8.2.4 Boundary conditions

Key boundary conditions are illustrated in **Figure 8.2**, providing a detailed overview of critical parameters.

8.2.4.1 Rainfall

The direct rainfall approach was applied to the model using the design events identified and defined in the hydrological analysis (**Section 7.5**). This method involves distributing rainfall uniformly across the model domain, allowing for the simulation of surface runoff and flow pathways across the terrain. A schematic representation of direct rainfall approach (Rain-on-Grid) is provided in **Figure 8.3**. The design events, which were defined based on intensity, duration, and frequency characteristics, ensure that the model captures a range of flood scenarios. By integrating this approach, the model accounts for spatial and temporal variations in rainfall distribution, enabling a more detailed representation of overland flow and catchment response. This facilitates the assessment of flood extents, depths, and velocities, providing valuable insights for flood risk management and mitigation planning.

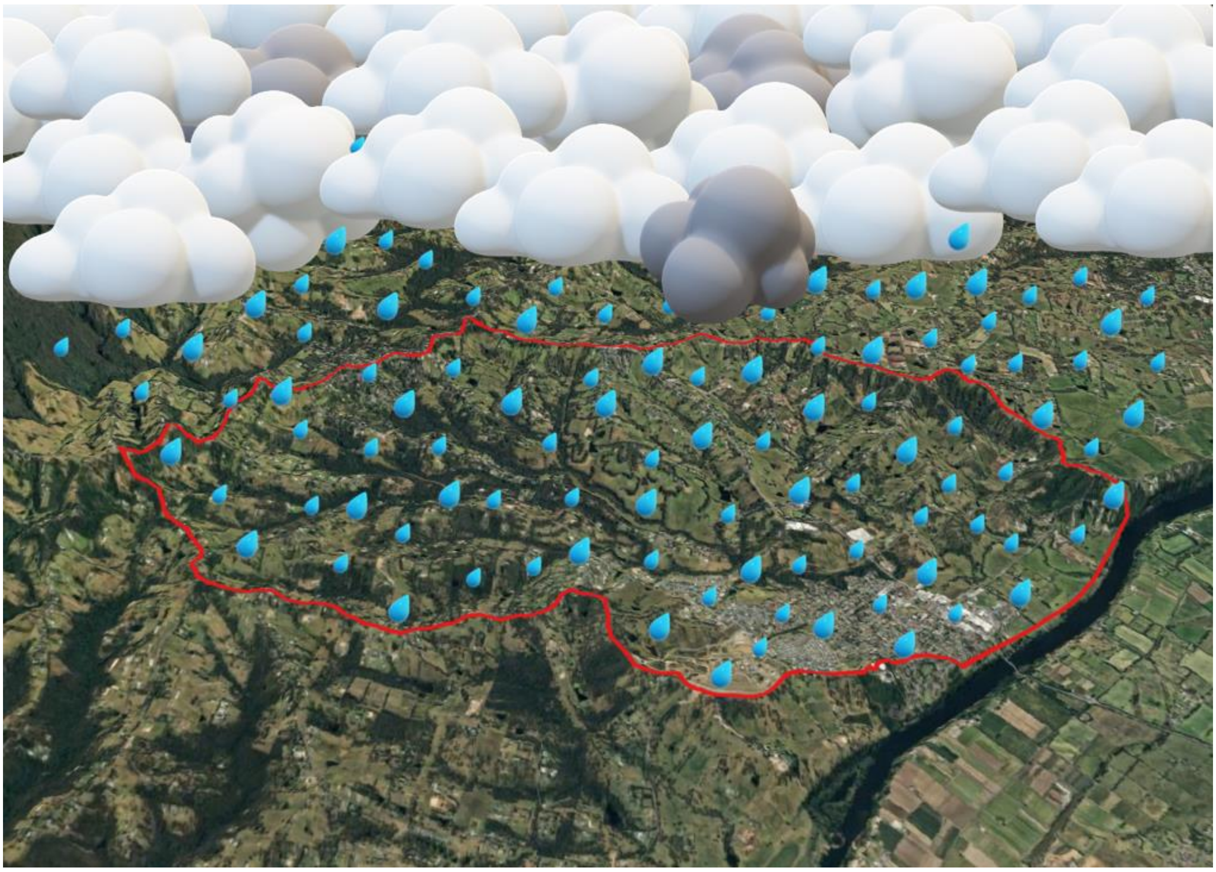

Figure 8.3 Schematic representation of direct rainfall approach

8.2.4.2 Downstream boundary condition

Downstream water levels were determined following an approach consistent with the Floodplain Risk Management Guide: Modelling the interaction of catchment flooding and oceanic inundation in coastal waterways (OEH, 2015) and in conjunction with the reported water levels in the Hawkesbury River for representative design events (Rhelm and Catchment Simulation Solutions, 2024).

Table 8.2 summarises the recommended combinations of catchment flooding and downstream water levels scenarios following an approach consistent with (OEH, 2015) as well as adopted downstream water levels and their sources. For events more frequent than and including 5% AEP, a level-flow (HQ) boundary condition was adopted representing the outflows from the model area to the Hawkesbury River. For events rarer than and including 2% AEP, modelled water levels at the Hawkesbury River at North Richmond bridge were obtained from the Hawkesbury-Nepean River Flood Study, Technical Volume 11: Design Flood Modelling (Rhelm and Catchment Simulation Solutions, 2024).

Table 8.2 Downstream water level conditions

