication would be reduced.

The system has been termed a “communication” system as its purpose is not to issue warnings or alerts (which are the purview of BoM and SES) but rather to facilitate the communication of these warnings and alerts from the SES to building occupants. It is envisaged that the system would be able to issue both pre-recorded and live announcement, both on- and off-site, at the discretion of the SES.

However, with this considered, it is important to recognise that the SES has identified that there will be difficulties in managing the evacuation of the proposed Precinct, and this should be considered in any decisions for the feasibility of the development. This was further iterated by the SES during the Technical Working Group 3 and 4 discussions.

The subsequent controls identified in this report (**Section 14**) have been prepared on the basis that the development does proceed. On that basis, the controls have been prepared to minimise, as much as possible, the SES emergency response requirements.

Any flood communication system developed for the Precinct should:

- Be capable of issuing pre-recorded and live announcements / warnings / alerts both on- and off-site at the discretion of the SES. The communications could be staged, with an initial warning given to occupants to allow time to process the need for evacuation before the official evacuation order is given. This would serve to maximise the time available for the actual evacuation process.
- Have appropriate redundancies to ensure that it remains operable in a flood event.
- Incorporate regular testing to ensure it remains operable, and that occupants become familiar with the warnings that would be issued in a large flood event.

- Be maintained by a suitability qualified third party. It is not considered suitable that building owners be responsible for this system. Building developers/owners should be required to contribute to the costs of implementing and maintaining the system, but the maintenance should lie with a third party and operation should be by the building operator / manager at the direction the SES. This ensures that the system will be maintained and operated appropriately and serves to mitigate the risks that the system would fall into dis-use, or, in the case of the building being sold on, that subsequent owners are not fully aware of its use and requirements.
- While the assumption that the flood communication system is able to offer improvements in the warning and response timeline are reasonable, it is noted that the SES would still be required to visit the property, and whilst it would be expected that many occupants would respond to the warnings, it is not possible to state conclusively the extent to which this would be the case.

Flood warning systems and site flood response plans are not without challenges.

To address these issues, it is recommended that any flood communication system developed be designed and maintained by an appropriately experienced and qualified third party, with both upfront and ongoing costs leveraged on the Precinct developers / owners. Such an arrangement ensures that that the building owners retain financial responsibility for the warning system, and that funds for the ongoing costs of the system are made available, irrespective of ownership of the buildings. The third party would then be responsible for maintenance, and testing, with the SES retaining responsibility for communications, alerts, and warnings.

Whilst beyond the scope of this study, Council may also wish to ensure that any system developed has the potential to be expanded upon so as to draw in both existing and future development if and when required.

Planning and Policy Review

A review was undertaken of relevant NSW Government and Council planning and policy documents.

The primary aim of the review was to determine if the proposed Precinct landform and associated works would be compatible with NSW Government and Council's planning and development control requirements (being those in force as of September 2022).

The review found that the proposed Precinct plan of raised buildings pads, accompanied, if necessary, by flood mitigation works, would be in accordance with the Shoalhaven Local Environment Plan (LEP) (2014) and Development Control Plan (DCP) (2014), and would generally be in accordance with the Ministers Local Planning Directions issued on 1 March 2022 under Section 9.1(2) of the *Environmental Planning and Assessment Act*, 1979.

The key exceptions to this are:

- The construction of residential development within high hazard zones (only applicable if the PMF is adopted as the residential FPL), which conflicts with Planning Direction 4.1(3);
- The location of the Wharf Road sub-precinct in the PMF floodway, which conflicts with Planning Direction 4.1(4)(a);
- The increased residential development within the PMF extent, which conflicts with Planning Direction 4.1(4)(c) – it is noted that some regions of the Mandalay Avenue sub-precinct are outside of the PMF, and as such, are in compliance with this control; and,

- The additional burden placed on emergency services to manage the evacuation of the Precinct, which conflicts with Planning Direction 4.1(4)(f).

The Planning Direction does allow for inconsistencies with these requirements if:

> *the planning proposal is supported by a flood and risk impact assessment accepted by the relevant planning authority and is prepared in accordance with the principles of the Floodplain Development Manual 2005 and consistent with the relevant planning authorities' requirements (Direction 4.1 (5) (c)).*

This Flood and Risk Impact Assessment has been prepared to demonstrate that the proposed development of the Precinct can be undertaken in such a way as to reduce the impacts of these departures from the Planning Directions to an acceptable level and enable a future Planning Proposal to comply with it.

The residual risk present across the Precinct is proposed to be managed by planning and development controls (refer **Section 14**), which contain explicit controls to reduce the risk to occupants and the burden placed on emergency services in the event of a flood event.

A summary of all planning controls that are either non-compliant, or not fully compliant are summarised in **Table i**.

Precinct-Specific Draft Development Controls

Development within the Precinct will be guided by site-specific development control plan provisions. As part of this study, draft flood-related controls were prepared for inclusion in this future document. The focus of the controls is on managing the considerable residual flood risk present on the site as a result of the significant PMF depths.

Controls were developed with regard to:

- Building Pad Levels – The adoption of an FPL, based on the 0.5% AEP, incorporating sea level rise and freeboard;
- Fill - Allowable extents and levels of filling within the floodplain, to achieve the building pad levels and extents;
- Flood warning and evacuation - requiring buildings developed on site to be connected to a flood communication system;
- Carparking (both open and basement) - to ensure that these locations remain safe for users during a flood event, and that vehicles do not become caught up in flood waters;
- Structural soundness - The PMF depths over the proposed buildings in the Precinct would be in excess of 3m, and as a result, all buildings will be required to demonstrate that they are capable of withstanding these flood forces.

Table i Partial and Non-Compliance with Relevant Plans and Directions

Clause	Objective / Control	Compliance
SLEP 5.21 (adopted)	Development will not affect the safe occupation and efficient evacuation of people in a flood event	**Largely Compliant**. Actions have been taken to ensure that occupants of the Precinct are made as safe as possible during large flood events. FPLs have been set at the 0.5% AEP + 2100 SLR + 0.5m freeboard, providing long term flood protection for events up to and including the 0.5% AEP. For larger events, development controls are recommended to manage residual risk, including flood warning and the provision of rising road or pedestrian access at the FPL to facilitate evacuation. However, not all flood risk can be removed from the Precinct and some residual risk will remain despite these measures.
SDCP G9 5.1	The development will not increase the risk to life or safety of persons during a flood event on the development site and adjoining land.	**Largely Compliant**. Similar to the SLEP above, the risk has been mitigated as far as reasonably practical, but some residual flood risk in extreme events remains. To manage the risk to life, FPLs have been set at the 0.5% AEP + 2100 SLR + 0.5m freeboard, providing long term flood protection for events up to and including the 0.5% AEP. For larger events, development controls are recommended to manage residual risk, including flood warning, use of flood compatible building materials, and the use of the PMF to inform structural soundness. SES evacuation modelling has been undertaken to inform what development densities can be evacuated within the available warning time.
	The development will not unduly increase dependency on emergency services.	**Partly Compliant**. Development controls for the site require the implementation of a communication system. The system would be capable of issuing flood communications and directions from the SES in order to facilitate the actions of the SES during a flood event. Ultimately however, it would be up to the SES to comment on how much assistance the proposed system would offer. It has been recommended that the system be developed in consultation with the SES in order to ensure if provides as much assistance as possible.
SDCP G9 5.4.5	Owners (within the Riverview Road FMRP Study Area) must have measures in place to enable them to self-evacuate to not place additional burden on Emergency Services	**Partially Compliant** The site specific DCP controls include controls to reduce the impact of the development on emergency services. However, an explicit control to have owners provide measures to enable self-evacuation has not been included.

Clause	Objective / Control	Compliance
	No new subdivisions within the Riverview Road FMRP Study Area	**Compliant provided that no subdivision was proposed.** Compliance against this criterion is dependent on the development proposal and would be compliant provided that no subdivision was proposed as part of the development.
Ministerial Directions 4.1(3)(a)	permit development in floodway areas	**NOT COMPLIANT**. The Wharf Road sub-precinct sits within the PMF floodway. All other sub-precincts are compliant. It is not feasible to alter the floodway of the Shoalhaven River. As such, compliance with this direction would require that the Wharf Road sub-precinct remain undeveloped.
Ministerial Directions 4.1(3) (c)	permit development for the purposes of residential accommodation in high hazard areas	**NOT COMPLIANT** In the PMF event, the Scenic Way, and Wharf Road sub-precincts, as well as portions of all other sub-precincts are within H5 or H6 flood hazard categories. Locating residential development on higher ground within the Mandalay Avenue, Hyam Street and Bridge Road developments, and restricting residential development on the Scenic Drive and Wharf Road sub-precincts would limit the extent of the non-compliance.
Ministerial Directions 4.1(3) (d)	permit a significant increase in the dwelling density of that land	**NOT COMPLIANT**. The proposed development would result in a significant increase in the dwelling density of the land within the PMF. Adopting a low population scenario and/or limiting residential land uses would limit the extent of the non-compliance.
Ministerial Directions 4.1(3) (g)	are likely to result in a significantly increased requirement for government spending on emergency management services, and flood mitigation and emergency response measures, which can include but not limited to road infrastructure, flood mitigation infrastructure and utilities	**Partially Compliant**. While the development of the Precinct is likely to impose a cost relating to emergency management and response, the planning controls developed for the Precinct aim to transfer the additional funding responsibility to the developer/owner (via the imposition of Covenants) with regard to emergency warning and evacuation. However, the development would likely increase resourcing requirements for the SES, even with the warning system and other emergency related development controls in place.
Ministerial Directions 4.1(4)(a)	A Planning Proposal will not permit development in floodway areas	**NOT COMPLIANT**. The Wharf Road sub-precinct sits within the PMF floodway. All other sub-precincts are compliant. It is not feasible to alter the floodway of the Shoalhaven River. As such, compliance with this direction would require that the Wharf Road sub-precinct remain undeveloped.

Clause	Objective / Control	Compliance
Ministerial Directions 4.1(4) (c)	A Planning Proposal will not permit a significant increase in the dwelling density of that land	**NOT COMPLIANT**. The proposed development would result in a significant increase in the dwelling density of the land within the PMF. Adopting a low population scenario and/or limiting residential land uses would limit the extent of the non-compliance.
Ministerial Directions 4.1(4) (d)	A Planning Proposal will not permit the development of centre-based childcare facilities, hostels, boarding houses, group homes, hospitals, residential care facilities, respite day care centres and seniors housing in areas where the occupants of the development cannot effectively evacuate	**To be determined**. The final usage of the proposed premises of the Precinct have not yet been determined. It is noted that the direction has the potential to limit what activities may be able to be approved for the development.
Ministerial Directions 4.1(4) (f)	A Planning Proposal not likely to result in a significantly increased requirement for government spending on emergency management services, and flood mitigation and emergency response measures, which can include but not limited to road infrastructure, flood mitigation infrastructure and utilities	**Partially Compliant**. While the development of the Precinct is likely to impose a cost relating to emergency management and response, the planning controls developed for the Precinct aim to transfer the additional funding responsibility to the developer/owner (via the imposition of covenants, conditions, or development consents) with regard to emergency warning and evacuation. However, the development would likely increase resourcing requirements for the SES, even with the warning system and other emergency related development controls in place.

Recommendations

As a result of the assessments undertaken as part of this study it has been recommended that:

- Raised building pads be adopted as the preferred flood management strategy. The recommend layout of the raised pads is shown in **Figure i**. Raised building pads were determined to be the primary means by which flood risk could be managed on site as this design approach seeks to provide a level of flood protection and immunity for the proposed buildings and occupants for both local catchment and riverine flood events, and to assist with flood evacuation though the provision of additional evacuation time.
- That these pads be set at an FPL level based on the 0.5% AEP + Sea Level Rise (SLR) + Freeboard, which is also consistent with the Lower Shoalhaven Flood Study (Cardno, 2022).
- The proposed pads result in a flood level increase across Hyam Street for the 1% AEP local catchment event. This impact can be managed via two mechanisms:
    - The construction of an additional outlet culvert from the central open space region.
    - Alternatively, a 7.5m reduction in the width of the building pad adjacent to the open space region can applied to the Mandalay, Scenic Drive and Hyam Street sub-precinct pads to provide additional storage and remove this impact.

- A property flood and ground level survey has been recommended for those properties on Hyam Street affected by the increase in 1% AEP local flood levels. The purpose of this assessment is to determine what impact the 0.04m has on property freeboard, and to assist in determining if compensation for or voluntary purchase of these properties is a viable alternative to the implementation of one of the above structural options.
- Site specific development controls be implemented to address and manage the residual flood risk.
- Residential development has been recommended to be focused on those regions with rising road access, namely Mandalay Avenue, Scenic Drive and Hyam Street sub-precincts. The remaining pads, which are all low flood islands in the PMF, have been recommended as more suited to lower population density land uses such as tourist accommodation or commercial premises.
- Land uses for each sub-precinct, as summarised in **Table i**.

Table i Recommended Land Uses for Sub-Precincts

Sub-Precinct	Recommended Land Uses	Not Recommended Land Uses
Mandalay	All uses suitable. Residential recommended to be located here in preference to eastern sub-precincts	
Hyam Street		
Scenic Drive		
Bridge Road	Tourist, Commercial	Residential
Pleasant Way		
Wharf Road		

Overall, the FIRA report has demonstrated that flooding risks for the western sub-precincts excluding Bridge Road (Mandalay, Scenic Drive, and Hyam Street) have been appropriately addressed, and that the proposed land use types for these sub-precincts are consistent with the flood risk profile.

The eastern sub-precincts (Pleasant Way and Wharf Road) and Bridge Road are all low flood islands and present a higher flood risk profile. Whilst the FIRA has demonstrated that lower population density land-uses are suitable for these sub-precincts (such as commercial or tourist uses), the inclusion of residential development within the sub-precincts would require further, sub-precinct specific assessments into, at a minimum:

- The ability to provide pedestrian egress routes to higher ground west of the Princes Highway for all eastern sub-precincts (noting that SES does not support pedestrian evacuation as the primary evacuation strategy); and,
- Raising of Pleasant Way to facilitate the evacuation of Pleasant Way and Wharf Road sub-precincts. Coincident works to the Pleasant Way highway intersection may also be required, or desired, in order to improve emergency management. These works would alter the risk profile of the eastern sub-precincts by changing the emergency response classification of these sub-precincts from low flood islands to rising road. This would be beneficial for any future development in the Wharf Rd and Pleasant Way sub-precincts and would also provide improvements to evacuation ability for the existing Riverview Road area.

Figure i Recommended Raised Pad Extents to Prevent Adverse Flood Impacts

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RG-06-04	Riverine Impacts – Large FPL Pad
RG-06-05	Riverine Impacts – Small FPL Pad
RG-06-06	Riverine Impacts – Large 0.2% AEP Pad
RG-06-07	Riverine Impacts – Small 0.2% AEP Pad
RG-08-01	Riverine Developed Results – Flood Depth and Water Level
RG-08-02	Riverine Developed Results – Flood Velocity
RG-08-03	Riverine Developed Results – Flood Hazard
RG-08-04	Riverine Developed Results – Flood Impacts
RG-08-05	Local Catchment Developed Results – Flood Depth and Water Level
RG-08-06	Local Catchment Developed Results – Flood Velocity
RG-08-07	Local Catchment Developed Results – Flood Hazard
RG-08-08	Local Catchment Developed Results – Flood Impacts
RG-08-09	Sensitivity to Climate Change

1 Introduction

The Nowra Riverfront Precinct Flood Impact and Risk Assessment (FIRA) has been prepared for Shoalhaven City Council (Council) to define the existing flood behaviour in the catchment and to assess, and address, if necessary, the potential impacts arising from the future development of the Precinct.

1.1 Study Area

The study area is located in Nowra, immediately south of Nowra Bridge, the Princes Highway crossing of the Shoalhaven River. The Precinct is broadly bounded by Scenic Drive to the north, Hawthorn Avenue to the east, Hyam Street and Graham Street to the south and Shoalhaven Street to the west.

Existing land use across the site is varied and includes:

- SCC Administration Centre and Shoalhaven Entertainment Centre;
- Graham Lodge and former visitor information centre;
- Nowra Aquatic Park;
- Residential properties around the Precinct fringe;
- Occasional commercial developments;
- The former Easts Willows Van Park (now vacant); and,
- Open space along the river frontage and the central and southern portions of the Precinct comprised of a mix of private and Council owned or managed land.

The site lies immediately adjacent to the Lower Shoalhaven River and is subject to flooding from both local catchment flows and riverine flooding.

The study area is shown in **Figure 1-1**.

Figure 1-1 Study Area (Source: Shoalhaven City Council)

1.2 Study Background and Context

Located at the northern entrance to Nowra, the Precinct is an important location that Council plan to utilise to strengthen the role of the Nowra Riverfront Precinct as a civic, community, tourism, and recreational hub for the Shoalhaven region.

Urban design consultants, Studio GL, were engaged in 2018 to prepare recommendations for planning and development controls to guide future development in the Precinct. Studio GL made a number of recommendations for changes to existing zones, floor space ratios and height controls, and prepared preliminary masterplans, an example of which is shown in **Figure 1-2**.

Given the proximity to the river, it was noted during this study that future planning controls and zonings would be dependent on the results of detailed flood studies. In order to progress the design of the Precinct, Council commissioned the Nowra Riverfront Precinct Flood Impact and Risk Assessment.

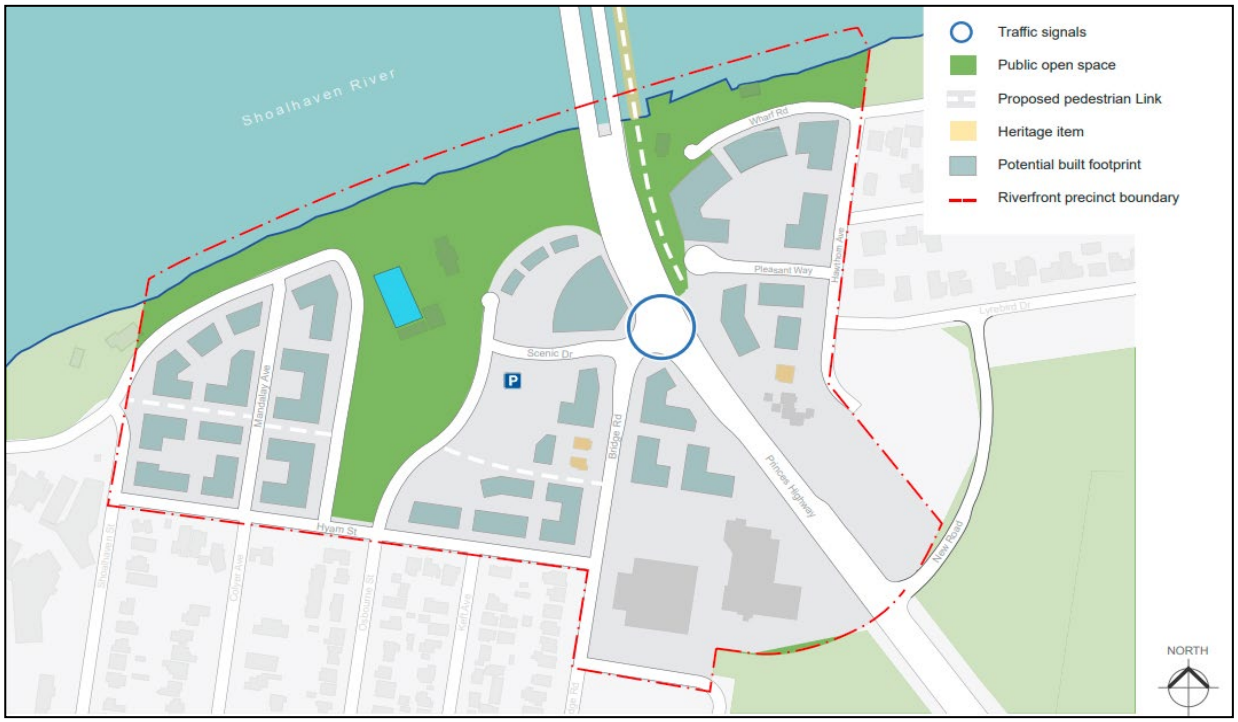

Figure 1-2 Possible Future Layout (Studio GL, 2019)

1.3 Study Objectives

The Study is being conducted to determine if:

- Changed flood behaviour could arise and have adverse impacts on the flood risk to the existing community and development;
- The future development envisaged in the preliminary Nowra Riverfront Precinct Masterplan and its users or occupants can safely be enabled with an acceptable level of flood risk; and
- Effective flood emergency response is achievable without adverse impacts on the ability of the existing community to respond to floods.

The FIRA is required to establish whether impacts are localised and / or can be readily managed and to support/inform land-use rezoning processes, planning proposals and the establishment of development controls for future development in the Precinct.

1.4 Technical Working Groups

The involvement of key stakeholders has been an important part of this study. To this end, a TWG was set up at the commencement of the study. The purpose of the TWG was to:

- Provide a means of focused engagement with key stakeholders;
- Provide an avenue for review and feedback throughout the study;
- Ensure that concurrent assessments by others were captured as necessary in the FIRA;
- Provide technical review of options and solutions developed in the FIRA; and,
- Ensure that the FIRA accurately and appropriately reflected the requirements and concerns of stakeholders.

The TWG representatives are noted in **Table 1-1**.

Table 1-1 TWG Representatives

Group / Agency	Name
Nowra Riverfront Advisory Taskforce (NRAT)	[redacted]
DPE – Planning and Assessment (South Coast Region)	[redacted]
DPE – South East Flood team	[redacted]
NSW State Emergency Service (SES)	[redacted]
Transport for NSW (TfNSW)	[redacted]
Shoalhaven City Council, City Futures – Strategic Planning	[redacted]
Shoalhaven City Council, Environmental Services – Coast and Floodplains	[redacted]
Shoalhaven City Council, City Futures – Transport	[redacted]
FIRA Consultants – Rhelm Pty Ltd	[redacted]

Throughout the study, a series of four TWG workshops have been undertaken over the course of the study, namely:

- TWG1: Undertaken on 15 December 2021, the first TWG workshop was held to present the results of the base case flood modelling, and to invite comments and suggestions for the development of future scenarios and options for assessing in the hydraulic model. The presentation and comments received are provided in **Appendix B**.
- TWG2: Undertaken on Monday 21 February 2022. The workshop was held to present the results of the concept option flood modelling, and to invite comments and suggestions for the development of scenarios that warranted further assessment. The presentation from the workshop is provided in **Appendix C**.
- TWG3: The third TWG workshop was held on 7 June 2022. The workshop was held to present the results of the FPL assessment, the NSW SES evacuation modelling, site specific development controls, and the development of a set of performance criteria for the assessment of various landform options. The presentation from the workshop is provided in **Appendix D**.
- TWG4: The draft FIRA was reviewed by stakeholders, namely SES, DPE and TfNSW prior to its finalisation. As part of this review, an initial workshop with SES and DPE was held on 21 February 2023 to discuss the comments submitted. Following this, a fourth TWG workshop was convened on 3 April 2023 to further discuss comments received and how the FIRA should be revised to address them. Provided in **Appendix G** is a summary of how the report was revised in light of these comments, as well as the submissions received from stakeholders.

2 Review of Available Data

2.1 Site Inspection

Due to COVID-19 restrictions in effect at the commencement of the study, a physical site inspection was not initially possible. Photographs at key locations were collected by Council in lieu of a site inspection.

The purpose of the collected photographs was to gain an appreciation of the catchment and likely flood risks. The site photographs also identified additional survey requirements and assisted with the definition of the hydraulic model extents.

Following the initial stages for the study, a physical site inspection was subsequently undertaken on 24 January 2022. This site inspection provided the opportunity to ground verify the results of the study.

2.2 Previous Studies and Reports

Key previous studies for the locality were provided by Council and are summarised in **Table 2-1**.

Table 2-1 Previous Flood-related Studies and Reports

Document	Relevance to the Study
Riverview Road Area – Nowra Floodplain Risk Management Study and Plan (WMAwater, 2002)	This Floodplain Management Study examined flooding issues relating to the area east of the Princes Highway generally bounded by the Shoalhaven River, the Shoalhaven Caravan Park, and Moss Street. This area comprises the eastern portion of the current study area. The study recommended a number of flood management options for the region including: • Levee audits; • Local drainage improvements; • Entrance management; • Revisions to planning controls; • Flood proofing; • House raising; • Improved flood warning system; and, • Improved flood awareness. The modelling utilised in the assessment has since been superseded. For the current study, reference will be made to the proposed management options to determine if any are suited to inclusion in the current study.

Document	Relevance to the Study
Lower Shoalhaven River Floodplain Risk Management Study and Plan (Webb, McKeown, and Associates, 2008)	This Floodplain Risk Management Study examines flooding issues relating to the floodplain area associated with the Lower Shoalhaven River. The assessed area extends from approximately 2km upstream of the Nowra Bridge, through to the river entrance. The modelled area incorporates the current study area. The study recommended a number of management options throughout the region. With regard to the current study area, relevant options were: • Improved local drainage; • House raising; • Flood proofing; • Revisions to planning controls; and, • Improved flood warning systems. The modelling utilised in the assessment has since been superseded. For the current study, reference will be made to the proposed management options to determine if any are suited to inclusion in the current study.
Nowra Riverfront Entertainment and Leisure Precinct: Strategic Direction Review and Analysis (Studio GL, 2019)	The Strategic Direction document provides a review of previous strategic studies, a concise summary of opportunities and constraints, and identifies objectives and planning and design principles. The key objectives for the Nowra Riverfront Precinct as outlined in the Strategic Directions Report were to: • Increase safety so that it's a place that more people want to visit; • Enhance the open space so that it's a place where it's easier to spend more time; • Improve connections so that it's a place that's easier to find and easier to get around; • Strengthen the gateway to showcase the attractions and make it easier to access the place; and, • Be a catalyst for renewal - encourage investment and development to improve the quality of the place. The report also prepared preliminary development scenarios and building controls to guide the development of the Precinct. For the current study, the identified objectives, and the preliminary masterplan developed, will be used to define the development scenarios to be assessed, and the types of development incorporate within the Precinct.

Document	Relevance to the Study
Lower Shoalhaven River Calibration Report (Cardno, 2020)	The report details the establishment and calibration of updated hydrological and hydraulic models for the Lower Shoalhaven River. Hydrological modelling was undertaken in XP-RAFTS, and hydraulic modelling in TUFLOW. The models were calibrated / validated to three events, namely June 2013, August 2015, and June 2016. The hydrological model was assessed against flow gauge records from 11 flow gauges throughout the catchment area. The hydraulic model was assessed against water level gauge records from 7 gauges throughout the catchment area, and a number of surveyed flood marks based on observations from the local community. For all three storms, the hydrological model was found to reasonably replicate peak flows and timings compared to the gauge records, and the hydraulic model replicated flood levels to generally within 0.1m of historical levels. The report concludes that the models are appropriate for use in defining design flood events. The study is ongoing, with design event modelling currently being completed.
Lower Shoalhaven River Flood Study (Cardno, 2021)	This report defined the existing flood behaviour for the Lower Shoalhaven River. Flood behaviour was modelled and assessed for the 20%, 10%, 5%, 2%, 1% and 0.2% AEP events, and the PMF. It was found that: • Flooding was typically well contained up to the 10% AEP, with the exception of some low-lying areas. • In the 5% AEP widespread flooding was observed, and the Broughton Creek floodplain becomes connected to the Shoalhaven floodplain. The Terrara levees overtop south of Pig Island. • The 2% and 1% AEP extents were similar to the 5% AEP, though depths increase significantly for each event. • In the 0.2% AEP, depths exceed 3m across the majority of the floodplain. Assessment of the impacts of rainfall increases and sea level rise due to climate change was undertaken along with assessment of tidal inundation and sensitivity to various model parameters. The report also provides guidance on the adoption of Flood Planning Levels and Emergency Response parameters for use in planning and by the NSW SES.

Document	Relevance to the Study
Lower Shoalhaven River Flood Study, PMF revision (Stantec, 2022)	As part of the peer review process of the above Flood Study, it was identified that the approach used to estimate the PMF may result in an under-estimate of peak flows. Following this comment from the peer reviews, the PMF approach was updated, with the result that PMF levels at Nowra increased by approximately 1.5m. This update to the PMF behaviour was made after the initial option testing and the landform optimisation discussed in **Section 6** and **Section 8** of this report had been undertaken. These assessments were not updated with the revised PMF results. The assessment of the impacts of the final adopted landform discussed in **Section 11** was updated with the revised PMF flows and it was found to satisfy all performance criteria. Existing and developed scenario mapping of the PMF presented in **Section 5** and **Section 11** respectively, along with the associated discussion, have been updated based on the latest PMF data.

2.3 Survey Information

2.3.1 LiDAR Data

Point cloud data is also available for the study area via the Foundation Spatial Data Framework's online portal, ELVIS (Elevation and Depth Foundation Spatial Data), available from http://elevation.fsdf.org.au/. While the 1m DEM is of sufficient resolution for most modelling requirements, the point cloud data can be useful to ensure that terrain features such as retaining walls, or items with sub-metre sizes are appropriately included in the terrain model.

2.3.2 Ground Survey

Ground survey was collected as part of this study to obtain:

- Detailed cross sections of the central open channel, as well as ground levels of the wider open space;
- Road and gutter levels;
- Stormwater pipe inverts and sizes; and,
- A historical flood level.

The survey is attached in Appendix A.

2.4 Historical Data

2.4.1 Flood Data from Events

A single historic flood mark was collected from the August 2020 event, at the low point of Scenic Drive at the intersection of the aquatic centre driveway. Photographs were also collected of the river at its peak and of the damage sustained to the pier at Ponte Bar.

2.4.2 Rainfall

The nearest rainfall gauge to the study area is located at the Council Administration Building.

The gauge (BoM ID 068213) commenced operations in December 2000 and is currently active.

Pluvio data from this gauge was supplied by Council for the period from 1 October 2019 to 8 November 2021. This period covers the historical event from which the flood mark was surveyed.

2.4.3 Water Level

A water level gauge is located on the Shoalhaven River at the Nowra Boat Shed. The gauge is currently active.

Water level data from the gauge was supplied by Council for the period from 1 October 2019 to 8 November 2021. This period covers the historical event from which the flood mark was surveyed.

2.4.4 Flow Data

No measured flow data is available for the waterways within the local catchment.

2.5 GIS Data

Digitally available information such as aerial photography, cadastral boundaries, topography, watercourses, drainage networks, land zoning, vegetation communities and soil landscapes were provided by Council in the form of GIS datasets.

3 Flood Model Development

3.1 Modelling Approach

The site is affected by flooding from both the Lower Shoalhaven River and the local catchment. The flood behaviour of the Lower Shoalhaven River is defined by the *Lower Shoalhaven River Flood Study* (Cardno, 2022), with the subsequent and *Lower Shoalhaven River Floodplain Risk Management Study and Plan Review* expected to commence in 2023.

Data from the Flood Study has been used to define the flood behaviour arising from riverine flooding.

To assess the local catchment flood behaviour, a local hydrological and hydraulic model has been developed. The development of these models is detailed below.

3.2 Hydrological Model Development

Hydrological modelling for the local catchment area has been completed using the hydrological model XP-RAFTS. The subcatchment delineation is shown in **Figure 3-1**.

The hydrology has been based on Australian Rainfall and Runoff 2019 (ARR2019) with the parameters extracted from the ARR DataHub shown in **Table 3-1**.

Inputs to the model and the data sources for those inputs are summarised in **Table 3-2**.

Figure 3-1 **Subcatchments – Local Flood Model**

Table 3-1 ARR DataHub MetaData

Parameter	Value
Latitude	-34.871755
Longitude	50.595549
Storm Initial Losses (mm)	14.8
Storm Continuing Losses (mm/h)	4.5
River Region - Division	South East Coast (NSW)
River Region - Number	15
River Region	Shoalhaven River
Point Temporal Pattern Code	SSmainland
Point Temporal Pattern Label	Southern Slopes (Vic/NSW)
Version	2016_v2

Table 3-2 Hydrological Model Input Data

Parameter	Data Source
Sub-catchment area and slope	LiDAR data is available for full catchment and was used for this mapping for the base case local catchment modelling.
Percentage impervious	Percentage impervious areas are largely a factor of development intensity and were determined from aerial imagery. High resolution aerial imagery has been sourced from NearMap (October, 2021).
Roughness	Roughness parameters influence how quickly runoff occurs in a sub-catchment. Similar to the percentage impervious, the values have been determined from an examination of aerial imagery and have been largely dependent on land use. Delineation of roughness zones refer to Council's LEP mapping, particularly in areas that are undergoing development or redevelopment.
Runoff routing	Routing refers to the transfer of flows from one sub-catchment to another. This routing can be done in XP-RAFTS through either specifying a lag time between sub-catchments (10 minutes for example) or inputting a typical cross section, roughness and length and allowing XP-RAFTS to compute the lag time based on the flow volume. For this model, the lag approach has been adopted due to the highly urban nature of the catchment, and relatively small subcatchment sizes Lag times were based on a typical flow rate of 1m/s.
Rainfall losses	Under the new methodology set out in ARR2019, rainfall parameters for hydrological modelling are all available from the ARR Data Hub. The parameters relevant to the modelling locations have been downloaded directly from this website. In the absence of calibrated site losses, the NSW adjusted losses from the Data Hub have been adopted: • Initial Loss = 14.8mm / 1mm (pervious / impervious) • Continuing Loss = 1.8mm / 0mm (pervious / impervious)

3.2.1 Application of ARR2019

ARR2019 has a number of changes to the hydrological methods that have been traditionally employed. This includes updated design rainfall intensities, new ensemble storms and other catchment parameters such as losses.

One of the key challenges with the new approaches is the application of ensemble storms, with a number of storms to be run for each duration. This can result in challenges for large direct rainfall models, where it can be difficult to analyse all the temporal patterns due to the run times involved.

Our approach in the current study has been to run the full set of durations and temporal patterns through the XP-RAFTS model to determine the critical duration(s). The critical duration(s) were then run through the hydraulic model for each of the 10 temporal patterns.

The results were then processed to:

- Extract the median plus one event from the peak water levels from the 10 temporal patterns for each duration, and
- Determine the maximum results from the set of median results.

3.3 DEM Development

A Digital Elevation Model (DEM) has been developed for input into the hydraulic models. This DEM is based on the survey data collected, including the LiDAR and ground survey.

One of the important components in the development of hydraulic models is to ensure that key hydraulic controls and features are defined appropriately within the DEM. This includes features such as embankment crest details, road levels where roads overtop etc. These have been incorporated where appropriate through the use of breaklines and other features in TUFLOW.

3.4 Hydraulic Model Development

3.4.1 Model Area

The full upstream catchment area has been included in the hydraulic model. This was feasible due to the relatively small size of the catchment and allows for the full extent of the drainage lines to be included. It is expected that the drainage network will have a significant influence over the flood behaviour, particularly in the smaller events, due to the highly urban nature of the catchment. Incorporating the full system in the hydraulic model ensures that the flows within the drainage system are appropriately modelled.

The model extent is shown in **Map RG-03-01**.

3.4.2 Grid Cell Resolution

The urban areas of the study area will require a grid cell resolution fine enough to appropriately define flood risk. A grid cell of 2x2 metres was adopted which provided a reasonable balance between run times and representation of flood behaviour.

3.4.3 Buildings

Buildings within the catchment were incorporated as null objects, which effectively removes them from the model domain. This approach was undertaken due to the highly developed nature of the catchment, so as to represent both the obstruction of the buildings and the flow between buildings appropriately.

The raised buildings are shown in **Map RG-03-01**.

3.4.4 1D Components

Stormwater infrastructure and culvert crossings within the study area has been included within the 1D portion of the model, with the floodplain defined in the 2D domain. Stormwater drainage has been included where it is available in Council's data sets and from the available survey data.

Some regions of the pipe network had missing data for both inverts and pipe sizes. This data was infilled based on the following assumptions:

- 600mm cover of pipes and culverts, unless otherwise suggested by nearby survey.
- Missing pipe sizes were assumed to be the same as the largest of any upstream pipes.
- For a reach of pipes with missing data where sizes increased dramatically between known upstream and downstream sizes, a stepped increase was assumed through the missing reach.

Blockages has been assumed for the 1D network, namely:

- 20% blockage of on grade inlets;
- 50% blockage of sag pits; and,
- 15% blockage of the inlet to the culvert under the aquatic centre (based on ARR2019 guidance).

The included 1D elements are shown in **Map RG-03-01**.

3.4.5 Roughness

Roughness values extents were determined based on land use mapping and aerial photography, with reference made to ARR Project 15. The values adopted are summarised in **Table 3-3**.

Table 3-3 Adopted Roughness Values

Land Use	Manning's 'n'
Open space	0.04
Residential (buildings elevated; roughness for surrounding lot)	0.06
Commercial (buildings elevated; roughness for surrounding lot)	0.03
Maintained Grass and Recreational Areas	0.03
Dense vegetation	0.10
Medium Vegetation	0.06
Light vegetation	0.045
Roads / Carparks	0.02

3.4.6 Fences

There are numerous ways to incorporate fences within a 2D hydraulic model. While the techniques can be quite advanced, the reality is that the behaviour of fences in flooding can be quite uncertain and difficult to represent appropriately. Fences have been incorporated in the hydraulic model through a property-averaged roughness value.

3.4.7 Inflows

Inflows were applied to the hydraulic model via SA polygons utilising three difference approaches:

- Pit SA polygons, whereby flow is applied to the 1D nodes within the polygon. This approach was used across the urban areas where the pipe network was present in order to ensure that flows first entered the pits and only proceeded overland once the stormwater network capacity was exceeded.
- RF SA polygons, whereby flow is applied to the whole polygon, similar to direct rainfall. This approach was used in a single subcatchment which was located on the model boundary with no upstream subcatchments. This approach was used to generate flows within this isolated subcatchment.
- Standard SA polygons, whereby flows are applied to the lowest cell within the polygon. This approach was used across the remaining subcatchments.

The breakdown of these inflow approaches across the model area is shown in **RG-03-02**.

3.4.8 Downstream Boundary Conditions

There are two downstream boundary approaches utilised in the hydraulic model.

The first is a stage-discharge boundary for the eastern edges of the model. In large events there is cross catchment flow across this boundary. It has been assumed that there is no tailwater interaction across this boundary, and that flow is able to discharge freely, subject to the underlying grade and roughness.

The second boundary is the Shoalhaven River. In order to determine if there was any relationship between local catchment rainfall and Shoalhaven River levels, an assessment was undertaken to examine river levels during local catchment storms and local rainfall during elevated river levels.

The assessment was undertaken using the Nowra Boat Shed rainfall and water level data for the preceding two years. Whilst this is a short period of data which introduces some uncertainty, it does capture recent events, both rainfall and riverine, that have occurred in the study area. This data is plotted in **Figure 3-2**. The results of the assessment are summarised in **Table 3-4** and **Table 3-5**.

The assessment indicated that there was no strong correlation between rainfall and river levels. Given the rapid response of the local catchment to rainfall events, particularly compared to the Lower Shoalhaven response time, this outcome seems reasonable.

Of the eight largest rainfall events, only one (in Feb 2020) occurred at the same time as elevated river levels. For all the other events, the river levels appeared to be at typical non-flood affected levels.

Similarly, the rainfall recorded at the times of peak river levels was, for the most part, minimal.

These was some connection between rainfall and river levels for some events, however the rainfall and river peaks were separated by a period of hours to days for these events.

It is worth noting that all these rainfall events are relatively modest – in the order of 50 – 20% AEP events, and that some connection may be discernible in larger events.

In the absence of any at-site data, the guidelines prepared by DPE (then OEH), *Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways* (OEH, 2015) were adopted. The adopted boundaries are summarised in **Table 3-6**.

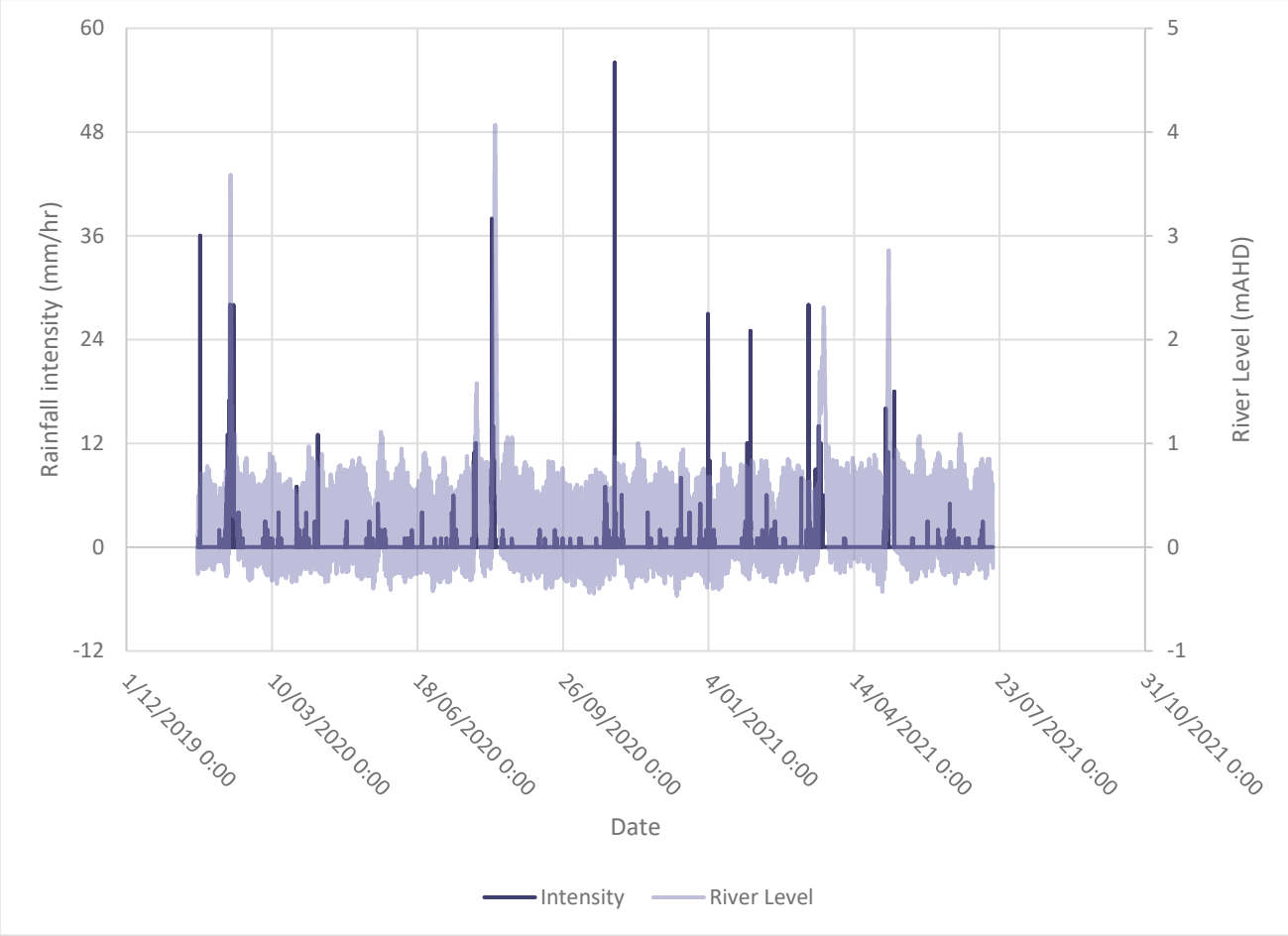

Figure 3-2 **Plot of Recorded Local Rainfall and River Levels**

Table 3-4 **River level at times of high rainfall**

Date and Time	Intensity (mm/hr)	River Level (mAHD)
20/01/2020 15:00	36	-0.09
10/02/2020 5:00	28	2.76
12/02/2020 16:00	28	0.7
8/08/2020 5:00	38	0.56
31/10/2020 11:00	56	0.87
3/01/2021 17:00	27	0.32
1/02/2021 21:00	25	-0.22
13/03/2021 19:00	28	-0.25

Table 3-5 Rainfall at times of elevated river levels

Date and Time	River Level (mAHD)	Intensity (mm/hr)
10/02/2020 13:00	3.59	0
10/08/2020 8:00	4.07	1
24/03/2021 3:00	2.31	0
7/05/2021 20:00	2.86	0

Table 3-6 River Boundary Assumptions

Design Event AEP	Catchment Flood AEP	Boundary AEP	River Level (mAHD)
50% AEP	50% AEP	HHWSS	0.95
20% AEP	20% AEP	HHWSS	0.95
10% AEP	10% AEP	HHWSS	0.95
5% AEP	5% AEP	HHWSS	0.95
2% AEP	2% AEP	5% AEP	5.3
1% AEP	1% AEP	5% AEP	5.3
0.5% AEP	0.5% AEP	1% AEP	6.0
0.2% AEP	0.2% AEP	1% AEP	6.0
PMF	PMF	1% AEP	6.0

4 Model Calibration / Validation and Downstream Sensitivity

4.1 Calibration / Validation

In a typical flood study, a calibration is undertaken by comparing observed flood behaviour, including recorded flood levels where available, against the flood behaviour determined from the flood model. This is done by obtaining or estimating the historical rainfall on the catchment for a particular historical flood event, and then reviewing the flood behaviour in the flood model to determine if it is consistent with observations. This provides greater confidence in the flood model results and assists in understanding the level of potential uncertainty.

A limited calibration/validation was undertaken for an event in August 2020. For this event, the local rainfall and river level were recorded via the Nowra Boat Shed gauges. In addition, the flood peak was captured in a photo and later surveyed. The collection of single flood mark does not allow for a full model calibration. However, the collected mark was at an area of concern (the low point of Scenic Drive) and allows the model behaviour at this location to be validated.

The rainfall was incorporated into the XP-RAFTS model. Losses were assumed in line with ARR2019. Due to the small size of the catchment, the gauged rainfall was applied uniformly over the catchment. Hydrographs were extracted from the XP-RAFTS model for each subcatchment and applied to TUFLOW via the SA polygons (refer **Section 3.4.7**). The river level gauge data was applied to the downstream boundary.

It was noted that the rainfall and river peaks were quite distinct, with the rainfall peaking at 5am on 8 August 2020, and the river peaking at 8am on 10 August 2020. The model was run across both of these peaks.

A photograph was taken at the height of the riverine flood, which clearly shows the debris line from the catchment flood peak. This debris line was surveyed and found to be at a level of 4.31mAHD.

The model was initially run with the historical rainfall and riverine levels applied. These results showed that the model was under-estimating the peak flood level at the location of the surveyed mark by approximately 0.3m.

Additional runs were undertaken with lower rainfall losses, including a run with no rainfall losses applied. These runs showed a similar behaviour. This is due to the highly urban nature of the catchment. The impervious regions already had a continuing rainfall loss of 0mm applied, so further reductions across the pervious areas had a minimal impact.

The flood behaviour in this region is controlled by the large culvert discharging under the aquatic centre and into the Lower Shoalhaven River. Runs were undertaken with increasingly high blockages applied to this culvert. However, a blockage of 50% still under reported the flood level at the surveyed flood mark. Furthermore, no major blockage was observed or reported at this culvert, so a very large blockage is not considered appropriate for the historical event.

A review was then undertaken on the potential losses associated with the flood gate on the culvert. References such as *Flap Gate Performance in Hydraulic Models* (Pennington, 2010) discuss the representation of flap gates in hydraulic models.

One of the challenges in representing these structures is that even very small flows are able to pass out of the culvert as soon as there is any head difference between the culvert water level and the adjacent

river level. In reality, some head will be required to build up behind the flap in order to force it open and allow flow to commence.

Pennington (2010) undertook a literature review and identified one type of flood flap for which data was available was a Calco Gate. These gates are made of steel and are double hinged. For a 0.9m diameter pipe, such a flood flap has a head loss of approximately 0.05m. The paper noted that no mention of downstream conditions was made, and it was assumed that this head loss applied to a free outfall.

Given the lack of available data on head loss through flood flaps, a range of losses were assessed in the hydraulic model. These losses were applied by artificially increasing the boundary level at the flood flap with respect to the river. For example, a 0.1m head loss was modelled by increasing levels at the culvert by 0.1m with respect to the recorded river levels.

Head losses of 0.1, 0.2 and 0.3m were modelled.

The results showed that the 0.2m head loss resulted in a peak water level similar to that surveyed. The modelled peak level was 4.28m AHD, compared to the survey level of 4.31m AHD; a difference of 0.03m. The photograph taken of the debris line is shown in **Figure 4-2**, and the model results at this location are shown in **Figure 4-2**.

The results show that the model is showing a similar flood extent, with ponded water extending up to the pit on the northern side of the intersection, with the intersection fully inundated. Flooding also extends south to along Scenic Drive, as shown in the photograph.

Based on these results, a 0.2m minimum difference between river levels and the level at the culvert outlet was adopted for the design event modelling.

Figure 4-1 Historical Photo of August 2020 Event

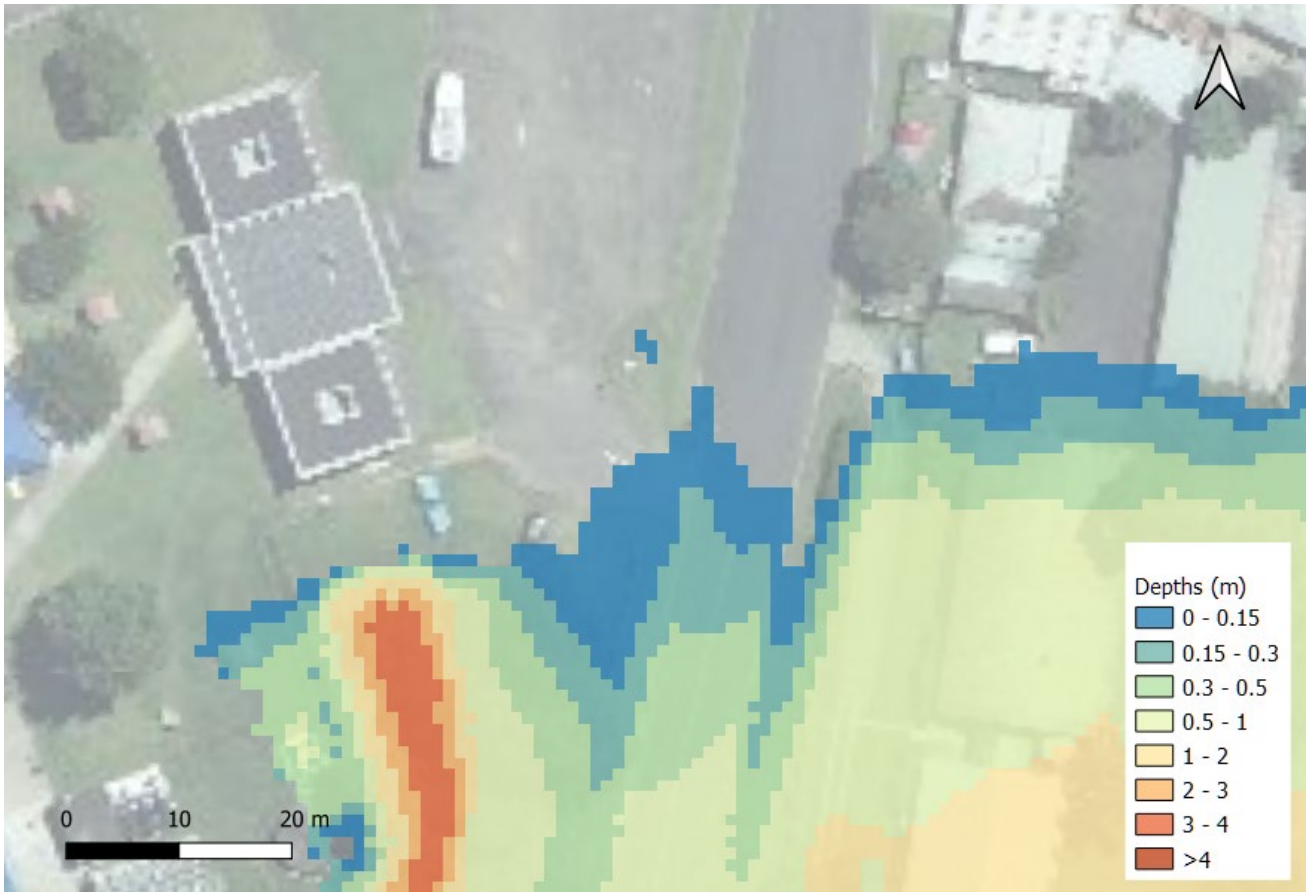

Figure 4-2 **Calibration/Validation Results**

4.2 Downstream Boundary Sensitivity

A sensitivity assessment was undertaken on the downstream boundary to determine the influence riverine flood levels have over catchment flooding.

To test the sensitivity, the 1% AEP was modelled with riverine levels of:

- 0.95mAHD (HHWSS)
- 5.3mAHD (5% AEP)
- 6.0mAHD (1% AEP)

The results are shown in **Figure 4-3** and **Figure 4-4**.

The results show that the changes in model behaviour as a result of changes to the downstream boundary are typically restricted to the area of influence of riverine flooding. Within the central area of the site, peak levels increased and decreased directly in-line with changes to the river level. These changes were restricted to the backwater region of the Shoalhaven River and did not result in any changes to the catchment flow behaviour.

East of the Highway, some differences were observed in catchment flow behaviour driven by changes in the outlet conditions of the local drainage. Lower river levels increased the conveyance of the piped system, while increased river levels reduced it.

Overall, the results show that the model is relatively insensitive to changes in the boundary level.

Figure 4-3 **Increased Boundary Sensitivity**

Figure 4-4 **Decreased Boundary Sensitivity**

5 Existing Flood Behaviour

5.1 Design Flood Events

5.1.1 Critical Duration

The critical duration plots for the 10% and 1% AEP events are shown in **Map Series RG-05-01**.

Due to the relatively small size of the catchment area, the critical durations for the events are relatively short. The 120-minute event is critical for all events within the central storage area of the study area.

The smaller, overland flowpaths at the eastern and western boundaries are governed by short duration events with high rainfall intensities, with the 10 – 15-minute events being typically critical.

It should be noted that due to the shallow flow depths along these flowpaths, all the modelled durations report similar levels for these locations.

5.1.2 Behaviour

Flood modelling has been undertaken for the 20%, 10%, 5%, 1%, 0.5% and 0.2% AEP events and the PMF event.

Flood depths for the local catchment flooding are shown in **Map Series RG-05-02**, and for selected Lower Shoalhaven River flood events in **Map Series RG-05-03**.

For catchment flood events, outside of the central storage area, the flood affectation is minimal, and typically confined to the road reserve for all modelled events. The exception to this is that in the PMF, the portion of the Precinct east of the highway experiences inundation of developed areas as a result of backwater from the Lower Shoalhaven River.

Flooding in the central storage area is predominantly governed by the assumed tailwater level in the river. In events up to the 5% AEP, where the river level was set at the HHWSS (1.1mAHD), the ponding in the centre of the Precinct does not significantly impact existing development.

In the local catchment 1% AEP, when the river was assumed to be a 5% AEP level (5.3mAHD), the ponding inundates Hyam Street upstream, the rear half of properties along Mandalay Avenue, as well as properties along Scenic Drive, including the aquatic centre.

In larger local catchment events, the river was assumed to be at the 1% AEP (6.0mAHD). The ponding depths increased in line with the river levels, however the extent did not increase significantly in events up to the PMF, due to the terrain rising relatively quickly at the edge of the central storage area.

For riverine floods, the riverbank first overtops in the 5% AEP event. Flow first breaks out of the river adjacent to the western embankment of the bridge and flows through the existing low point adjacent to the aquatic centre. The 5% AEP levels in the central depression are 0.08m higher for a riverine flood, compared to the 5% AEP local catchment event. This trend intensifies for larger events, with the 1% AEP being 0.5m higher in a riverine flood compared to a local flood event, and the PMF 5m higher for riverine floods. As such, catchment driven flooding governs the local flood behaviour up to the point at which the riverbank overtops (the 5% AEP), after which peak flood levels in the Precinct are governed by riverine flood levels.

5.2 Flood Hazard

Flood hazard varies with flood severity (i.e., for the same location, the rarer the flood the more severe the hazard) and location within the floodplain for the same flood event. This varies with both flood behaviour and the interaction of the flood with the topography.

It is important to understand the varying degree of hazard and the drivers for the hazard, as these may require different management approaches. Flood hazard can inform emergency and flood risk management for existing communities, and strategic and development scale planning for future areas.

There are two industry standard approaches for defining flood hazard; the high-low hazard approach as detailed in the Floodplain Development Manual (2005), and the H1-H6 hazard approach as detailed in the AIDR Guideline (2007). Each of these is discussed below.

5.2.1 Floodplain Development Manual

This approach splits the flood extent into a high hazard zone and a low hazard zone, with a smaller transitional zone between them. The definition of these categories is based on depth and velocity thresholds, as shown in **Figure 5-1**.

FDM flood hazard mapping is provided for local catchment flooding in **Map Series RG-05-04**, and for selected Lower Shoalhaven River flood events in **Map Series RG-05-05**.

In events up to the 5% AEP, the majority of the flooding within the Precinct was classed as low hazard, the exception being the central channel for the catchment events as a result of higher velocities in this area.

For events above the 5% AEP, where significant ponding was observed in the centre of the Precinct, this ponding was classed as high hazard.

The flow over Hyam Street was classed as high hazard for the 1% AEP and above for riverine floods, and 0.5% AEP and above for catchment flooding.

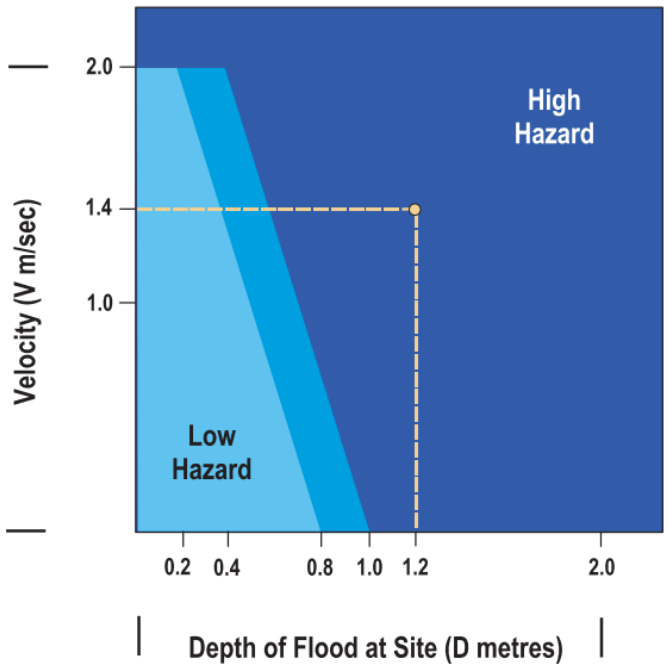

Figure 5-1 FDM Flood Hazard Categorisation

5.2.2 Australian Institute of Disaster Resilience (AIDR)

The AIDR hazard categories are also based on depth and velocity thresholds. The thresholds have been based on vulnerability curves for pedestrians, vehicles, and buildings within the flood extent. The hazard categories mapped are summarised in **Table 5-1** and **Figure 5-2**.

Flood hazard mapping is provided for local catchment flooding in **Map Series RG-05-06**, and for selected Lower Shoalhaven River flood events in **Map Series RG-05-07**.

For catchment driven events, outside of the central region, hazard classes were typically H1 or H2, with some localised H3 occurring at road low points in larger events.

The central channel was classed as H4 in events up to the 5% AEP, with overbank hazard H1 to H3.

In larger events, when the ponding was more pronounced, the central flowpath increased to a H6 hazard class, with large areas of H5 across the storage zone.

Riverine flooding produced similar results with the central zone typically experiencing H5 to H6 hazard for events above the 5% AEP. In the 5% AEP, the minimal overtopping that occurred resulted in less severe hazard classes of H1 to H3.

Table 5-1 AIDR Hazard Categories

Category	Description
H1	Generally safe for vehicles, people, and buildings
H2	Unsafe for small vehicles
H3	Unsafe for vehicles, children, and the elderly
H4	Unsafe for vehicles and people
H5	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust building types vulnerable to failure
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure

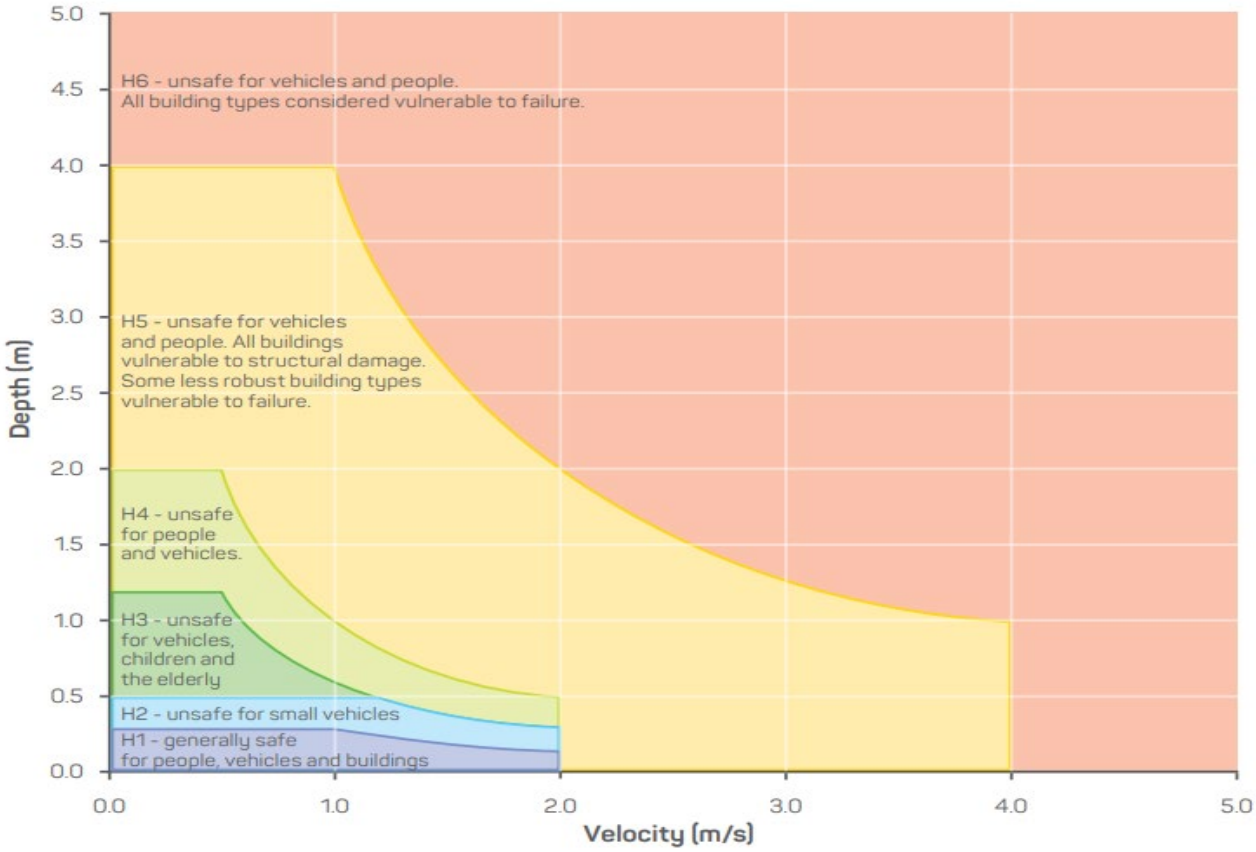

Figure 5-2 Flood Hazard Categories (AIDR, 2017)

5.3 Flood Function

Maintaining the flood function of the floodplain is a key objective of best practice in flood risk management in Australia, because it is essential to managing flood behaviour. The flood function of areas of the floodplain will vary with the magnitude in an event. An area which may be dry in small floods may be part of the flood fringe or flood storage in larger events and may become an active flow conveyance area in an extreme event. In general flood function is examined in the defined flood event (DFE), so it can be maintained in this event, and in the PMF so changes in function relative to the DFE can be considered for planning and management.

The flood function categories, as defined in the Floodplain Development Manual (2005), are:

- Floodway - areas that convey a significant portion of the flow. These are areas that, even if partially blocked, would cause a significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas.
- Flood Storage - areas that are important in the temporary storage of the floodwater during the passage of the flood. If the area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges.
- Flood Fringe - remaining area of flood prone land, after Floodway and Flood Storage areas have been defined. Blockage or filling of this area will not have any significant effect on the flood pattern or flood levels.

It is noted that there is no "one size fits all approach" to hydraulic category / flood function definition. Thomas & Golaszewski (2012) investigated a number of different approaches in some case study catchments. However, it was emphasised in this paper to test the underlying assumptions through methods such as "encroachment", testing the impact of reducing or increasing the floodway.

An initial categorisation (based on Thomas & Golaszewski, 2012) was undertaken based on the criteria below:

- Floodway – Velocity x Depth Product is greater than 0.5m^2/s;
- Flood Storage – Velocity x Depth product is less than 0.5m^2/s and depth is greater than 0.5m; and
- Flood Fringe – areas in the flood extent outside of the above criteria.

Encroachment testing was undertaken on the above criteria. Testing was undertaken for the 1% AEP event. In the model, the roughness outside of the floodway described by the criteria above was increased to a very high value of 0.2, effectively restricting the full flow to only the floodway zone.

This run demonstrated minimal impacts on peak flood levels, with changes across the Precinct less than 0.1m.

As the floodway only covers the minimum possible extent (that is, between the tops of the channel banks) additional encroachment testing of restricting the floodway zone was not undertaken.

The above indicates that the filtering adopted is appropriate for an initial definition of hydraulic categories. Minor manual edits were then undertaken to ensure that floodways were continuous, and to remove small, isolated zones of floodway or flood storage occurring within the wider flood fringe zone.

The flood function mapping is provided for the catchment design events in **Map Series RG-05-08**.

For catchment driven events up to and including the 0.2% AEP, the floodway was contained within the banks of the open channel through the central portion of the Precinct. The central region was predominately storage, with regions of fringe around the edges.

In the PMF, the floodway increased significantly, due to an additional flowpath over the riverbank becoming activated.

5.4 Climate Change Sensitivity

An indication of the impacts that may arise from future changes to sea level rise and increased rainfall intensity has been undertaken by comparing the 1% AEP to the 0.5% and 0.2% AEP events.

Difference plots are shown in **Map Series RG-05-09**.

The results show that for the portion of the Precinct west of the highway, the differences are driven by the change in the river level. The 1% AEP adopted a 5% AEP river level of 5.3m AHD, while the 0.5% and 0.2% AEP both adopted a 1% AEP river level of 6.0mAHD. This change is responsible for the increase of 0.55m within the central storage.

East of the highway increases of 0.04m and 0.06m were observed in the 0.5% and 0.2% AEP comparison respectively. It is expected that these increases are due to a combination of the increased river level (reducing the conveyance of the piped system) as well as the increased rainfall intensity.

6 Future Scenario and Options Assessment

6.1 Preliminary Options

Flood risk is a combination of the likelihood of occurrence of a flood event and the consequences of that event when it occurs. It is the human interaction with a flood that results in a flood risk to the community. This risk will vary with the frequency of exposure to this hazard, the severity of the hazard, and the vulnerability of the community and its supporting infrastructure to the hazard. Understanding this interaction can inform decisions on which treatments to use in managing flood risk.

As defined in the *Australian Disaster Resilience Handbook 7 – Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (AIDR, 2017), there are three types of flood risk:

- **Existing flood risk** – the risk associated with current development in the floodplain. Knowing the likelihood and consequences of various scales of floods can assist with decisions on whether to treat this risk and, if so, how
- **Future flood risk** – the risk associated with any new development of the floodplain. Knowing the likelihood and consequences of flooding can inform decisions on where not to develop and where and how to develop the floodplain to ensure risks to new development and its occupants are acceptable. This information can feed into strategic land-use planning.
- **Residual flood risk** – the risk remaining in both existing and future development areas after management measures, such as works and land-use planning and development controls, are implemented. This is the risk from rarer floods than the management measures were designed for. Residual risk can vary significantly within and between floodplains. Emergency management and recovery planning, supported by systems and infrastructure, can assist to reduce residual risk.

A set of preliminary options for addressing flood risk in the study area was developed for discussion with the Technical Working Group (TWG). These options are summarised in **Table 6-1** and the structural options are shown in **Map RG-06-01**.

6.2 Future Scenario Workshop

A Technical Working Group (TWG) workshop for the project was held virtually on Wednesday 15 December 2021.

The workshop was held to present the results of the base case flood modelling, and to invite comments and suggestions for the development of future scenarios and options for assessing in the hydraulic model.

The presentation was made using Miro, which allowed for real-time notes and comments to be made on the slides by all participants throughout the meeting. The agenda, attendance list, presentation slides, and the participant notes, are provided in **Appendix B**.

Those options identified in the workshop for further assessment, and the reasons behind other options being ruled out, are noted in **Table 6-1**.

Table 6-1 Preliminary Flood Management Options

ID	Option	Description	Expected Benefit	Constraints	Proceed With?
Structural Options (to manage existing flood risk under both current and developed site conditions)					
S1	River levee	Construction of a levee along the front of the Precinct to protect from riverine floods. Levee height would be up to 0.8m high to protect in the 1% AEP and 1.6m high to protect in the 0.5% AEP (plus any required freeboard)	Prevention of flooding from riverine floods up to the levee design event. Note that the levee would provide no benefit in catchment driven flood events.	Primary issue is the adverse impacts on amenity and aesthetics, particularly in the east, adjacent to the highway where the levee height would be greatest. Potential to adversely affect local flooding.	No. Other options deliver similar protection without sacrificing the usage and connectivity of the open space.
S2	Upgrade to culvert and outlet at aquatic centre	The outlet at the aquatic centre is currently a combination of a twin 1.65m diameter pipe, transitioning to twin 1.85 x 1.1m culvert at Scenic Drive with a large steel flood gate at the outlet. The option would see an additional pipe/culvert constructed, and a more efficient flood gate installed on both new and existing culverts. Works to the existing culvert are not proposed due to its location under the aquatic centre.	The combination of increasing the pipe capacity and improving the performance of the culvert will better allow the draining of the upstream flood storage, reducing peak flood levels and/or the period of inundation. It is noted that the performance will be dependent on the downstream river levels.	Upgrading current alignment not feasible. Would require new alignment round the aquatic centre. The region will be undergoing works as part of the Precinct development, and these upgrades could be undertaken at this time. The option would require works on the riverbank, which would have additional environmental constraints that would require further consideration.	Yes
S3	Diversion and retention of flow in Nowra Recreation Park	A diversion structure to be constructed at the intersection of North Street and Shoalhaven Street (likely a local regrading of the road) to force upstream flows into the Nowra Recreation Park. A detention basin and outlet structure would be constructed to control these flows.	The diversion is expected to reduce peak flood levels downstream and reduce the storage volume required within the Precinct.	Being located so far up the catchment, the amount of flow able to be diverted will be limited. Disruption to access along North Street and Shoalhaven Street, and the parking lot for the hospital. The Park is currently owned by Crown Lands.	No. Land has recently been purchased for expansion of the hospital. Fill platforms based on the riverine FPL (2100 1% AEP +0.5m) are above the local catchment PMF, reducing the need for local catchment control measures.
S4	Detention basin upstream of Hyam Street	Construction of a detention basin in the open space upstream of Hyam Street.	The basin is expected to reduce peak flood levels downstream and reduce the storage volume required within the Precinct.	The available area is small, and coupled with the grade of the local terrain, will limit the storage available. Existing development surrounds the site, complicating access, and ease of construction. Basin area is inundated in the 1% AEP catchment flood via backwater from the storage area, so would only offer a benefit if the downstream levels could be reduced first.	No. The limited size (and hence limited potential benefits) and substantial constraints result in the option not being considered feasible, given other options are available. Fill platforms based on the riverine FPL (2100 1% AEP +0.5m) are above the local catchment PMF, reducing the need for local catchment control measures.
S5	Central storage for flood control	A flood storage region in the centre of the Precinct, at the location of the existing low point and outlet structure. Storage to manage the flood volume in excess of the outlet capacity.	Prevention of the lateral expansion of the ponded water into developed areas. Allows to more safely manage local minor flood events and allows this central flood storage area to be integrated with WSUD measures, improving the overall aesthetics of the open space area.	Potential safety constraints due to depth of ponding. Terrain may limit the amount of storage that can be provided. The region operates in this manner currently, albeit with ponding water impacting adjacent development. Works planned for region as part of Precinct development.	Yes.

ID	Option	Description	Expected Benefit	Constraints	Proceed With?
S6	Raising of building pads to FPL	The development footprint (that is, the roads and buildings pads) to be raised to the FPL. The open space can remain lower.	Prevents inundation of roads and development in events up to the design flood event. Removes the need for other structural mitigation options. Assists in emergency management.	May require a substantial volume of fill. May require compensatory cut depending on classification of overbank region (fringe or storage). Could be coupled with S5 above to provide this storage. Raised pads will need to tie into adjacent areas where Precinct works are not proposed. Possible afflux on properties upstream of the pads.	Yes.
S7a	Regrading of open space region	Open space region would be regraded to allow the direct discharge of catchment flows to the river without the need for storage within the Precinct.	Reduces residual flood risk within the Precinct. Provides greater flexibility in land use within the Precinct.	Would require works on the riverbank to construct an overflow. Would reduce a region of riverbank height from the current 5mAHD to 1mAHD.	No. The extent of changes required to the riverbank are not considered feasible. Makes the region more susceptible to riverine flooding.
S7b	Raising and regrading of open space region	As above, but central region would also be raised to create a central flowpath and prevent the need for changes the riverbank.	Reduces residual flood risk within the Precinct. Provides greater flexibility in land use within the Precinct.	Would require substantial fill. Some minor works to riverbank may be required to achieve required flowpath grades.	No. Levels and grades within the site do not make this option achievable.
	Planning Options (to manage future flood risk)				
P1	Appropriate development controls	Update to Council's DCP controls with specific controls for this development.	Reduction in future flood risk	No major constraints	Yes
P2	Provision of rising road access	Ensure that the layout of roads within the Precinct allows for rising road access to a flood free area.	Reduction in future flood risk	No major constraints	Yes
P3	Provision of elevated pedestrian ways to flood free land	Option would see pedestrian walkways link the upper floors of buildings whose lower level(s) are flood affected to a flood free location.	Ensuring residents have a flood free egress route once the lower floor of a building is inundated.	Complex and costly to construct, due to the length required. Would likely require buildings to be connected to each other via high level walkways.	To be further investigated. Whilst not considered an appropriate evacuation option for the wider precinct, the provision of elevated access may be suitable as part of a risk management strategy for identified low flood islands, namely Wharf Road, Pleasant Way, and Bridge Road sub-precincts.
	Emergency Response Options (to manage residual risk, that is events above the 1% AEP)				
E1	Flood warning	Construction of a flood warning system for the Precinct. Travel time from Tallowa Dam is ~5-6 hours. Warning could be tied to existing gauges, or newly installed gauges.	Reduction in residual flood risk. Provides opportunity for people to evacuate in advance of expected flooding. May offer benefits to wider region also. Allows Precinct to self-evacuate without, or with minimal SES assistance, as SES will have limited resources available in an extreme event.	No Major constraints	Yes. Would need to be tied in with existing systems operated by the Bureau of Meteorology and Manly Hydraulics Laboratory (on behalf of DPE).

ID	Option	Description	Expected Benefit	Constraints	Proceed With?
E2	Flood evacuation plans	Building owners to prepare a flood response plan that includes: • Details of roles and responsibilities in the case of a flood event. • Sources of information to inform when actions detailed in the plan are required. • Trigger levels for river levels and / or rainfall for implementing the plan. • Identifies alternative meeting / accommodation locations for residents during and after a flood event.	Reduction in residual flood risk. Helps to ensure that evacuation is undertaken effectively and efficiently. Allows Precinct to self-evacuate without, or with minima, SES assistance, as SES will have limited resources available in an extreme event.	No Major constraints	Yes
E3	Flood awareness	Flood warning signs and flood information provide safety advice to the community during flood events, as well as serving as a reminder of flood risk outside of flood events. Signs and information may include: • Depth markers at road overtopping locations. • Flood warning signs at parks and community grounds. • Historic markers placed on prominent buildings or light / telegraph poles.	Reduction in residual flood risk. Increased compliance with directives during floods. An understanding that flood risks are present, and that action may be required in the future in response to these risks.	No Major constraints	Yes
E4	Update of emergency response documentation	These documents include discussions on flood behaviour, loss of access, and flood emergency classifications across floodplains in the Shoalhaven LGA. It is recommended that these documents be updated to incorporate the flood data developed as part of this study, particularly the access and flood affected infrastructure	Reduction in residual flood risk. Helps to ensure that evacuation is undertaken effectively and efficiently.	No Major constraints	Yes

6.3 Summary of Outcomes

The full assessment of the concept options is provided in **Appendix D**.

With regard to the raised building pads, the results indicated that some form of filling within the site is achievable. Whilst filling of the whole developable area has adverse impacts in larger flood events, the fact that the smaller fill extent did not have adverse effects, suggested that some optimisation of fill extent beyond a small extent is possible.

Overall, the region was more sensitive to changes in fill extent than to changes in pad level. If a pad location was found to not significantly affect flood behaviour when filled to the 2100 1% AEP + 0.5m, it was generally able to be filled to higher levels without adversely affecting flood behaviour.

If, however, impacts were observed at the 2100 1% AEP + 0.5m pad level, they were exacerbated by further raising.

The sub-precincts are shown in **Figure 6-4**.

A summary of the behaviour of the individual sub-precincts is provided in **Table 6-5**.

With regard to the culvert and basin works, the basin results indicated that the available volume was not sufficient to significantly change peak flood levels. The basin filled quickly, in advance of the peak, so that resulting flood levels were not measurably different from the raised landform scenario levels.

The construction of an additional culvert was more effective. The addition of a second culvert line, with a size as per the current culvert, was sufficient to reduce levels within the central region (and consequently across Hyam Road the adjacent properties) by 0.05m.

Figure 6-1 Proposed Sub-precincts

Table 6-2 Summary of Sub-precinct Assessment Outcomes

Sub-precinct	Outcome
Mandalay	Sub-precinct generally compatible with flood behaviour. Raising of sub-precinct above the 0.5% AEP + 0.5m feasible. Rising Road evacuation is achievable but requires additional assessment to confirm feasibility.
Hyam Street	Sub-precinct generally compatible with flood behaviour. Raising of sub-precinct above the 0.5% AEP + 0.5m feasible. Rising Road evacuation is achievable but requires additional assessment to confirm feasibility.
Scenic Drive	Raising sub-precinct has flood impacts in events above the 0.2% AEP. Some raising of the southern portion likely feasible, so that conveyance is retained adjacent to the river. Rising Road evacuation is achievable but requires additional assessment to confirm feasibility (via Hyam St Sub-precinct).
Bridge Road	Sub-precinct located on high point that remains flood-free in the 0.05% AEP event but is inundated in the PMF. No changes were modelled in this sub-precinct. Is a low flood island.
Pleasant Way and Graham Lodge	Southern portion flood-free in the 0.05% AEP event but becomes inundated in the PMF. Raising remaining portion generally feasible from a flood impact perspective. Is a low flood island.
Wharf Road	Raising sub-precinct has modest impacts in the 0.05% AEP and significant impacts in the PMF. Eastern portion of the site has structurally achievable rising road for events up to 0.5% AEP (feasibility subject to capacity assessment). Is a low flood island.

6.4 Technical Working Group Meeting 2

The second TWG workshop was held virtually on Monday 21 February 2022. The workshop was held to present the results of the concept option flood modelling, and to invite comments and suggestions for the development of scenarios that warranted further assessment.

As per the first workshop, the presentation was made using Miro, which allowed for real-time notes and comments to be made on the slides by all participants throughout the meeting. The presentation slides, and the participant notes, are provided in **Appendix C**.

The consensus at the workshop was that creating raised pads for the development was generally desirable, subject to the resolution of some key concerns:

- That sufficient warning time is available to fully evacuate the sub-precincts, as shelter in place was not considered feasible due to the long duration of flooding;
- That the existing road network was capable of evacuating the proposed additional residents within the evacuation period; and,
- That the design does not result in significant adverse impacts to adjacent developments.

The development of a suitable landform that addresses the above concerns is documented in **Section 7** and **Section 8** below.

7 Flood Planning Level

Historically, flood planning levels have typically been set at the 1% AEP plus a 0.5m freeboard. This was in response to the now-repealed Planning Circular PS-07-003 which mandated this approach unless exceptional circumstances were present, with any deviation requiring approval from the Minister for Planning. While the previous approach theoretically allowed for other FPLs to be adopted, in practise this was not widespread, except for vulnerable land use.

The 2021 flood prone land planning package removed this mandated approach and allows Councils to set local FPLs based on the flood behaviour and risk identified in Flood Studies and Floodplain Risk Management Studies and Plans.

This allows Councils to adopt higher planning levels in response to greater flood risks. In the case of the Nowra Riverfront Precinct, there is a significant residual risk associated with the PMF, which cannot be managed through the design of the Precinct. The residual flood risk is the flood risk that remains even when development is undertaken in line with all relevant controls.

To inform a Precinct Flood Planning Level (FPL) going forward in the study, taking account of this residual risk and other factors, an assessment was undertaken on three FPL options:

- The 1% AEP + Sea Level Rise (SLR) + Rainfall Increase (RI) + Freeboard (FB)
- The 0.5% AEP + Sea Level Rise (SLR) + Freeboard (FB)
- The 0.5% AEP + Sea Level Rise (SLR) + Rainfall Increase (RI) + Freeboard (FB).

For this assessment:

- Sea level rise at Nowra was assumed to 0.36m, which is Council's currently adopted 2100 condition;
- Rainfall increase was assumed to 16.3%, which is Council's currently adopted 2100 condition, based on the RCP8.5 emission pathway; and,
- Freeboard was assumed to be 0.5m.

The pad levels for the sub-precincts relating to these options are summarised in **Table 7-1**.

Table 7-1 Pad Levels for FPL Assessment (mAHD)

Sub-precincts	1% AEP + SLR + RI + FB (1% AEP Pad)	0.5% AEP + SLR + FB (0.5% AEP Low Pad)	0.5% AEP + SLR + RI + FB (0.5% AEP High Pad)
Pads East of Highway	6.0	6.3	6.6
Pads West of Highway	6.75	7.25	8.0

Each scenario was assessed for:

- Benefits to flood warning and evacuation
- Benefits to risk in likelihood of flooding
- Impact on developable area
- Integration with adjacent infrastructure
- Aesthetic and open space integration considerations.

The results of these assessments are presented below.

7.1 Benefits to Flood Warning and Evacuation

To assess the benefits relating to flood warning and evacuation, the relative timing of inundation of the proposed pad levels was assessed for the 24-hour duration PMF event. This event was not the critical PMF, but it had the steepest rate of rise, and hence, the shortest warning time.

Starting from the point at which the 1% AEP pad level was inundated it was found that:

- The 0.5% AEP low pad remained flood free for an additional 45 minutes.
- The 0.5% AEP high pad remained flood free for an additional 1 hour and 45 minutes.

This additional time before inundation allows for a longer warning and evacuation period.

However, it was noted for the 0.5% AEP high pad scenario, that the pad was located above the level of several adjacent roads, namely:

- The reconstructed Mandalay Avenue would be higher than Hyam Street;
- Scenic Drive would be higher than Bridge Road; and,
- Internal roads within the Hyam Street sub-precinct may be higher than Hyam, depending on where these connections are made.

Internal roads within the Wharf Road sub-precinct are also higher than surrounding roads for all FPL scenarios.

Any raising of the pads beyond the level of the adjacent external road does not offer any benefits to warning and evacuation as all evacuation would be required to be completed by the time external roads are inundated.

Furthermore, raising the pads above the level of adjacent roads would result in them becoming flood islands, where external evacuation routes are cut prior to the pads becoming inundated. As such, raising the pads beyond the level of the surrounding roads leads to a potential increase in flood risk (primarily isolation risk) for the occupants.

7.2 Benefits to Likelihood of Flood Inundation

Higher pad levels offer reductions in the frequency of flood inundation which translates into lower annual average damages for developments, reductions in social and community costs arising from flood events, and potential reductions in flood insurance costs.

7.3 Impacts on Developable Area

Due to the extent of the pads being constrained by zoning and existing development, raising the pad level higher results in a smaller developable area, as the pad batter slopes take up an increasing amount of space for higher scenarios.

The impact on developable area of higher FPL scenarios were estimated on an assumed batter slope of 1 in 4 and are summarised in **Table 7-2**. The table reports the percentage reduction in developable area relative to the 1% AEP pad scenario. It is noted that a 1 in 4 slope is relatively steep, and therefore these loss of area estimates are likely conservative (i.e., the loss of area is likely to be greater for the final masterplan and design). However, they provide an indication of the relative loss of land between the different scenarios.

The results showed that the impact is most pronounced for Scenic Drive and Wharf Road pads as they have batters on multiple sides, resulting in area being lost along multiple pad edges. For Scenic Drive

and Wharf Road, the loss of developable area under the 0.5% AEP high pad scenario was 22 – 24% compared to the 1% AEP pad level.

The Scenic Drive developable region lies between two batters. As such, this region is constricted as FPL heights increase. The developable width reduces from 38m in the lowest scenario, to 30m in the middle scenario to 16m in the highest scenario. While a 30m width would remain developable, constricting the pad width to 16m would substantially restrict the scope of development within the Scenic Drive sub-precinct.

Other sub-precincts typically lost 1 – 4% developable area by stepping up to the middle pad, and 3 – 8% developable area by stepping up to the highest pad.

Table 7-2 Impact on Developable Area (% Reduction based on 1% AEP + SLR + RI + FB Scenario)

Sub-precincts	Reduction to 0.5% AEP + SLR + FB	Reduction to 0.5% AEP +SLR +RI + FB
Mandalay	-2%	-4%
Hyam	-4%	-8%
Scenic	-11%	-24%
Pleasant Way	-1%	-3%
Wharf Rd	-11%	-22%

7.4 Integration with Adjacent Infrastructure

As previously noted above, the 0.5% AEP high pad scenario results in internal roads being located higher than the existing external roads. Whilst the prior discussion was focussed on the impacts this has on warning and evacuation times, it also creates challenges for integrating these roads with the external road network.

The 0.5% AEP low pad scenario has pads that reach to approximately the height of Mandalay Avenue and Bridge Road. The 0.5% AEP high pad scenario would result in roads being located 0.7m higher within the Mandalay and Scenic Drive / Hyam Street sub-precincts. It would be possible to grade these roads down to meet the existing roadway, but it may limit access, driveways, and the like along the falling sections of road.

No significant issues with regard to integration with existing infrastructure were identified for the lower two FPL scenarios.

7.5 Aesthetic and Open Space Integration

The Nowra Riverfront Precinct is going to be a highly visible gateway into the Nowra, and wider Shoalhaven region. The central portion of the site will become a large open space region for use by the local community and visitors.

While flood considerations are the primary focus of this study, it is important to recognise that the proposed building pads will represent a significant part of the landform, and that where flood behaviour permits, to be integrated into the wider region.

Shown in **Figure 7-1** is a typical east-west cross section taken through the central open space region.

The figure shows the relative heights of the three FPL scenarios compared with the surrounding terrain, as well as an indication of where the Mandalay and Hyam Street sub-precinct pads would be located.

The section shows that the batter slope of the Mandalay pad is not very different from the existing terrain slope in this region, albeit located further west. In contrast the Hyam Street pad batter slope is steeper than the existing terrain slope.

With regard to the pad heights, all the proposed FPL scenarios would see a pad level some height above the central open space. The 1% AEP pad scenario pad level is approximately 4.5m above the central region, with pad levels increasing to approximately 5m and 6m above the central region for the higher FPL scenarios.

While lower pad levels would provide an easier integration with the open space region, the cross section shows that the raised pads are going to be significant features regardless of which FPL is adopted.

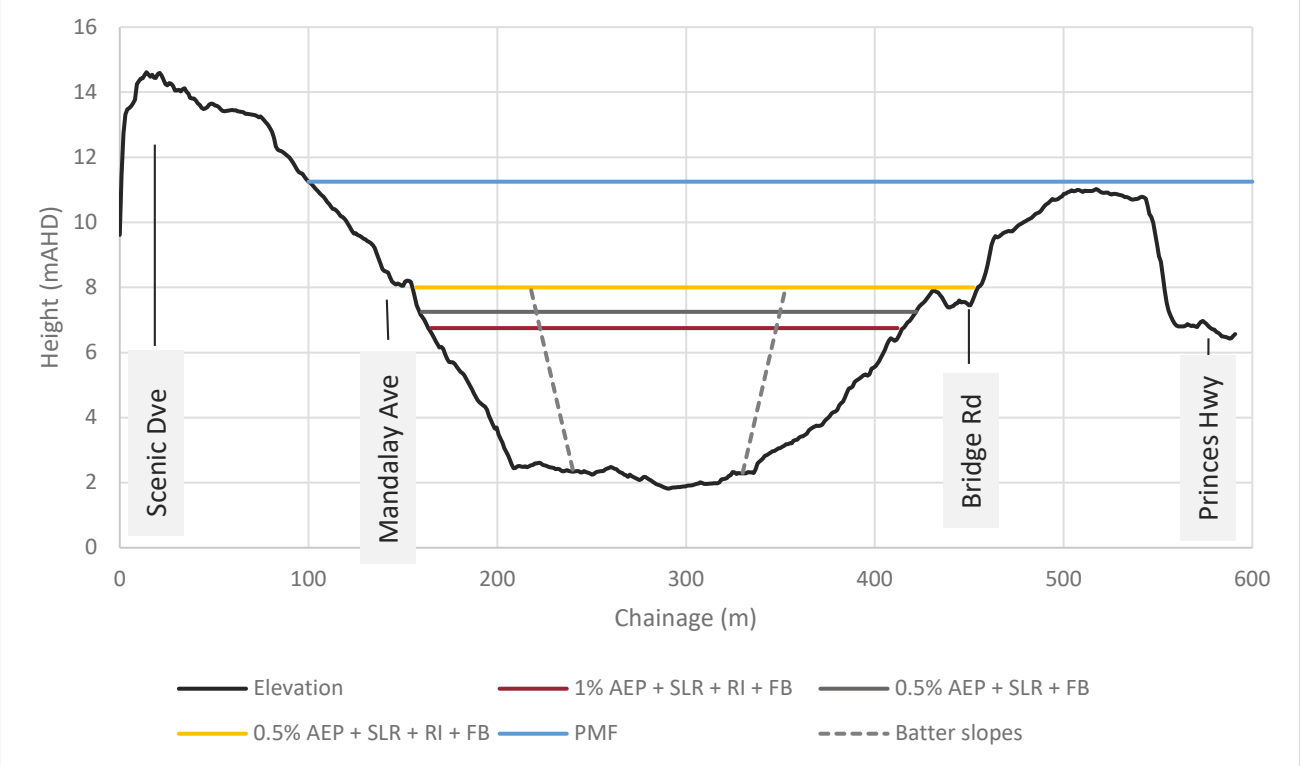

Figure 7-1 Typical East-West Section through the central region and possible FPLs

7.6 Other Studies

Council has recently completed the *Lower Shoalhaven Flood Study* (Cardno, 2022), which has reported a reduction in 1% AEP levels compared to the earlier Flood Study (Webb, McKeown, and Associates, 2008) generally as a result of the update of the assessments to ARR2019. As such, adopting a defined flood event (DFE) based on the revised 1% AEP level would result in the FPL being lower than the currently adopted FPL.

The *Lower Shoalhaven River Flood Study* (Cardno, 2022) has recommended that the FPL be adopted based on the 0.5% AEP DFE. This Flood Study was endorsed by the Northern FRMC in December 2022, and was adopted by Council in early 2023. The recommendations of the Nowra Riverfront FIRA are consistent with the outcomes of this flood study.

Council is currently planning to undertake a revision of the *Lower Shoalhaven Floodplain Risk Management Study and Plan* (FRMSP) in 2023. In the interim, it is understood that Council is planning to investigate the adoption a DFE based on the 0.5% AEP for the wider Shoalhaven floodplain through this FRMSP.

7.7 FPL Outcomes

Within the Nowra Riverfront Precinct, there is a residual risk associated with the PMF, which generally cannot be managed through the design of the Precinct. The residual flood risk is the flood risk that remains even when development is undertaken in line with all relevant controls. As such, it is recommended that a higher planning level be adopted for the Precinct to assist in managing this risk, namely the 2100 0.5% AEP plus 0.5m, incorporating sea level increases.

Compared to the historically typical planning level of the 1% AEP plus climate change impacts plus 0.5m freeboard, the recommended FPL is 0.5m higher which confers the following advantages:

- Additional flood immunity for the Precinct. Over time, the flood immunity will be reduced because of climate change impacts. The development of the Precinct is a long-term proposition, and there will not be future opportunities to raise the pads further. Adopting a higher pad level now assists with managing the risk of projected changes to flooding.
- The additional height increases both the flood warning time and the evacuation time. Evacuation will be necessary in extreme flood events and this extra time will facilitate the safe evacuation of people from the Precinct. It is noted that higher pad levels do not benefit Wharf Road, as the evacuation of this precent is controlled by external roads, with a lower flood immunity.
- As there is insufficient warning time for the NSW SES to evacuate the Precinct (refer **Section 9**) the additional pad height will serve to assist occupants to evacuate themselves (supported by Emergency Evacuation controls discussed in **Section 14**) by providing extra flood warning evacuation time.

It is noted that the 0.5m higher pad level will result in some loss of developable area (as a result of the batter slopes). However, as discussed in **Section 7.3**, this loss of area was not significant for the recommended FPL.

The highest assessed scenario of the 2100 0.5% AEP incorporating both sea level rise and rainfall increase, whilst notionally providing some additional flood immunity and warning time, was ultimately not found to be suitable as:

- The internal sub-precinct roads would require a step down to match existing roads, negating the benefits of the higher pads as warning and evacuation times would be governed by these lower roads;
- The higher pads would become flood islands, presenting an isolation risk to occupants and emergency responders.
- Mandalay Avenue would require reconstruction, which would present challenges for acquisition and staging; and,
- A substantial reduction (up to 24%) of the developable area.

As a result, an FPL based on the 2100 0.5% AEP incorporating sea level rise and freeboard is recommended for the Precinct.

8 Landform Optimisation and Sensitivity

8.1 Performance Criteria

To allow the assessment and comparison of the various options for the management of flood risk to be assessed, and to determine which options could be considered feasible, a set of performance criteria were developed. The adopted criteria evolved from discussion at the second TWG concerning what a "successful" option would deliver, as well as consultation with Council and DPE technical advisors.