Catchment flood scenario	Boundary type	Water level boundary scenario	Adopted downstream water levels (m AHD)	Source
20% AEP	HQ	-	-	-
10% AEP	HQ	-	-	-
5% AEP	HQ	-	-	-
2% AEP	HT	10% AEP	14.5	(Rhelm and Catchment Simulation Solutions, 2024)
1% AEP	Envelope of HT and HQ	10% AEP	14.5	(Rhelm and Catchment Simulation Solutions, 2024)
1 in 200 AEP	HT	10% AEP	14.5	(Rhelm and Catchment Simulation Solutions, 2024)
1 in 500 AEP	HT	10% AEP	14.5	(Rhelm and Catchment Simulation Solutions, 2024)
1 in 1,000 AEP	HT	5% AEP	15.6	(Rhelm and Catchment Simulation Solutions, 2024)
1 in 2,000 AEP	HT	5% AEP	15.6	(Rhelm and Catchment Simulation Solutions, 2024)
1 in 5,000 AEP	HT	5% AEP	15.6	(Rhelm and Catchment Simulation Solutions, 2024)
PMF	HT	1% AEP	17.5	(Rhelm and Catchment Simulation Solutions, 2024)

8.2.5 Buildings

Visual inspection of the available LiDAR data at the location of building footprints revealed that the building footprints were removed as part of the post-processing approach from the LiDAR dataset and in majority of the locations it resulted in misrepresentation of the ground level at the building footprints. Therefore, the majority of the building footprints were adjusted using the 85 percentiles of the topography level within the building footprint excluding big commercial / industrial buildings that were built in various levels. Also, high hydraulic roughness coefficient was applied to building footprints, refer to **Section 8.2.3**. This approach allow flow to enter buildings which is a more realistic representation of the flooding behaviour for buildings. The buildings GIS layer was reviewed using aerial imagery from 2024 (Google Earth) to confirm no significant changes had occurred. Moreover, commercial / industrial building walls were represented as a fence with 90% blockage giving the possibility of flow entering the building through doors / windows.

8.2.6 Blockage

Bridges and culverts are structures that allow water to flow under roads, railways or other obstruction from one side to the other. These structures can be affected by various blockage mechanisms, resulting in increased flood levels, changes to stream flow patterns, changes to erosion and deposition patterns in channels, and physical damage to the structures. Blockage of these structures is discussed in ARR 2019.