The performance criteria are presented in **Table 8-1**.

Each performance criteria had three possible outcomes:

- Green – the option meets this performance criteria.
- Red – the option fails this performance criteria (and by extension, is not a feasible option).
- Orange – the option results in some additional impacts that may be deemed acceptable, provided that the option meets most of the other performance criteria.

Table 8-1 Performance Criteria

Performance Criteria	Acceptable	Possibly Acceptable	Not Acceptable
For the 0.5% AEP (the design flood event)			
Water Surface Elevation (WSE) Impacts (m)	None *	<0.02	>0.02
Velocity Impacts (m/s)	None *	<0.1	>0.1
Hazard Impacts (increase in hazard category)	None *	1	>1
For the 0.05% AEP			
WSE Impacts (m)	<0.05	<0.1	>0.1
Velocity Impacts (m/s)	<0.2	<0.5	>0.5
Hazard Impacts (increase in hazard category)	None *	1	>1
For the PMF			
WSE Impacts (m)	<0.1	<0.2	>0.2
Velocity Impacts (m/s)	<0.5	<1	>1
Hazard Impacts (increase in hazard category)	None *	1	>1

** No impact defined as less than +/-10mm afflux*

8.2 Landform Assessments

Building from the outcomes of the TWG2 workshop, an iterative assessment was undertaken to explore the behaviour of the various sub-precincts during flood events, and to optimise the possible landform from the flood hydraulics perspective. The assessment undertook:

- Iterative modelling of various Scenic Drive and Wharf Road pad extents to determine their impact on flood behaviour;
- Sensitivity of increasing the Wharf Road and Pleasant Way pads to a higher FPL based on the adjacent river flood levels, rather than local flood levels. This was to ensure that if the adjacent levee were to fail, these locations would still retain a similar level of flood immunity to other sub-precincts.

- Sensitivity testing of improved conveyance along Pleasant Way to address adverse velocity impacts.
- Sensitivity testing of a fully blocked Wharf Road pad.
- Iterative modelling of various Wharf Road pad extents and configurations to resolve adverse water level impacts.

Full details of the assessment are provided in **Appendix E**.

The assessment ultimately delivered pad extents, levels, and alignments for the various sub-precincts, for which all performance criteria were met with an acceptable rating.

The final pad arrangement and associated performance with respect to flooding is discussed in **Section 11**.

9 Assessment of Potential for Evacuation During a Flood Event

Following the determination of pad levels and extents that are feasible from a hydraulic perspective, advice was sought from the NSW SES of an estimate of the population that could be safely evacuated from these sub-precincts in rare and extreme flood events, given the warning time available.

It is noted for a 0.5% AEP Shoalhaven River event that the warning time is in the order of 8 – 10 hours, and that the duration of inundation estimated to be up to 24 hours and for a PMF event, up to 36 hours. As such, evacuation of the sub-precincts is recommended for at least this period of time.

The SES undertook an evacuation assessment, based on the methodology described in *Timeline modelling of flood evacuation operations* (Opper, Cinque and Davies, 2010).

The methodology arose from discussions and recommendations made as part of the NSW State Government's Hawkesbury-Nepean Flood Management Advisory Committee (1997). The report, and its recommendations, were aimed at improving the management of flood risk for (at that time) 60,000 people living in the Hawkesbury-Nepean floodplain.

Under the SES methodology, the evacuation timeline was broken down into discrete stages:

- Flood prediction: the identification that a flood is imminent or expected based on rainfall, stream gauges, or modelling data.
- Warning delivery: The delivery of the flood warning to residents. This also includes time for residents to process the warning, decide to evacuate, and to pack necessary items.
- Evacuation operation: the actual evacuation of residents from their property to flood safe refuges.

Based on these stages, current SES policy is that a minimum of 10 hours is required to safely evacuate a region during a flood event. This is based on:

- 6 hours for SES mobilisation;
- 3 hours of warning time to alert occupants to the flood risk; and,
- 1 hour of traffic movement to evacuate to a safe location.

The SES applied this methodology to each sub-precinct individually, for low, medium, and high population estimates, for an assumed one, two or three teams.

Future population estimates are provided in **Table 9-1**. The estimates were prepared by Council for the purpose of undertaking the evacuation calculations. The results of the SES assessment are provided in **Table 9-2**.

Table 9-1 Riverfront Sub-precinct Population Estimates

Sub-precinct	Low	Medium	High
Mandalay Avenue	190	590	1000
Hyam Street	130	170	420
Pleasant Way	100	200	400
Wharf Road	240	340	450
Scenic Drive	50	100	190
Bridge Road	20	80	140
TOTAL	730	1,480	2,600

Table 9-2 Time (hours) to evacuate sub-precincts, based on 1, 2 and 3 SES teams

Sub-precinct	One Team			Two Teams			Three Teams		
	Low*	Medium*	High*	Low	Medium	High	Low	Medium	High
Mandalay Avenue	8	22	35	6	9	19	6	10	14
Hyam Street	7	9	17	5	7	11	5	6	8
Pleasant Way	7	11	18	5	7	11	5	6	9
Wharf Road	9	12	14	7	8	9	6	6	7
Scenic Drive	5	6	8	5	5	6	5	6	5
Bridge Road	5	7	9	5	6	5	5	5	6

* See Table 9-1 for Low, Medium, and High population estimates

The assessment found that all sub-precincts had sufficient time to evacuate, subject to the population and SES team assumptions:

- Scenic Drive and Bridge Road had sufficient time to evacuate under all population and SES team assumptions;
- Mandalay Avenue had sufficient time to evacuate under the low population scenario, or if two or more teams were deployed, the medium population scenario;
- Hyam Street had sufficient time to evacuate under the medium population scenario, or if three SES teams were deployed, the high population scenario;
- Pleasant Way was sensitive to the SES team assumptions. Evacuation was feasible only for the low population scenario with one team, up to the medium population scenario with two teams, or up to the high population scenario with three teams;
- Wharf Road had sufficient time to evacuate for all population scenarios if two or more SES teams were deployed. If only one team was deployed, Wharf Road could only be evacuated under the low population scenario.

Following the initial assessment, the SES provided the following comments:

- The SES do not recommend residential or tourist development in places where people may be trapped in a low flood island (i.e., the Wharf Road Sub-precinct).
- In large flood events SES resources will be required to be deployed across much of the South Coast and regional access routes are likely to be cut due to flooding. As such, while the assessment indicated that evacuation is feasible within the available warning time, it needs to be recognised that the ability of the SES to respond in a large flood event will be constrained by regional flooding and that occupants should be provided with the information necessary to self-evacuate.
- Flooding in the Nowra Riverfront Precinct offers significant risks to those that choose not to evacuate or become trapped by flood waters. PMF flood depths and velocities are such that rescue and/or resupply may be too risky for emergency personal to attempt.
- There is never a complete uptake of evacuation commands. A portion of occupants will always elect to remain, and their eventual rescue puts SES personnel at risk.

The SES noted that the assessment tool used to report the results in **Table 9-2** was developed to inform the evacuation time and road capacity for the evacuation of large urban regions that would be affected by Hawkesbury-Nepean River flooding, and who would be required to travel significant distances to

reach a flood safe refuge. The study area is different in that the population required to evacuate is much smaller, and the distance to a flood-free location is much shorter (i.e., it is immediately adjacent to the site). As such, the SES noted that the estimates may not necessary be accurate but have been adjusted in an attempt to reflect the local conditions.

10 Site Flood Communication System

Given the differences between the study area and the regions for which the evacuation timeline methodology was developed, there are potential additional measures to assist in the evacuation of the Riverfront Precinct that would be feasible, most notably a flood communication system capable of manual alerts, issued by the SES. The purpose of this communication system is to reduce the time required for the mobilisation and warning stages of the evacuation timeline above.

Providing a means by which occupants are able to assist in their own evacuation is desirable. While the SES has undertaken an assessment assuming up to three teams may be available (**Table 9-2)**, the reality is that a flood of greater than the 0.5% AEP (which would threaten to inundate the proposed pads) would see widespread flooding and road closures across potentially numerous areas on the South Coast, placing substantial numbers of people at risk, and stretching the ability of the SES to respond in all locations. Flood communications that can issued remotely (via SMS), will assist in allowing the study area to evacuate, without the physical presence of SES teams.

The system has been termed a "communication" system as its purpose is not to issue warnings or alerts (which are the purview of BoM and SES) but rather to facilitate the communication of these warnings and alerts from the SES to building occupants. It is envisaged that the system would be able to issue both pre-recorded and live announcement, both on- and off-site, at the discretion of the SES.

However, with this considered, it is important to recognise that the SES has identified that there will be difficulties in managing the evacuation of the proposed Precinct, and this should be considered in any decisions for the feasibility of the development. This was re-iterated by the SES during the Technical Working Group 3 and 4 discussions.

The controls identified in this report (**Section 14**) have been prepared on the basis that the development does proceed. On that basis, the controls have been prepared to minimise, as much as possible, the SES management requirements.

10.1 Key Requirements of a Site-Specific Flood Communication System

Any flood communication system developed for the Precinct should:

- Be capable of issuing pre-recorded and live announcements / warnings / alerts both on- and off-site at the discretion of the SES. The communications could be staged, with an initial warning given to occupants to allow time to process the need for evacuation before the official evacuation order is given. This would serve to maximise the time available for the actual evacuation process.
- Have appropriate redundancies to ensure that it remains operable in a flood event.
- Incorporate regular testing to ensure it remains operable, and that occupants become familiar with the warnings that would be issued in a large flood event.
- Be maintained by a suitability qualified third party. It is not considered suitable that building owners be responsible for this system. Building developers/owners should be required to contribute to the costs of implementing and maintaining the system, but the maintenance should lie with a third party and operation should be by the SES. This ensures that the system will be maintained and operated appropriately and serves to mitigate the risks that the system would fall into dis-use, or, in the case of the building being sold on, that subsequent owners are not fully aware of its use and requirements.

10.2 Benefits of a Communication System on the Evacuation Timeline

With respect to the SES evacuation timeline (**Section 9**), a site flood warning system has the potential to offer improvements to the:

- Warning Time – the 3 hours of warning time for the SES is based on the requirement to door knock and speak with all occupants to direct them to evacuate. The system should be able to issue an "evacuate now" or similar command in order to reduce the burden on the SES. It is noted that not all occupants may head the warning, and that the SES would still be required to physically visit the site, but the goal of the warning system would be to have as many occupants as possible to evacuate on their own, and significantly reduce the number of people the SES team(s) are required to engage with.
- Warning Lag Factor – the system will not reduce the actual time taken by occupants to organise and prepare themselves for evacuation. However, by allowing the system to issue a "Get Ready" or "Evacuation Imminent" announcement, this time can be moved out of the critical path, to sit concurrently with other mobilisation tasks, effectively reducing the overall evacuation timeline by up to an hour.
- Vehicle Movement Time – as noted in the SES response, the nominal one hour allowed for in the evacuation methodology for travel to a flood free refuge is also high for this particular location. All of the sub-precincts are within 200m of flood-free land and 1.5km of a flood free refuge, a distance which could be traversed, even on foot, in much less than one hour.

While these improvements in the warning timeline are reasonable, it is noted that the SES would still be required to visit the property, and whilst it would be expected that while many occupants would respond to the warnings, it is not possible to state conclusively the extent to which this would be the case.

Flood warning systems are also subject to several challenges as discussed further below.

10.3 Challenges with Flood Communication Systems and Private Flood Plans

Flood communication and warning systems, and site flood response plans are not without challenges.

The document *Support for Emergency Management Planning* (Flood Risk Management Guide EM01) by the Department of Planning and Environment (DPE, 2022), notes that with respect to flood warning systems:

- Messaging and response are unique to each situation / area;
- Comprehensive community awareness strategies are also required to ensure understanding of warnings and directions;
- To be affective flood warning systems require:
    - Significant ongoing investment in operations, maintenance, testing and exercise of systems, in addition to their upfront costs;
    - Planning arrangements are coordinated and robust, led by the combat agency, and allowing for inherent uncertainties in prediction; and,
    - Significant upfront and ongoing community awareness efforts.
- The NSW SES does not generally support private or site-specific warning systems for individual developments that have not been developed in a strategic context.

The NSW Floodplain Development Manual (NSW Government, 2005), notes that with respect to private flood plans:

- They are typically only prepared in order to secure development, and not because of a genuine commitment to personal responsibility for risk management;
- These is no process for quality control;
- The legal status of a private flood plan endorsed by a Local Emergency Management Committee (LEMC) against the policy of the legal combat agency (the SES) has not been tested; and
- Private flood plans as a consent condition have been tested in the NSW Land and Environment Court and the policy of the SES has been recognised as valid.

To address these issues, it is recommended that any flood communication system developed be designed and maintained by an appropriately experienced and qualified third party, with both upfront and ongoing costs leveraged on the Precinct developers / owners. Such an arrangement ensures that that the building owners retain financial responsibility for the warning system, and that funds for the ongoing costs of the system are made available, irrespective of ownership of the buildings. The third party would then be responsible for maintenance, and testing, with the SES retaining responsibility for communications, alerts, and warnings.

Whilst beyond the scope of this study, Council may also wish to ensure that any system developed has the potential to be expanded upon so as to draw in both existing and future development if and when required.

11 Final Landform Testing

11.1.1 Final Landform Layout

The final landform developed for the region is shown in **Figure 11-1**.

A summary of how the individual sub-precinct areas have changed (with respect to the original concept shown in **Figure 1-2**) as a result of the flood assessment are provided in **Table 11-1**.

As the SES evacuation modelling results (**Section 9**) indicated that evacuation of each sub-precinct was feasible (subject to population density), no change to the pad extents were undertaken based on the outcomes of the SES modelling. Although the challenges with evacuation should be considered as part of the feasibility assessment for each sub-precinct.

It should be noted that the final extents represent the maximum pad sizes that are feasible without adversely impacting flood behaviour. However, hydraulic flooding considerations are only a single, albeit important, aspect of the overall Precinct development. Other criteria and constraints may serve to further refine the landform of the building pads.

Based on the testing undertaken, it is not feasible to make the pads larger. However, the testing has also indicated that making them smaller is unlikely to make the flood impacts worse; if anything, it should reduce the minor impacts that are observed in larger flood events.

Should future detailed design result in pad extents that are different from those proposed in this report, it is recommended that both the riverine and local hydraulic models be re-run to ensure that the pads still behave as documented in this report.

The behaviour of the raised pads is discussed for both riverine and local catchment flood events in the sections below.

Figure 11-1 Recommended Maximum Building Pad Extents

Table 11-1 Changes in Sub-precinct Extents as a Result of Flood Impact Assessment

Sub-precinct	Changes from Initial Concept
Mandalay Avenue	Batter slope reduced extent by approximately 10 – 15m on the eastern boundary. The north-eastern point was trimmed to allow flow over the riverbank in large events.
Hyam Street	Batter slope reduced extent by 5 – 15m on the western boundary. No other significant changes.
Scenic Drive	Batter slope reduced extent by approximately 10m on west, north and east boundaries. The northern extent has been pulled south by approximately 30m to resolve flood impacts, and to allow sufficient conveyance through the sub-precinct and over the highway in large flood events.
Bridge Road	No significant changes to initial concept.
Pleasant Way	Batter slope reduced extent by 5m on northern boundary. No other significant changes.
Wharf Road	The eastern third of the site was not able to be raised. This region was required to remain at existing levels to allow flood level increases occurring due to the raised pad to dissipate before reaching adjacent development. Batter slope reduced extent by 5m on all edges.

11.1.2 Riverine Flood Impact Assessment

Flood model results for riverine floods are shown for the 5%, 1%, 0.5%, 0.2%, and 0.05% AEP events and the PMF in:

- **Map Series RG-08-01** for flood depths and water levels;
- **Map Series RG-08-02** for flood velocities; and,
- **Map Series RG-08-03** for flood hazard.

Water level impact plots for the 0.5%, 0.2% and 0.05% AEP events and the PMF are shown in **Map Series RG-08-04**. Impact plots for the smaller events have not been presented as the proposed landforms did not have a measurable impact for these flood events.

Flood waters first break out of the river upstream of the Nowra Bridge in the 5% AEP event. The proposed landform does not affect this behaviour. For events up to and including the 0.2% AEP, the central open space is largely storage with no active flow. As the loss of storage within the site is negligible compared to the wider Shoalhaven River floodplain, the proposed pads have a no significant impact on flood behaviour for events up to and including the 0.2% AEP riverine flood.

The raised pads remain flood free in events up to and including the 0.5% AEP. The 0.2% AEP results in overtopping of the raised pads by depths of up to approximately 0.1m.

In the 0.05% AEP event, flow commences over the Princes Highway, and overtops the raised pads by approximately 0.2m. The reduction in conveyance due to the filling of the Wharf Road pad, results in

the flow over the highway reducing, leading to increases upstream of the highway of 0.01 – 0.02m, and decreases downstream of the Wharf Road pad of 0.07m at the Precinct boundary.

The PMF behaviour was similar to the 0.05% AEP, although the differences were greater. Upstream of the highway, localised increases within the site boundary were observed of up to 1m due to the blockage of the Wharf Road pad, although outside of the site within the river, the increases were smaller, typically 0.02 – 0.03m. Downstream of the Wharf Road pad, reductions of 0.06m were observed at the Precinct boundary, with reductions of 0.01 – 0.02m extending to Ferry Land, 600m downstream.

11.1.3 Local Catchment

Flood model results for local catchment floods are shown for the 5%, 1%, 0.5%, 0.2%, and 0.05% AEP events and the PMF in:

- **Map Series RG-08-05** for flood depths and water levels;
- **Map Series RG-08-06** for flood velocities; and,
- **Map Series RG-08-07** for flood hazard.

The local catchment results demonstrate that the raised pads are elevated above the local catchment PMF level. That is, the raised pads are flood free for all local catchment flood events.

Velocities through the open space corridor were observed to be highest in the 10% and 5% AEP events, as a result of the low tailwater condition, reaching just below 2m/s in both events. In larger events, the tailwater condition results in inundation of the open space from the river, and velocities drop to 0.2 – 0.5m/s for all larger events.

As per the existing scenario, the open space region remains an area of elevated flood hazard. The central channel has a hazard rating of H5 – H6 for all modelled events. Overbank flooding was H3 in the 10% and 5% AEP events and increased to H5 – H6 in the larger events, as a result of higher river levels assumed at the boundary.

Water level impact plots for the 10%, 5% and 1% AEP events and the PMF event are shown in **Map Series RG-08-08**. Impact plots were not shown for the 0.5% and 0.2% AEP events as these did not have a measurable impact on flood behaviour.

In the 10% and 5% AEP, an increase of 0.02m was observed at the intersection of Pleasant Way and Hawthorn Avenue. The impact was fully contained within the road reserve and did not increase the local hazard. The impact occurred as a result of the Pleasant Way pad extending up to this intersection and forcing more water into the road reserve.

In the 1% AEP event, levels increased within the central open space region by 0.04m. This increase extends across Hyam Street, and onto adjacent properties on the southern side of Hyam Street.

In the PMF event, increases of 0.01m were observed in the central open space, over Hyam Street, at the Pleasant Way and Hawthorne Street intersection, and along Riverview Road to the east of the Precinct. These increases were all minor, do not translate to any change in hazard, and are not considered significant in the PMF event.

With regard to the 1% AEP impacts, previous assessments have indicated that an additional outlet to supplement the existing culvert would be able to mitigate these impacts across Hyam Street and the adjacent existing development (refer **Section 6.3.2**). However, such an option is expected to be

expensive, and subject to a reasonably extensive approvals process due to the amount of works required on the riverbank.

An alternative was assessed based on the final landform whereby increasingly larger widths of 5m, 7.5m and 10m were removed from the edges of Mandalay Avenue, Scenic Drive and Hyam Street pads adjacent to the open space corridor. The 5m pad reduction reduced the impacts from 0.04m to 0.02m, and the 7.5m reduction was sufficient to remove the impacts entirely. This 7.5m trimmed extent is shown in **Figure 11-1**.

One of these mitigation options would be required to be adopted in order to ensure there are no adverse impacts arising from the raised building pads in the local catchment 1% AEP event.

It is noted that the increase over Hyam Street and the adjacent properties is relatively modest and does not significantly affect the hazard classification of the region. The hazard classification across Hyam Street is H3, which is unsafe for vehicles. As such, an increase of 0.04m on top of the existing flooding does not affect trafficability as road access is lost under existing conditions. For the residential properties, it is recommended that a site survey be undertaken to better understand property ground and floor levels in order to determine if the properties have sufficient freeboard to accommodate a 0.04m rise in levels without their freeboard dropping below 0.5m.

Once the extent of the impact on existing properties is quantified, options such as voluntary purchase or compensation could be considered prior to implementing one of the structural options discussed above.

11.1.4 Sensitivity to Climate Change

An indication of the impacts that may arise from future changes to rainfall intensity has been undertaken by comparing the riverine 1% AEP to the 0.5% AEP event results and the 0.5% AEP to the 0.2% AEP event results for the developed scenario. The developed scenario incorporates a 0.36m sea level rise.

Difference plots are shown in **Map Series RG-08-09**.

The 0.5% AEP was approximately 0.7m higher than the 1% AEP through the central open space region, and 0.4m higher immediately downstream of Nowra Bridge. As the raised pads have been set at a level 0.5m above the 0.5% AEP, this increase did not have any impact on the proposed development.

The 0.2% AEP was approximately 0.6m higher than the 0.5% AEP through the central open space region, and 0.5m higher immediately downstream of Nowra Bridge. This increase resulted in the raised pads becoming overtopped by depths of up to approximately 0.1m.

The results indicate that the pads will continue to provide flood protection for buildings and occupants, however, the extent of this protection will reduce as a result of future climate change.

The change in rainfall intensity between the 1% AEP and 0.5% and 0.2% AEP events was approximately 10% and 25% respectively. The difference between the 0.5% AEP and the 0.2% AEP was approximately 12%.

11.1.5 Landform Outcome

The assessment demonstrated that the proposed landform does not typically have adverse impacts on flood behaviour. Minor increases of 0.01 – 0.03m were observed in the river in the 0.05% AEP and PMF

riverine floods, however these impacts are considered acceptable based on the adopted design criteria (**Section 8.1**) for these large and rare events.

The exception was the local catchment 1% AEP, which resulted in increases across Hyam Street and adjacent properties of 0.04m. Further analysis demonstrated that this impact can be resolved in this event by either:

- Constructing an additional outlet to the river, to supplement the existing culvert; or,
- By reducing the extent of Mandalay, Scenic Drive and Hyam Street pads adjacent to the open space by 7.5m to provide additional storage volume.

12 Emergency Response

12.1 Emergency Response

12.1.1 Flood Warning

The Shoalhaven River catchment upstream of Nowra has several river gauges that can be used to inform flood warning for the Lower Shoalhaven River floodplain. Those nearest to Nowra are shown in **Figure 12-1**.

The travel time of the flood peak between these locations is summarised in **Table 12-1**.

The travel times have been determined from the hydrological model developed as part of the *Lower Shoalhaven River Flood Study* (Cardno, 2022).

All these gauges provide a reasonable representation, as the Lower Shoalhaven River does not have any major incoming tributaries downstream of these gauges.

While these travel times represent the time between the peak at each location, the warning time will likely be longer, as the BoM will provide forecasts based on forecast rainfall. The exact warning times should be determined in conjunction with the BoM and SES.

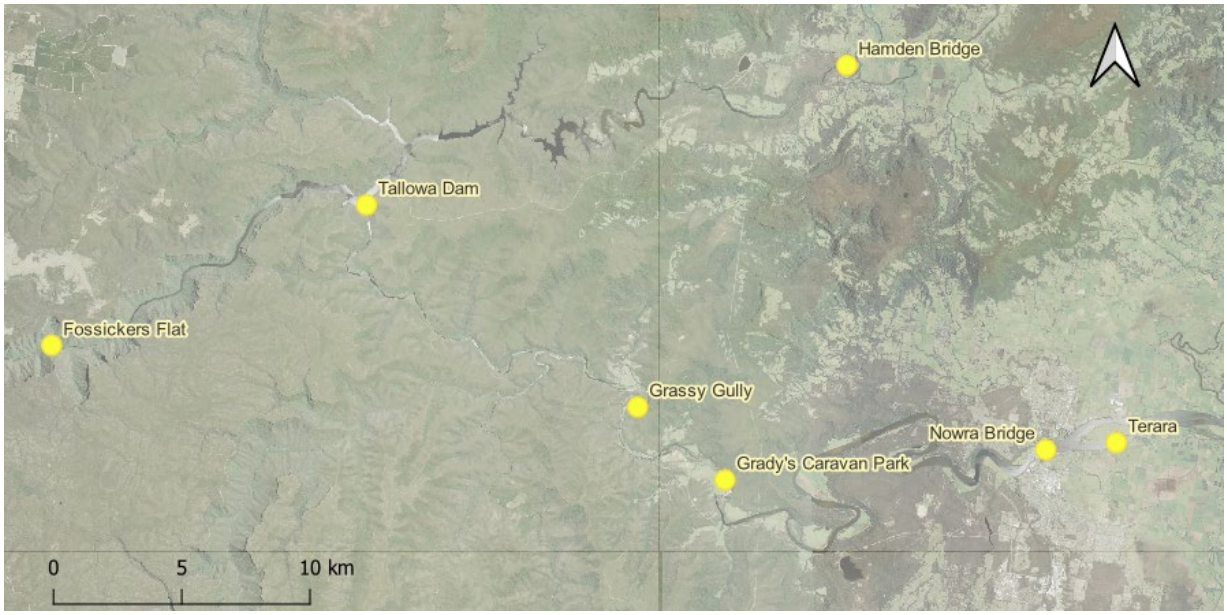

Figure 12-1 Shoalhaven River Gauge Locations

Table 12-1 Travel Time Between Shoalhaven River Gauges (Shoalhaven Local Flood Plan)

Gauge	Distance Upstream of Nowra (km)	Flood Travel Time to Nowra Bridge (hrs)
Fossickers Flat	66	8-9
Hampton Bridge	78	8-9
Tallowa Dam	52	4
Grassy Gully	35	2-3
Grady's Caravan Park (Burrier)	28	2
Nowra Bridge	-	-

12.1.2 Emergency Evacuation Potential

An assessment of the evacuation potential of the site has been undertaken, with the results presented in **Figure 12-2**.

Figure 12-2 Evacuation Potential

All sub-precincts were found to have the potential for rising road access for events up to and including the 0.5% AEP. The SES evacuation review (refer **Section 9**) found that the local roads had sufficient capacity to evacuate the sub-precincts.

The Mandalay, Scenic Drive and Hyam Street sub-precincts abut higher ground and have rising road access to flood free land in the PMF event.

The Bridge Road, Pleasant Way and Wharf Road sub-precincts are all low flood islands in the PMF. The Bridge Road and Pleasant Way sub-precincts are largely flood free in the 0.05% AEP. These regions are classed as a low flood islands and become isolated prior to the pad overtopping.

At the PMF peak, the Wharf Road sub-precinct is covered by H6 hazard flooding and velocities in excess of 4m/s. Such flooding conditions are likely to prevent any SES rescue by boat (in the event that occupants refused or where unable to evacuate). The higher points within the Bridge Road and Pleasant Way sub-precincts have a hazard class of H1, although H6 hazard is present along all surrounding roadways. While velocities between these two highpoints exceeds 4m/s along the highway, the

surrounding velocities are lower, in the order of 1-2m/s. These lower hazard and velocities may enable access via boat during the course of the flood, although this should not be relied upon.

From a flood risk perspective, constructing high density residential development on a low flood island is considered to be an unsuitable land use under the current arrangement. To permit development on these sub-precincts, some form of pedestrian, if not vehicle, access must be provided at the FPL, from which access to a point above the PMF should be reachable. Other land use types such as low density residential or tourist accommodation are considered more appropriate (provided that the above access requirements are met) as they present a lower flood risk due to the reduced population density.

The Pleasant Way and Bridge Road sub-precincts have this overland connection at the FPL (and at higher events up to and including the 0.05% AEP event). When the pads first overtop, there is overland access across the Princes Highway from the Pleasant Way sub-precinct to the Bridge Road sub-precinct, and from there to flood free land and flood refuges in Nowra CBD. These access routes are lost approximately 6 hours prior to the full sub-precinct becoming inundated in the PMF event.

The Wharf Road pad is more materially affected. Access along surrounding roads, and to the adjacent Pleasant Way sub-precinct are lost prior to the pad being inundated. This occurs in the 0.05% AEP when flows overtop the highway from the west and flow down Pleasant Way. At this point, the pad remains dry, but all access is lost.

While this would ultimately be up to any future development to address, it is suggested that possible strategies may be:

- Raising some portion of the western end of Pleasant Way to allow for pedestrian access at the FPL from the Wharf Road sub-precinct across the highway to flood free land west of the Bridge Road sub-precinct. It is noted that the SES do not support relying on pedestrian evacuation in an emergency.
- Raising the western end of Pleasant Way to allow vehicular access from Pleasant Way to the Highway at the FPL as a minimum. This would improve the evacuation potential of both Wharf Road and Pleasant Way sub-precincts. The provision of road access at the FPL would change the emergency classification from low flood island to rising road, providing an improved risk profile to residents. It is noted that TfNSW has indicated that access onto the highway could be permitted via a controlled intersection in an emergency. Further re-design of the intersection may be warranted if Pleasant Way is raised in order to further facilitate evacuation from both the sub-precinct and wider Terara area.
- Filling of the western depression between the Wharf Road pad and the Princes Highway to the FPL to allow pedestrian access onto the Highway, and from there to the Pleasant Way sub-precinct from which overland access is available to flood free land in Nowra CBD. It is noted that this land is owned by TfNSW.
- Construction of a pedestrian bridge or similar over Pleasant Way to allow for overland evacuation from the Wharf Road sub-precinct to the Pleasant Way sub-precinct from which overland access is available to flood free land in the Nowra CBD. It is noted that the SES do not support pedestrian evacuation.

More detailed assessments will be required on the evacuation options for the Wharf Road Sub-precinct to demonstrate its viability.

For events above the 0.5% AEP, and subject to further assessment as to feasibility:

- The Mandalay, Hyam Street and Scenic Drive sub-precincts have potential rising road access to flood free regions for all events up to and including the PMF.
- The Bridge Road and Graham Lodge sub-precincts lose access to evacuation routes above the 0.2% AEP. Most of these sub-precincts remain flood free in the 0.05% AEP but become inundated in the PMF. They have been classed as low flood islands in the PMF.
- The Wharf Road sub-precinct loses access to evacuation routes in the 0.2% AEP. The site losses access prior to becoming inundated and is classed as a low flood island in the PMF event.

As previously noted, the SES has identified that there will be difficulties in managing the evacuation of the proposed Riverfront Precinct, and this should be considered in any decisions for the feasibility of the development.

12.1.3 Flood Impacts on Access

There are several key access routes through the study area, both major arterials (such as the Princes Highway) and secondary roads providing access between and out of the Precinct areas. Understanding when these routes are overtopped by floodwaters and the duration in which they are flooded is useful, particularly for emergency response planning.

An analysis was undertaken on road inundation in the design events. The assessed locations are shown in **Figure 12-3**. The results are summarised in **Table 12-2** for overtopping depths, and **Table 12-3** for overtopping duration. It is noted that these durations are based on the design events provided for the Lower Shoalhaven River, and other, non-critical, storms may result in longer inundation periods.

Roads throughout the study area remain open for smaller flood events. In the 1% AEP event, flooding of Mandalay Avenue, Scenic Drive and Hyam Street is observed, due to the riverbank overtopping upstream of Nowra Bridge and inundating the central open space region.

In the 0.5% AEP, loss of road access is significant throughout the region, including a number of key evacuation routes for the eastern sub-precincts, namely, Shearwater Way, Hawthorn Avenue and Riverview Road, as well as the Princes Highway, immediately south of the Riverfront Precinct.

The 0.05% AEP sees the Princes Highway overtop within the Precinct.

The road closures have a modest impact on the sub-precincts west of Bridge Road, with access being lost for 3 – 5 hours. It is noted that some routes have much longer inundation times, but alternative routes are available that avoid these areas. Substantially longer road inundation times of typically 30 – 40 hours was observed in the PMF.

Loss of access for the sub-precincts east of Bridge Road is more significant with access being lost for 20 – 30 hours in the 0.5% and 0.2% AEP events, and 30 – 40 hours in the 0.05% AEP and the PMF events.

Table 12-2 Depth of Road Inundation Summary for Riverine Floods (at intersection, in metres)

ID	Intersection	5% AEP	1% AEP	0.5% AEP	0.2% AEP	0.05% AEP	PMF
1	Mandalay Avenue and Scenic Drive	0	0.3	0.8	1.4	2.0	5.2
2	Mandalay Avenue and Hyam Street	0	0	0	0	0	3.2
3	Hyam Street and Osborne Street	0	1.0	1.8	2.3	2.9	6.1
4	Hyam Street and Keft Avenue	0	0	0	0	0.2	3.3
5	Bridge Road and Scenic Drive	0	0	0	0	1.1	4.3
6	Princes Highway and Pleasant Way	0	0	0	0	0.2	3.1
7	Riverview Road and Hawthorn Avenue	0	0	0.3	0.5	1.0	1.3
8	Elia Avenue and Hawthorn Avenue	0	0	0.6	0.8	1.4	4.1
9	Lyrebird Drive and Hawthorn Avenue	0	0	0	0	0.7	2.7
10	Lyrebird Drive and Shearwater Way	0	0	1.0	0.9	1.6	3.8
11	Princes Highway and Shearwater Way	0	0	0.4	0.2	1.0	3.0
12	Elia Avenue and Lyrebird Drive	0	0	0.9	0.7	1.5	3.4
13	Lyrebird Drive and Riverview Road	0	0	0.6	0.3	1.2	2.9

Table 12-3 Duration of Road Inundation for Riverine Floods (at intersection, in hours)

ID	Intersection	5% AEP	1% AEP	0.5% AEP	0.2% AEP	0.05% AEP	PMF
1	Mandalay Avenue and Scenic Drive	0	14	25	31	40	46
2	Mandalay Avenue and Hyam Street	0	0	0	0	0	32
3	Hyam Street and Osborne Street	0	15	30	36	45	48
4	Hyam Street and Keft Avenue	0	0	0	0	3	32
5	Bridge Road and Scenic Drive	0	0	0	0	5	33
6	Princes Highway and Pleasant Way	0	0	0	0	5	28
7	Riverview Road and Hawthorn Avenue	0	0	20	24	35	38
8	Elia Avenue and Hawthorn Avenue	0	0	20	24	35	38
9	Lyrebird Drive and Hawthorn Avenue	0	0	0	0	35	38
10	Lyrebird Drive and Shearwater Way	0	0	26	29	36	38
11	Princes Highway and Shearwater Way	0	0	22	26	33	37
12	Elia Avenue and Lyrebird Drive	0	0	21	28	36	38
13	Lyrebird Drive and Riverview Road	0	0	24	31	39	42

Figure 12-3 Road Inundation Assessment Locations

12.1.4 Flood Evacuation Locations

Once those evacuating have reached the flood-free land south of the Precinct, there is flood-free access available to both Nowra Hospital and the Nowra CBD.

Based on the road inundation periods identified above, emergency accommodation would be necessary for some days.

Within the Nowra region, if evacuees are not able to stay with family or friends, there are several sites which may be re-purposed as emergency flood shelters for which space, cooking and bathrooms may be made available for a large number of people:

- St Michael's Catholic Parish Primary School;
- Nowra Public School
- Club Nowra Bowling Club.

Each of these locations are located within 1.5km of the Precinct. All are flood -free in the PMF event and maintain flood-free routes to Nowra Hospital and supermarkets in the CBD.

12.1.5 Shelter in Place

Shelter in place is not supported by the SES nor Council, as a means of providing refuge from flooding within the Nowra Riverfront Precinct. Furthermore, the ability to provide some flood warning, coupled with the significant periods of inundation (in the order of 40 hours for the PMF) argue against adopting a shelter in place policy. However, while evacuation remains the preferred approach, some occupants may not evacuate when directed and as such may become stranded in large flood events.

This report does not recommend a shelter in place approach for the Precinct. However, through the use of the site-specific planning controls, a relatively robust refuge could be provided for occupants who refuse to leave or cannot leave for other reasons when directed.

With sub-precinct building pads raised to the 0.5% AEP level, PMF depths over these pads are in the order of 3.75m for the western pads and 3.2m for the eastern pads.

The construction of either car parking or commercial premises on the ground floor level of any developments would serve to provide floor levels at least 3m above this level for any subsequent residential dwellings. As such, Council could opt to have the PMF as the residential flood planning level with little impact on developments, which would ensure that any residential premises are located above the PMF event.

The proposed planning controls for the Precinct require the demonstration of structural soundness in the PMF event, ensuring that developments would be structurally stable in a PMF event. The incorporation of additional controls to flood-proof all electrical infrastructure below the PMF would serve to provide a relatively secure refuge for occupants during the PMF event.

It is noted again that refuge is not considered suitable for this region due in part to the long period of isolation in large flood events. Occupants would be forced to isolate in their properties for at least 40 hours, and likely longer, in the PMF event. During this time, they would not be able to access supplies (either food or medical) and while building power may remain in working order, power disruptions off site may result in loss of power, while water and sewer systems may be impacted as well.

Evacuation is the recommended approach for occupants to take during a large flood event. However, the above does indicate that options are available to reduce the risk to life for those who elect to remain without significantly adversely affecting development across the Precinct.

12.2 Regional Evacuation

During the course of a flood event, the wider riverfront community would also require evacuation, notably the Riverview Road community, which is inundated by flooding in the 5% AEP event.

The SES currently have an evacuation plan in place for this community.

It is noted that the placement of additional occupants in the riverfront floodplain has the potential to impact on the evacuation of the Riverview Road Community through increased traffic on existing evacuation routes.

It is noted that the evacuation of the Riverview Road community and the Nowra Riverfront Precinct are unlikely to be undertaken at the same time. The Riverview Road community would be required to be evacuated in advance of the Riverfront Precinct as it is lower lying and becomes flood-affected earlier. This difference in timing will serve to reduce the impact of additional vehicles on existing evacuation routes.

It is also noted that any flood communication system developed for the Riverfront Precinct (refer **Section 10**) may be able to be expanded to this community to improve regional emergency communication.

It is also noted that the wider region has a highly variable population throughout the year, with large influxes of tourists in holidays and summer months.

Additional traffic modelling may be warranted (by the SES or others) if higher density or residential land uses are proposed for the eastern sub-precincts to ensure that the increase in population does not adversely affect the evacuation ability of the existing community, and that existing roads have sufficient capacity to service the increased population during peak tourist periods.

13 Planning and Policy Review

13.1 Purpose

Within the study area, development is largely controlled through the Shoalhaven Local Environmental Plan 2014 (SLEP 2014) and Shoalhaven Development Control Plan (DCP) 2014. The LEP is an environmental planning instrument (EPI) which designates land uses and development in the study area, while the DCP regulates development in the relevant zones with specific guidelines and parameters.

The purpose of the review is twofold:

- To determine if the proposed Precinct development is in accordance with these flood-related development controls, and if not, whether these departures are justified; and,
- To determine what additional flood-related development controls may be warranted in the site specific DCP to guide development of the sub-precincts.

This review does not specifically deal with matters related to building construction (such as the National Construction Code, which includes the Building Code of Australia, both of which are updated every three years by the Australian Building Codes Board). However, it is important to note that these types of controls are sometimes called or referenced in planning controls and therefore their content and direction are of relevance. In this regard, how they are applied is directed under the NSW Planning System via numerous mechanisms but primarily via Building System Circulars issued by the Department of Planning and Environment. The most relevant circular is BS 13-004, dated 16 July 2013 entitled *The NSW Planning System and the Building Code of Australia 2013: Construction of Buildings in Flood Hazard Areas*. Importantly the BCA deals with the concept of the 'defined flood event' (DFE) and imposes minimum a construction standard across Australia for specified building classifications 'flood hazard areas' (FHA) up to the DFE. However, the 2023 version of the BCA contains flood-related guidance largely for Class 1 buildings only and does not directly apply to the types of residential buildings anticipated in the Precinct.

Note that there are a number of State Environmental Planning Policies (SEPPs) that apply to the Precinct. A review of these EPIs has not been completed as part of this assessment.

13.2 Policies and Plans

13.2.1 Shoalhaven Local Environment Plan 2014

The Shoalhaven Local Environmental Plan 2014 (SLEP 2014) sets the direction for land use and development in the study area by providing controls and guidelines for development. It determines what can be built, where it can be built and what activities can occur on land.

The SLEP 2014 is based on a standard format used by all Councils in NSW and can be viewed on the NSW legislation website (www.legislation.nsw.gov.au).

13.2.1.1 Land Use Zones

The SLEP defines the land-use zoning for the study area, thereby determining which type of development are allowable through the study area. The land zoning for the study area at the time of preparation of this report is illustrated in **Figure 13-1**. Note that the B4 zone is now known as MU1 as a result of state-wide changes to zoning nomenclature in April 2023.

Note that the Precinct planning process may result in a change to the zonings shown in **Figure 13-1**.

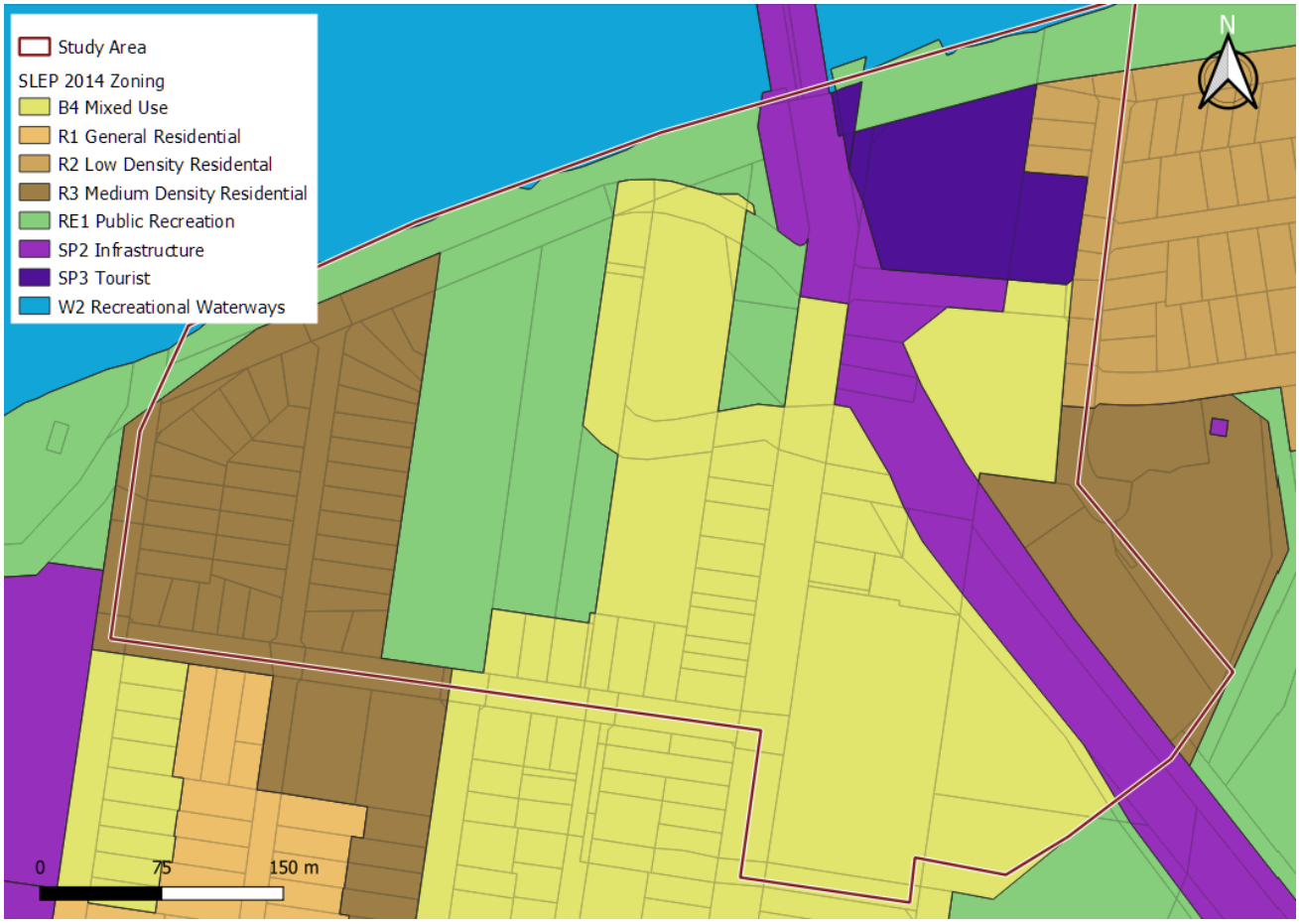

Figure 13-1 SLEP 2014 Land Use Zones

13.2.1.2 Flood Mitigation Works

The SLEP permits flood mitigation works in the following zones:

- RU1 Primary Production
- RU2 Rural Landscape
- RU4 Rural Production Small Lots
- RU5 Village
- R2 Low Density Residential.

It is noted that flood mitigation work may be carried out by or on behalf of a public authority for certain uses without consent on any land under *State Environmental Planning Policy (Transport and Infrastructure) 2021*.

13.2.1.3 Environmental and Heritage Considerations

The SLEP contains an Acid Sulfate Soils (ASS) Map, which shows Class 4 ASS across much of the study area. Clause 7.1 of the SLEP specifies where and when development consent is required for the carrying out of works on land shown on the ASS Map, with the objective of the clause being to ensure that development does not disturb, expose, or drain ASS and cause environmental damage.

The SLEP also contains a Heritage Map, which shows items of state and local heritage significance as well as Aboriginal Places of Heritage Significance and heritage conservation areas throughout the LGA. Within the study area the Heritage Map shows several items of local heritage significance.

There is an array of other environmental and heritage considerations under the LEP as well as under other legislation. Reference should be made to other studies related to the Precinct for information with respect to other environment and heritage considerations.

13.2.1.4 Flood Planning

The objectives for development within the Flood Planning Area (which is defined in Council's DCP) are outlined in Clause 5.21 of the SLEP. The objectives of this clause are:

- to minimise the flood risk to life and property associated with the use of land;
- to allow development on land that is compatible with the flood function and behaviour on the land, taking into account projected changes as a result of climate change;
- to avoid adverse or cumulative impacts on flood behaviour and the environment; and,
- to enable the safe occupation and efficient evacuation of people in the event of a flood.

It is stated that development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

- is compatible with the flood function and behaviour on the land;
- will not adversely affect flood behaviour in a way that results in detrimental increases in the potential flood affectation of other development or properties;
- will not adversely affect the safe occupation and efficient evacuation of people or exceed the capacity of existing evacuation routes for the surrounding area in the event of a flood;
- incorporates appropriate measures to manage risk to life in the event of a flood; and,
- will not adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of riverbanks or watercourses.

13.2.1.5 2021 Flood Prone Land Package

The 2021 Flood Prone Land Package provided advice to Council regarding the consideration of flooding in land-use planning. Part of the package was a revision to the standard LEP instrument.

It is noted that Section 5.21 was inserted in the LEP (in July 2021) in accordance with the 2021 Flood Prone Land Package.

It is also understood that Council has opted into the optional Section 5.22 (Special Flood Considerations), which applies controls and restrictions to land beyond the FPA. The Special Considerations Clause allows for Council to implement and enforce planning controls between the FPL and the PMF.