ARR 2019 blockage procedure presented in the Blockage Assessment Form was followed. Cross-drainage structures were identified from Council GIS.

Each cross-drainage was assigned a “High”, “Medium” or “Low” rating for the following ARR 2019 attributes:

- Debris availability – this rating was based on aerial imagery to assess the upstream catchment and the availability of debris;
- Debris mobility – this rating was defined using contours based on steepness of the source area and proximity of source area to streams;
- Debris transportability – based on stream dimension in comparison to potential debris as well as stream shape;
- Debris length L_{10} : ARR 2019 defines this value as:
    - The average length of the longest 10% of the debris reaching the site and should preferably be estimated from sampling of typical debris loads. However, if such data is not available, it should be determined from an inspection of debris on the floor of the source area, with due allowance for snagging and reduction in size during transportation to the structure.
    - In an urban area the variety of available debris can be considerable with an equal variability in L_{10}. In the absence of a record of past debris accumulated at the structure, an L_{10} of at least 1.5 m should be considered as many urban debris sources produce material of at least this length such as palings, stored timber, sulo bins and shopping trolleys.

- A value of 1.5 m has been adopted for L_{10} for all blockage structures in the model.

Based on the above approach, the majority of cross-drainages have opening lower than the selected L_{10} and have a design blockage varying between 25% and 100% depending on the AEP of the event. The culvert on Redbank Creek near Terrace Road has a larger opening and the blockage would vary between 10% and 20% depending on the AEP of the event.

Following the Western Sydney Engineering Design Manual (Western Sydney Planning Partnership, 2021), a 20% design blockage was adopted for on-grade and letterbox pits and 50% design blockage was adopted for all other pits and headwalls.

8.2.7 Structures

In accordance with the available structures data and topographic data the following structures were included in the hydraulic model:

- All pits, pipes and culverts within the study area were modelled as 1D elements. Pit and pipe location and size data provided by Council was incorporated in the modelling, refer to **Figure 8.4**.
- The following bridges were modelled as 2D elements:
  - Crooked Lane Bridge (item 3) in **Figure 5.3**
  - Bells Line of Road Bridge over Redbank Creek (item 39) in **Figure 5.3**
  - Bells Line of Road Suspension footbridge over Redbank Creek (item 39) in **Figure 5.3**
  - Terrace Road Bridge over Redbank Creek (item 1) in **Figure 5.3**
  - Unnamed footbridge situated in the open area at the back of Monti Place (item 33) **Figure 5.3.**