The Special Considerations clause applies to:

- Sensitive and hazardous development; and,
- Land that Council considers to be land that, in the event of flood, may cause a particular risk to life, and require the evacuation of people or other safety concerns.

The Riverfront Precinct would potentially be captured by this clause for the second reason, as the site retains a significant residual risk due to the PMF depths, despite any structural or planning risk mitigation options that may be implemented.

The clause requires that the consent authority not approve development on the site unless it is satisfied that the development:

- Will not affect the safe occupation and efficient evacuation of people in a flood event;
- Incorporates appropriate measures to manage risk to life in a flood event; and,
- Will not adversely affect the environment in a flood event.

13.2.1.6 Compliance with SLEP

A summary of relevant SLEP controls, and if and how the proposed development complies these controls is provided in **Table 13-1**.

Table 13-1 Compliance with SLEP Controls

Clause	Objective / Control	Compliance
5.21	Minimise the flood risk to life and property associated with the use of land	**Compliant**. FPLs have been set at the 0.5% AEP + 2100 SLR + 0.5m freeboard, providing long term flood protection for events up to and including the 0.5% AEP. For events exceeding this level, development controls have been implemented to manage residual risk, including flood warning, use of flood compatible building materials, and the use of the PMF to inform structural soundness.
	Allow development on land that is compatible with the flood function and behaviour on the land, taking into account projected changes as a result of climate change	**Compliant**. Proposed development is compatible with the flood function and behaviour. It does not adversely affect regional flood behaviour under existing or climate change scenarios.
	Avoid adverse or cumulative impacts on flood behaviour and the environment	**Compliant**. Study has demonstrated that the proposed development will not result in changes to flood behaviour (including depth, velocity, and hazard) off site. The assessment incorporated 2100 sea level rise, and a sensitivity test of 2100 rainfall.
	Enable the safe occupation and efficient evacuation of people in the event of a flood	**Compliant**. FPLs have been set at the 0.5% AEP + 2100 SLR + 0.5m freeboard, providing long term flood protection for events up to and including the 0.5% AEP. For larger events, development controls have been implemented to manage residual risk, including flood warning and the provision of rising road or pedestrian access at the FPL to facilitate evacuation.
5.22	Development will not affect the safe occupation and efficient evacuation of people in a flood event	**Largely Compliant**. Actions have been taken to ensure that occupants of the Precinct are made as safe as possible during large flood events. FPLs have been set at the 0.5% AEP + 2100 SLR + 0.5m freeboard, providing long term flood protection for events up to and including the 0.5% AEP. For larger events, management actions have been identified to manage residual risk, including flood warning and the provision of rising road or pedestrian access at the FPL to facilitate evacuation. However, not all flood risk can be removed from the Precinct and some residual risk will remain despite these measures.

Clause	Objective / Control	Compliance
	Development incorporates appropriate measures to manage risk to life in a flood event	**Compliant**. The development incorporates a higher than typical FPL to provide flood protection up to the 0.5% AEP, and development controls enforce flood warning, appropriate building materials and structural soundness, and the provision of rising road access to facilitate evacuation.
	Development will not adversely affect the environment in a flood event	**Compliant**. Study has demonstrated that the proposed development will not result in changes to flood behaviour (including depth, velocity, and hazard) off site.

13.2.2 Local Strategic Planning Statement – Shoalhaven 2040

The *Shoalhaven Local Strategic Planning Statement* (LSPS) is a strategic document, setting out a 20-year vision for land use planning in the city. It outlines how growth and change will be managed to ensure high levels of liveability, prosperity and environmental protection are achieved in the LGA.

With respect to flooding, the LSPS identifies the following actions:

- Consider the preparation of Resilience Action Plans for settlements and areas considered susceptible to isolation or at risk from floods and/or bushfire.
- Consider the preparation of resilience action plans for settlements and areas at risk from floods and/or bush fires, continue to develop flood risk studies and management plans, and consider the development of an Urban Greening Strategy.

13.2.3 Shoalhaven Development Control Plan 2014

A Development Control Plan (DCP) gives effect to the requirements of the LEP by specifying detailed development guidelines and controls.

The primary chapter for the provision of flood controls is *G9 Development on Flood Prone Land.*

Chapter G9 incorporates four key control themes:

- General controls – provides controls to ensure that development is undertaken in accordance with the objectives of the SLEP, NSW Flood Prone Land Policy and NSW Floodplain Development Manual;
- Fill and Excavation within the floodplain – applies more specific controls relating to fill and excavation to ensure that works in the floodplain do not result in adverse flood behaviour;
- Subdivision within the floodplain – ensures subdivisions take account of future climate conditions by requiring assessment of 2100 climate change scenarios; and,
- Site specific development controls – which provide specific controls for various suburbs and catchments, based on recommendations from completed Floodplain Risk Management Plans.

With respect to flood planning, other DCP chapters have minor additional relevant controls:

- DCP Chapter G2 Sustainable Stormwater Management has flood related controls to:
    - Preclude the need for onsite detention on sites within the 20% AEP extent; and,
    - Require onsite detention to be located above the 20% AEP level.
- DCP Chapter G11 Subdivision has flood related controls to:
    - Prevent subdivision on flood prone land;

- Ensure the drainage system is able to effectively convey the minor storm event;
- All bridges designed for the 1% AEP event, and consider the effects of the PMF;
- Siting of lots above the FPL; and,
- Ensuring that proposed works do not adversely impact mainstream or overland flow paths.

It is noted that DCP Chapter G21 Car Parking and Traffic does not contain any flood-specific controls. Site specific controls are proposed to manage both open and basement car parking within the Nowra Riverfront Precinct (refer **Section 14**).

A summary of relevant DCP controls, and if and how the proposed development complies these controls is provided in **Table 13-2**.

Table 13-2 Compliance with DCP Controls

Clause	Performance Criteria	Compliance
G9 5.1	The development will not increase the risk to life or safety of persons during a flood event on the development site and adjoining land.	**Largely Compliant**. The risk has been mitigated as far as reasonably practical, but some residual flood risk in extreme events remains. To manage the risk to life, FPLs have been set at the 0.5% AEP + 2100 SLR + 0.5m freeboard, providing long term flood protection for events up to and including the 0.5% AEP. For larger events, management actions have been identified to manage residual risk, including flood warning, use of flood-compatible building materials, and the use of the PMF to inform structural soundness. SES evacuation modelling has been undertaken to inform estimates of potential development densities in each sub-precinct that can be evacuated within the available warning time.
	The development or work will not unduly restrict the flow behaviour of floodwaters.	**Compliant**. Flood impacts for water levels, velocity and hazard have been assessed across the full range of design events for both local and riverine flooding and have demonstrated that the proposed development does not result in unacceptable impacts off site.
	The development or work will not unduly increase the level or flow of floodwaters or stormwater runoff on land in the vicinity.	
	The development or work will not exacerbate the adverse consequences of floodwaters flowing on the land with regard to erosion, siltation and destruction of vegetation.	
	The structural characteristics of any building or work that are the subject of the application are capable of withstanding flooding in accordance with the requirements of the Council.	**Compliant**. Development controls require flood compatible materials up to the PMF, and the demonstration of structural soundness in the PMF.

Clause	Performance Criteria	Compliance
	The development will not become unsafe during floods or result in moving debris that potentially threatens the safety of people or the integrity of structures.	**Compliant**. The development controls contain provisions to address vehicles becoming mobilised during a flood event.
	Potential damage due to inundation of proposed buildings and structures is minimised.	**Compliant**. Development controls require flood compatible materials up to the PMF, and the demonstration of structural soundness in the PMF.
	The development will not obstruct escape routes for both people and stock in the event of a flood.	**Compliant**. The development does not obstruct escape routes and allows for the provision of rising road or pedestrian access at the FPL to facilitate evacuation.
	The development will not unduly increase dependency on emergency services.	**Partly Compliant**. The Precinct will require the implementation of a flood warning communications system. The system would be capable of issuing flood communications and directions from the SES in order to facilitate the actions of the SES during a flood event. Ultimately however, it would be up to the SES to comment on how much assistance the proposed system would offer. It has been recommended that the system be developed in consultation with the SES in order to ensure it provides as much assistance as possible.
	Interaction of flooding from all possible sources has been taken into account in assessing the proposed development against risks to life and property resulting from any adverse hydraulic impacts.	**Compliant**. The study has assessed both local and riverine flooding across the full range of design events, up to and including the PMF.
	The development will not adversely affect the integrity of floodplains and floodways, including riparian vegetation, fluvial geomorphologic environmental processes, and water quality.	**Compliant**. The development does not result in changes to the riverine flood behaviour and does not propose any works on or within the riverbanks.
G9 5.2	High hazard floodway areas are kept free of fill and/or obstructions.	**Compliant**. Comprehensive testing of the proposed fill pads has demonstrated that they do not adversely affect flood behaviour, either within or outside the site.
	The proposed fill or excavation will not unduly restrict the flow behaviour of floodwaters.	
	The proposed fill or excavation will not unduly increase the level or flow of floodwaters or stormwater runoff on land in the vicinity, including adjoining land.	

Clause	Performance Criteria	Compliance
	The proposed fill or excavation will not exacerbate erosion, siltation and destruction of vegetation caused by floodwaters flowing on the land.	**Compliant**. The development does not result in changes to the riverine flood behaviour and does not propose any works on or within the riverbanks.
	The proposed fill or excavation will not be carried out on flood prone land if sufficient flood free area is available for development within the subject property.	**Compliant**. The filling is proposed because there was insufficient flood free land to support the proposed development.
	The proposed excavation does not create new habitable rooms, non-habitable storage areas or carparks with floor levels below the existing ground level.	**Compliant**. The raised pads and the selection of a conservative Precinct FPL will prevent the construction of habitable rooms, storage areas or carparks below existing ground level.
G9 5.4.5	No new subdivisions within the Riverview Road FMRP Study Area	**Compliant provided that no subdivision was proposed.** Compliance against this criterion is dependent on the development proposal and would be compliant provided that no subdivision was proposed as part of the development.
	The minimum required floor level for infill development and reconstruction is the 1 in 100-year pre levee flood level plus a freeboard of 0.5m for habitable rooms.	**Compliant.** The recommended site-specific development controls for the Riverfront incorporate a higher FPL than that from the Riverview Road FRMP.
	Structural soundness of completed works to withstand water and debris damage up to the 0.2% AEP (1 in 500 year) event is to be certified by a suitably qualified structural engineer.	**Compliant.** The recommended site specific DCP controls require a structural soundness assessment for the PMF flood event.
	Owners must have measures in place to enable them to self-evacuate to not place additional burden on Emergency Services	**Partially Compliant** The site specific DCP controls include controls to reduce the impact of the development on emergency services. However, an explicit control to have owners provide measures to enable self-evacuation has not been included.
	No Dual Occupancies or subdivisions will be permitted for new residential buildings within: • Riverview Road, • Elia Avenue • Lyrebird Drive subdivision Lot 7 DP809132, Lot 1 DP1053438, Lot 2 DP1053438, Lot 6 DP538956, and Lot 1 DP449102 • All vacant land not already subdivided. .	**Compliant.** The proposed Nowra Riverfront Development does not propose any development within these locations.

13.2.4 NSW Flood Inquiry

During the course of this study, the outcomes of the NSW Independent Flood Inquiry were released (July, 2022[1]). It is noted that the response to the Inquiry is a work in progress and the outcomes and consequences of the Inquiry with regard to planning and emergency management were in development.

Early indications from the recommendations from the Inquiry are that there is the potential for changes to practices and policies related to:

- Land use, planning and zoning within floodplains;
- The determination of appropriate FPLs, particularly for locations with a high flood risk;
- Flood warning; and,
- Flood evacuation.

While the Inquiry outcomes are still in flux, this report has endeavoured to align with the current understanding of the inquiry outcomes by developing a site-specific FPL, based on the sites flood risk profile, and to proactively consider how flood warning and evacuation can be managed for the site.

The report has aimed to present these assessments transparently so as to allow later consideration of the suitability of this report's recommendations in light of any final outcomes and directions from the Inquiry process.

13.2.5 Local Planning Directions

The Minister for Planning can issue Ministerial Directions to issues directions to planning authorities about the preparation of planning schemes and amendments to planning schemes.

Planning authorities must comply with the Ministerial Direction on the Form and Content of Planning Schemes, issued under Section 9.1(2) of the *Environmental Planning and Assessment Act 1979*. The direction applies to planning scheme layout and required information – including amendments to those planning schemes – and should be read together with the Planning Provisions.

On 1 March 2022, revised Local Planning Directions were issued relating to, in part, flood resilience and hazard. The Directions (Direction 4.1 Flooding) were issued to commence 1 March 2022 (replacing previous Direction 4.3).

The objectives of this direction are to:

(a) Ensure that development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy and the principles of the Floodplain Development Manual 2005, and

(b) Ensure that the provisions of an LEP that apply to flood prone land are commensurate with flood behaviour and includes consideration of the potential flood impacts both on and off the subject land.

Of relevance to the Riverfront Precinct, the Directions stated under Direction 4.1(3) and 4.1(4).

[1] https://www.nsw.gov.au/sites/default/files/noindex/2022-08/VOLUME_ONE_Summary.pdf, accessed 19 October 2022.

Direction 4.1(3) states that:

A planning proposal must not contain provisions that apply to the flood planning area which:

(a) permit development in floodway areas,
(b) permit development that will result in significant flood impacts to other properties,
(c) permit development for the purposes of residential accommodation in high hazard areas,
(d) permit a significant increase in the development and/or dwelling density of that land,
(e) permit development for the purpose of centre-based childcare facilities, hostels, boarding houses, group homes, hospitals, residential care facilities, respite day care centres and seniors housing in areas where the occupants of the development cannot effectively evacuate,
(f) permit development to be carried out without development consent except for the purposes of exempt development or agriculture. Dams, drainage canals, levees, still require development consent,
(g) are likely to result in a significantly increased requirement for government spending on emergency management services, flood mitigation and emergency response measures, which can include but are not limited to the provision of road infrastructure, flood mitigation infrastructure and utilities, or
(h) (h) permit hazardous industries or hazardous storage establishments where hazardous materials cannot be effectively contained during the occurrence of a flood event.

Direction 4.1(4) states that:

A planning proposal must not contain provisions that apply to areas between the flood planning area and probable maximum flood to which Special Flood Considerations apply which:

(i) permit development in floodway areas,
(j) permit development that will result in significant flood impacts to other properties,
(k) permit a significant increase in the dwelling density of that land,
(l) permit the development of centre-based childcare facilities, hostels, boarding houses, group homes, hospitals, residential care facilities, respite day care centres and seniors housing in areas where the occupants of the development cannot effectively evacuate,
(m) are likely to affect the safe occupation of and efficient evacuation of the lot, or
(n) are likely to result in a significantly increased requirement for government spending on emergency management services, and flood mitigation and emergency response measures, which can include but not limited to road infrastructure, flood mitigation infrastructure and utilities.

A summary of if and how the proposed development complies these directions is provided in **Table 13-3** and **Table 13-4** for Directions 4.1(3) and 4.1(4) respectively.

It is noted that 4.1(3), which applies to land below the flood planning level, would only be applicable to the site if the PMF was adopted as the residential FPL, in which case it would only apply to residential developments. Otherwise, development will be above the FPL in which case only 4.1(4) would be applicable.

Table 13-3 Compliance with Ministerial Directions 4.1(3)

Clause 4.1(3)	Performance Criteria	Compliance
A planning proposal must not contain provisions that apply to the flood planning area which:		
(a)	permit development in floodway areas	**NOT COMPLIANT (Wharf Road Sub-Precinct Only)**. The Wharf Road sub-precinct sits within the PMF floodway. All other sub-precincts are compliant. It is not feasible to alter the floodway of the Shoalhaven River. As such, compliance with this direction would require that the Wharf Road sub-precinct remain undeveloped.
(b)	permit development that will result in significant flood impacts to other properties	**Compliant**. Comprehensive testing of both riverine and local catchment floods has demonstrated no significant impacts beyond the site boundary.
(c)	permit development for the purposes of residential accommodation in high hazard areas	**NOT COMPLIANT** In the PMF event, both the Scenic Way and Wharf Road sub-precincts, as well as portions of all other sub-precincts are within H5 or H6 flood hazard categories. Locating residential development on higher ground within the Mandalay Avenue, Hyam Street and Bridge Road sub-precincts, and restricting residential development on the Scenic Drive and Wharf Road sub-precincts would limit the extent of the non-compliance.
(d)	permit a significant increase in the dwelling density of that land	**NOT COMPLIANT**. The proposed development would result in a significant increase in the dwelling density of the land within the PMF extent. Adopting a low population scenario and/or limiting residential land uses would limit the extent of the non-compliance.
(e)	permit the development of centre-based childcare facilities, hostels, boarding houses, group homes, hospitals, residential care facilities, respite day care centres and seniors housing in areas where the occupants of the development cannot effectively evacuate	**To be determined**. The final usage of the proposed premises of the Precinct have not yet been determined. It is noted that the direction has the potential to limit what activities may be able to be approved for the development.
(f)	permit development to be carried out without development consent except for the purposes of exempt development or agriculture. Dams, drainage canals, levees, still require development consent	**Compliant.** Development within the Precinct will require development consent to be issued by Council.
(g)	are likely to result in a significantly increased requirement for government spending on emergency management services, and flood mitigation and emergency response measures, which can include but not limited to road infrastructure, flood mitigation infrastructure and utilities	**Partially Compliant**. While the development of the Precinct is likely to impose a cost relating to emergency management and response, the planning controls developed for the Precinct aim to transfer the additional funding responsibility to the developer/owner (via the imposition of Covenants) with regard to emergency warning and evacuation. However, the development would likely increase resourcing requirements for the SES, even with the warning system and other emergency related development controls in place.

Clause 4.1(3)	Performance Criteria	Compliance
(h)	permit hazardous industries or hazardous storage establishments where hazardous materials cannot be effectively contained during the occurrence of a flood event.	**Compliant.** Hazardous industry and hazardous storage are not within the Precinct.

Table 13-4 Compliance with Ministerial Directions 4.1(4)

Clause 4.1(4)	Performance Criteria	Compliance
A planning proposal must not contain provisions that apply to areas between the flood planning area and probable maximum flood to which Special Flood Considerations apply which:		
(a)	permit development in floodway areas	**NOT COMPLIANT (Wharf Road Sub-Precinct Only)** The Wharf Road sub-precinct sits within the PMF floodway. All other sub-precincts are compliant. It is not feasible to alter the floodway of the Shoalhaven River. As such, compliance with this direction would require that the Wharf Road sub-precinct remain undeveloped.
(b)	permit development that will result in significant flood impacts to other properties	**Compliant**. Comprehensive testing of both riverine and local catchment floods has demonstrated no significant impacts beyond the site boundary.
(c)	permit a significant increase in the dwelling density of that land	**NOT COMPLIANT**. The proposed development would result in a significant increase in the dwelling density of the land within the PMF. Adopting a low population scenario and/or limiting residential land uses would limit the extent of the non-compliance.
(d)	permit the development of centre-based childcare facilities, hostels, boarding houses, group homes, hospitals, residential care facilities, respite day care centres and seniors housing in areas where the occupants of the development cannot effectively evacuate	**To be determined**. The final usage of the proposed premises of the sub-precinct have not yet been determined. It is noted that the direction has the potential to limit what activities may be able to be approved for the development.
(e)	are likely to affect the safe occupation of and efficient evacuation of the lot	**Compliant**. The site is located in a region with significant flood risk. This FIRA has undertaken to examine these risks, and to provide recommendations for their management. The planning and development controls recommended for the Precinct aim to allow the safe occupation and evacuation of the Precinct.
(f)	are likely to result in a significantly increased requirement for government spending on emergency management services, and flood mitigation and emergency response measures, which can include but not limited to road infrastructure, flood mitigation infrastructure and utilities	**Partially Compliant**. While the development of the Precinct is likely to impose a cost relating to emergency management and response, the planning controls developed for the Precinct aim to transfer the additional funding responsibility to the developer/owner (via the imposition of Covenants) with regard to emergency warning and evacuation. However, the development has the potential to increase resourcing requirements for the SES, even with the warning

Clause 4.1(4)	Performance Criteria	Compliance
		system and other emergency related development controls in place. It is not clear as to whether this would represent a 'significant' increase in government spending.

Overall, the proposed development is generally consistent with the requirements of the Planning Direction. The key exceptions to this are:

- The construction of residential development within high hazard zones (only applicable if the PMF is adopted as the residential FPL);
- The location of the Wharf Road sub-precinct in the PMF floodway;
- The increased residential population within the PMF extent; and,
- The potential additional burden placed on emergency services to manage evacuation of the Precinct in rare and extreme events.

The Planning Direction does allow for a departure from these requirements if:

> *the planning proposal is supported by a flood and risk impact assessment accepted by the relevant planning authority and is prepared in accordance with the principles of the Floodplain Development Manual 2005 and consistent with the relevant planning authorities' requirements (Direction 4.1 (5) (c)).*

This Flood Risk Impact Assessment has been prepared to demonstrate that the proposed development of the Precinct can be undertaken in such a way as to minimise the impacts of these departures from the Ministerial Directions.

The residual risk present across the Precinct is proposed to be managed by planning and development controls (refer **Section 14**), which contain explicit controls to reduce the risk to occupants and the burden placed on emergency services in the event of a flood event.

14 Draft Development Controls for Precinct

The raising of the building pads to the proposed FPL based on a 0.5% AEP plus 0.5m level effectively addresses several flood controls within the current planning framework. Site specific controls are thus concerned with managing the residual risk of floods greater than the planning flood event.

Draft controls for the Precinct are presented in **Table 14-1**.

Table 14-1 Draft Development Controls for the Riverfront Precinct

Item	Details
FPL	**Control:** FPL to be set for habitable and non-habitable floor levels as per figure … *[Figure to be inserted at time of writing site DCP].* The levels are based on the 0.5% AEP + SLR (0.36m) + Freeboard (0.5m). **Rationale:** The 2021 flood prone land package allows Councils to set local FPLs based on the flood behaviour and risk identified in Flood Studies and Floodplain Risk Management Studies and Plans. This allows Councils to adopt higher planning levels in response to higher flood risks. In the case of the Nowra Riverfront Precinct, there is a residual risk associated with the PMF, which cannot be managed through the design of the Precinct. The residual flood risk is the flood risk that remains even when development is undertaken in line with all relevant controls. As such, it is recommended that a higher planning level be adopted for the Precinct to assist in managing this risk, namely the 0.5% AEP plus 0.5m, incorporating sea level increases to 2100. Compared with the historically typical planning level of the 1% AEP plus climate change impacts plus 0.5m freeboard, the recommended FPL is 0.5m higher. Given the batter slopes of 1 in 4 for fill platforms, this additional 0.5m in height results in the loss of a 2m strip at the edge of the edge of the buildings pads, compared to a pad based on the 1% AEP. This loss of area is minor compared to the full pad extent, and the additional height offers distinct advantages: • Additional flood immunity for the Precinct. Over time, the flood immunity will be reduced because of climate change impacts. The development of the Precinct is a long-term proposition, and there will not be future opportunities to raise the pads further. Adopting a higher pad level now aids in managing future flooding risks. • The additional height increases both the available flood warning time and the evacuation time. Evacuation will be necessary in extreme flood events and this extra time will facilitate the safe evacuation of people from the Precinct. It is noted that higher pad levels do not benefit Wharf Road, as the evacuation of this sub-precinct is controlled by external roads with a lower flood immunity. • The addition pad height will serve to assist occupants to evacuate themselves (supported by Emergency Evacuation controls below) by providing extra flood warning evacuation time.

Item	Details
	As a result of these advantages, and the relatively minor impact on developable extent, a higher FPL based on the 0.5% AEP design flood event is recommended for the Precinct.
	Control: A continuous landform to be provided at the FPL as a minimum to existing high ground at each sub-precinct boundary. It is noted that this would require appropriate staging to ensure that there is continuous access. **Rationale:** This control is to ensure that even if a sub-precinct is first developed away from existing high ground, that a continuous pad will be raised up as part of that development. It has been included as a control to prevent any initial development becoming a 'flood island' until such time as subsequent development raises the remaining landform. It also ensures that the raised pad is extended to existing high ground, and that no low points or depressions around the pad edges will impede pedestrian evacuation in a large flood event. Further assessments will be required for the Wharf Road sub-precinct to achieve this control.
	Optional Control: Residential FPL across the Precinct to be set at the PMF as per figure … *[Figure to be provide at time of writing site DCP].* **Rationale:** While evacuation is the recommended approach for managing occupant risk during flood events, it is appreciated that not all occupants will not adhere to evacuation warnings, and that others may not be able to do so. To reduce the risks to these occupants the residential FPL could be set at the PMF. The PMF has depths over the proposed sub-precinct pads in the order of 3.2 – 3.8m. This control could be met by either locating all residential properties on the second floor and higher, or having a higher ground floor height, such that the first-floor levels were at the PMF (noting that normal internal floor to ceiling height is 2.7 m).
	Control: Type H land use categories as per Schedule 1 in DCP Chapter G9 to be located outside the PMF extent. **Rationale:** Type H land uses are buildings and activities requiring special evacuation consideration, namely childcare, community facility, educational establishment, emergency services facility, health services facility, hospital, residential care facility, schools, and seniors housing. These locations have occupants more who are more at risk during a flood event and/or are services that will need to continue operating during extreme flood events. Under current Council controls, these land uses require floor levels to be above the PMF. In the Nowra Riverfront Precinct, this could result in these flood sensitive developments becoming isolated in large flood events. As such, it is recommended that they be located outside the PMF extent. This will largely prevent these land uses being permitted within the Precinct, with the

Item	Details
	exception of the western portion of the Mandalay Avenue sub-precinct which retains some flood-free land in the PMF event.
Filling in the floodplain	**Control**: Filling to the FPL required within the regions shown on … *[Figure to be provided at time of writing site DCP].* Except if shown, no filling or development is permitted within or over areas identified as floodway (up to and including the PMF floodway). **Rationale**: The study has demonstrated that the only feasible method of protecting the proposed Precinct from riverine flooding is to elevate the development pads. The study has also demonstrated that the final Precinct pad levels and extents do not result in off-site impacts in the 0.5% AEP, and result in acceptable and minor impacts in larger events.
Emergency evacuation	**Control:** All buildings to have a flood communication system capable of issuing manual alerts and warnings, with the issuing of alerts and warnings provided by the building owner / manager at the direction of the SES, whilst either on- or off-site. The warning system should incorporate sirens with voiced directions in accordance with the Australian Warning System, as well as the ability to transmit SES voice or recordings during a flood event. **Rationale:** The preparation of flood response plans is often a requirement for developments for which a residual flood risk is present. However, feedback from the NSW SES and Council suggests that these Plans are often poorly formulated and adhered to, with the result that owners and occupants are not fully prepared to manage large flood events and are therefore reliant on the NSW SES. It is noted that the Shoalhaven River catchment is included in the BoM Flood Warning Service. Furthermore, the SES is currently transitioning to standardised communication in accordance with the Australian Warning System classifications (Advice, Watch & Act, Emergency Warning) from September 2022, allowing community-based warnings to be issued, rather than catchment-based, as has historically occurred. These existing systems already provide some level of warning for the lower Shoalhaven region. This control is not intended to duplicate these existing warnings that may be issued by BoM or NSW SES, nor to provide alerts or warnings separate from these agencies, but rather to provide targeted warning and evacuation alerts to occupants of the buildings at the direction of the SES. These warnings and alerts should incorporate alarms/sirens and voiced directions to guide occupants in responding appropriately to floods, similar to the approach adopted for fire alarms and evacuation directions. This style of warning is necessary for the Precinct, as it will also serve as a commercial hub, and not all visitors to the Precinct can be expected to understand the flood risk and appropriate responses. The ownership and operation of the system would be determined from further discussions between Council, NSW SES and DPE. It is recommended any system

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	developed be independent of building owners / operators. Some form of contributions plan, or specific tax/levy should be implemented to ensure that costs (both upfront and ongoing) are covered by developers, but that responsibility for undertaking maintenance and testing lies elsewhere.
	Control: All developments to prepare and maintain a Flood Emergency Response Plan, with the plan to be approved by Council Flood Engineers in consultation with the SES. **Rationale**: The residual risk that remains for the Precinct due to the PMF depths and hazard requires conscious and active management by property owners and/or building managers. Whilst historically flood evacuation plans are anecdotally unused, an effort has been made as part of this control to ensure that they remain a live document. Similar to warning system checks and drills associated with fire emergency plans, a similar approach should be undertaken for flood warning and response, so that all involved (building mangers, owners, residents, etc) are familiar with the warnings, and the actions to be taken at each warning stage. A pro-forma should be developed by Council to attach to the DCP for individual developments to complete and submit with their applications. At a minimum, the pro-forma Plan should detail: • The actions and responsibilities arising from alerts and warnings issued from the flood warning system (see above). • The evacuation procedure for the building and relevant muster points. • Evacuation route(s) from the development to a location flood free in the PMF event. • A schedule for the regular testing of the warning system, to ensure that it remains active, and that residents / businesses are aware of the alerts and what they mean.
	Control: All internal roads within development sub-precincts to provide constant rising road access to the Precinct boundary. **Rationale:** The safe evacuation of the Precinct is a key issue in managing the residual flood risk. As part of this, all roads constructed within the Precinct should have constant rising road access to roads at the Precinct boundary. This is to prevent local low points that would be at risk of interfering with the evacuation of the sub-precincts.
Open Car Parking	**Control:** The flood hazard within the carpark is not exceed H1 in the 0.5% AEP event. **Rationale:** Limiting the hazard to H1 in the 0.5% AEP ensures that people are able to safely access their vehicles for evacuation purposes for events up to and including the 0.5% AEP. This would allow some open carking on the batter slopes of the pads if desired.
	Control: All open car parks to provide rising road access to the exit of the carpark.

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	Rational: The control ensures that people do not become trapped in carparks, by ensuring that the exit from the car park is at the high point of the carpark, and that the road that the car park exits on to is also higher than the carpark, allowing for safe evacuation.
	Control: Car park design to account for vehicle stability in events up to and including the PMF. Some flexibility in this control may be warranted for small car parks (e.g., Up to 3 light vehicle parking spaces). **Rational:** Cars can be moved or become caught up in flood waters, particularly as depths and velocities increase. They can pose a hazard to people and structures and can contribute to culvert and bridge blockage. It is noted that due to the significant depths in the PMF event, bollards or fencing is unlikely to be suitable for preventing vehicle movement. A more robust method, such as under croft parking, could potentially control vehicle movements in extreme events, such as the PMF event.
Basements and Basement Carparking/Storage	**Control:** Basements (including) carparking to proactively address and manage flood risk to people and vehicles for the full range of flood events, including consideration of flood risk and response in the PMF. Mechanical and electrical services should not be placed in flood-affected basements (up to and including the PMF). **Acceptable Solutions:** All basement car parking entry, exit and access points to be set at or above the 0.05% AEP flood level with active flood protection up to the PMF level. **Performance Criteria**: Basement design to demonstrate: • Floodwaters are excluded from the basement through passive protection of all car parking entry, exit and access points up to the 0.05% AEP flood level and with active protection (i.e., flood gates or similar) between the 0.05% AEP flood level and PMF. • That emergency evacuation of people within the basement is feasible to a flood-free level for all flood events up to and including the PMF event. • That flooding will not result in flood-affected (floating) vehicles impacting the ability of people to evacuate the basement (such as by blocking doors). • That rising flood waters will naturally direct people to evacuation routes (effectively rising road access within the basement). **Rationale:** Basement use (carparking and storage) presents a significant flood risk in the Riverfront Precinct. PMF depths are such that a basement is likely to be fully inundated (i.e., flood waters will reach the ceiling), creating a high-risk environment for any persons trapped within the basement. The design of basements should take this risk into account and proactively demonstrate how this risk is being managed.
Structural Soundness	**Control**: All structures to be designed to withstand the forces of floodwaters (including debris and buoyancy forces) in the PMF event. **Rationale**: While the early evacuation of all occupants is proposed for the Precinct in extreme flood events, should people be unable or unwilling to

Item	Details
	evacuate, they will be obliged to shelter in place for the duration of the flood event as an option of last resort.
Hydraulic Impact	**Control**: Any proposed changes to the extents and levels of the filled pads requires a Flood Impact and Risk Assessment. **Rationale**: Designs developed for the site may opt for different levels or extents for the fill pads in order to facilitate the proposed development. For example, a smaller fill extent may be proposed to save costs if the development is only taking up a portion of the site. Such changes are reasonable to explore, but they should be required to demonstrate that the changes have no impact on flood behaviour for the full range of design events (including the 0.05% AEP at which overtopping of the Princes Highway first occurs) and for both riverine and local catchment flooding.
Building Components	**Control**: All structures to have flood compatible building components below the PMF. **Rationale**: The use of flood compatible building components below the PMF has two primary goals. Firstly, is seeks to ensure the continued operation of building systems during extreme events such that occupants who elect not to evacuate when directed or are unable to evacuate continue to have access to power, water and sewer throughout the event. It is noted that while this control can ensure that the building remains functional, failure of the system elsewhere may still result in loss of services at the site. Secondly, it will reduce potential flood damages and post flood recovery costs and time arising from extreme flood events.

15 Precinct Land Use

Land use has the potential to affect the risk profile of a region by controlling the number and types of occupants that may be expected to be onsite during a flood event.

Commercial, industrial and tourist zonings have a lower flood risk than residential due to:

- The sites not being used full time (most businesses close overnight for example)
- The sites not being always used to capacity (tourist sites would have lower numbers in the off season for instance)
- Occupants do not have a significant personal investment in the site (business owners excepted) so are more likely to leave, or to not have visited in the first place during heavy rain.
- The lack of personal connection would also make occupants more likely to leave in response to an evacuation order as they would not be tempted to remain behind to protect belongings.

Conversely, the transitory nature of these land uses reduces the ability to build up an awareness of the flood risk and appropriate actions to take in a flood event.

A summary of the currently proposed sub-precinct land uses by Council, their suitability with respect to the flood behaviour, and how the proposed planning controls may affect development are presented in **Table 15-1**.

The SES assessment found that all sub-precincts could be evacuated within the available warning time, given various assumptions on development density and the number of SES door knocking teams available. While the SES has undertaken this assessment assuming up to three teams may be available, the reality is that a flood of greater than the 0.5% AEP (which would threaten to inundate the proposed pads) would see widespread flooding and road closures across potentially numerous areas on the south coast and the Greater Sydney region, placing substantial numbers of people at risk, and stretching the ability of the SES to respond in all locations.

It is acknowledged that different density scenarios from those modelled in each sub-precinct could potentially be possible, but that these would require revised evacuation modelling using the NSW SES timeline evacuation procedure if they were put forward in the future. Alternative population scenarios should also consider the flood risk and potential implications on the safe occupation of the development as part of a Flood Impact and Risk Assessment prepared in accordance with the *Flood Risk Management Guideline LU01: Flood Impact and Risk Assessment*, of the *NSW Flood Risk Management Manual: the policy and manual for flood liable land* (DPE, 2023).

Considering the results of the NSW SES timeline evacuation modelling, the flood risk for each sub-precinct and the proposed measures to manage residual risk, it is recommended that the development density for each sub-precinct be based on the following population scenarios:

- The low population scenario for the Wharf Road and Pleasant Way sub-precincts;
- The medium population scenario for the Mandalay Avenue, Hyam Street and Bridge Road sub-precincts; and,
- The high population scenario for the Scenic Drive sub-precinct.

Refer **Table 9-1** for Low, Medium, and High population estimates.

Table 15-1 Suitability of Proposed Sub-Precinct Land Use

Mandalay Avenue	**Zoning**	R3 Medium Density Residential
	Flood Risk	This land use is considered appropriate. Of all the sub-precincts, Mandalay Avenue is the most appropriate for flood-compatible residential development. Portions of the site remain flood free in the PMF, and access to flood free land and flood refuges is short, utilising rising road access routes.
	Building Controls	Accommodation would be permitted on all floors, including the ground flood, based on the recommended FPL and the pad levels. Alternatively, if the adoption of the PMF as the residential FPL was implemented, this would prevent ground floor residential development in this sub-precinct. The development in this sub-precinct could utilise the ground floor for parking, which would have the additional benefit of removing the need for basement car parking.
Hyam Street	**Zoning**	MU1 Mixed Use **R3 Medium Density Residential Recommended as Suitable**
	Flood Risk	An R3 land use is considered appropriate, provided sensitive land uses (such as childcare, aged care, etc) are not permitted as per the proposed development controls. While this pad is fully inundated in the PMF, it has direct rising road access to flood free land and potential flood refuges. Since this sub-precinct has the second lowest flood risk profile after Mandalay Avenue, it is suggested that this would be a more suitable location for residential zoning than the Pleasant Way sub-precinct (see below).
	Building Controls	Accommodation and commercial use would be permitted on all floors, including the ground flood, based on the recommended FPL and the pad levels. Alternatively, if the adoption of the PMF as the residential FPL was implemented, this would prevent ground floor residential development in this sub-precinct. If the PMF was adopted as the residential FPL, utilisation of the ground floor for commercial premises or car parking would be acceptable.

Scenic Drive	**Zoning**	SP3 Tourist
	Flood Risk	This land use is considered appropriate. The sub-precinct has rising road access to flood free land and refuges via the Hyam Street sub-precinct. The risk profile of this pad is lower than other sub-precincts for which more intensive development is proposed (Bridge Road and Pleasant Way). Whilst it is noted that having tourist infrastructure close to the river is desirable, it is recommended that consideration be given to locating the more intensive development within this sub-precinct, in preference to it being located in a low flood island elsewhere.
	Building Controls	Accommodation and commercial use would be permitted on all floors, including the ground flood, based on the recommended FPL and the pad levels. Alternatively, if the adoption of the PMF as the residential FPL was implemented, this would prevent ground floor residential development in this sub-precinct. If the PMF was adopted as the residential FPL, utilisation of the ground floor for commercial premises or car parking would be acceptable.
Bridge Road	**Zoning**	MU1 Mixed Use
	Flood Risk	This land use is considered appropriate, provided sensitive land uses (such as childcare, aged care, etc) are not permitted as per the proposed development controls. However, it is noted that this sub-precinct is a low flood island. It is recommended that FSR ratios and/or building heights be reduced for this sub-precinct in order to limit the number of medium to long term occupants within the sub-precinct. **If residential development is desired for this sub-precinct, a pedestrian egress route to higher ground west of the highway would be required. It is noted that despite the relatively short distances to be traversed to flood-free ground, the SES have identified that they do not support pedestrian evacuation as the primary evacuation strategy.**
	Building Controls	Accommodation and commercial use would be permitted on all floors, including the ground flood, based on the recommended FPL and the pad levels. Alternatively, if the adoption of the PMF as the residential FPL was implemented, this would prevent ground floor residential development in this sub-precinct. If the PMF was adopted as the residential FPL, utilisation of the ground floor for commercial premises or car parking would be acceptable.

Pleasant Way	**Zoning**	R3 Medium Density Residential
	Flood Risk	**This land use is not considered appropriate.** Whilst the development controls would see all residential properties located above the PMF, this sub-precinct is a low flood island, which is not a suitable location for residential development. Other sub-precincts (such as Hyam Street and Scenic Drive) allow for the provision of rising road access and would be a more suitable location for residential developments. **If residential development is desired for this sub-precinct, a pedestrian egress route to higher ground west of the highway would be required. It is noted that despite the relatively short distances to be traversed to flood-free ground, the SES have identified that they do not support pedestrian evacuation as the primary evacuation strategy.**
	Building Controls	The adoption of the PMF as the residential FPL would prevent ground floor residential development in this sub-precinct. The develop could utilise the ground floor for parking, which would have the additional benefit of removing the need for basement car parking.
Wharf Road	**Zoning**	SP3 Tourist
	Flood Risk	This land use is considered appropriate. The Wharf Road sub-precinct has the highest flood risk of all the sub-precincts, due to it being a low flood island, and that access from the pad is lost earlier than other sub-precincts. Restricting the amount of long-term occupants in this region is appropriate. The SP3 Tourist zoning would permit some short to medium stay accommodation, but as discussed in Section 10, these occupants are more likely to evacuate in response to a flood warning as they will not have substantial personal possessions to pack or protect. **Residential development is not considered suitable for this sub-precinct under the current arrangements due to the risk profile of the sub-precinct. If residential development is desired then works to Pleasant Way would be required to provide rising road access to the FPL, and a high-level pedestrian to higher ground west of the highway would be required. It is noted that despite the relatively short distances to be traversed to flood-free ground, the SES have identified that they do not support pedestrian evacuation as the primary evacuation strategy.**
	Building Controls	Accommodation and commercial use would be permitted on all floors, including the ground flood, based on the recommended FPL and the pad levels. Alternatively, if the adoption of the PMF as the residential FPL was implemented, this would prevent ground floor residential development in this sub-precinct. If the PMF was adopted as the residential FPL, utilisation of the ground floor for commercial premises or car parking would be acceptable.

16 Conclusion and Recommendations

16.1 Study Process and Deliverables

The Nowra Riverfront Precinct Flood Impact and Risk Assessment (FIRA) has been prepared for Shoalhaven City Council (Council) to define the existing flood behaviour in the catchment and to assess, and address, if necessary, the potential impacts arising from the future development of the Precinct.

The Study was being conducted to determine if:

- Changed flood behaviour could arise and have adverse impacts on the flood risk to the existing community and development;
- The future development envisaged in the preliminary Nowra Riverfront Precinct Masterplan and its users or occupants can safely be enabled with an acceptable level of flood risk; and
- Effective flood emergency response is achievable without adverse impacts on the ability of the existing community to respond to floods.

The Precinct is an important location that Council plan to utilise to strengthen the role of the Nowra Riverfront Precinct as a civic, community, tourism, and recreational hub for the Shoalhaven region.

Urban design consultants, Studio GL, were engaged in 2018 to prepare recommendations for planning and development controls to shape the region. Studio GL made a number of recommendations for changes to existing zones, floor space ratios and height controls, and prepared preliminary masterplans.

Given the sites proximity to the river, it was noted during this study that future planning controls and zonings would be dependent on detailed flood studies.

The FIRA was required to establish whether impacts are localised and / or can be readily managed and to support/inform land-use rezoning processes / planning proposals and establishment of development controls for future development in the Precinct.

To undertake this assessment:

- A review was undertaken of available data and studies. Of particular relevance was the updated *Lower Shoalhaven Flood Study* (Cardno, 2022) which was used to define the riverine flood behaviour.
- A local catchment flood model was constructed to define the flood behaviour arising from local catchment events. The model was validated against a single historic flood mark from the August 2020 flood event.
- The existing flood behaviour (depth, levels, velocity, and hazard) were defined for both the local catchment and riverine flood events.
- An iterative assessment of potential flood management options was undertaken to inform the types and extents of flood management options that were feasible and did not result in adverse flood impacts.
- A review of flood risk across the Precinct was undertaken, and a recommendation made as to an appropriate Flood Planning Level for the Precinct.
- An assessment was undertaken to examine flood warning time and potential emergency response and evacuation for the Precinct.

- As part of this assessment, an evacuation assessment was undertaken by the SES, which was used to inform site-specific development controls.
- A review was undertaken of Council's existing plans and policies to ensure that the proposed Precinct development is compatible with these controls.

16.2 Recommendations

As a result of the assessments undertaken as part of this study it has been recommended that:

- Raised building pads be adopted as the preferred flood management strategy. A raised building pad was determined to be the primary means by which flood risk could be managed on site as this design approach seeks to provide a level of flood protection for the proposed buildings for both local catchment and riverine flood events, and to assist with flood evacuation though the provision of additional evacuation time.
- That these pads be set at an FPL level based on the 0.5% AEP + SLR + Freeboard. This is in accordance with the recommendations made for the wider Lower Shoalhaven River as part of the Lower Shoalhaven River Flood Study (Cardno, 2022).
- It is noted that the proposed pads result in a flood level increase across Hyam Street and adjacent private properties for the 1% AEP local catchment event. This impact can be managed via two mechanisms:
    - The construction of an additional outlet culvert from the central open space region. It is noted that this culvert would potentially be subject to a substantial approval process due to the work required on the riverbank.
    - Alternatively, a 7m reduction in width can applied to the Mandalay, Scenic Drive and Hyam Street sub-precinct pads adjacent to the central open space. This provides additional storage within the open space, which is sufficient to offset the impacts from the sub-precinct pads.

  A property flood and ground level survey has been recommended for those properties on Hyam Street affected by the increase in 1% AEP local flood levels. The purpose of this assessment is to determine what impact the 0.04m has on property freeboard, and to assist in determining if compensation for or voluntary purchase of these properties is a viable alternative to the implementation of one of the above structural options.
- The Bridge Road, Pleasant Way and Wharf Road sub-precincts are all low flood islands in the PMF event. The Bridge Road and Pleasant Way sub-precincts are largely flood free in the 0.05% AEP. These regions are classed as a low flood islands and become isolated prior to the pad overtopping.

  At the PMF event peak, the Wharf Road sub-precinct is affected by H6 hazard flooding (with velocities in excess of 4m/s). Such flooding conditions are likely to prevent any SES rescue by boat, in the event that occupants refused or where unable to evacuate. The higher points within the Bridge Road and Pleasant Way sub-precincts have a hazard class of H1, although H6 hazard is present along all surrounding roadways. While velocities between these two highpoints exceeds 4m/s along the highway, the surrounding velocities are lower, in the order of 1-2m/s. These lower hazard and velocities may enable access via boat during the course of the flood, although this should not be relied upon.

  From a flood risk perspective, residential development on a low flood island is considered to be an unsuitable land use under the current arrangement. To permit development on these sub-

precincts, some form of pedestrian, if not vehicle, access must be provided at the FPL, from which access to a point above the PMF should be reachable. It is noted that the SES are not supportive of pedestrian evacuation as the primary evacuation strategy.

The Pleasant Way and Bridge Road sub-precincts have this overland connection at the FPL (and at higher events up to and including the 0.05% AEP event). When the pads first overtop, there is overland access across the Princes Highway from the Pleasant Way sub-precinct to the Bridge Road sub-precinct, and from there to flood-free land and flood refuges in the Nowra CBD. These access routes are inundated approximately 6 hours prior to the full sub-precinct becoming inundated in the PMF event.

The Wharf Road pad has a more adverse flood behaviour. Access along surrounding roads, and to the adjacent Pleasant Way sub-precinct are lost prior to the pad being inundated. This occurs in the 0.05% AEP when flows overtop the highway from the west and flow down Pleasant Way. At this point, the pad remains dry, but all access is lost.

While this would ultimately be up to any future development to address, it is suggested that possible strategies may be:

- Raising some portion of the western end of Pleasant Way to allow for pedestrian access at the FPL from the Wharf Road sub-precinct across the highway to flood free land west of the Bridge Road sub-precinct.
- Filling of the western depression between the Wharf Road pad and the Princes Highway to the FPL to allow pedestrian access onto the Highway, and from there to the Pleasant Way sub-precinct from which overland access is available to flood free land in Nowra CBD. It is noted that this land is owned by Transport for NSW.
- Construction of a pedestrian bridge or similar over Pleasant Way to allow for overland evacuation from the Wharf Road sub-precinct to the Pleasant Way sub-precinct from which overland access is available to flood free land in the Nowra CBD.

These works would alter the risk profile of the eastern sub-precincts by changing the emergency response classification of these sub-precincts from low flood islands to rising road. This would be beneficial for any future development in the Wharf Rd and Pleasant Way sub-precincts and would also provide improvements to evacuation ability for the existing Riverview Road area.