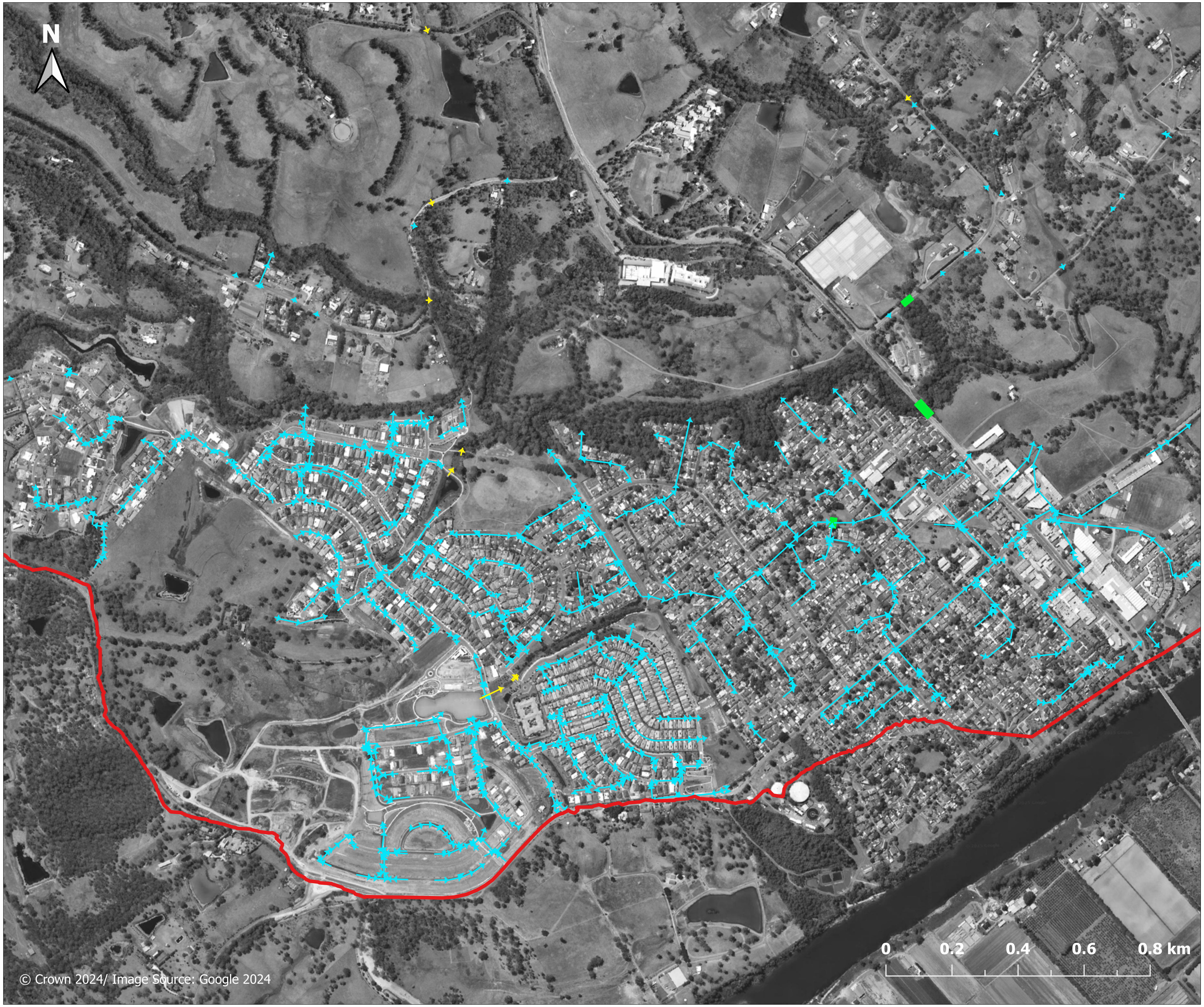

Figure 8.4

Hydraulic model structures and 1D model layout

Legend

- Study area
- Culvert
- Pipe
- Bridge

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8.2.8 Initial water level

The initial water levels in the farm dams, reservoirs, and ponds were assumed to be at full capacity at the start of the modelled events, thereby minimising the storage capabilities in the model. Also, at the downstream end of Redbank Creek, initial water level polygons were utilised to represent the area of inundation caused by corresponding water level conditions in the Hawkesbury River, as tabulated in **Table 8.3**.

For events more frequent than and including 5% AEP, the annual average of High High Water Solstices Springs (HHWS) at the Hawkesbury River at Windsor gauge was obtained from MHL2786 report on NSW Tidal Planes Analysis (MHL, 2023) to represent the initial water level at the confluence of Redbank Creek and Hawkesbury River. For events rarer than and including 2% AEP, modelled water levels at Hawkesbury River at North Richmond bridge were obtained from the Hawkesbury-Nepean River Flood Study, Technical Volume 11: Design Flood Modelling (Rhelm and Catchment Simulation Solutions, 2024) representing initial water level conditions within the study area.