- Site-specific DCP provisions will be developed at a later stage of the Precinct planning process. This study has prepared a draft set of development controls for inclusion in the DCP with respect to managing flood risk within the Precinct. The draft controls address:
  - Flood planning levels;
  - Filling in the floodplain;
  - Emergency warning and evacuation;
  - Carparking (both open and basement); and,
  - Structural soundness.
- That a Flood Communication System be implemented for the Precinct that:
  - Is capable of issuing manual and automatic flood and evacuation alerts. The alerts could be staged, with an initial warning given to occupants to allow time to process the need for

evacuation before the official evacuation order is given. This would serve to maximise the time available for the actual evacuation process.
    - Has appropriate redundancies to ensure that it remains operable in a flood event.
    - Incorporates regular testing to ensure it remains operable, and that occupants become familiar with the warnings that would be issued in a large flood event.
    - Is developed and designed and maintained by an appropriately experienced and qualified third party, with both upfront and ongoing costs leveraged on the Precinct developers / owners. Such an arrangement ensures that that the building owners retain financial responsibility for the warning system, and that funds for the ongoing costs of the system are made available, irrespective of ownership of the buildings. The third party would then be responsible for maintenance, testing and operation, in consultation with Council and the SES.
    - Whilst beyond the scope of this study, Council may also wish to ensure that any system developed has the potential to be expanded upon, so as to draw in both existing and future development if and when required.
- The timely evacuation of the Precinct was indicated to be feasible by SES evacuation modelling by one door knocking team for the low-density scenario, two teams for the medium-density scenario, and three teams for the high-density scenario (with the exception of high-density in the Mandalay sub-precinct).
- Recommended land uses for each Precinct, as summarised in **Table 17-1**.

Table 17-1 Recommended Land Uses for Sub-Precincts

Sub-Precinct	Recommended Land Uses	Not Recommended Land Uses
Mandalay	All uses suitable. Residential recommended to be located in these sub-precincts in preference to the eastern sub-precincts	N/A
Hyam Street		
Scenic Drive		
Bridge Road	Tourist (Non-permanent population), Commercial	Residential
Pleasant Way		
Wharf Road		

It was found that the Precinct development is generally in accordance with relevant plans and policies. The possible exceptions to this were with regard to Ministerial Directions issued 1 March 2022. Aspects of the sub-precincts that may potentially conflict with these Directions are:

- The construction of residential development within high hazard zones (only applicable if the PMF is adopted as the residential FPL);
- The Wharf Road sub-precinct, which is located within the PMF floodway, and results in a significant increase in population density with the PMF; and,
- The Scenic Drive sub-precinct, which results in a significant increase in population density within the PMF.
- The potential additional burden placed on emergency services to manage any evacuation of the Precinct.

Overall, this report has demonstrated that flooding risks for the western sub-precincts (Mandalay, Hyam Street and Bridge Road) have been appropriately addressed, and that the proposed land use types for these sub-precincts are consistent with the flood risk profile.

The eastern sub-precincts (Bridge Road, Pleasant Way, and Wharf Road) are all low flood islands and present a higher flood risk profile. Whilst the study has demonstrated that lower population density land-uses are suitable for these sub-precincts (such as commercial or tourist uses), the inclusion of residential development within the sub-precincts would require further, sub-precinct specific assessments into, as a minimum:

- The ability to provide pedestrian egress routes for relatively short distances to higher ground for all eastern sub-precincts (noting that SES does not support pedestrian evacuation as the primary evacuation strategy); and,
- Raising of Pleasant Way to facilitate the evacuation of both the Pleasant Way and Wharf Road sub-precincts. Coincident works to the Pleasant Way works, a highway intersection upgrade may also be required, or desired, in order to improve emergency access.

17 References

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DPE (2023). *Flood risk management manual: The policy and manual for the management of flood liable land.*

NSW Government (2005). *Floodplain Development Manual.*

Opper, Cinque and Davies (2010). *Timeline modelling of flood evacuation operations*. Procedia Engineering, Volume 3, 2010, Pages 175 – 187.

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Thomas & Golaszewski (2012). *Methodology for Determining Floodway / Flow Conveyance Extent in Australian Floodplains*. Hydrology and Water Resources Symposium 2018.

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WMAwater (2002). *Riverview Road Area – Nowra Floodplain Risk Management Study and Plan*. Prepared for Shoalhaven City Council.

Appendix A

Collected Survey

SCIMS
MGA

MANDALAY AVE

HYAM STREET

SCENIC DR

SWP

SURVEYED: S.A.	DRAWN: J.S.S.	ORIGIN OF LEVELS:SSMI2226	RL: 5.286
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Shoalhaven City Council

CITY OF SHOALHAVEN

NOWRA RIVERFRONT DETAIL SURVEY
OCTOBER 2020I

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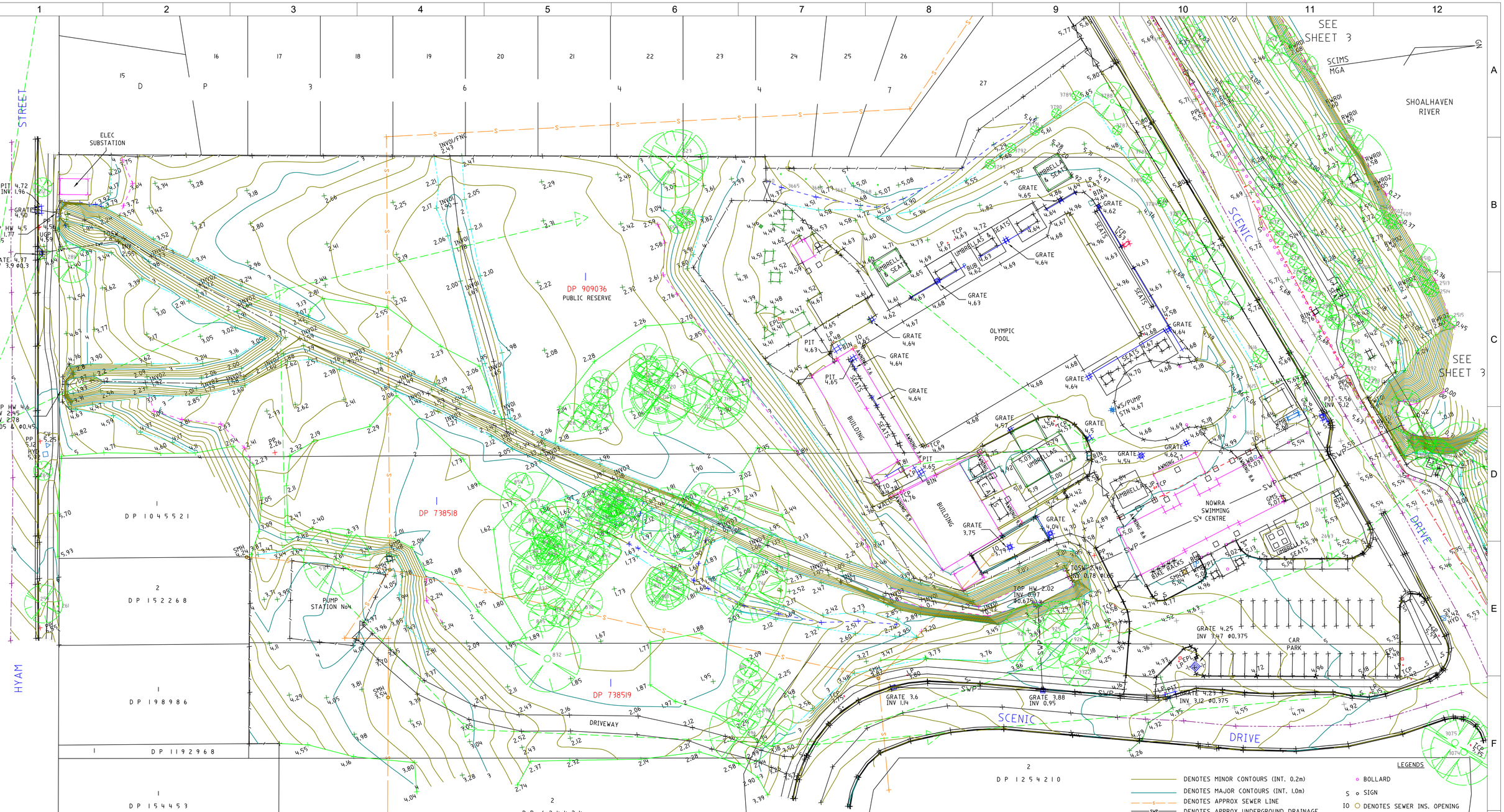

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TREES AND SERVICES ARE SHOWN SYMBIC & MAY NOT REPRESENT THE ACTUAL FEATURE.
BOUNDARIES SHOWN ARE FROM SHOALHAVEN CITY COUNCILS GIS AND ARE INDICATIVE ONLY.
UNDERGROUND SERVICES SHOWN ARE INDICATIVE ONLY, POTHOLING MUST BE UNDERTAKE PRIOR TO ANY CONSTRUCTION.

Point	Elevation	Code
212	4.778	T×S4/.3X4
259	6.513	T×S8/.6X8
261	6.417	SHRUB
265	5.492	T×S4/.3X4
284	4.954	T×S8/.6X8
531	3.750	T×S14/1.3X14
623	3.382	T×S12/.7X12
624	3.331	T×S14/1.3X14
657	3.303	T×S4/.3X4
658	3.306	T×S4/.3X4
659	3.241	T×S4/.3X4
710	2.143	T×S6/.3X6
711	1.919	T×S6/.3X6
712	2.387	T×S12/.7X12
713	2.577	T×S12/.7X12
714	2.448	T×S14/1.3X14
715	2.450	T×S6/.3X6
716	1.989	T×S14/1.3X14

Point	Elevation	Code
717	1.993	T×S6/.3X6
718	2.007	T×S14/1.3X14
719	2.229	T×S8/.6X8
720	2.084	T×S14/1.3X14
721	2.195	T×S8/.6X8
722	2.349	T×S6/.3X6/X6
723	2.426	T×S8/.6X8
724	2.306	T×S6/.3X6/X6
725	2.349	T×S6/.3X6/X6
726	2.321	T×S6/.3X6/X6
727	2.273	T×S6/.3X6/X6
728	2.464	T×S6/.3X6/X6
729	2.401	T×S6/.3X6/X6
760	2.720	T×S14/1.3X14
761	2.624	T×S14/1.3X14
762	2.300	T×S14/1.3X14
790	2.137	T×S12/.7X12
791	2.096	T×S14/1.3X14

Point	Elevation	Code
792	2.042	T×S14/1.3X14
794	2.131	T×S6/.3X6/X6
795	2.148	T×S6/.3X6/X6
796	2.127	T×S6/.3X6/X6
797	2.170	T×S4/.3X6
798	2.370	T×S6/.3X6/X6
799	2.245	T×S8/.6X8
800	2.006	T×S8/.6X8
801	1.808	T×S6/.3X6/X6
802	1.840	T×S6/.3X6/X6
803	2.061	T×S8/.6X8
804	2.181	T×S8/.6X8
805	2.286	T×S8/.6X8
806	2.312	T×S6/.3X6/X6
814	2.155	T×S4/.3X4
815	2.187	T×S6/.3X6/X6
818	2.115	T×S8/.6X8
819	2.168	T×S8/.6X8

Point	Elevation	Code
820	2.187	T×S8/.6X8
821	2.165	T×S8/.6X8
832	2.088	T×S14/1.3X14
833	1.902	T×S6/.3X6/X6
834	1.905	T×S6/.3X6/X6
835	1.905	T×S6/.3X6/X6
836	1.827	T×S6/.3X6/X6
837	1.979	T×S12/.7X12
838	1.914	T×S12/.7X12
839	1.914	T×S12/.7X12
840	1.990	T×S8/.6X8
841	1.997	T×S8/.6X8
842	1.862	T×S6/.8X6
843	2.099	T×S8/.6X8
844	1.964	T×S14/1.3X14
845	1.912	T×S6/.3X6/X6
846	1.869	T×S6/.3X6/X6
847	1.969	T×S6/.3X6/X6

Point	Elevation	Code
848	1.895	T×S6/.3X6/X6
849	1.954	T×S12/.7X12
850	1.932	T×S6/.3X6/X6
851	1.940	T×S12/.7X12
852	2.090	T×S8/.6X8
853	2.065	T×S14/1.3X14
854	1.664	T×S6/.3X6/X6
896	2.496	T×S14/1.3X14
897	2.240	T×S6/.3X6/X6
898	2.536	T×S14/1.3X14
924	3.906	T×S14/1.3X14
925	3.982	T×S14/1.3X14
926	4.035	T×S14/1.3X14
1541	6.713	T×S6/.3X6
1608	6.205	T×S3/.2X3
1609	6.201	T×S3/.2X3
1712	5.806	T×S14/1.4X14
2643	5.450	SHRUB

Point	Elevation	Code
2644	5.299	SHRUB
2645	5.483	SHRUB
3074	5.460	T×S14/1.4X14
3075	5.583	T×S14/1.4X14
3322	4.229	T×S6/.3X6
3602	5.339	SHRUB
3615	5.518	SHRUB
3616	5.629	T×S3/.2X3
3660	4.488	SHRUB
3665	4.685	SHRUB
3666	4.858	SHRUB
3667	5.014	SHRUB
3668	5.137	SHRUB
3780	5.775	T×S8/.5X8
3781	5.795	T×S8/.5X8
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3784	5.496	T×S2/.1X2

Point	Elevation	Code
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3790	5.589	T×S2/.1X2
3791	5.662	T×S2/.1X2
3792	5.647	T×S2/.1X2
3793	5.604	T×S2/.1X2

LEGENDS

- DENOTES MINOR CONTOURS (INT. 0.2m)
- DENOTES MAJOR CONTOURS (INT. 1.0m)
- DENOTES APPROX SEWER LINE
- DENOTES APPROX UNDERGROUND DRAINAGE
- DENOTES CENTRELINE
- DENOTES BOTTOM OF BANK
- DENOTES TOP OF BANK
- DENOTES OVERHEAD ELECT

- BOLLARD
- S SIGN
- IO DENOTES SEWER INS. OPENING
- SV DENOTES STOP VALVE
- HYD DENOTES HYDRANT
- TCP DENOTES TELSTRA PIT
- WB DENOTES WATER BOX
- ELP DENOTES ELECTRIC POWER POLE
- WMR DENOTES WATER METER
- LP DENOTES LIGHT POLE
- PP DENOTES POWER POLE
- SMH DENOTES SEWER MAN HOLE
- DENOTES SHRUB
- GMS DENOTES GAS METER
- TOSW DENOTES TOP OF STORM WATER
- BUB DENOTES BUBBLER
- EJP DENOTES ELEC JUNCTION PIT
- ELC DENOTES ELECTRIC CABINET
- EPL DENOTES PILLAR BOX

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Shoalhaven City Council

CITY OF SHOALHAVEN

NOWRA RIVERFRONT DETAIL SURVEY
OCTOBER 20201

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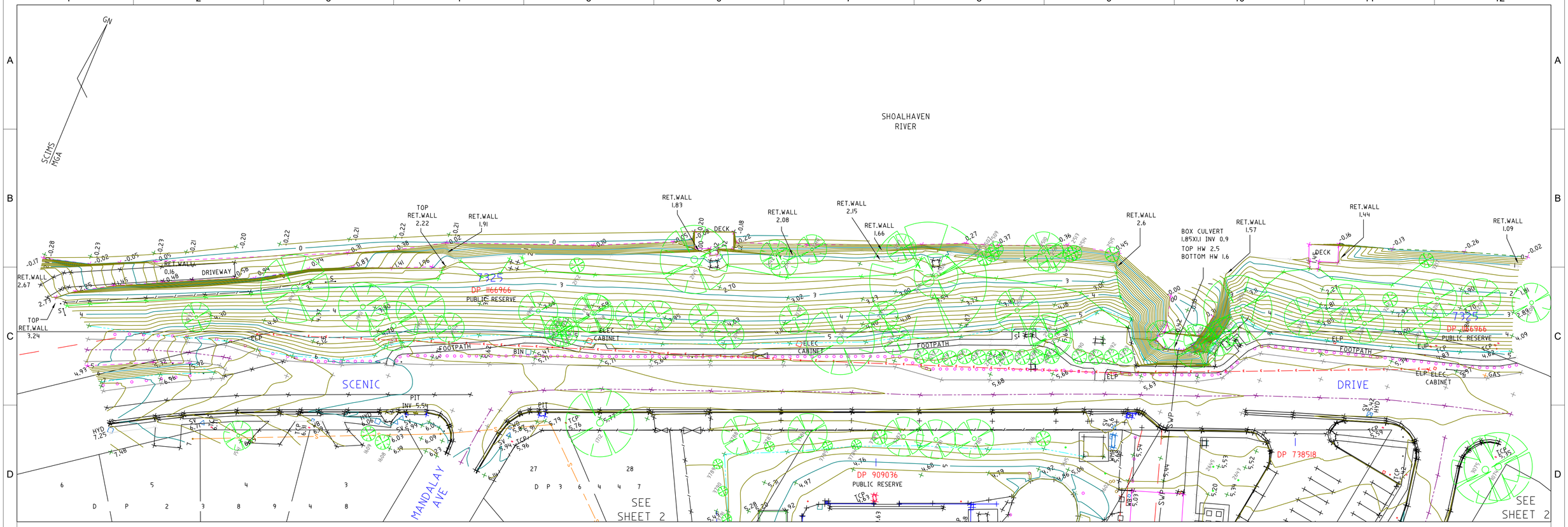

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1953	3.873	T×S10/.6X10
1954	4.809	T×S6/.3X6
1991	3.837	T×S8/.5X8
1992	4.809	T×S3/.2X3
1993	4.723	T×S3/.2X3
1994	4.037	T×S8/.5X8
2130	5.671	T×S3/.2X3
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2135	4.228	T×S6/.3X6
2136	2.937	T×S24/2X24
2137	1.445	T×S6/.3X6

Point	Elevation	Code
2138	4.904	T×SIN/1.4XIN
2139	4.043	T×S6/.3X6
2140	2.298	T×S6/.3X6
2141	2.353	T×S6/.3X6
2142	1.814	T×S6/.3X6
2143	4.609	T×S6/.3X6
2144	4.006	T×S6/.3X6
2145	2.347	T×SIN/1.4XIN
2146	3.903	T×S6/.3X6
2147	3.979	T×S6/.3X6
2148	3.818	T×S8/.5X8
2149	4.898	T×S6/.3X6
2150	4.846	T×S6/.3X6
2152	2.567	T×S3/.2X3
2284	5.679	T×S3/.2X3
2285	5.649	T×S3/.2X3
2286	5.637	T×S3/.2X3
2287	5.646	T×S3/.2X3

Point	Elevation	Code
2288	5.674	T×S3/.2X3
2289	5.704	T×S3/.2X3
2290	5.622	T×S3/.2X3
2291	5.571	T×S3/.2X3
2292	5.588	T×S3/.2X3
2293	5.440	T×S3/.2X3
2476	5.584	T×S8/.5X8
2504	5.559	T×S9/.5X9
2505	4.354	T×S9/.5X9
2506	2.525	T×S9/.5X9
2507	1.762	T×S3/.2X3
2508	1.838	T×S3/.2X3
2509	1.362	T×S3/.2X3
2510	1.429	T×S8/.5X8
2511	1.841	T×S6/.3X6
2513	1.615	T×S3/.2X3
2514	1.469	T×S3/.2X3
2515	1.758	T×S3/.2X3

Point	Elevation	Code
3147	3.526	T×S9/.5X9
3148	5.208	T×S6/.3X6
3151	4.977	T×S6/.3X6
3154	4.338	T×SIN/1.4XIN
3208	2.304	T×S8/.5X8
3209	2.296	T×S8/.5X8
3210	2.454	T×S8/.5X8
3211	3.562	T×S8/.5X8
3212	2.494	T×S3/.2X3
3214	3.594	T×S8/.5X8
3215	2.920	T×S8/.4X8
3216	3.743	T×S8/.4X8
3217	1.299	T×S3/.2X3
3347	0.854	T×S6/.3X6
3355	1.417	T×S6/.3X6

LEGENDS

- DENOTES MINOR CONTOURS (INT. 0.2m)
- DENOTES MAJOR CONTOURS (INT. 1.0m)
- DENOTES APPROX SEWER LINE
- DENOTES APPROX UNDERGROUND DRAINAGE
- DENOTES CENTRELINE
- DENOTES BOTTOM OF BANK
- DENOTES TOP OF BANK
- DENOTES OVERHEAD ELECT

- BOLLARD
- S SIGN
- IO DENOTES SEWER INS. OPENING
- SV DENOTES STOP VALVE
- HYD DENOTES HYDRANT
- TCP DENOTES TELSTRA PIT
- WB DENOTES WATER BOX
- ELP DENOTES ELECTRIC POWER POLE
- WMR DENOTES WATER METER
- LP DENOTES LIGHT POLE
- PP DENOTES POWER POLE
- SMH DENOTES SEWER MAN HOLE
- DENOTES SHRUB
- GMS DENOTES GAS METER
- TOSW DENOTES TOP OF STORM WATER
- BUB DENOTES BUBBLER
- EJP DENOTES ELEC JUNCTION PIT

SURVEYED: S.A.	DRAWN: J.S.S.	ORIGIN OF LEVELS:SSMI2226	RL: 5.286
CHECKED: S.A.	SURVEY DATE: 18/10/21	ORIGIN OF COORDINATES:SSMI2226	
DRAWING FILE:98-2021-NowraRiverDetail.dwg		E: 280568.334	N: 6138883.493
MAGNET FILE:98-2021-NowraRiverDetail.mjo		DATUM: MGA94	CSF: 1.000189
SURVEYOR REF: 98-2021		SOURCES: SCIMS	DATE: 18/10/21

Shoalhaven City Council

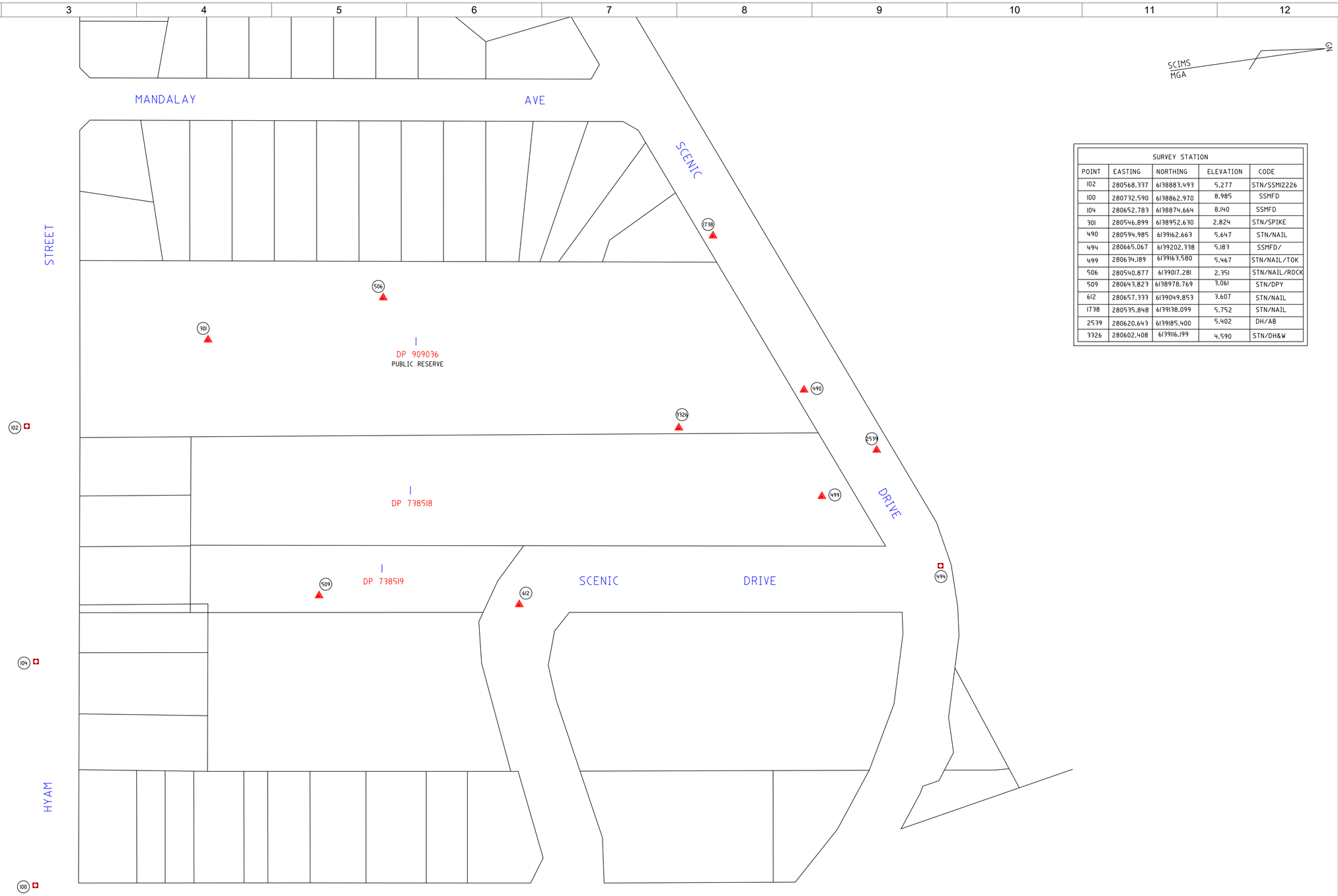
CITY OF SHOALHAVEN

NOWRA RIVERFRONT DETAIL SURVEY
OCTOBER 2020I

SIZE:	SCALE:	SHEET:	REV. NOTE:
AI	1:400	3	N/A

PROPERTY SERVICES MANAGER: DATE:

- DRAWING NUMBER -



SURVEY STATION				
POINT	EASTING	NORTHING	ELEVATION	CODE
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100	280732.590	6138862.970	8.985	SSMFD
104	280652.783	6138874.664	8.140	SSMFD
301	280546.899	6138952.630	2.824	STN/SPIKE
490	280594.985	6139162.663	5.647	STN/NAIL
494	280665.067	6139202.338	5.183	SSMFD/
499	280634.189	6139163.580	5.467	STN/NAIL/TOK
506	280540.877	6139017.281	2.351	STN/NAIL/ROCK
509	280643.823	6138978.769	3.061	STN/DPY
612	280657.333	6139049.853	3.607	STN/NAIL
1738	280535.848	6139138.099	5.752	STN/NAIL
2539	280620.643	6139185.400	5.402	DH/AB
3326	280602.408	6139116.199	4.590	STN/DH&W

SURVEYED: S.A.	DRAWN: J.S.S.	ORIGIN OF LEVELS:SSMI2226	RL: 5.286
CHECKED: S.A.	SURVEY DATE: 18/10/21	ORIGIN OF COORDINATES:SSMI2226	
DRAWING FILE:98-2021-NowraRiverDetail.dwg		E: 280568.334	N: 6138883.493
MAGNET FILE:98-2021-NowrarRiverDetail.mjo		DATUM: MGA94	CSF: 1.000189
SURVEYOR REF: 98-2021		SOURCES: SCIMS	DATE: 18/10/21

Shoalhaven City Council

CITY OF SHOALHAVEN

NOWRA RIVERFRONT DETAIL SURVEY
OCTOBER 20201

SIZE:	SCALE:	SHEET:	REV. NOTE:
A1	N/A	4	N/A

PROPERTY SERVICES MANAGER: DATE:

- DRAWING NUMBER -

Appendix B

Technical Working Group 1

Agenda, Presentation, and Notes

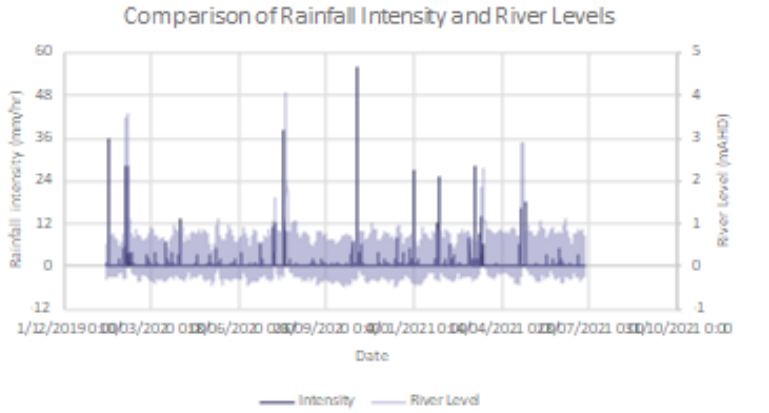
Nowra Riverfront Precinct Flood Impact and Risk Assessment

Technical Working Group Workshop 1

Content

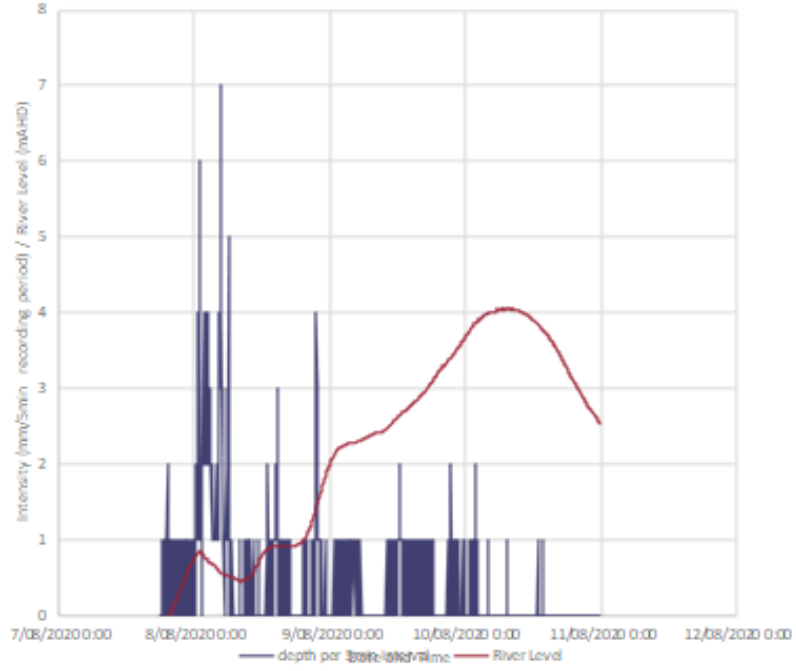
- Development of Local Flood Model
- Comparison of Riverine and Local Catchment Flooding
- Preliminary Options

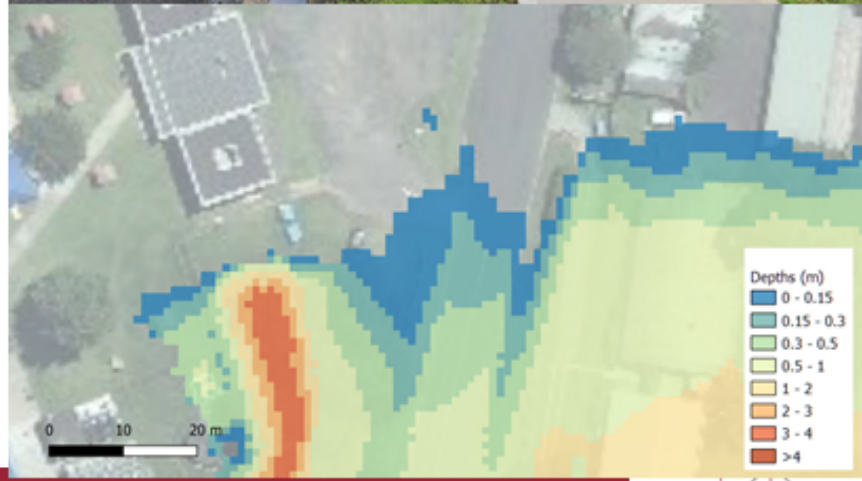
Local Flood Model – Extent and Inputs



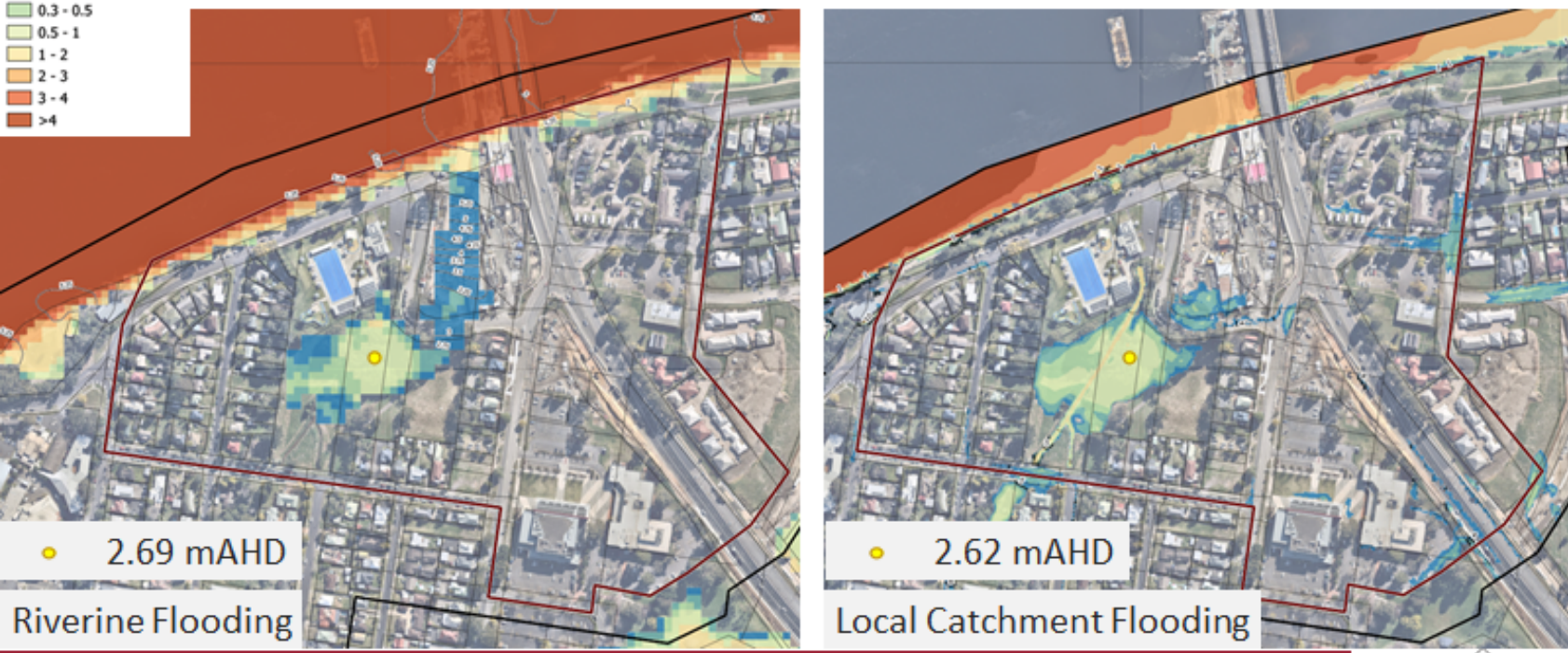
Design Event AEP	Catchment Flood AEP	Boundary AEP	River Level (mAHD)
50% AEP	50% AEP	HHWSS	0.95
20% AEP	20% AEP	HHWSS	0.95
10% AEP	10% AEP	HHWSS	0.95
5% AEP	5% AEP	HHWSS	0.95
2% AEP	2% AEP	5% AEP	5.3
1% AEP	1% AEP	5% AEP	5.3
0.5% AEP	0.5% AEP	1% AEP	6.0
0.2% AEP	0.2% AEP	1% AEP	6.0
PMF	PMF	1% AEP	6.0

Model – Validation

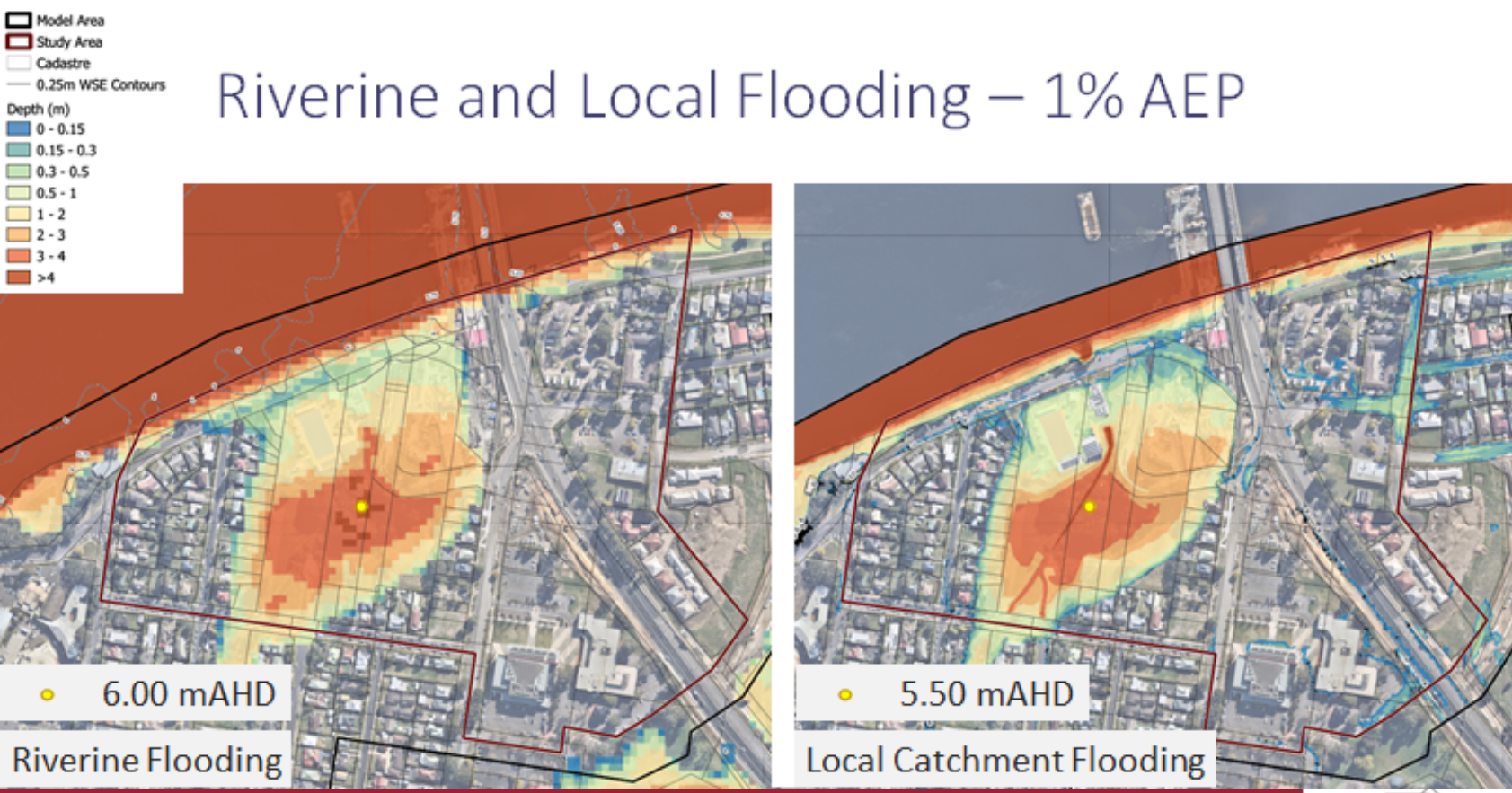




Riverine and Local Flooding – 5% AEP



Riverine and Local Flooding – 1% AEP



Riverine and Local Flooding - PMF

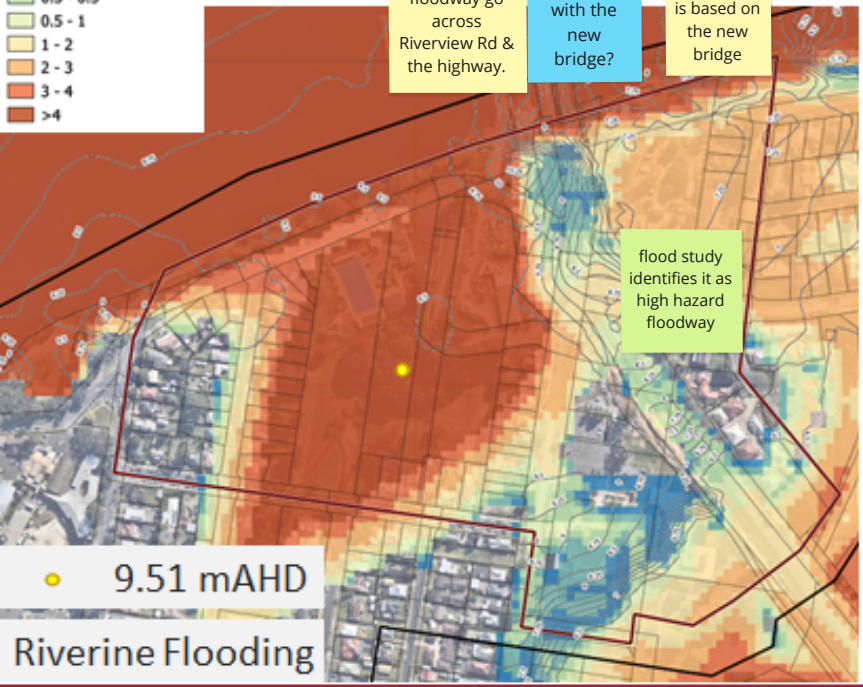
Model Area
Study Area
Cadastre
0.25m WSE Contours
Depth (m)
0 - 0.15
0.15 - 0.3
0.3 - 0.5
0.5 - 1
1 - 2
2 - 3
3 - 4
>4

does the floodway go across Riverview Rd & the highway.

maybe not with the new bridge?

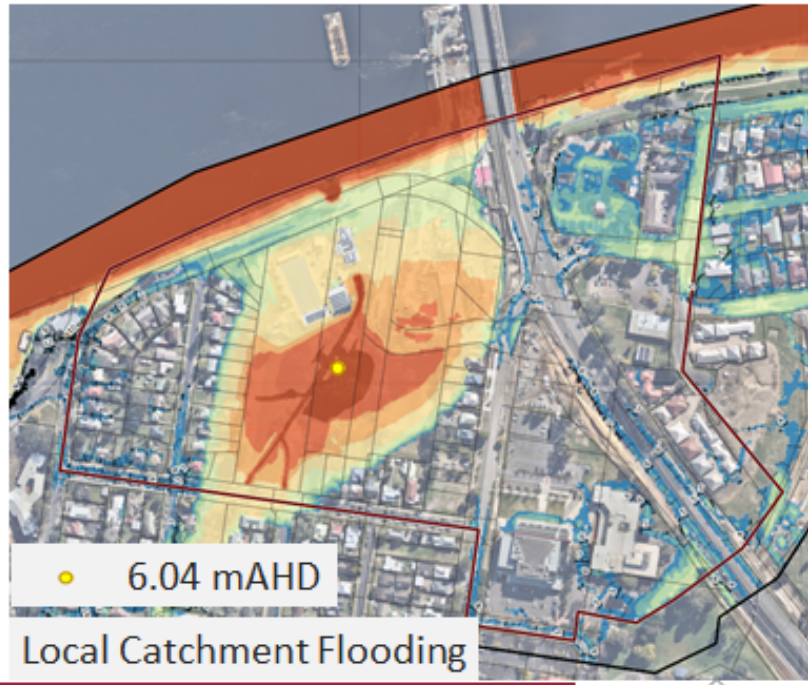
flood study is based on the new bridge

flood study identifies it as high hazard floodway



9.51 mAHD

Riverine Flooding



6.04 mAHD

Local Catchment Flooding

Rhelm

Local Flooding – 1% AEP Flood Function

Preliminary Management Options

Risk Types

- **Existing flood risk** – the risk associated with current development in the floodplain.
- **Future flood risk** – the risk associated with any new development of the floodplain.
- **Residual flood risk** – the risk remaining in both existing and future development areas after management measures, such as works and land-use planning and development controls, are implemented. This is the risk from rarer floods like the PMF, which may exceed the management measures.

Management Measures to Address Risks

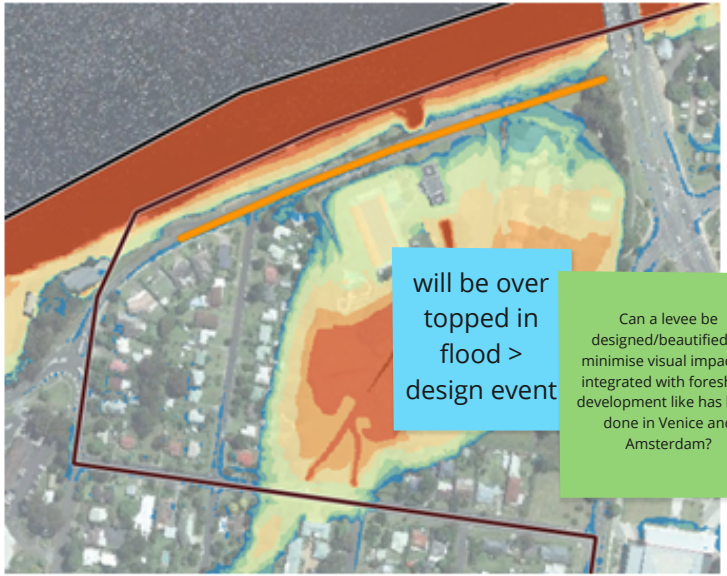
- **Structural Options** address existing flood risk
- **Planning Options** address future flood risk
- **Emergency Response Options** to address residual flood risk

The options here won't all be feasible. But important to identify and rule out, to demonstrate they were considered.

Key outcome of todays workshop will be the determination of which options to progress

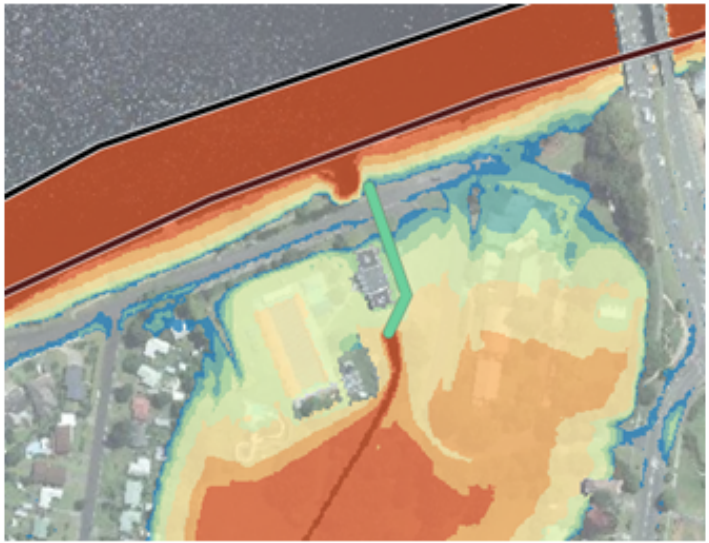
- Up to five structural options (or groups of options) to be assessed in the hydraulic model.
- Additional hydraulic assessment has been allowed for later in the study for optimisation.

S1 – River Levee



Description	Construction of a levee along the front of the precinct to protect from riverine floods. Levee height would be up to 0.8m high to protect in the 1% AEP and 1.6m high to protect in the 0.5% AEP (plus any required freeboard.
Expected Benefit	Prevention of flooding from riverine floods up to the levee design event. Note that the levee would provide no benefit in catchment driven flood events.
Constraints	Primary issue is the adverse impacts on amenity and aesthetics, particularly in the east, adjacent to the highway where the levee height would be greatest. Potential to adversely affect local flooding.
nsider rther?	No. Other options deliver similar protection without sacrificing the usage and connectivity of the open space.

S2 – Culvert Upgrade



Description	The option would see an additional pipe/culvert constructed, and a more efficient flood gate installed on both new and existing culverts. Works to the existing culvert are not proposed due to its location under the aquatic centre.
Expected Benefit	Improving the draining of the upstream flood storage, reducing peak flood levels and/or the period of inundation. Performance will be dependent on the downstream river levels.
Constraints	No major constraints. The region will be undergoing works as part of the precinct development, and these upgrades could be undertaken at this time.
Consider Further? potential to consider with other options	Yes. Modelling to be undertaken to quantify the benefits of the works on both peak levels and period of inundation. Modelling to be undertaken for both low and high river levels.

S3 – Diversion and Detention

Description	A diversion structure to be constructed at the intersection of North Street and Shoalhaven Street to force upstream flows into the Nowra Recreation Park. A detention basin and outlet structure would be constructed to control these flows.
Expected Benefit	The diversion is expected to reduce peak flood levels downstream, and reduce the storage volume required within the precinct
Constraints	Being located so far up the catchment, the amount of flow able to be diverted will be limited. Disruption to access along North Street and Shoalhaven Street, and the parking lot for the hospital. The Park is currently owned by Crown Lands.
Consider Further?	Yes. Preliminary investigations suggest that the diversion ld divert 20-25% of the total flow entering storage area, and reduce the peak flow into rom 15 cumecs to 11 cumecs.

No Go - NSW Health - proposed hospital extension

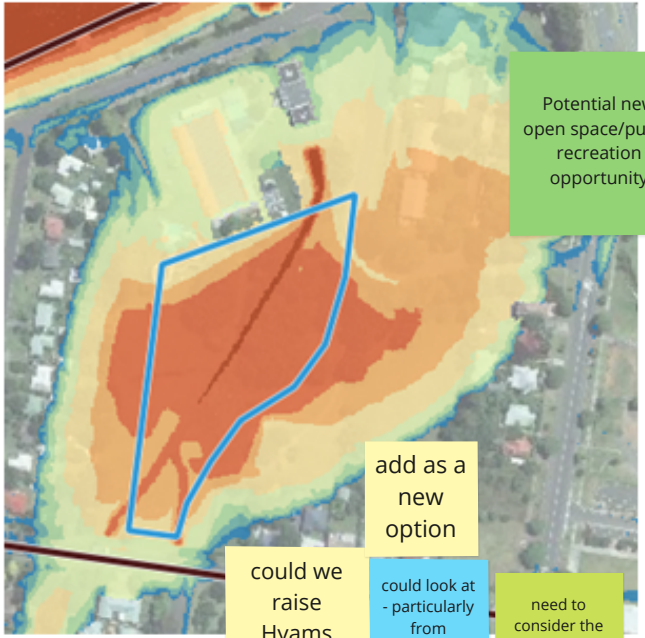
Could the detention be incorporated as part of proposed hospital development e.g water feature or diverted to another site?

S4 – Hyam St Detention

this land is essentially privately owned - difficult to proceed

Description	Construction of a detention basin in the open space upstream of Hyam Street.
Expected Benefit	The basin is expected to reduce peak flood levels downstream, and reduce the storage volume required within the precinct.
Constraints	The available area is small, and coupled with the grade of the local terrain, will limit the storage available. Existing development surrounds the site, complicating access and ease of construction. Basin area is inundated in the 1% AEP catchment flood via backwater from the storage area, so would only offer a benefit if the downstream levels could be reduced first.
Consider Further?	No. The limited size (and hence limited potential benefits) and substantial constraints result in the option not being considered feasible, given other options are available.

S5 – Central Storage



Potential new open space/public recreation opportunity

add as a new option

could we raise Hyams Road?

could look at - particularly from evacuation

need to consider the bridge/ culvert structure

Description	A flood storage region in the centre of the precinct, at the location of the existing low point and outlet structure. Storage to manage the flood volume in excess of the outlet capacity.
Expected Benefit	Prevention of the lateral expansion of the ponded water into developed areas.
Constraints	Potential safety constraints due to depth of ponding. Terrain may limit the amount of storage that can be provided. The region operates in this manner currently, albeit with ponding water impacting adjacent development. Works planned for region as part of precinct development.
Consider Further?	Yes. Modelling to be undertaken to determine the volume needed to safely manage catchment flows.

potentially with other options

currently being considered through urban design/ open space consultant

is there a potential for the fill to

S6 – Raised Pads

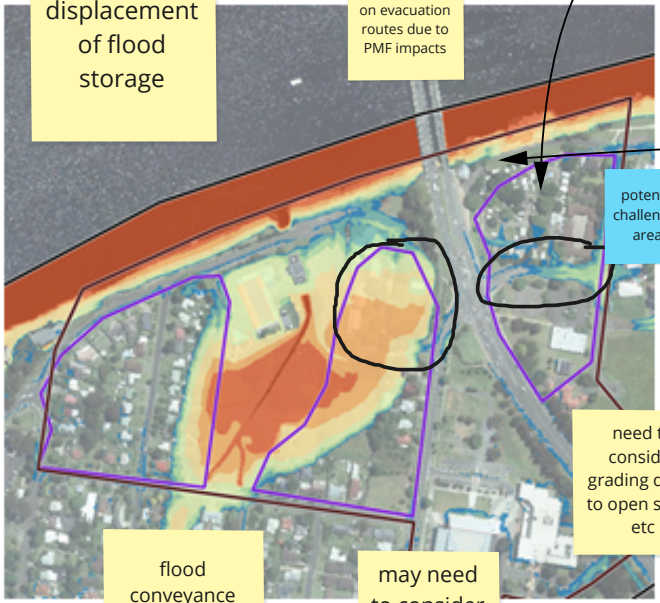
displacement of flood storage

does it impact on evacuation routes due to PMF impacts

are there issues here for evacuation

can we do the development on piers?

can look at some near edges of fill



potential challenging areas

need to look at the levee overtopping here

river model levee levels based on survey

what are the geotechnical constraints on ground?

Council to commence on this soon

need to consider levee freeboard

need to consider the stage delivery of the fill

need to consider grading down to open space etc

flood conveyance improvements to reduce fill

may need to consider variable level of fill

evacuation required where it becomes isolated

maybe run more than one raised pad option

would be good to achieve development without evac requirements

tion	The development fo roads and buildings pads) to be raised to the FPL. The open space can remain lower.
Expected Benefit	Prevents inundation of roads and development in events e event. other structur anagement.
Constraints	ntial volume of May requ satory cut depending on classificat bank region (fringe or storage). Could be couple bove to provide this storage. Alternative to be coupled with S7b (flowpath) Raised pads will need to tie into adjacent areas where precinct works are not proposed. Possible afflux on properties upstream of the pads.
Consider Further?	Yes. Modelling to be undertaken to test the feasibility of raising the roads and building areas.

S6 – Raised Pads

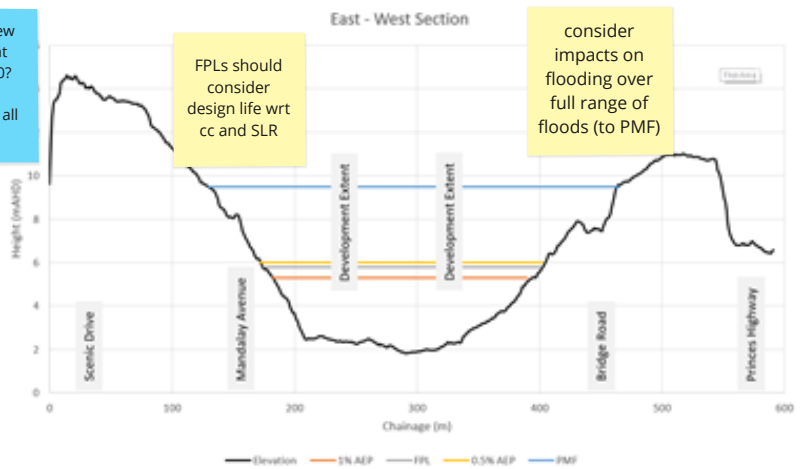
all lines shown are existing, not CC

should the new development consider 2100? should be considered in all options

what is the expected population?

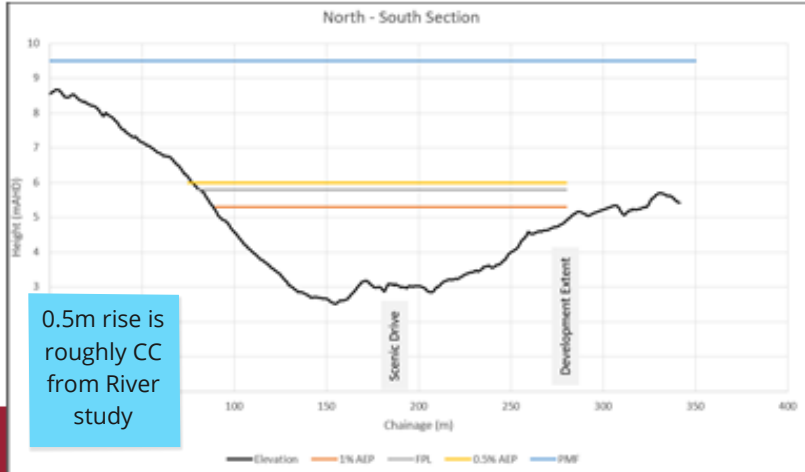
at this stage 200 - 1000

will be informed by flood study/ other specialist studies



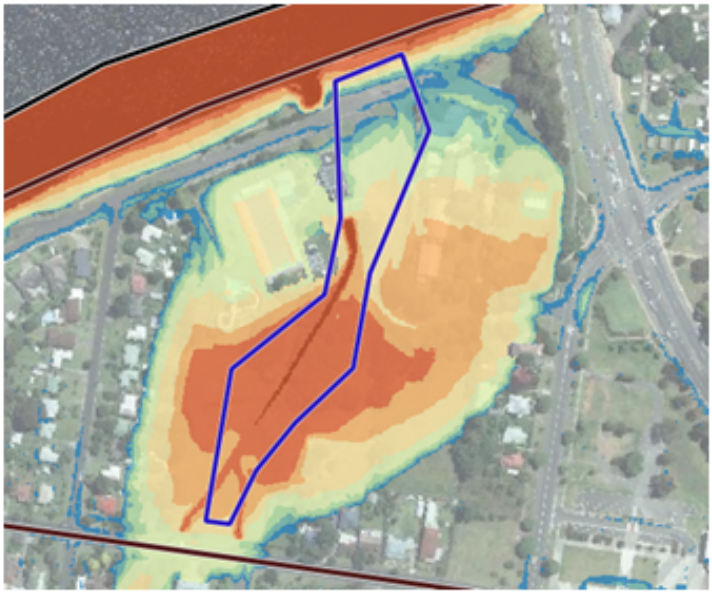
FPLs should consider design life wrt cc and SLR

consider impacts on flooding over full range of floods (to PMF)



0.5m rise is roughly CC from River study

S7a – Low-level regrading



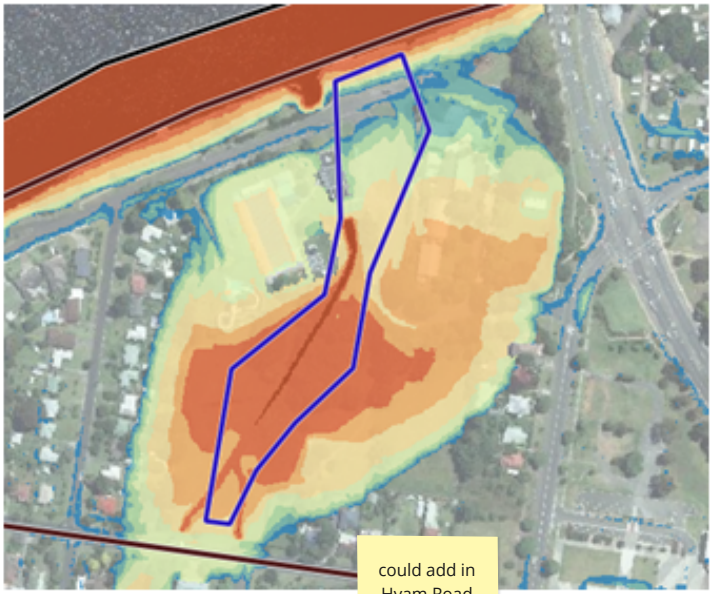
Description	Open space region would be regraded to allow the direct discharge of catchment flows to the river without the need for storage within the precinct.
Expected Benefit	Reduces residual flood risk within the precinct. Provides greater flexibility in land use within the precinct.
Constraints	Would require works on the riverbank to construct an overflow. Would reduce a region of riverbank height from the current 5mAHD to 1mAHD.
Consider Further?	No. The extent of changes required to the riverbank are not considered feasible.

S7b – High-level regrading

would require culverts

Description	As above, but central region would also be raised to create a central flowpath, and prevent the need for changes the riverbank.
Expected Benefit	Reduces residual flood risk within the precinct. Provides greater flexibility in land use within the precinct.
Constraints	Would require substantial fill. Some minor works to riverbank may be required to achieve required flowpath grades. Would need to be done in conjunction with S6
Consider Further?	Yes. Preliminary assessment to confirm grades are achievable. Modelling to be undertaken if so.

loss of river based storage



could add in Hyam Road Raising/ bridge/ culvert

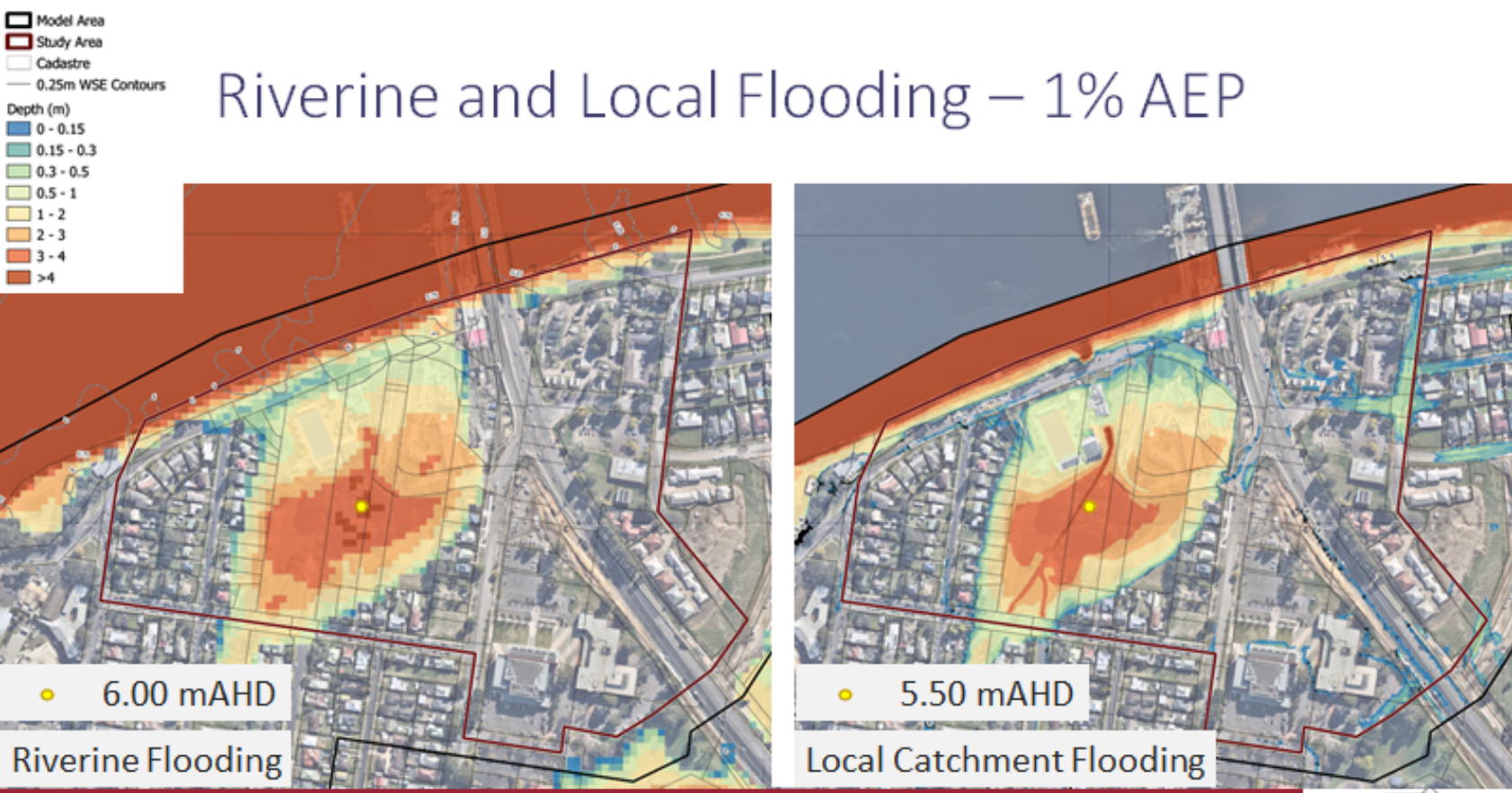
will be looking at impacts for a range of AEP events to see how it performs

PMF - concerned on impacts for evac and land impacts (depending on threshold)

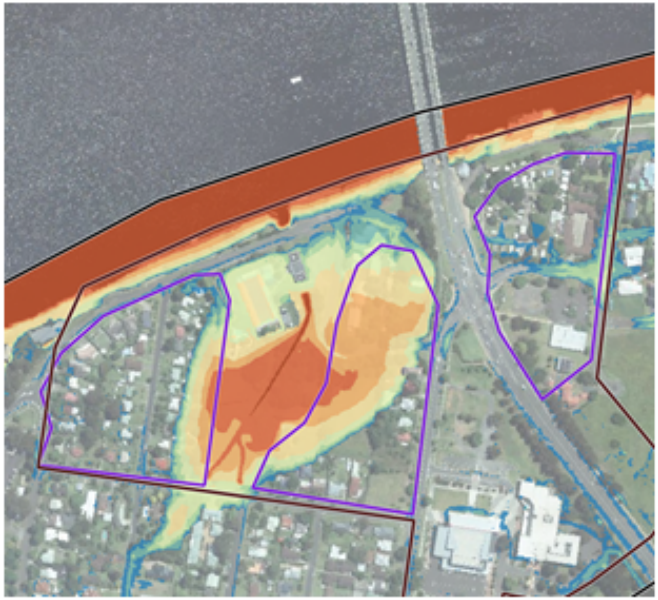
2000yr - TfNSW shows much more inundation at this event (relative to 500)

martin to follow up on availability of TfNSW study

Riverine and Local Flooding – 1% AEP



S6 – Raised Pads



Description	The development footprint (that is, the roads and buildings pads) to be raised to the FPL. The open space can remain lower.
Expected Benefit	Prevents inundation of roads and development in events up to the design flood event. Removes the need for other structural mitigation options. Assists in emergency management.
Constraints	May require a substantial volume of fill. May require compensatory cut depending on classification of overbank region (fringe or storage). Could be coupled with S5 above to provide this storage. Alternative to be coupled with S7b (flowpath) Raised pads will need to tie into adjacent areas where precinct works are not proposed. Possible afflux on properties upstream of the pads.
Consider Further?	Yes. Modelling to be undertaken to test the feasibility of raising the roads and building areas.

Nowra Riverfront – Flood Impact and Risk Assessment (FIRA)

Technical Working Group – Meeting 1

9:30-11:30am, Wednesday 15 December 2021
(via Microsoft Teams)

AGENDA

1. Introductions (see Attachment 1 – List of Members)
2. Terms of Reference (see Attachment 2)
3. Project Overview (NRAT)
4. Flooding Overview (Council)
5. FIRA / Lower Shoalhaven Flood Modelling (Rhelm)
6. Mitigation Options – Summary & Recommendations (Rhelm)
7. Discussion / decision on the mitigation options to be taken forward (All)
8. Next steps

Attachments:

1. List of Members
2. Draft Terms of Reference

Attachment 1 – List of Members

Group/Agency	Name
Nowra Riverfront Advisory Taskforce (NRAT)	Gordon Clark Director City Futures, Shoalhaven City Council
DPIE – Planning and Assessment (South Coast Region)	George Curtis Senior Planner, Southern Region
DPIE-EES-BCD-South East Flood team	John Bucinskas Senior Team Leader, Water Floodplains & Coast – South East
	Nathan Pomfret Senior Natural Resource Officer
NSW State Emergency Service (SES)	Joanne Humphries
	Rodney Whalan Planning and Research Officer / Hazard Planning
Transport for NSW (TfNSW)	Martin Cocca Senior Manager Transport Technical Solution, South Regional and Outer Metropolitan
Shoalhaven City Council, City Futures – Strategic Planning	Molly Porter Strategic Planner – Local Planning Team
	Ryan Jameson Coordinator – Local Planning Team
Shoalhaven City Council, Environmental Services – Coast and Floodplains	Mark Stone Senior Floodplain Engineer
Shoalhaven City Council, City Futures – Transport	Scott Wells Principal Traffic Engineer
FIRA Consultants – Rhelm Pty Ltd	Luke Evans Rhys Thomson

Attachment 2 – Draft Terms of Reference

DRAFT

Nowra Riverfront Flood Impact and Risk Assessment (FIRA) Technical Working Group

Terms of Reference

Background

A Flood Impact and Risk Assessment (FIRA) is being undertaken for the Nowra Riverfront Precinct. The FIRA will provide the basis of flood information and assessment of risks to inform land-use rezoning processes / planning proposals and establishment of development controls for future development applications in the precinct.

The FIRA will determine if:

- Changed flood behaviour could arise and have adverse impacts on the flood risk to the existing community and development;
- The proposed development and its users or occupants can safely be enabled with an acceptable level of flood risk; and
- Effective flood emergency response is achievable without adverse impacts on the ability of the existing community to respond to floods.

Purpose

The purpose of the Technical Working Group is to facilitate agency input and consultation processes at key stages of the development of the Flood Impact and Risk Assessment (FIRA).

Underpinning principles

The following principles underpin the establishment of the Technical Working Group:

- All members will have the opportunity to contribute equally;
- There will be mutual respect, trust and transparency;
- There will be mutual benefits to members and the groups they represent;
- All parties commit to a timely progression and resolution of matters arising from the Working Group; and
- Decisions will be made based upon the underpinning principles and objectives above.

Membership

The Technical Working Group will consist of representatives from the following agencies who will form core members of the group:

- Nowra Riverfront Advisory Taskforce (NRAT)
- DPIE – Planning and Assessment (South Coast Region)
- DPIE-EES-BCD-South East Flood team
- NSW State Emergency Service (SES)
- Transport for NSW (TfNSW)

- Shoalhaven City Council
    - City Futures – Strategic Planning
    - Environmental Services – Coast and Floodplains
    - City Futures – Transport

Meetings

The organisation of meetings will be coordinated by Council's Strategic Planning Unit.

Meetings will be held at key stages of the project via Microsoft Teams.

Agendas will be circulated to members at least seven (7) days prior to the meeting.

Appendix C

Technical Working Group 2
Presentation, and Notes

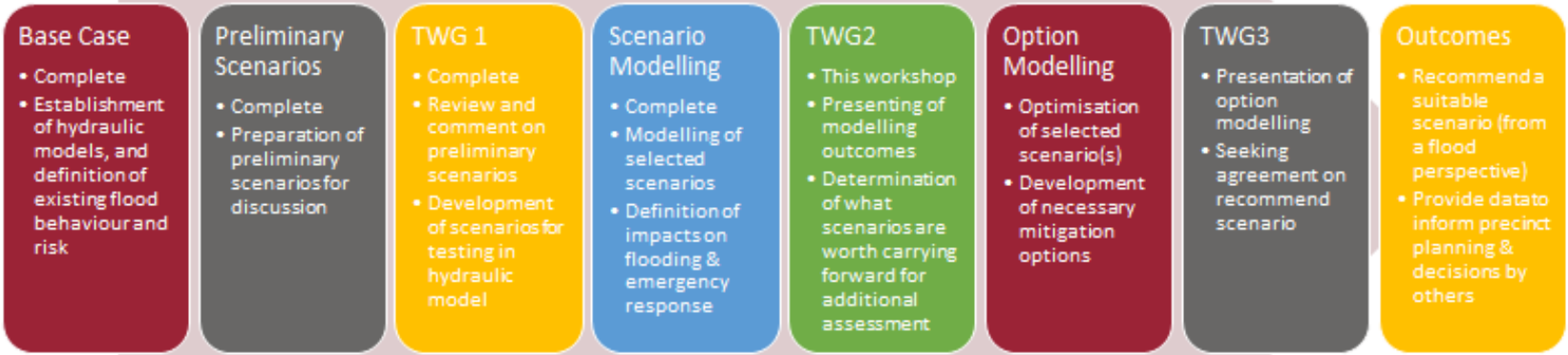
Nowra Riverfront Precinct Flood Impact and Risk Assessment

Technical Working Group Workshop 2

Workshop Overview

- Overview of Study Process
- Summary of Previous Meeting Outcomes
- Development and Population Scenarios
- Development of Landform Options
- Local Flooding Option Results
- Riverine Flooding Option Results
- Discussion on options and potentially viable landforms / options for further consideration

Study Overview



Technical Working Group 1 Outcomes

ID	Option	Consider Further?
Structural Options (to manage existing/developed flood risk)		
S1	River levee	No.
S2	Upgrade to culvert and outlet at aquatic centre	Yes.
S3	Diversion and retention of flow in Nowra Recreation Park	No.
S4	Detention basin upstream of Hyam Street	No.
S5	Central storage for flood control	Yes.
S6	Raising of building pads to FPL	Yes.
S7a	Regrading of open space region	No.
S7b	Raising and regrading of open space region	No.
Planning Options (to manage future flood risk)		
P1	Appropriate development controls	Yes
P2	Provision of rising road access	Yes
P3	Provision of elevated pedestrian ways to flood free land	Not at this time.
Emergency Response Options (to manage residual risk, that is events above the 1% AEP)		
E1	Flood warning	Yes.
E2	Flood evacuation plans	Yes
E3	Flood awareness	Yes
E4	Update of emergency response documentation	Yes

Development Scenarios

	Low		
	Dwellings	People	Vehicles
Mandalay Ave	62-86	133-186	86-120
Hyam St	44-61	95-131	61-85
Pleasant Way/ Graham Lodge	45	97	63
Wharf Road	113	244	158
Scenic Drive	22	47	30
Bridge Road triangle	9	20	12
Total	295-336	636-725	410-468

	Medium		
	Dwellings	People	Vehicles
Mandalay Ave	274	592	383
Hyam St	78	169	109
Pleasant Way/ Graham Lodge	90-93	194-201	126-130
Wharf Road	159	343	222
Scenic Drive	44	95	61
Bridge Road triangle	38	82	53
Total	683-686	1,475-1,482	954-958

	High		
	Dwellings	People	Vehicles
Mandalay Ave	466	1,006	652
Hyam St	196	423	274
Pleasant Way/ Graham Lodge	180-186	388-401	252
Wharf Road	210	453	294
Scenic Drive	88	190	123
Bridge Road triangle	63	138	88
Total	1,203-1,209	2,598-2,611	1,683

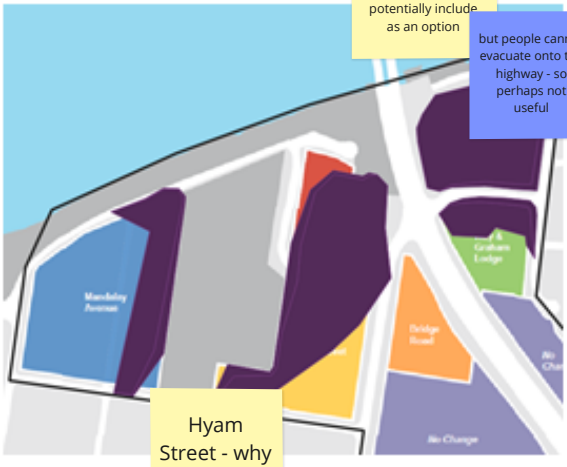
Raised Landform Scenarios

flood batters are 1 in 4, have been implemented in model

need to consider shallower slopes in future scenario

Pleasant Way could be raised (kept on same alignment) - should look to potentially include as an option

but people cannot evacuate onto the highway - so perhaps not useful



Two raised landforms were developed:

- Large footprint
- Small footprint

Each was raised to two heights

- The 2100 FPL
- The 0.2% AEP

Layouts constrained by

- Not encroaching on open space
- Heritage buildings
- Retained roads

- Other regions remain as per existing

Hyam Street - why not raised?

important for flood free access to Hospital

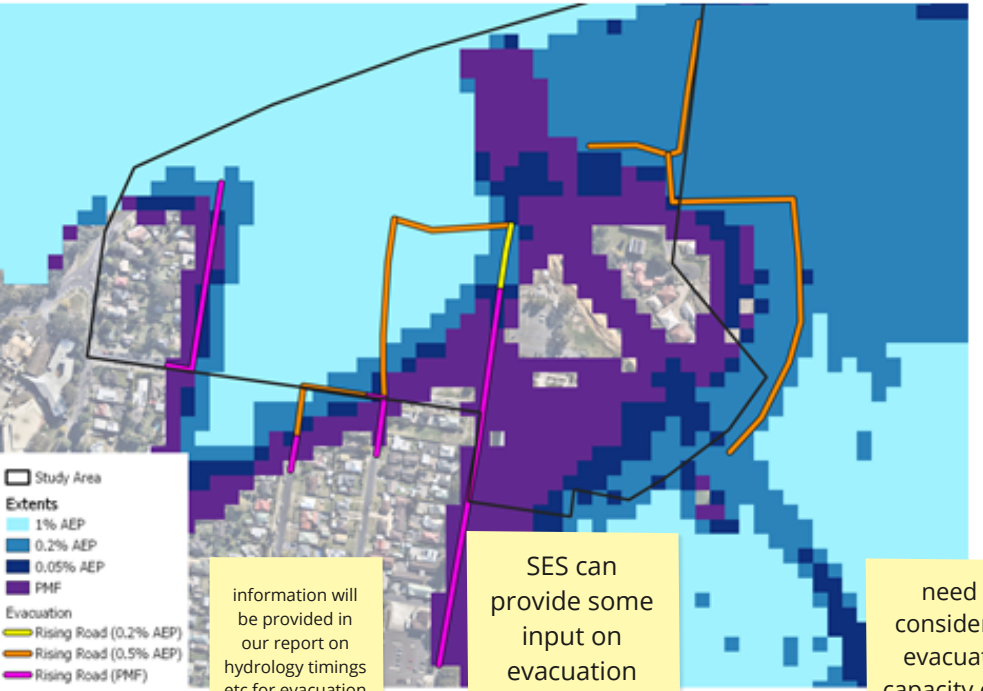
north south roads remain flood free at present

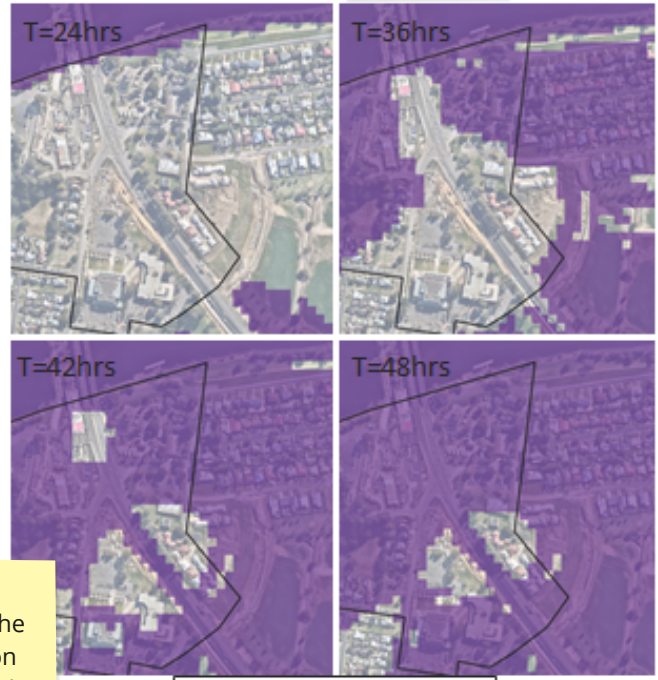
issues with capacity on Mandalay Avenue

Rhelm

Emergency Response & Evacuation

what is the effective warning time





PMF Flood Progression

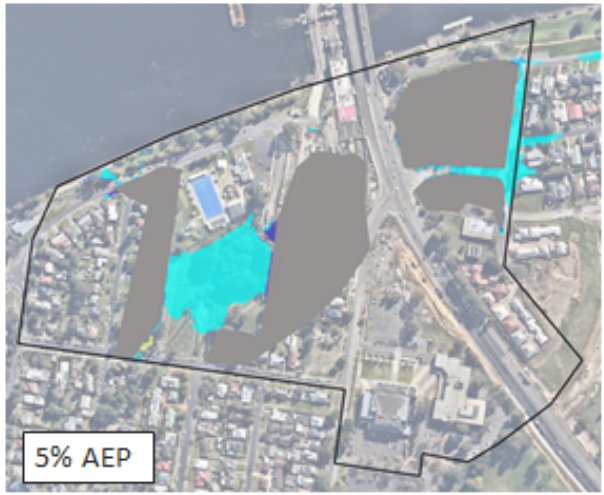
information will be provided in our report on hydrology timings etc for evacuation

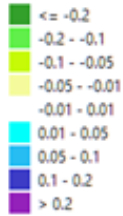
SES can provide some input on evacuation timing etc

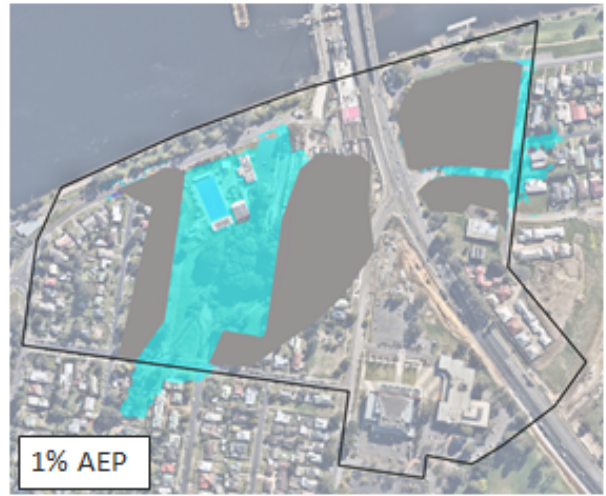
need to consider the evacuation capacity of the roads

Rhelm

Option Outcomes – Local Flooding

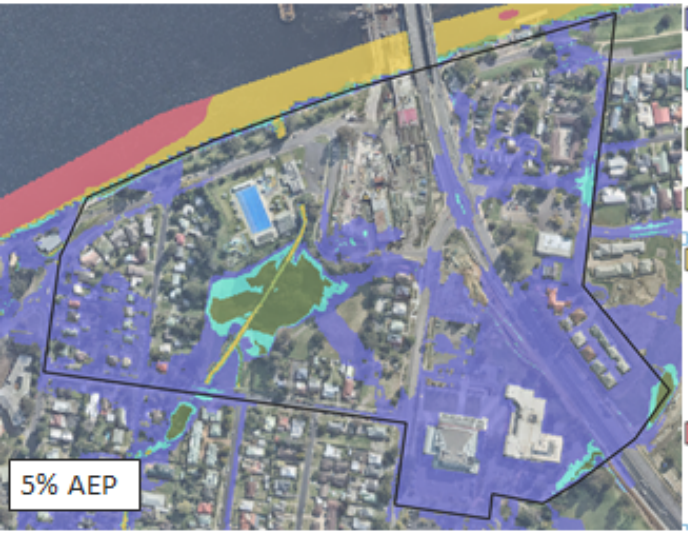






Results are for the large pad scenario.
Small pad option has no impacts in central area, and a less pronounced impact in the east.
Central impacts extending off site in 1% AEP are able to mitigated by local works.
Negligible differences in events larger than the 1% AEP, as flood levels governed by river levels.
Pad levels above PMF local flood height.

Option Outcomes – Hazard



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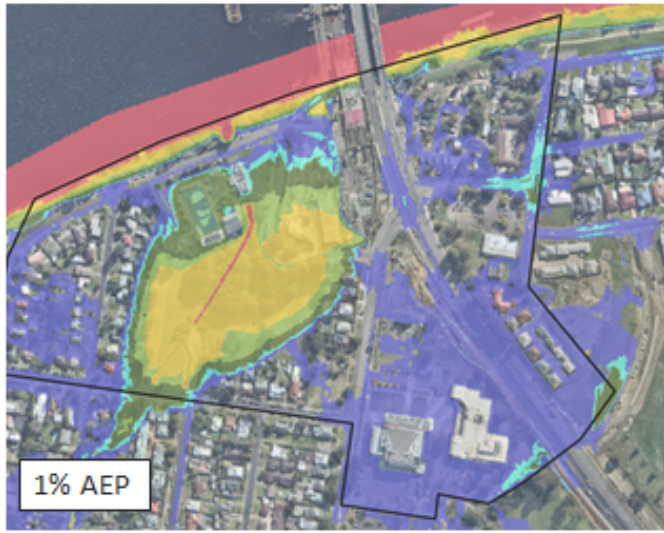


Option Outcomes – Riverine Flooding

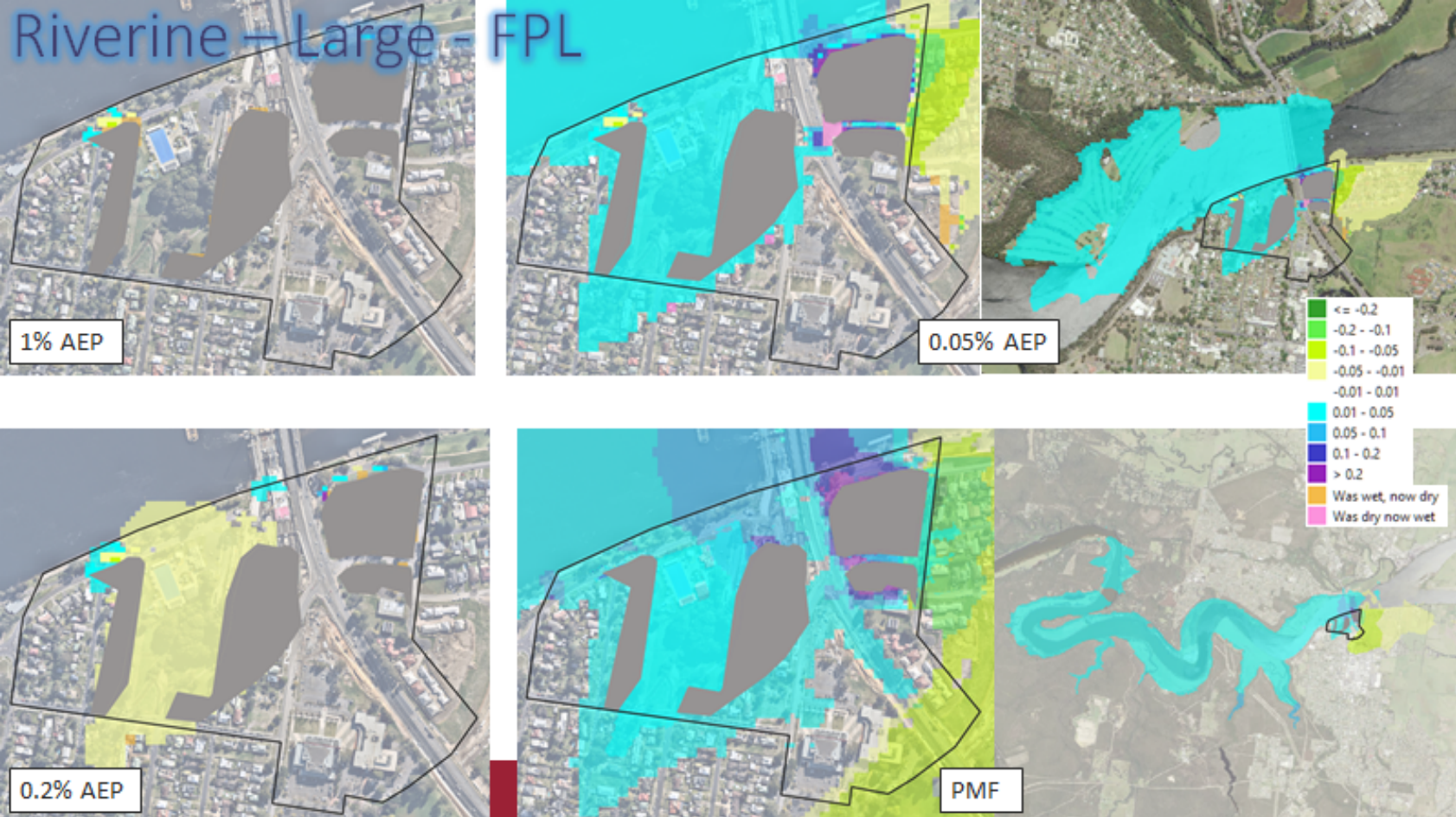
Following slides will present results for the four scenarios assessed:

- Large fill areas, raised to the 2100 FPL
- Small fill areas, raised to the 2100 FPL
- Large fill areas, raised to the 0.2% AEP
- Small fill areas, raised to the 0.2% AEP

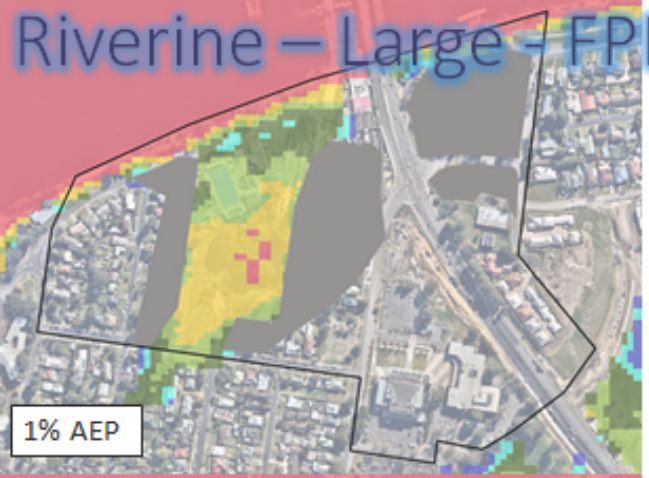
Each slide will show water level difference plots for:

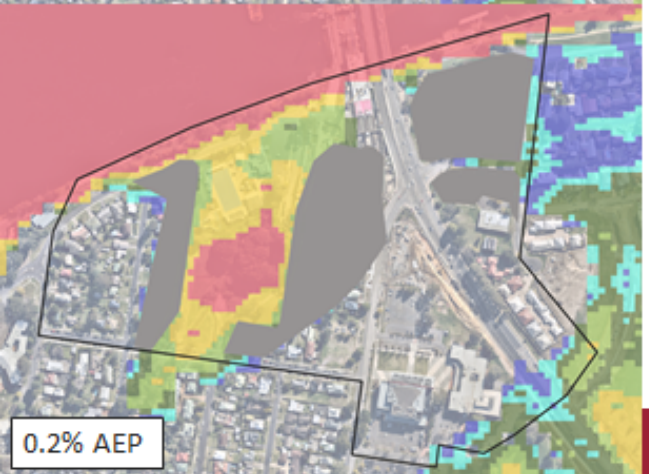
- 1% AEP
- 0.2% AEP (the 0.5% AEP results were all very similar to these, so just showing the largest)
- 0.05% AEP
- PMF (some PMF plots will have both a local and a region map)

Riverine – Large - FPL



Riverine – Large - FPL





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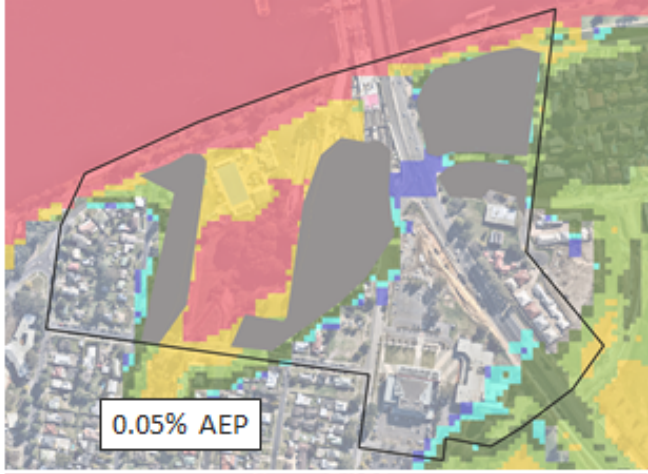
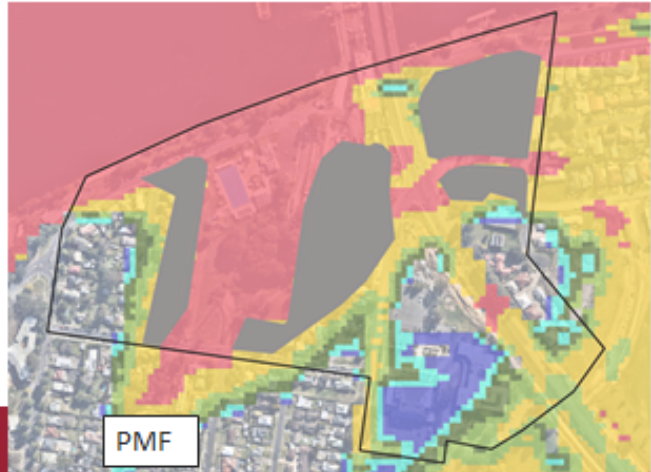
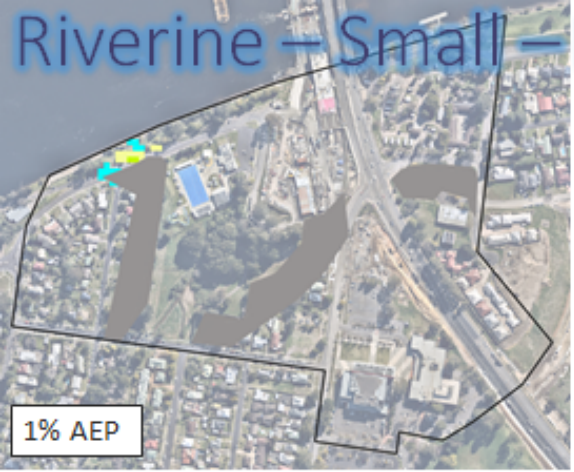
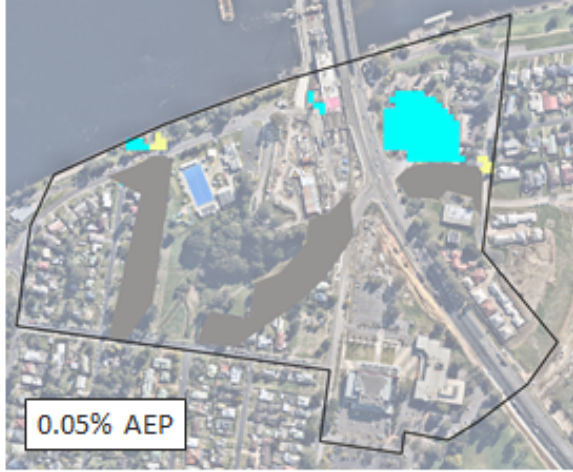
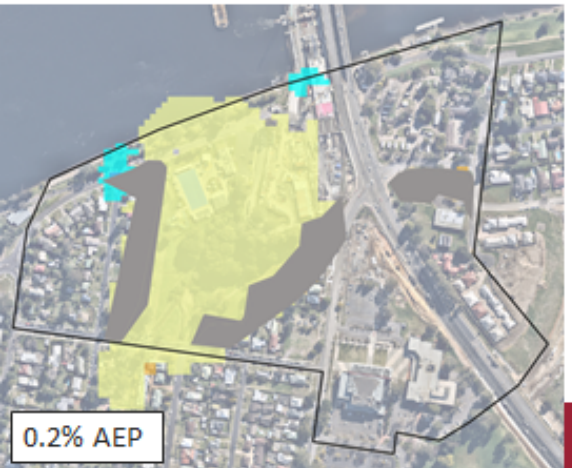


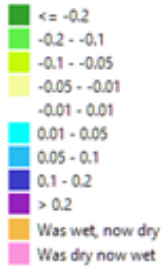


Riverine – Small – FPL

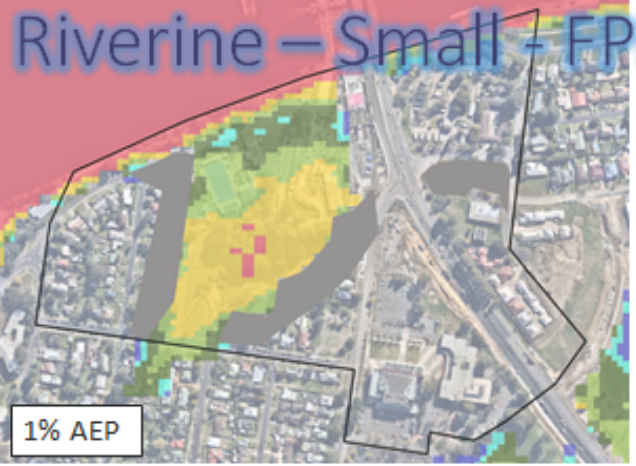


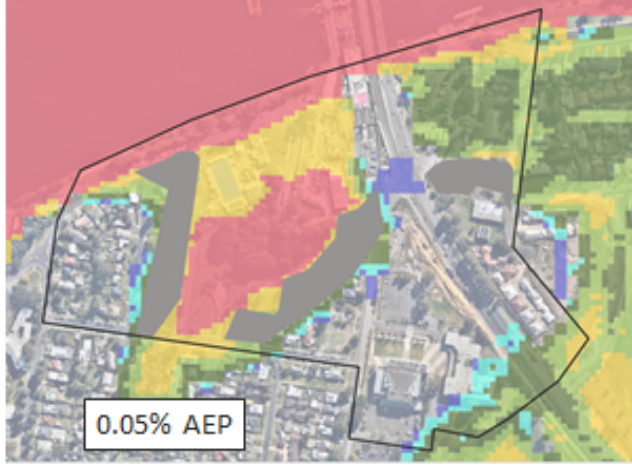


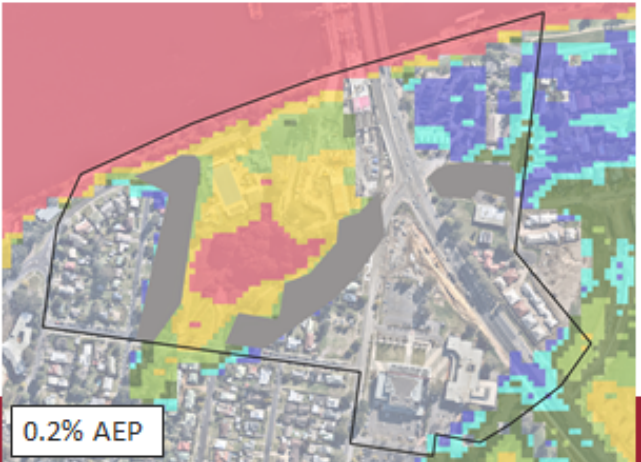


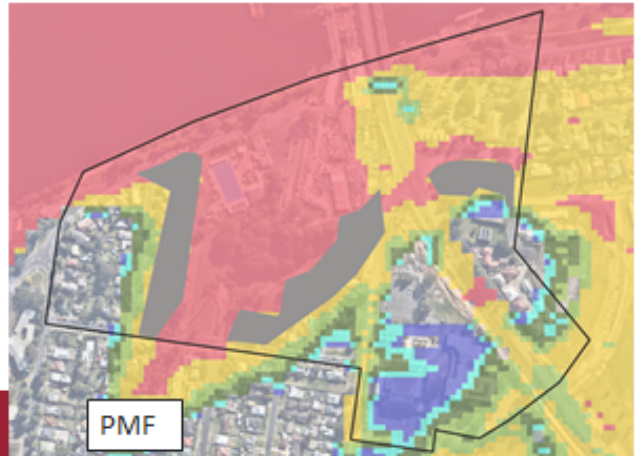


Riverine – Small - FPL









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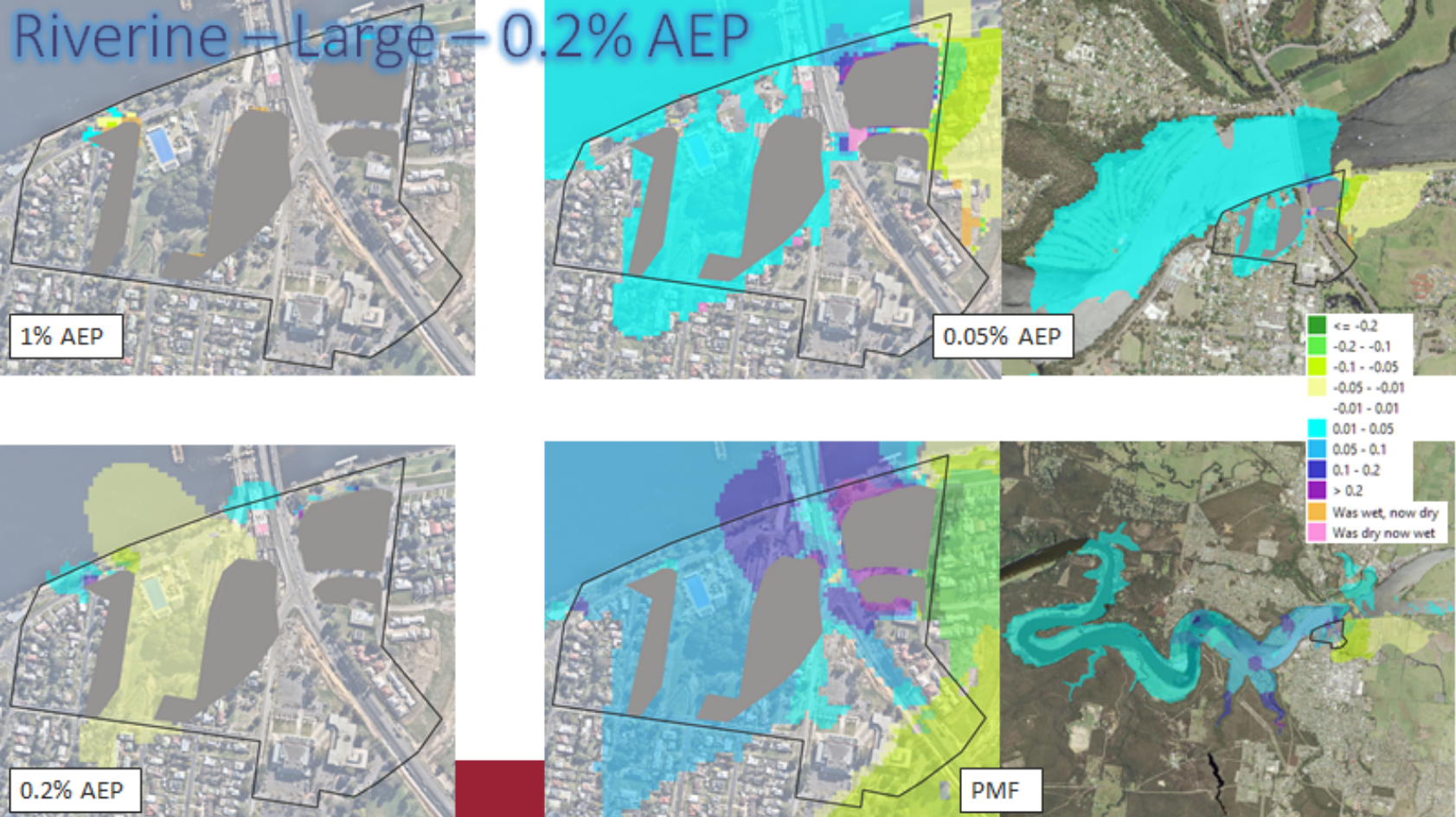
Riverine – Large – 0.2% AEP



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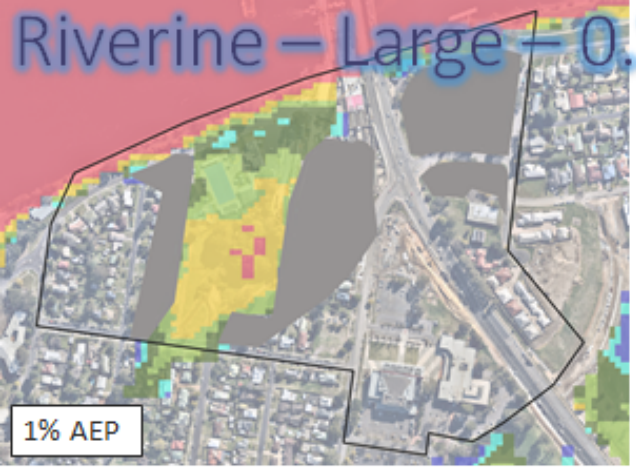

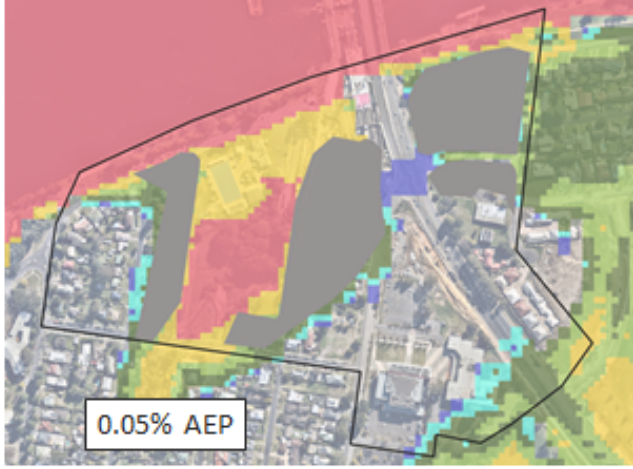

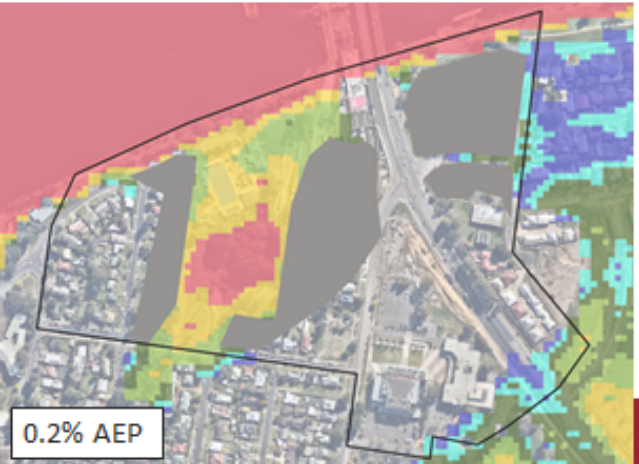

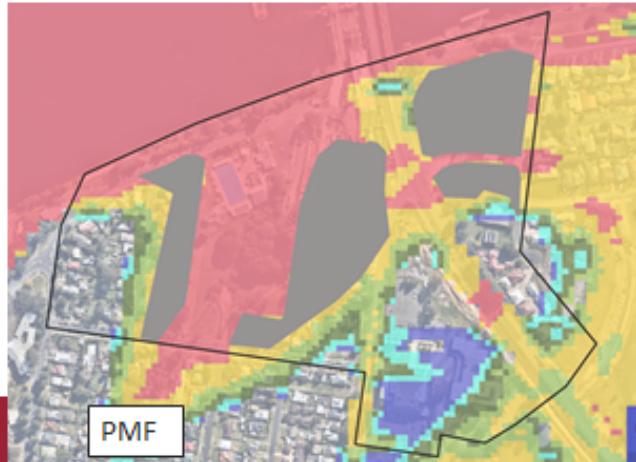

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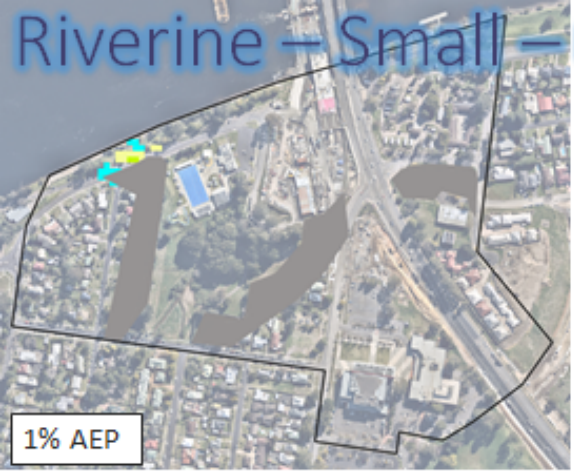
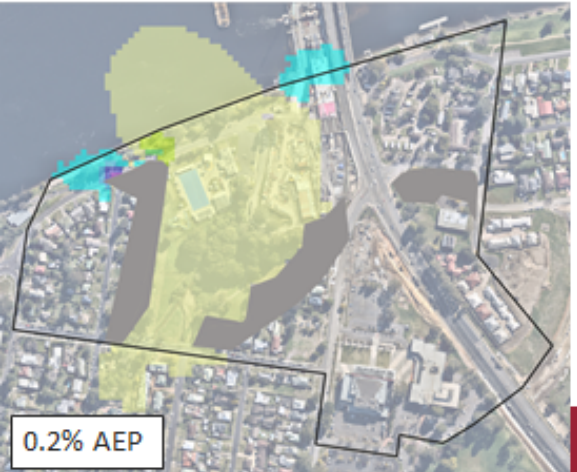
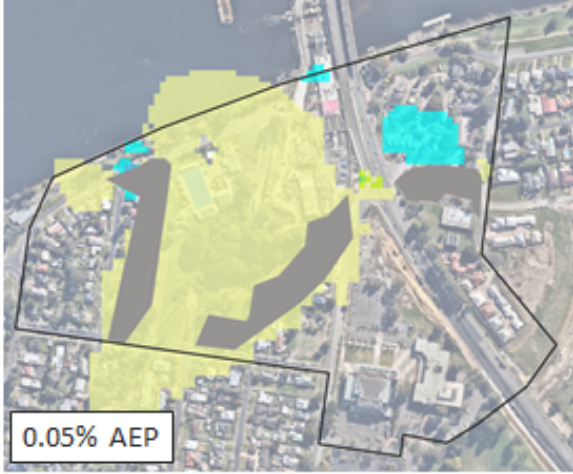
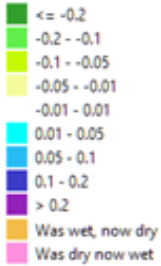
Riverine – Small – 0.2% AEP

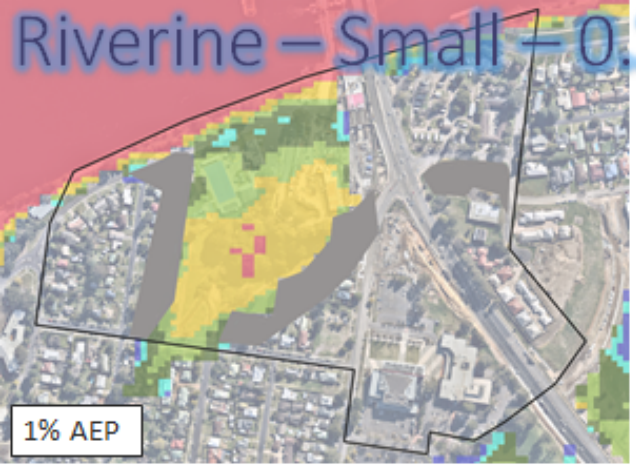


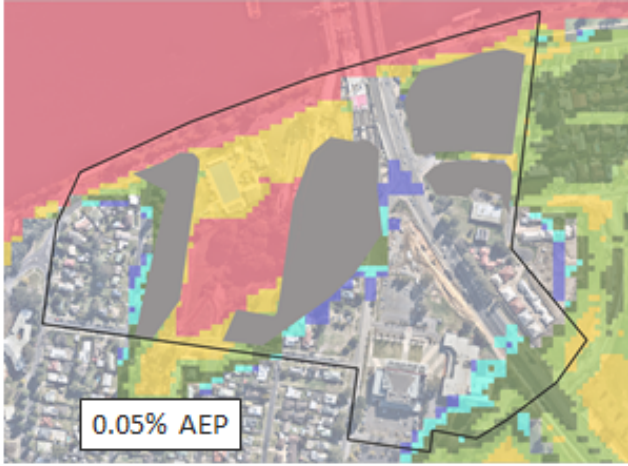


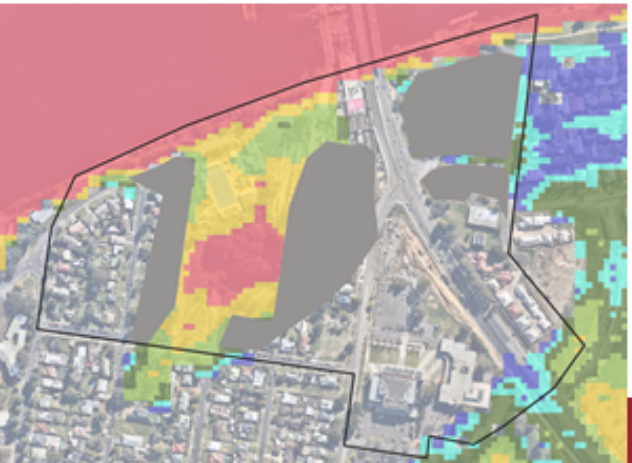


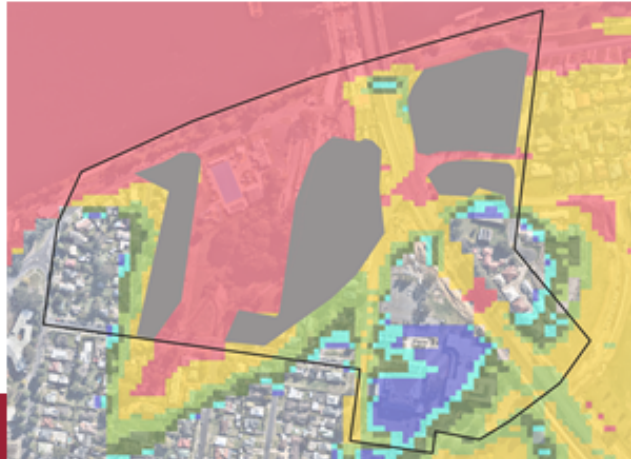


Riverine – Small – 0.2% AEP









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Option Modelling Summary

HOw are the pads modelled

need to make sure that landform is considered in the next stage of design - structural integrity of buildings

battered up to the top, and then "flat top" with lot average roughness

Local Flooding

- Some minor impacts in the events up to and including the 1% AEP. Minor increases in the east. Increase in level over Hyam St in the 1% AEP large pad scenario.
- Flooding in larger events governed by riverine levels.
- Local impacts likely able to be managed by either additional works (extra culvert outlet) or optimisation of the landform (additional flow capacity down Pleasant Way).

Riverine Large Pad Scenario

- Minimal impacts in events up to and including the 0.2% AEP
- Activates flow over the highway in the 0.05% AEP
- PMF has large scale impacts. Magnitude typically modest for FPL pad, more significant for 0.2% AEP pad.

Riverine Small Pad Scenario

- Minimal impacts in events up to and including the 0.05% AEP
- FPL pad has small local impacts in PMF off site within the river.
- 0.2% AEP pad has additional impacts that affect Hyam Street and adjacent properties.

Summary of Scenario Outcomes

Raising full precinct has flood impacts in events above the 0.2% AEP.
Feasibility of evacuation requires further assessment.

Precinct generally compatible with flood behaviour.
Feasibility of evacuation requires further assessment.

Precinct generally compatible with flood behaviour.
Feasibility of evacuation requires further assessment.

Raising precinct has modest impacts in the 0.05% AEP and significant impacts in the PMF. Feasibility of evacuation requires further assessment. Portions of the site are low flood islands.

Southern portion flood free in PMF.
Feasibility of evacuation requires further assessment.
Is a high flood island.

Precinct located on high point and is largely flood free in the PMF. Is a high flood island.

Performance Criteria Discussion

current policies focus on 1% and more frequent, hazard etc for above

maybe consider impacts on damages

assess impacts on roads, existing flood depths etc

Acceptable Impacts

- Are some impacts in very large events reasonable?
- In what events?
- If impacts confined to open space / road corridor, is this reasonable?

Loss of Storage

could look at % loss of storage in our area

- The proposed central basin cannot be made large enough to offset all fill, unless made much deeper, which would then likely make if off limits to the public.
- Is this loss of storage acceptable?
- Whilst not equitable, it is in line with Council's current planning instrument

would need to consider the potential impacts on others

cumulative impacts consideration

would be under the merits based approach.

Emergency Response and Access

need to consider the evacuation

- As noted, a number of precincts may be able to achieve rising road access from a purely structural point of view.
- However, an assessment would be needed to determine if the road capacity is sufficient to allow the proposed extra residents to all evacuate.
- Some precincts are classed as low and high flood islands. Is it reasonable to place extra people in these regions?
- Is shelter in place an option for some precincts?

but the numbers are draft - they will be governed by current study & other work

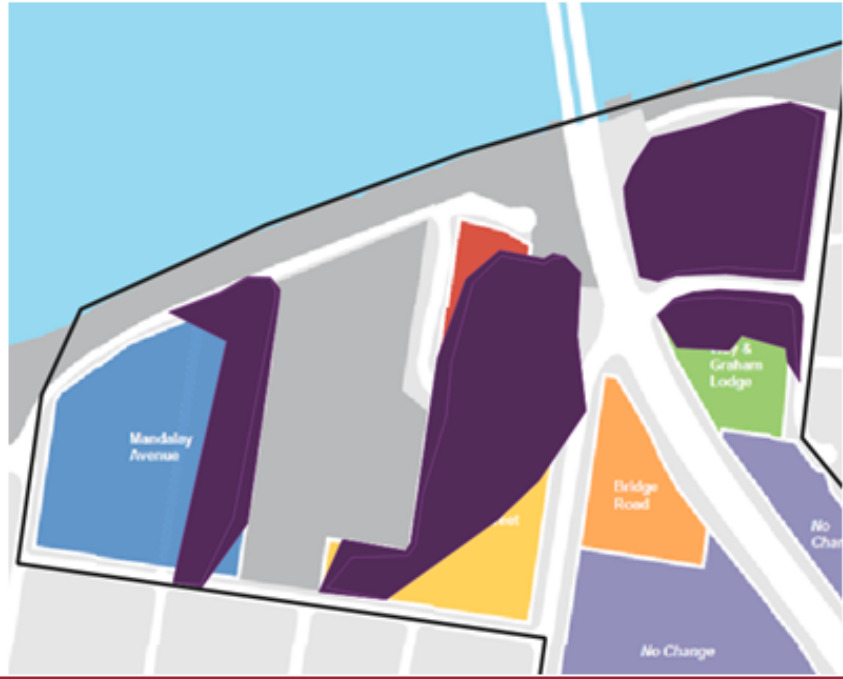
not ideal in this situation due to duration

Rhelm

Discussion – Large Pad Option

look at a refined "mid range" pad option

FPL (1%+0.5m+CC) vs 0.5% - not much difference between the two.
roughly 0.5m higher to 0.8m higher



can other land uses be considered in the Wharf Rd and Scenic Dr Precinct (e.g. Commercial)

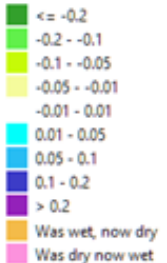
potentially could have pad level lower

less risk to public safety

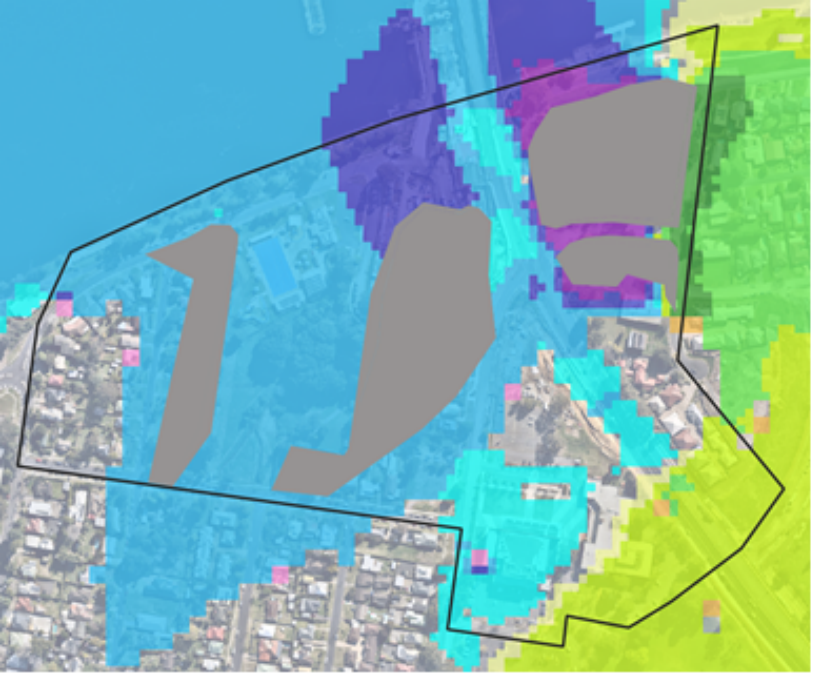
Discussion – Small Pad Option

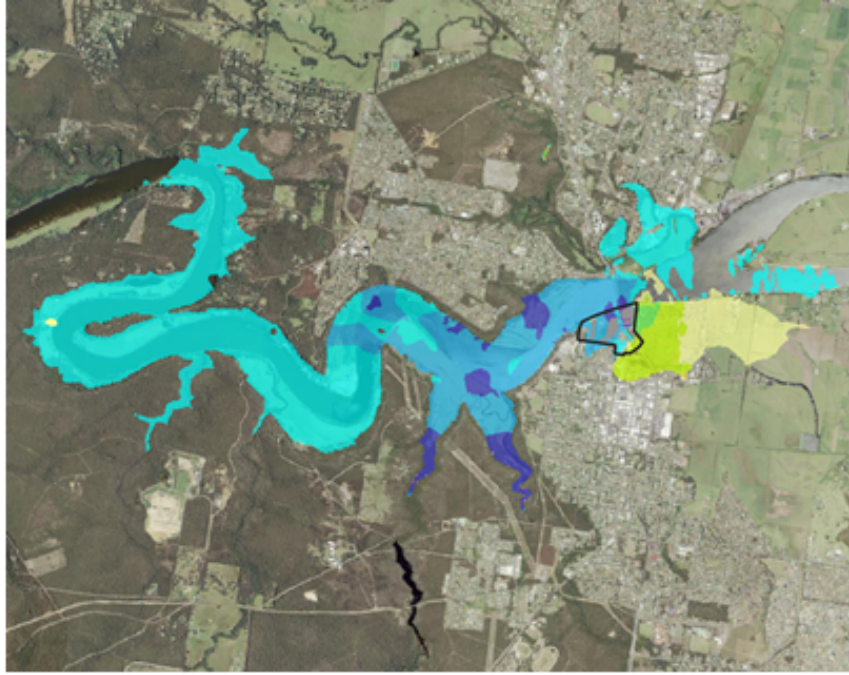
potential to require a raising of the levee as a part of WHarf Rd? benefits existing development as well

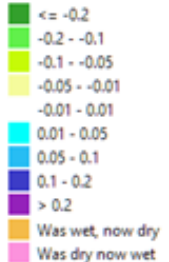
need to consider flood impacts



Large Landform, FPL Height, 0.05% AEP Impacts

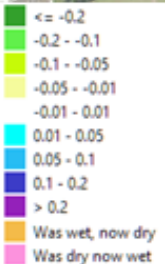




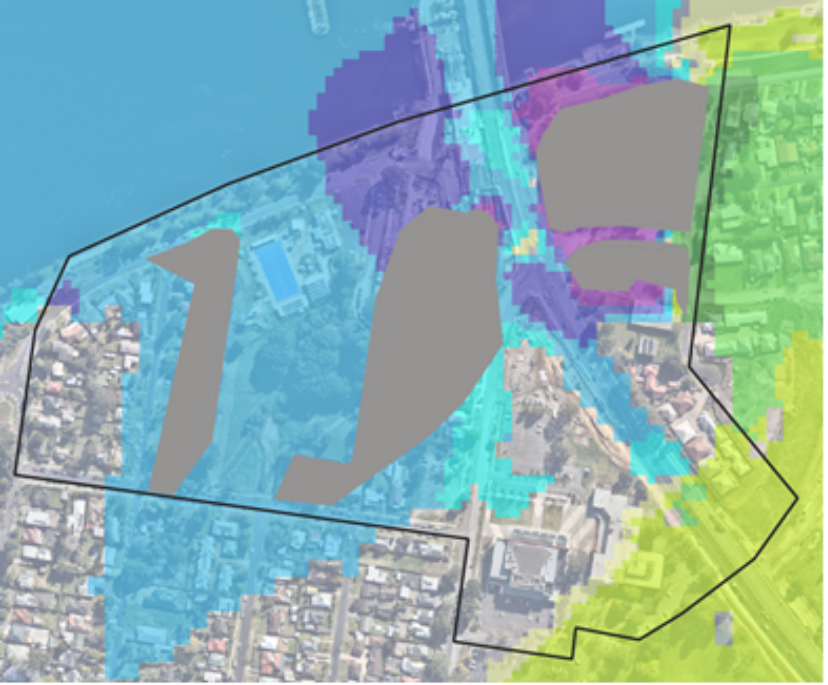


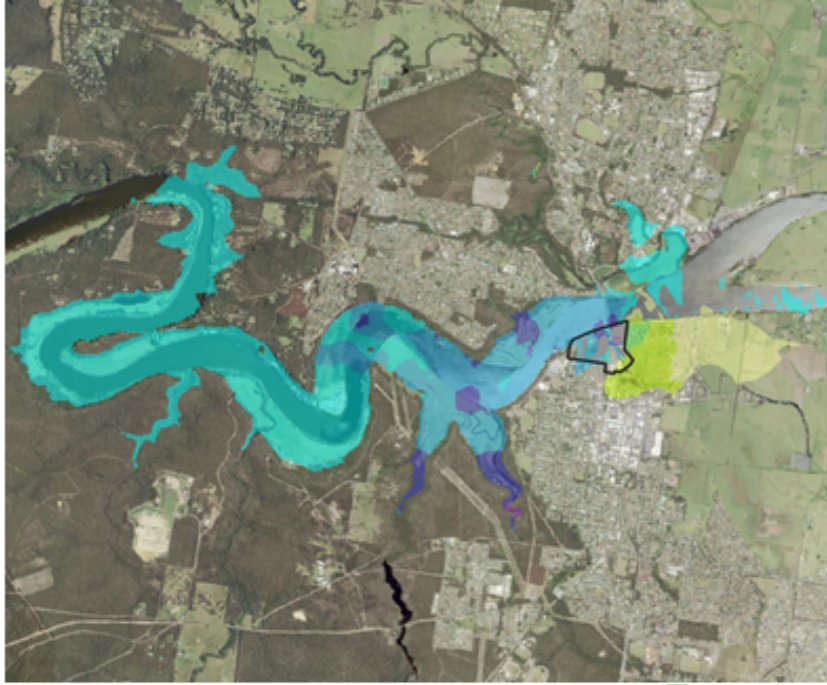
Large Landform, FPL Height, PMF Impacts

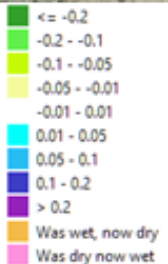
Small Landform, FPL Height, 0.05% AEP and PMF Impacts



Large Landform, 0.2% AEP Height, 0.05% AEP Impacts







Large Landform, 0.2% AEP Height, PMF Impacts

Appendix D

Technical Working Group 3
Presentation

Nowra Riverfront Precinct Flood Impact and Risk Assessment

Technical Working Group Workshop 3

Workshop Overview

- Study Overview
- Summary of Previous TWG Outcomes
- FPL Assessment
- NSW SES Modelling
- Site Specific Development Controls
- Performance Criteria and Landform Tests Undertaken
- Draft Landform

Study Overview

TWG 1 - Outcomes

ID	Option	Consider Further?
Structural Options (to manage existing/developed flood risk)		
S1	River levee	No.
S2	Upgrade to culvert and outlet at aquatic centre	Yes.
S3	Diversion and retention of flow in Nowra Recreation Park	No.
S4	Detention basin upstream of Hyam Street	No.
S5	Central storage for flood control	Yes.
S6	Raising of building pads to FPL	Yes.
S7a	Regrading of open space region	No.
S7b	Raising and regrading of open space region	No.
Planning Options (to manage future flood risk)		
P1	Appropriate development controls	Yes
P2	Provision of rising road access	Yes
P3	Provision of elevated pedestrian ways to flood free land	Not at this time.
Emergency Response Options (to manage residual risk, that is events above the 1% AEP)		
E1	Flood warning	Yes.
E2	Flood evacuation plans	Yes
E3	Flood awareness	Yes
E4	Update of emergency response documentation	Yes

Raised Landform Scenarios

Two raised landforms were developed:

Large footprint

Small footprint

Each was raised to two heights

- The 1% AEP + SLR + RI + FB
- The 0.5% AEP + FB

Layouts constrained by

- Not encroaching on open space
- Heritage buildings
- Retained roads

- Other regions remain as per existing

TWG 2 - Outcomes

Raising full precinct has flood impacts in events above the 0.2% AEP.
Feasibility of evacuation requires further assessment.

Precinct generally compatible with flood behaviour.
Feasibility of evacuation requires further assessment.

Precinct generally compatible with flood behaviour.
Feasibility of evacuation requires further assessment.

Raising precinct has modest impacts in the 0.05% AEP and significant impacts in the PMF.
Feasibility of evacuation requires further assessment. Portions of the site are low flood islands.

Southern portion flood free in PMF.
Feasibility of evacuation requires further assessment.
Is a high flood island.

Precinct located on high point and is largely flood free in the PMF. Is a high flood island.

Rhelm

FPL Assessment

Three FPL options were investigated:

- 1% AEP + 0.9m Sea Level Rise + 16.3% Rainfall Increase + 0.5m freeboard
- 0.5% AEP + 0.9m Sea Level Rise + 0.5m freeboard
- 0.5% AEP + 0.9m Sea Level Rise + 16.3% Rainfall Increase + 0.5m freeboard

Each scenario was assessed for:

- Benefits to flood warning and evacuation
- Benefits to risk in likelihood of flooding
- Impact on developable area
- Integration with adjacent infrastructure
- Aesthetic and open space integration considerations

FPL Assessment

Flood warning and evacuation

- Based on the Probable Maximum Flood rate of rise, each metre higher the pads are located provides approximately an extra hour of time before they become inundated.
- However, this is offset for the highest pad (0.5% AEP with rainfall increase) as it means for Scenic Drive and Hyam precincts adjacent roads overtop before the pad does, effectively turning these sites into low flood islands.

Flood immunity

- Higher pads deliver a higher flood immunity which translates into lower flood related economic, social and insurance costs

Event	**Chance of experiencing in a 70-year period**	
	at least once	at least twice
1% AEP	50%	16%
0.5% AEP	30%	5%

Rhelm

FPL Assessment

Impact on developable area (based on the assumed 1 in 4 batters)

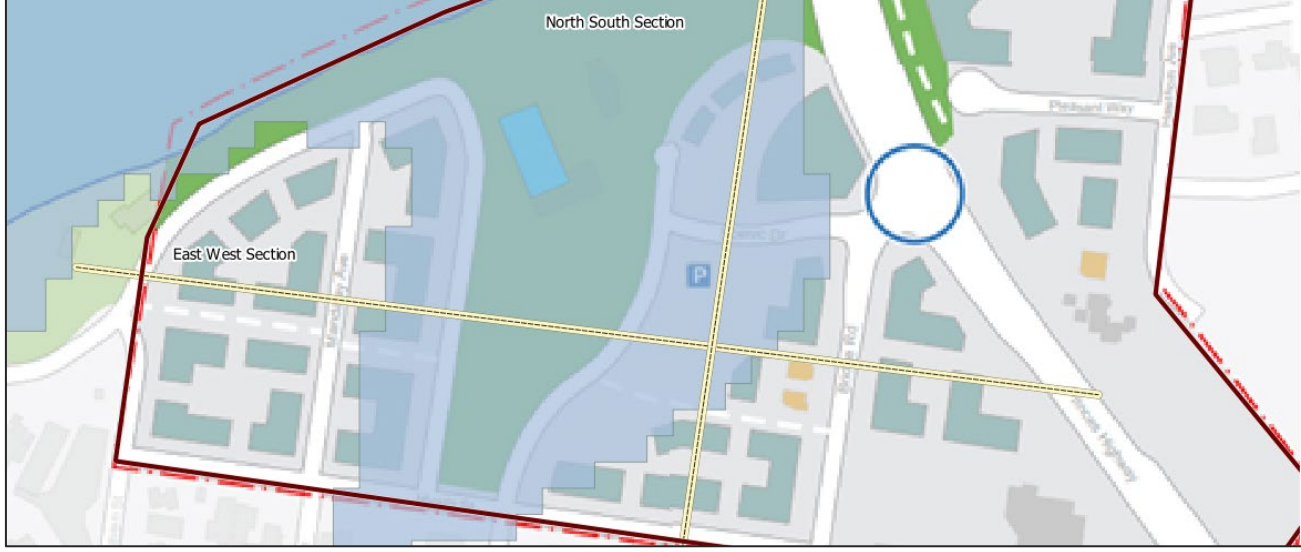
- Impact most pronounced for Scenic Drive and Wharf Road pads as they have batters on multiple sides.
- For these sites, the loss of developable area under the highest pad scenario was 22 – 24% compared to the lowest pad level.
- Other sites typically lost 1 – 4% by stepping up to the middle pad, and 3 – 8% by stepping up to the highest pad.

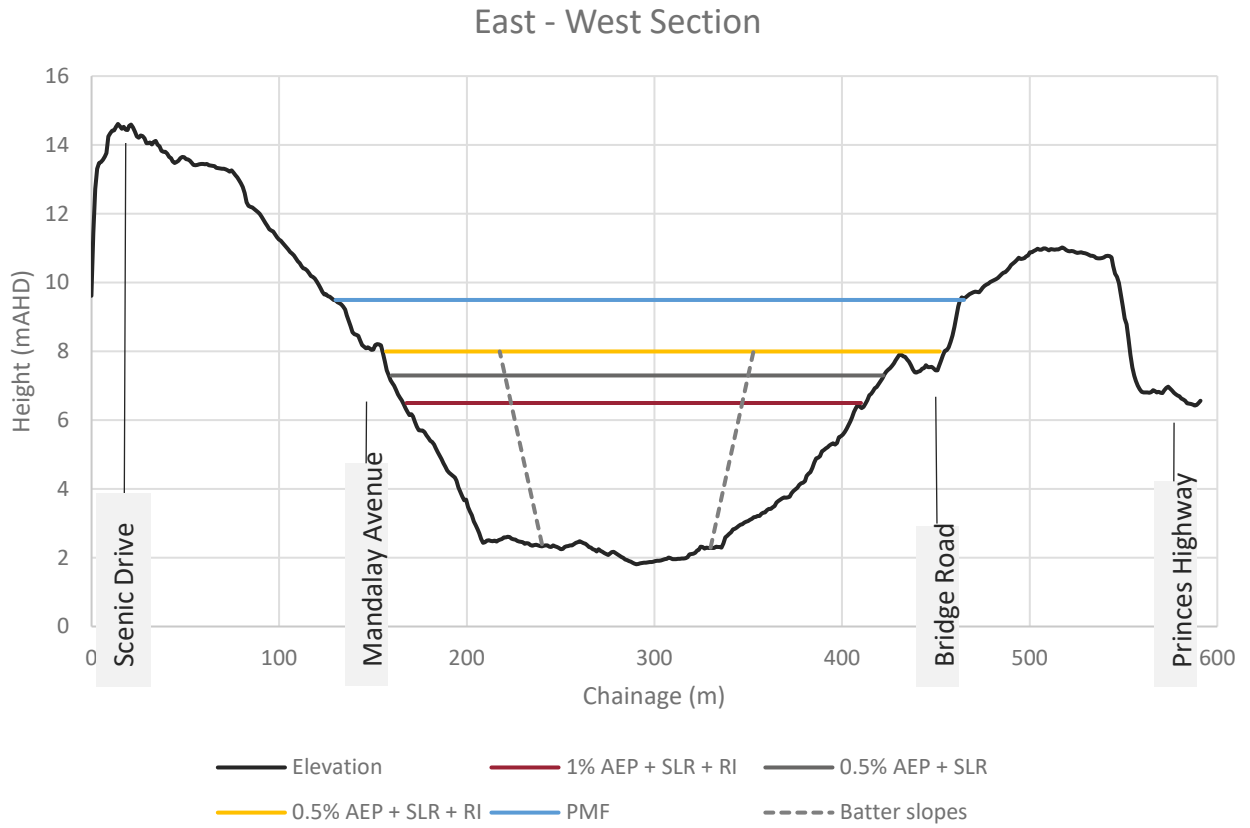
Precinct	Reduction to 0.5% AEP + SLR from 1% AEP + SLR + RI	Reduction to 0.5% AEP + SLR + RI from 1% AEP + SLR + RI
Mandalay	-2%	-4%
Hyam	-4%	-8%
Scenic	-11%	-24%
Pleasant Way	-1%	-3%
Wharf Rd	-11%	-22%

FPL Assessment

Integration and Aesthetic Considerations

- The 0.5% AEP + SLR+RI + FB pad would require the raising and reconstruction of Mandalay Avenue, which would pose challenges relating to staging and acquisition.
- Tying into Hyam Street and Bridge Road would become difficult in the highest scenario, due to the pads being higher than these roads.
- Even the lowest pad scenario would site ~4m above the central open space.





FPL Assessment Outcome

From the above, the decision was made with Council to adopt the 0.5% AEP + SLR for the pad FPL

- Not a significant loss of developable area across the precincts
- Provides additional warning and evacuation time
- The construction and staging is simplified by not requiring Mandalay Avenue to be reconstructed, and allows for rising road evacuation connections (save for Wharf Road) to existing external roads.
- Balances flood immunity with open space integration and accessibility.

NSW SES Evacuation Modelling

The SES has undertaken an assessment of their ability to undertake an evacuation. Evacuation timeline was broken down into discrete stages:

- Flood prediction
- Warning delivery
- Evacuation operation

Based on these stages, current SES policy is that a minimum of 10 hours is required to safely evacuate a region during a flood event:

- 6 hours for SES mobilisation;
- 3 hours of warning time to alert occupants to the flood risk; and,
- 1 hour of traffic movement to evacuate to a safe location.

The assessment found that no precinct could be safely evacuated within this timeframe. It found that the existing roads had sufficient capacity to allow an evacuation, but that insufficient time was available to door knock and warn all occupants.

NSW SES Evacuation Modelling

However, SES noted the tool was developed to inform the evacuation of the Hawkesbury-Nepean River floodplain, and that this study area is different:

- A concentrated, rather than a disperse population; and,
- A short (<200m) evacuation distance, rather than a long (>1hr)

As such, the SES noted that the estimates may not necessary be accurate. However, they are the best available.

As a result of the findings of the SES assessment:

- No changes were made to the pad extents based.
- Specific development controls were prepared to improve flood warning and evacuation for the precincts.

Draft Development Controls

FPL

- FPL set at 0.5% AEP + 0.5m freeboard (incorporating sea level increases)
- This control applies to both habitable and non-habitable floors.
- Type H land use categories as per Schedule 1 in DCP Chapter G9 to have an FPL set at the PMF.

Filling in the Floodplain

- Filling to the FPL required within the regions shown on … *[map to be provided]*

Draft Development Controls

Emergency Evacuation

- All buildings to have a flood warning system capable of issuing manual and automatic alerts, with trigger levels, warning times and gauges/data sources used agreed to by Council and the SES.
- All internal roads to provide constant rising road access to precinct boundary, where possible.
- Emergency pedestrian access to be provided at the FPL as a minimum to ground above the FPL at the precinct boundary.

Open Car Parking

- The flood hazard within the carpark is not exceed H1 in the 0.5% AEP event.
- All open car parks to provide rising road access to the exit of the carpark.
- Car park design to account for vehicle stability in events up to and including the PMF.

Draft Development Controls

Basement Carparking

- Basement carparking to proactively address and manage flood risk to people and vehicles for the full range of flood events, up to and including the PMF.

Structural Soundness

- All structures to be designed to withstand the forces of floodwaters (including debris and buoyancy forces) in the PMF flood event.

Hydraulic Impact

- Any proposed changes to the extents and levels of the filled pads requires a Flood Impact and Risk Assessment.

Building Components

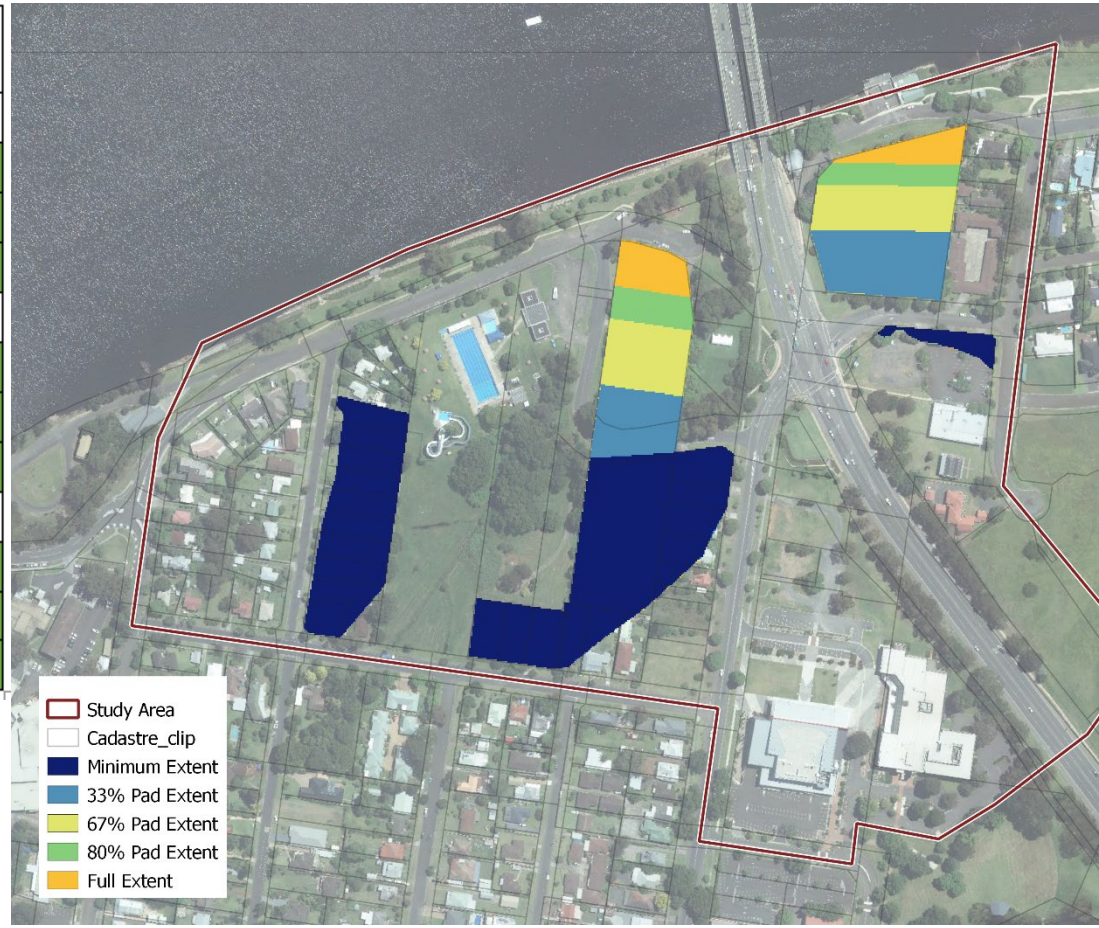
- No building component controls are required for this precinct.

Performance Criteria

Performance Criteria	Acceptable	Possibly Acceptable	Not Acceptable
For the 0.5% AEP			
WSE Impacts (m)	None	<0.02	>0.02
Velocity Impacts (m/s)	None	<0.1	>0.1
Hazard Impacts (increase in hazard category)	None	1	>1
For the 0.05% AEP			
WSE Impacts (m)	<0.05	<0.1	>0.1
Velocity Impacts (m/s)	<0.2	<0.5	>0.5
Hazard Impacts (increase in hazard category)	None	1	>1
For the PMF			
WSE Impacts (m)	<0.1	<0.2	>0.2
Velocity Impacts (m/s)	<0.5	<1	>1
Hazard Impacts (increase in hazard category)	None	1	>1

Landform Extent Testing

Performance Criteria	Full Extent	80% Pad	67% Pad	33% Pad	Minimum Pad
For the 0.5% AEP					
WSE Impacts					
Velocity Impacts					
Hazard Impacts					
For the 0.05% AEP					
WSE Impacts					
Velocity Impacts					
Hazard Impacts					
For the PMF					
WSE Impacts					
Velocity Impacts					
Hazard Impacts					



Landform Additional Testing

Performance Criteria	15m offset from Pleasant Way road corridor	River FPL 66% Pad	River FPL 33% Pad
For the 0.5% AEP			
WSE Impacts			
Velocity Impacts			
Hazard Impacts			
For the 0.05% AEP			
WSE Impacts			
Velocity Impacts			
Hazard Impacts			
For the PMF			
WSE Impacts			
Velocity Impacts			
Hazard Impacts			

Landform Additional Testing

Performance Criteria	67% Blocked	33% Blocked	West Blocked
For the 0.5% AEP			
WSE Impacts			
Velocity Impacts			
Hazard Impacts			
For the 0.05% AEP			
WSE Impacts			
Velocity Impacts			
Hazard Impacts			
For the PMF			
WSE Impacts			
Velocity Impacts			
Hazard Impacts			

Draft Landform

- The draft landform is shown to the right, showing the developable portion for each precinct.
- The precincts are discussed below, with respect to the initial precinct plan.
- Mandalay
  - Far northern tip removed as it was driving flood level increases.
  - Fill ends east of Mandalay Avenue, allowing this road to be maintained.
- Scenic Drive
  - Pulled slightly south to retain conveyance across highway in larger events.

Draft Landform

- Hyam Street
  - No substantial changes
- Bridge Street
  - No substantial changes
  - This precinct was already located on high ground, so does not require a precinct pad.
- Pleasant Way
  - No substantial changes.
- Wharf Road
  - The full development of this site was not found to be possible, as it resulted in off-site impacts.
  - The eastern third has been removed, to allow the impacts to dissipate before reaching adjacent development.
  - Requires further consideration relating to evacuation given rising road can't be achieved, and is a low flood island

engineering | environmental | economics | engagement

Appendix E

Concept Option Development and Testing

E Concept Option Development and Testing

E.1 Development of Concept Options

The outcome of the first TWG workshop was the identification of structural options and scenarios for concept modelling. The options selected for assessment in the hydraulic model were:

- Raised building pads;
- Additional culvert capacity; and,
- Central storage basin.

E.1.1 Raised Building Pads

The extent of the raised pads associated with each sub-precinct was confined by several factors:

- The central region on the western side of the Highway currently zoned as open space was to be fully retained. No landform works were permitted within this space. Any landform works would need to be undertaken fully within the adjacent residential and commercial zones.
- Mandalay Avenue, Pleasant Way and Hawthorn Avenue were to be retained as per existing site conditions. Any works would need to start from the edges of these road reserves.
- Works would not be able to impact on the heritage-listed Graham Lodge.

Based on these constraints, two pad extents were developed:

- raising the maximum area available given the constraints above.
- raising a smaller area and removed the filling of the Wharf Road sub-precinct and the Scenic Drive sub-precinct to retain conveyance through the overbank regions in large flood events.

Both scenarios incorporated batter slopes of 1 in 4 from the edge of the available area up to the pad level. This was adopted to maximise the potential extent of the pad. However, it is noted that it may be preferable to adopt a gentler slope, such as 1 in 6.

For each extent, two pad levels were assessed:

- 2100 1% AEP plus 0.5m. The 2100 scenario incorporated both sea level rise and rainfall intensity increases based on the RCP8.5 emissions pathway (refer **Section 5.4**). As the riverine 1% AEP level was greater than the local catchment 1% AEP level, the riverine flood was used to set the pad heights.
- the existing riverine 0.5% AEP plus 0.5m level. This height was modelled to assess how high the pads may be raised before adverse flood impacts were observed, and whether additional flood immunity may be achievable. The higher level did not change the overall pad extents, but rather increased the extent of the batters, and reduced the raised area at the top of the pad. The pad area available under each scenario is summarised in **Table E-1**

Both pads result in a loss of storage within the Precinct for both local and riverine driven flood events. The loss of storage in the 5% and 1% AEP events, and the PMF, are summarised in **Table E-2**.

The volume available from the central storage basin (refer Section **6.3.2**) is insufficient to offset this loss of storage in both local and riverine events.

The revision of the Lower Shoalhaven River Flood Study and Floodplain Risk Management Study & Plan will examine the cumulative impacts of the filling of storage areas within developable regions of the

floodplain, which will assist in informing how much impact filling such as this would be if applied across the whole floodplain.

At present, it is understood that if the development application for the Precinct were to follow the merits-based approach, this fill may be supported if it can be demonstrated that it is not having adverse impacts, and that it provides a benefit to the long term used of the Precinct.

The levels adopted are summarised in **Table E-3.**

The pad extents are shown in **Figure E-1** and **Figure E-2** for the large and small extents respectively.

Table E-1 Pad Top Area (m^2)

Pad Size	Large Pad	Small Pad
2100 1% AEP + 0.5m	56,800	28,200
0.5% AEP + 0.5m	48,500 (15% reduction)	23,700 (16% reduction)

Note: This is the size of the raised pad, not the size of the full Precinct.

Table E-2 Loss of Floodplain Storage Volumes (m^3)

Pad Size	Large Pad	Small Pad
Local		
5% AEP	630	75
1% AEP	33,500	10,200
PMF	47,100	17,300
Riverine		
5% AEP	700	0
1% AEP	41,300	16,350
PMF	60,600 / 86,800 (2100 1% AEP + 0.5m / 0.2% AEP level)	25,300 / 41,700 (2100 1% AEP + 0.5m / 0.2% AEP level)

Table E-3 Pad Fill Heights

Scenario	West of Highway	East of Highway
2100 1% AEP + 0.5m Pad Height	6.5mAHD	5.9mAHD
0.5% AEP + 0.5m Pad Height	7.3mAHD	6.3mAHD

Figure E-1 **Large Pad Scenario Extents**

Figure E-2 **Small Pad Scenario Extents**

E.1.2 Central Basin and Culvert Works

The two additional options were applicable to the local catchment only, as they do not have any influence over riverine flooding.

The location of the two options is shown in **Figure E-3**.

Both options were designed to offset potentially adverse impacts arising from loss of storage associated with the raised pads, and to seek to improve the inundation across Hyam Street. The central basin also provides controlled storage for smaller design events.

It is noted that both options are only feasible for events up to and including the 1% AEP event. For events larger than this, flooding across the Precinct is governed by overbank flows from the river, which will drown out both these options.

The culvert option involved the construction of a second culvert outlet from the existing low point within the central open space. As the existing culvert runs under the aquatic centre, which is to be retained, it was deemed too expensive to duplicate the existing line. As such, a separate, second line was modelled with dimensions as per the current culvert. It is noted that this option would require substantial works along the riverbank, which would necessitate additional environmental assessments and controls. It would also result in additional stormwater assets to be managed by Council. The ongoing management of this structure is important, as if the gates are jammed open by debris, it would allow the inundation of the central Precinct in minor river flood events, via backwatering up the culvert.

The basin option involved excavating a central basin to provide additional storage capacity in this region. To prevent the need for fences or barriers, the depth was limited to 1 metre. Batters were assumed to be 1 in 6 to cater to pedestrian traffic in the area. These restrictions limited the available additional volume the basin could contribute to 3,400m^3.

Figure E-3 Local Flood Management Options

E.2 Impacts Arising from Modelled Scenarios

The developed scenarios were run for both the local catchment and riverine flood models. The results for each are discussed below.

It is noted that Council's Engineering Design Guidelines do not allow afflux over existing urban land as a result of development. Council typically defines no afflux as +/-10mm, as impacts of this magnitude are considered to be within the precision of the hydraulic model and available data. As such, impacts are only shown and discussed if they exceed 10mm (0.01m).

E.2.1 Local Catchment Flooding

The landform options were in the local model for the 5%, 1%, and 0.2% AEP events and the PMF event. Both landform heights are above the local catchment PMF level, and as such, only the 2100 1% AEP + 0.5m pad height was assessed in the local catchment model.

Results are shown in:

- **Map Series RG-06-02** for the large footprint scenario
- **Map Series RG-06-03** for the small footprint scenario

Note that results are not shown for local flood events larger than the 1% AEP. No impacts were observed in these events as backwater effects from the Lower Shoalhaven River control the flood behaviour across the site, and this behaviour was not impacted by the change in landform.

The western pads, for the large pad scenario, resulted in increases within the central open space of 0.02m in both the 5% AEP and the 1% AEP. In the 5% AEP, these impacts were fully contained within the central open space. In the 1% AEP, the 0.02m increase extended over Hyam Street, and impacted properties immediately adjacent to the open space south of Hyam Street.

In the small pad extent scenario, these impacts were removed in the 5% AEP and kept within the Precinct boundary for the 1% AEP event.

The large eastern pads resulted in water level increases along Pleasant Way and Hawthorn Avenue of 0.01m in both 5% AEP and 1% AEP events. Impacts extended 50m east along Elia Avenue and affected properties at the intersection of Hawthorn Avenue and Elia Avenue.

The smaller eastern pad scenario (that is, with Wharf Road not raised) had localised increases along Pleasant Way and Hawthorn Avenue of 0.01m, that were largely contained within the road reserves.

To address the adverse impacts observed in the local 1% AEP two mitigation options were tested:

- The construction of a central basin; and,
- The construction of an additional culvert line.

The basin results indicated that the available volume was not sufficient to significantly change peak flood levels. The basin filled quickly, in advance of the peak, so that resulting flood levels were not measurably different from the raised landform scenario levels.

The construction of an additional culvert was more effective. The addition of a second culvert line, with a size as per the current culvert, was sufficient to reduce levels within the central region (and consequently across Hyam Road the adjacent properties) by 0.05m. The increase arising from the construction of the landforms was 0.02m. The results demonstrate that the addition of an additional

culvert is sufficient to remove the adverse impacts from the pad raising, and that this additional culvert can likely be smaller than the culvert currently in place.

Overall, the impacts arising in local catchment floods due to the raised pads were relatively modest. As will be discussed below, the impacts arising in riverine floods is more pronounced, and it is these riverine impacts, rather than the local impacts, that will dictate feasible options for the site.

E.2.2 Riverine Flooding

The landform options were in the local model for the 1%, 0.2% and 0.05% AEP events and the PMF event. Each event was run for both the 2100 1% AEP + 0.5m and 0.2% AEP level pads.

The more frequent events were not run, as the river flooding from these events does not interact with the proposed pad extents.

Results are shown in:

- **Map Series RG-06-04** for the large footprint, 2100 1% AEP + 0.5m height scenario
- **Map Series RG-06-05** for the small footprint, 2100 1% AEP + 0.5m height scenario
- **Map Series RG-06-06** for the large footprint, 0.5% AEP + 0.5m height scenario
- **Map Series RG-06-07** for the small footprint, 0.5% AEP + 0.5m height scenario

All the scenarios had a similar behaviour in events up to and including the 0.2% AEP.

In the 1% AEP, there was very little change in flood behaviour. Some local increases were observed immediately adjacent to the raised pads in all scenarios due to water pushing up against them.

In the 0.5% and 0.2% AEP events, there was some build-up of water behind the Mandalay pad, resulting minor reductions of 0.02m within the central portion of the site. Sensitivity testing was undertaken on this landform and found that the removal of the northern protrusion resulted in the removal of both the observed upstream increases and the downstream decreases in events up to 0.2% AEP.

This consistency between all the scenarios is because for events up to the 0.2% AEP event there is little conveyance of flood waters through the overbank areas. As such, all these changes are being undertaken in flood storage and fringe zones and are not substantially altering the flood behaviour.

This behaviour changes in the 0.05% AEP when river flows overtop the Riverview Road levee, and the overbank areas begin to convey a more substantial portion of the flow. In the PMF, the highway is overtopped, and overbank conveyance becomes activated in the western portion of the site also.

It is this change in conveyance behaviour that governs the impacts observed in the larger events.

The behaviour of the large and small landforms in these larger events is discussed below.

E.2.3 Large Pad Extent Impacts in Rare Events

The raising of the Wharf Road sub-precinct in the large 2100 1% AEP + 0.5m pad extent scenario resulted in upstream river levels typically increasing by 0.02m in the 0.05% AEP and up to 0.15m in the PMF. Localised increases immediately adjacent to the Wharf Road pad were up to 0.2m and 0.3m in the 0.05% AEP and PMF, but these quickly dropped to smaller differences. Increases of 0.01m extended 1,400m upstream in the 0.05% AEP and 8km in the PMF. Whilst largely contained within vegetated overbank areas, these increases did result in higher flood levels occurring at properties along Hyam Street adjacent to the site and over the golf course on the northern shore of the river.

In the existing scenario, there was ponding, but no flow across, the highway in the 0.05% AEP event. The minor increase because of raising the Wharf Road sub-precinct was sufficient to cause flow to commence across the highway. While this flow was relatively slow moving, it was then funnelled into Pleasant Way between the Wharf Road and Graham Lodge sub-precinct landforms, resulting in velocity increase down the roadway from 0.6m/s to 1.6m/s, and a subsequent increase in hazard from H3 to H4.

Due to the blockage of flow at Wharf Road, the downstream regions experienced some minor reduction in peak levels of up to 0.05m and 0.12m in the 0.05% AEP and PMF events respectively.

Results were similar for the 0.5% AEP +0.5m pad level scenario in the 0.05% AEP event. In the PMF, the higher landform resulted in a further loss of conveyance which resulted in additional increases throughout the river and upstream. Increases of 0.05 to 0.07m occurred for 3.2km upstream, while increases greater than 0.01m extended for 10.5km upstream. Reductions of 0.05 – 0.07m extended downstream behind the levee for 570m.

E.2.4 Small Pad Extent Impacts in Rare Events

In the rare events, the small pad scenario removed most of the impacts for both 2100 1% AEP + 0.5m and 0.5% AEP +0.5m pad levels.

In the 0.05% AEP, the smaller pad resulted in no adverse impacts off site. Some minor increases of 0.01 – 0.03m occurred for both 2100 1% AEP + 0.5m and 0.2% AEP pad heights over the Wharf Road sub-precinct (which was not raised in these runs). There were no significant changes in the western region of the site for the 2100 1% AEP + 0.5m pad, and the 0.5% AEP +0.5m pad height resulted in reductions of 0.01m in the central region because of flows being slightly held back by the protrusion of the Mandalay sub-precinct landform.

In the PMF event, impacts were significantly reduced compared to the large pad extent. The 2100 1% AEP + 0.5m pad height scenario had a region of 0.01m impacts over the Wharf Road sub-precinct, which extended 20m into the river. A reduction of 0.01m was observed in levels downstream of the Graham Lodge pad for 300m. No significant differences were observed in the west of the site.

In the PMF, the higher 0.5% AEP +0.5m pad level resulted a similar behaviour in the eastern sub-precincts (with a slightly larger region of reduction downstream), whilst the higher western landforms increased local levels by 0.01 – 0.02m. These impacts affected properties on Hyam Street but did not extend up the river beyond the immediate site boundary.

E.3 Summary of Outcomes

The results indicated that some form of filling within the site is achievable. Whilst filing of the full developable area has adverse impacts in larger flood events, the fact that the smaller fill extent did not, suggests that some optimisation of fill extent beyond the currently modelled small extent is possible.

Overall, the region was more sensitive to changes in fill extent than to changes in pad level. If a pad location was found to not significantly affect flood behaviour when filled to the 2100 1% AEP + 0.5m, it was generally able to be filled to higher levels without adversely affecting flood behaviour.

If, however, impacts were observed at the 2100 1% AEP + 0.5m pad level, they were exacerbated by further raising.

A summary of the behaviour of the individual sub-precincts is provided in **Table E-5**.

The sub-precincts are shown in **Figure E-4**.

Table E-3 Summary of Sub-precinct Outcomes

Sub-precinct	Outcome
Mandalay	Sub-precinct generally compatible with flood behaviour. Raising of sub-precinct above the 0.5% AEP + 0.5m feasible. Rising Road evacuation is structural achievable but requires additional assessment to confirm feasibility.
Hyam Street	Sub-precinct generally compatible with flood behaviour. Raising of sub-precinct above the 0.5% AEP + 0.5m feasible. Rising Road evacuation is structural achievable but requires additional assessment to confirm feasibility.
Scenic Drive	Raising sub-precinct has flood impacts in events above the 0.2% AEP. Some raising of the southern portion likely feasible, so that conveyance is retained adjacent to the river. Rising Road evacuation is structural achievable but requires additional assessment to confirm feasibility (via Hyam St Sub-precinct).
Bridge Road	Sub-precinct located on high point and is largely flood free in the PMF. No changes were modelled in this sub-precinct. Is a low flood island.
Pleasant Way and Graham Lodge	Southern portion flood free in PMF. Raising remaining portion generally feasible from a flood impact perspective. Is a low flood island.
Wharf Road	Raising sub-precinct has modest impacts in the 0.05% AEP and significant impacts in the PMF. Eastern portion of the site has structurally achievable rising road for events up to 0.5% AEP (feasibility subject to capacity assessment). In larger events, the site is a combination of potential raising road to a high flood island within the adjacent Graham Lodge sub-precinct, and a low flood island, for the western portion of the site, which losses access along the highway and Pleasant Way before the sub-precinct itself experiences flooding.

Figure E-4 **Proposed Sub-precincts**

Appendix F

Landform Optimisation and Sensitivity Testing

F Option Testing

Based on the preceding future scenario testing (refer **Section 6.4**) it was determined that the Mandalay, Hyam Street, Bridge St, and Pleasant Way sub-precincts could all incorporate pads without adversely impacting flood behaviour.

To determine which pad extents (if any) were possible for the Scenic Road and Wharf Road sub-precincts, a series of options were developed.

The option testing resulted in a progressively smaller portion of the Scenic Road and Wharf Road pads being incorporated into the landform, with the northern boundary being pulled south to reduce the pad extent. The pads tested are shown in **Figure F-1.**

Figure F-1 Option Pad Extents

Each of the above pad extents were assessed for the 0.5% AEP, 0.05% AEP and PMF events. The results are summarised in **Table F-1**.

Key difference maps are provided in:

- **Figure F-2** for the 0.5% AEP water level impacts for the Wharf Rd 80% and 67% scenarios.
- **Figure F-3** for the 0.5% AEP velocity impacts for the Wharf Rd 80% and 67% scenarios.
- **Figure F-4** for the 0.05% AEP water level impacts for the Wharf Rd Ful and 67% scenarios.
- **Figure F-5** for the 0.05% AEP velocity impacts for the Wharf Rd 67% and 33% scenarios.

These key difference maps demonstrate the local impacts that determine whether a scenario is feasible or not.

In the PMF event, all the landform extents met the performance criteria for water level, velocity, and hazard.

The results also showed that the minimal pad extent (i.e., no Wharf Road or Scenic Drive pads) also successfully met all performance criteria.

In the 0.5% AEP event, unacceptable impacts for water level and velocity were observed for the full extent scenario, and velocity impacts were also observed in the 80% scenarios.

Under the full scenario, increases of up to 0.24m were observed across properties immediately to the west of the Wharf Road sub-precinct. Smaller increases of 0.05 – 0.1m extended 100m east from the precinct boundary along both Riverview Road and Elia Avenue, with smaller impacts of up to 0.05m extending a further 140m along these roadways.

No water level impacts in the 0.5% AEP were observed once the pad was reduced to 80%.

Velocity impacts in the 0.5% AEP occurred along Pleasant Way, Riverview Road, and Elia Avenue. The increases were greatest at Pleasant Way, with velocities increasing by up to 1.1m/s. The impacts along Riverview Road and Elia Avenue were more modest, in the order of 0.3 – 0.4m/s.

Reducing the pad extent to 80% removed the velocity impacts on Riverview Road and Elia Avenue, though impacts of up to 0.6m/s were still observed along Pleasant Way.

Reducing the pad to 66% removed all velocity impacts in the 0.5% AEP event.

For the 0.5% AEP, the full extent scenario also had some impacts on hazard. These impacts resulted in the hazard class increasing by 1 for some locations east of the Wharf Road pad. However, these increases were not widespread, but rather occurred as several small, isolated pockets. The hazard impacts were removed in the 0.5% AEP by reducing the pad to 80%.

The 0.05% AEP event had unacceptable impacts in the full extent scenario for water level and velocity. Water level impacts occurred to the east of the Wharf Road pad across the adjacent residential lots. These lots experience increases of 0.22m in the full pad extent, reducing to 0.08m and 0.06m for the 80% and 67% pad extents respectively. Water level impacts were 0.05m in the 33% pad extent, which was classed as acceptable. The minimal pad extent removed all impacts in the region.

With respect to velocity in the 0.05% AEP, velocity impacts were observed along Pleasant Way and Hawthorn Avenue, because of the Wharf Road pad channelling highway overtopping flow along Pleasant Way, which also resulted in increases further downstream along Hawthorn Avenue. For the full, 80% and 67% extents, these impacts were 1.2m/s, 0.8m/s and 0.6m/s respectively. Reducing the pad extent served to 33% brought the impacts down to 0.3m/s, while removing the pad entirely removed all velocity impacts in the region.

Reducing the pad levels served to reduce these impacts, however, they were not reduced to an acceptable level until the Wharf Road pad was fully removed in the minimum scenario. This was due to the Wharf Road pad channelling flows along Pleasant Way, resulting in increased velocities along the roadway, and increases on adjacent properties to the east.

Table F-1 Performance Criteria Results of Pad Extent Testing

Performance Criteria	Full Extent	80% Pad	67% Pad	33% Pad	Minimum Pad
For the 0.5% AEP					
WSE Impacts		Figure F-2	Figure F-2		
Velocity Impacts		Figure F-3	Figure F-3		
Hazard Impacts					
For the 0.05% AEP					
WSE Impacts	Figure F-4		Figure F-4		
Velocity Impacts			Figure F-5	Figure F-5	
Hazard Impacts					
For the PMF					
WSE Impacts					
Velocity Impacts					
Hazard Impacts					

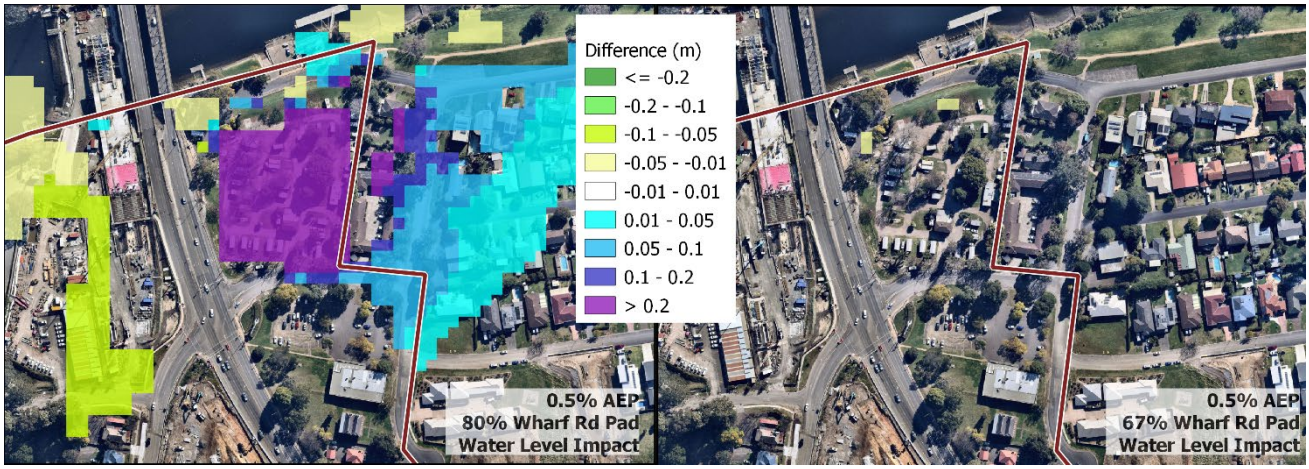


Figure F-2 Water Level Impacts for the 0.5% AEP Wharf Rd 80% and 67% Scenarios

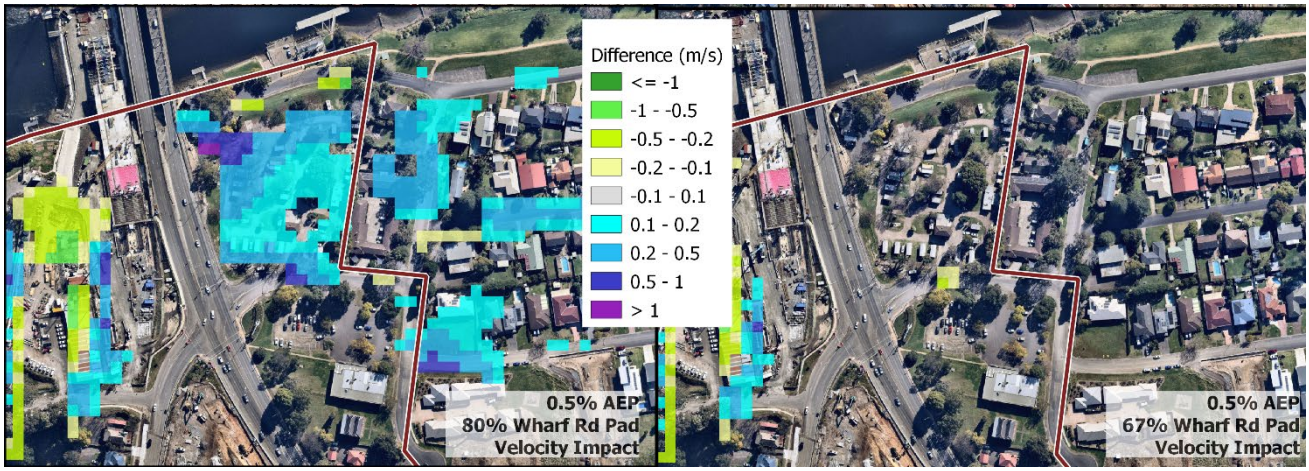


Figure F-3 Velocity Impacts for the 0.5% AEP Wharf Rd 80% and 67% Scenarios

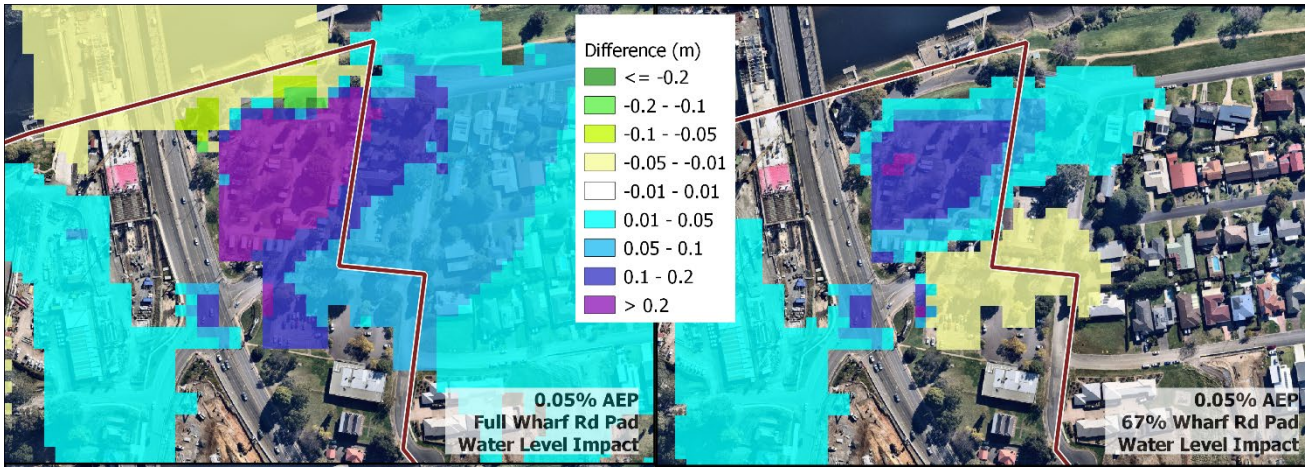


Figure F-4 **Water Level Impacts for the 0.05% AEP Wharf Rd Full and 67% Scenarios**

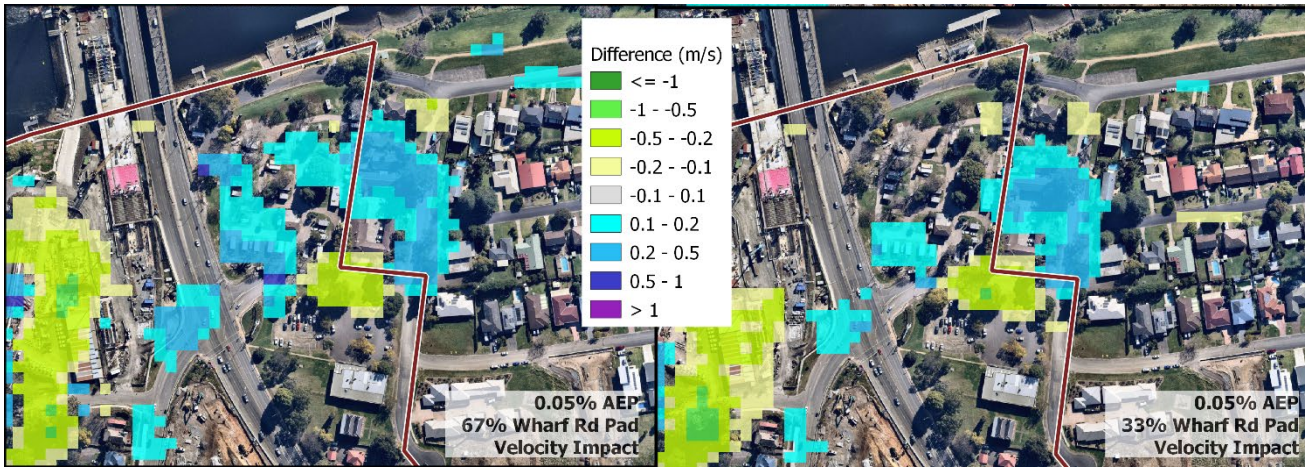


Figure F-5 **Velocity Impacts for the 0.05% AEP Wharf Rd 67% and 33% Scenarios**

Following this initial assessment, additional sensitivity tests were undertaken on the 67% pad scenario to better inform the final landform, namely:

- The Wharf Rd pad was pulled back from Pleasant Way by 15m (the smallest amount achievable given the grid cell size) in order to address velocity impacts along Pleasant Way.
- The Wharf Rd and Pleasant Ave pads were raised to an FPL based on the adjacent river level, rather than the level onsite, in order to ensure the building pads retain flood immunity in the 0.5% AEP even if the levee bank fails.

The results of the Pleasant Way and FPL testing are summarised in **Table F-2**.

Key difference maps are provided in **Figure F-6** for the 0.05% AEP water level impacts for the Riverine FPL Wharf Road 66% and 33% scenarios. These key difference maps demonstrate the local impacts that determine whether a scenario is feasible or not.

The provision of additional capacity along Pleasant Way was sufficient to resolve the velocity impacts in the 0.05% AEP event. Some minor increases were still observed in the order of 0.1 – 0.15m, but these were within permissible impacts based on the performance criteria.

The adoption of an FPL based on riverine rather than local flood levels resulted in the eastern pads being raised an additional 0.95m, from 5.55mAHD to 6.5mAHD. In the 0.05% AEP event, the higher pad levels did not affect velocity or hazard behaviour but did results in unacceptable water level increase for the 66% pad extent, and borderline impacts for the 33% pad extent.

These impacts occurred across the residential properties immediately to the east of the Wharf Road sub-precinct, where increases of up to 0.2m and 0.08m were observed for the 66% pad extent and 33% pad extent respectively.

The pad level change had no impact on results in the 0.5% AEP and PMF events, with similar behaviour observed in both the riverine FPL scenario and local FPL scenario.

Table F-2 Performance Criteria Results of Sensitivity Testing

Performance Criteria	15m offset from Pleasant Way road corridor	River FPL 66% Pad	River FPL 33% Pad
For the 0.5% AEP			
WSE Impacts			
Velocity Impacts			
Hazard Impacts			
For the 0.05% AEP			
WSE Impacts		**Figure F-6**	**Figure F-6**
Velocity Impacts			
Hazard Impacts			
For the PMF			
WSE Impacts			
Velocity Impacts			
Hazard Impacts			

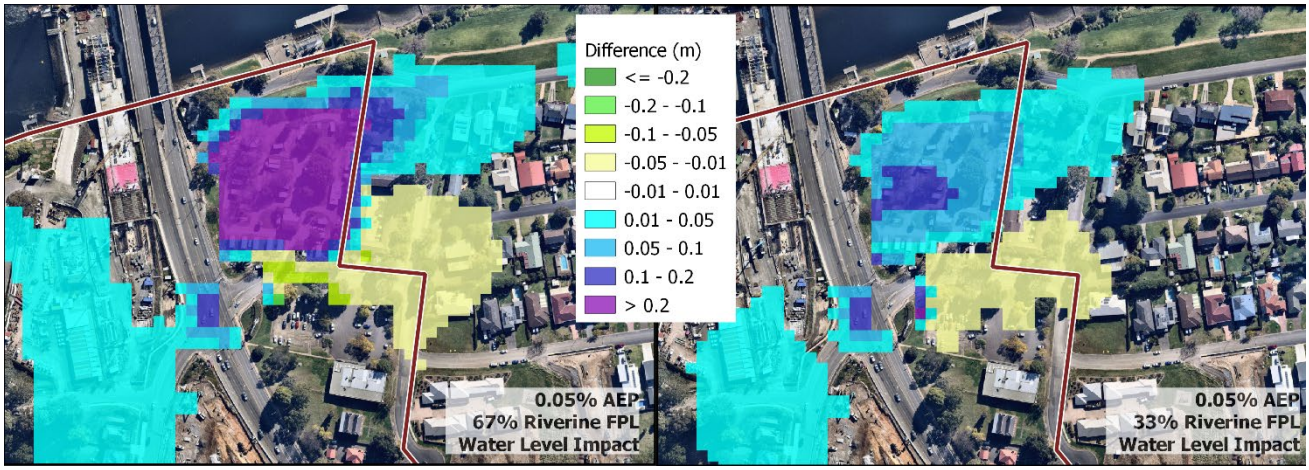


Figure F-6 Water Level Impacts for the 0.05% AEP Riverine FPL Wharf Rd 67% and 33% Scenarios

At this stage of the assessment process, preliminary plans for a proposed development were made available to Council. The plans indicated that the proposed development covered a significant portion of the site and was likely to offer a significant obstruction to the flow. To assess the more conservative scenario whereby development on the pad prevents flow completely, the tests have been undertaken with the full pad blocked out of the model.

To assess pad blockage, a series of scenarios were assessed:

- Blocking the 66% pad extent (where a 30m slice has been taken off the northern boundary of the Wharf Rd pad);
- Blocking the 33% pad extent (where a 60m slice has been taken off the northern boundary of the Wharf Rd pad); and,
- A western blockage scenario whereby the pad alignment was revised so that instead of removing a third from the northern edge of the pad, the slice was taken of the eastern edge.

The results of the pad blockage are summarised in **Table F-3**.

Key difference maps are provided in:

- **Figure F-7**for the 0.05% AEP water level impacts for the Wharf Road 66% and 33% blocked scenarios; and,
- **Figure F-8** for the PMF velocity impacts for the Wharf Road 33% blocked and West blocked scenarios.

These key difference maps demonstrate the local impacts that determine whether a scenario is feasible or not.

The full blockage of the 66% pad had significant impacts in both the 0.05% AEP and the PMF. Adverse impacts were due to water level and hazard changes in the 0.05% AEP and by velocity changes in the PMF.

In the 0.05% AEP, water level increases of 0.16m occurred across the residential properties immediately east of the Precinct. The change in hazard was driven by this increase, with the hazard increasing from H2 to H4 across these properties.

In the PMF event, velocities along Pleasant Way increased by 1.5m/s at the intersection with Hawthorn Avenue. This increase was driven by the fully blocked pad pushing water around the pad and down Pleasant Way, compared to the roughness pad scenario where flow was permitted across the pad.

The fully blocked 33% pad reduced the impacts in the 0.05% AEP, and while the water level and hazard impacts were no longer classed as unacceptable, they were still outside the desired threshold, with levels increasing by 0.08m, and hazard increasing by 1 from H2 to H3.

However, the smaller pad did not result in any benefit to the PMF velocities, with unacceptable increases still being observed at the eastern end of pleasant way.

The raising of the western portion of Wharf Rd resulted in better outcome, with the performance criteria goals being met for all events. This is due to having some buffer between the raised pad and the existing development on the eastern boundary, such that any significant changes in flood behaviour are able to dissipate within the Precinct boundary, and offsite impacts are within the performance criteria limits.

The western pad also resulted in improved PMF velocities, as the flowpath opens up earlier, allowing the flow to expand and slow. Although some velocity increases of up to 0.35m/s were observed, they were within acceptable limits based on the performance criteria.

The raising of the western region of Wharf Road, may also offer some opportunity to improve pedestrian access if the depression between the Wharf Road pad and the highway can be filled (noting that this is on TfNSW land).

The assessment demonstrated that, from a flood perspective, a reasonable portion of the Wharf Road pad can be retained without adversely affecting flood behaviour, even with the site modelled as fully blocked.

Table F-3 Performance Criteria Results of Pad Blockage Testing

Performance Criteria	67% Blocked	33% Blocked	West Blocked
For the 0.5% AEP			
WSE Impacts			
Velocity Impacts			
Hazard Impacts			
For the 0.05% AEP			
WSE Impacts	**Figure F-7**	**Figure F-7**	
Velocity Impacts			
Hazard Impacts			
For the PMF			
WSE Impacts			
Velocity Impacts		**Figure F-8**	**Figure F-8**
Hazard Impacts			

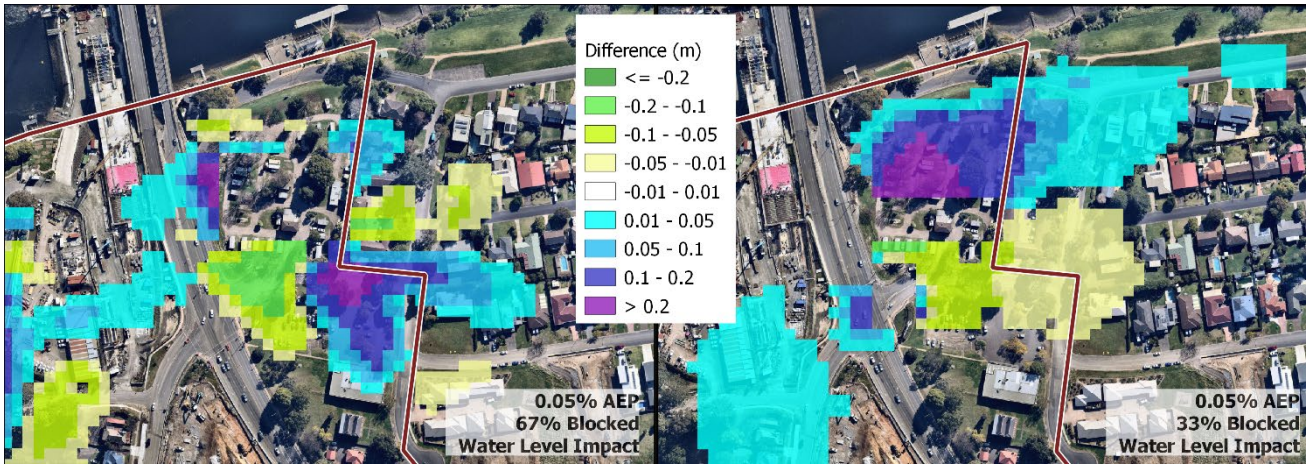


Figure F-7 Water Level Impacts for the 0.05% AEP Wharf Rd Blockage 67% and 33% Scenarios

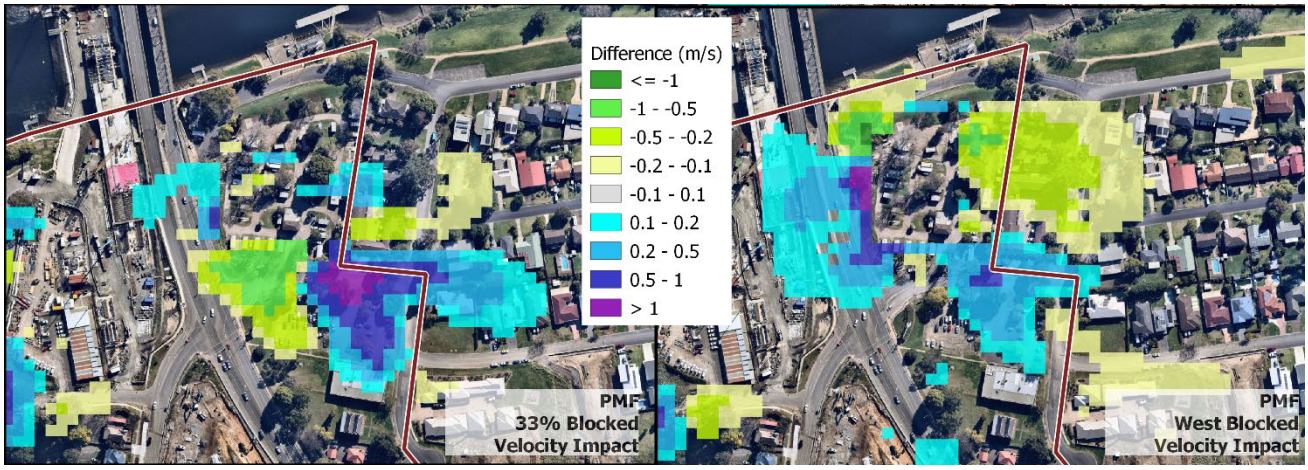


Figure F-8 **Velocity Impacts for the PMF Wharf Rd Blockage 33% and West Scenarios**

Appendix G

Agency Feedback and Technical Working Group 4 Agenda

G1 Agency Feedback and Technical Working Group 4

The draft FIRA report was provided to key agencies for review and feedback prior to finalising the report.

Feedback and comments from the report were received from:

- NSW SES
- NSW DPE – Floodplain Management
- NSW DPE – Planning, Southern Region
- Transport for NSW.

The agency submissions are provided at the end of **Appendix G**.

The key themes of the provided feedback are summarised in **Table 16-1**.

Table 16-1 Summary of Agency Feedback and Comments

Agency	Comment Summary
NSW SES	Development should not result in an increase in risk to life, health or property of people living on the floodplain.
	Risk assessment should consider the full range of flooding, including events up to the Probable Maximum Flood (PMF) and not focus only on the 1% AEP flood.
	Risk assessment should have regard to flood warning and evacuation demand on existing and future access/egress routes. Consideration should also be given to the impacts of localised flooding on evacuation routes.
	In the context of future development, self-evacuation of the community should be achievable in a manner which is consistent with the NSW SES's principles for evacuation. Future development must not conflict with the NSW SES's flood response and evacuation strategy for the existing community.
	Consent authorities should consider the cumulative impacts any development will have on risk to life and the existing and future community and emergency service resources in the future.
	The SES does not support: • Evacuation through flood waters; • Shelter in place / isolation management strategies; • Controls favouring private flood evacuation plans over sound planning and risk management; • The transfer of residual risk management to the SES; or, • Development strategies replying on mass evacuation, given evacuation may fail.
NSW DPE – Floodplain Management	Any future planning proposal will need to draw from the FIRA proposed measures to establish how the requirements of the local planning direction will be addressed relevant to the proposal and justify any inconsistencies in a clear and transparent way.
	The response to Ministerial Direction 4.1(4)(e) "the safe occupation and efficient evacuation of the lot" requires further development.
	Operational and legislative requirements for any warning system should be explored through advice from the SES and/or the BOM for planning decisions that require these systems for public safety.
	The appropriate population density of the proposed development should be clearly detailed in the Executive Summary and Conclusions.
	Executive Summary and Conclusion to be clearer on the compliance of the Wharf Road sub-precinct with Ministerial Directions.

Agency	Comment Summary
NSW DPE – Planning, Southern Region	Providing further clarification/justification for the setting of the FPL with regard to occupant safety.
TfNSW	TfNSW would not be supportive of development options that would cause road closures and impede emergency response efforts and general access that could otherwise be avoided.
	Noted that Scenic Drive and Bridge Road intersection is proposed to be closed.
	Any changes assumed pad batter slopes and extents by developers should require confirmation of design via modelling.

To further explore the comments and issues raised, a fourth TWG was convened. TWG4 was held on 3 April 2023. In attendance were representatives from the above agencies, as well as Shoalhaven City Council and Rhelm.

The TWG4 discussions focussed on the themes noted above, as detailed in the agency submissions.

Following TWG4, this report was updated to reflect the outcomes of the discussions, namely:

- Improved clarity on final recommendations and the need for additional assessments;
- Improved clarity on suitable development types for each sub-precinct;
- Revision of the previously proposed “flood warning system” to a “flood communication system” which does not issue alerts, but rather allows the SES to issue pre-recorded and live communications, both on- and off-site, to developments in the Precinct; and,
- Update of the evacuation timeline based on clarification at the TWG;
- Update of the Emergency Evacuation Section to provide a discussion on the impacts of the development on regional evacuation; and,
- Inclusion of this Section to provide transparency on the comments received and actions taken.

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