Table 8.3 Initial water levels downstream of Redbank Creek

Catchment flood scenario	Hawkesbury River flood scenario	Adopted initial water levels at downstream boundary (m AHD)	Source
20% AEP	HHWS(SS)[1]	0.94	MHL2786 (MHL, 2023)
10% AEP	HHWS(SS)	0.94	MHL2786 (MHL, 2023)
5% AEP	HHWS(SS)	0.94	MHL2786 (MHL, 2023)
2% AEP	10% AEP	14.5	(Rhelm and Catchment Simulation Solutions, 2024).
1% AEP	10% AEP	14.5	(Rhelm and Catchment Simulation Solutions, 2024).
1 in 200 AEP	10% AEP	14.5	(Rhelm and Catchment Simulation Solutions, 2024).
1 in 500 AEP	10% AEP	14.5	(Rhelm and Catchment Simulation Solutions, 2024).
1 in 1,000 AEP	5% AEP	15.6	(Rhelm and Catchment Simulation Solutions, 2024).
1 in 2,000 AEP	5% AEP	15.6	(Rhelm and Catchment Simulation Solutions, 2024).

[1] HHWS(SS): The annual average of High High Water Solstices Springs at Hawkesbury River at Windsor was obtained from MHL2786 report on NSW Tidal Planes Analysis (MHL 2023).

Catchment flood scenario	Hawkesbury River flood scenario	Adopted initial water levels at downstream boundary (m AHD)	Source
1 in 5,000 AEP	5% AEP	15.6	(Rhelm and Catchment Simulation Solutions, 2024).
PMF	1% AEP	17.5	(Rhelm and Catchment Simulation Solutions, 2024).

9 Model sensitivity and validation

9.1 Preamble

This report recognises the common limitations in data availability for studies of creeks and overland flow areas, acknowledging that gauging stations are typically located on larger watercourses. It is essential to acknowledge limitations in both input data and modelling when interpreting the results, and future work may explore alternative data sources to enhance model calibration and validation efforts. In the absence of data for calibration, best practice has been followed in accordance with NSW government guidance and this section details the sensitivity analyses completed to improve confidence in the study results.

A number of factors required some sensitivity analysis prior to completing the design runs. These factors include:

- Tailwater level: impact of various water levels in the Hawkesbury River was investigated.
- Losses: impact of no loss and ARR 2019 losses were investigated.
- Roughness: impact of reduced and increased roughness coefficient was investigated.
- Blockage: ARR 2019 recommends running two blockage sensitivity scenarios including double design blockage and no blockage.

Sensitivity results are provided in **Appendix D** . The results of these analyses are generally consistent with other similar studies.

9.2 Tailwater level sensitivity analysis

In order to analyse the influence of the tailwater level on the flood behaviour, the following scenarios were modelled:

- HHWS(SS) in Hawkesbury River (0.94 m AHD);
- 50% AEP water level in Hawkesbury River (6.7 m AHD);
- 20% AEP water level in Hawkesbury River (12.3 m AHD);
- 10% AEP water level in Hawkesbury River (14.5 m AHD); and
- 5% AEP water level in Hawkesbury River (15.6 m AHD).

Each of these scenarios were modelled for 120-minute critical durations with design blockage conditions for the 1% AEP flood event. The following observations were made:

- **Appendix D (Figure D.1)** illustrates the extent of flooding for various scenarios revealing that the tailwater level condition in the Hawkesbury River resulted in increases in flood levels and expansion of the flood extent along the lower reaches of Redbank Creek. However, tailwater levels have negligible impact on the flood extent and water level in areas upstream of Douglas Street, Crooked Lane and Bells Line of Road. It should be noted that for the areas where the tailwater influence is high, flooding from the Hawkesbury River would dominate considerations for planning purposes.
- **Figure 9.1** illustrates the peak water levels for 1% AEP flood event with various tailwater

conditions along Redbank Creek. It was observed that the corresponding 5%, 10%, 20% and 50% AEPs tailwater levels would extend the tailwater influence up to approximately 3.2, 3.0, 2.3 and 0.6 km along Redbank Creek from the Hawkesbury River.

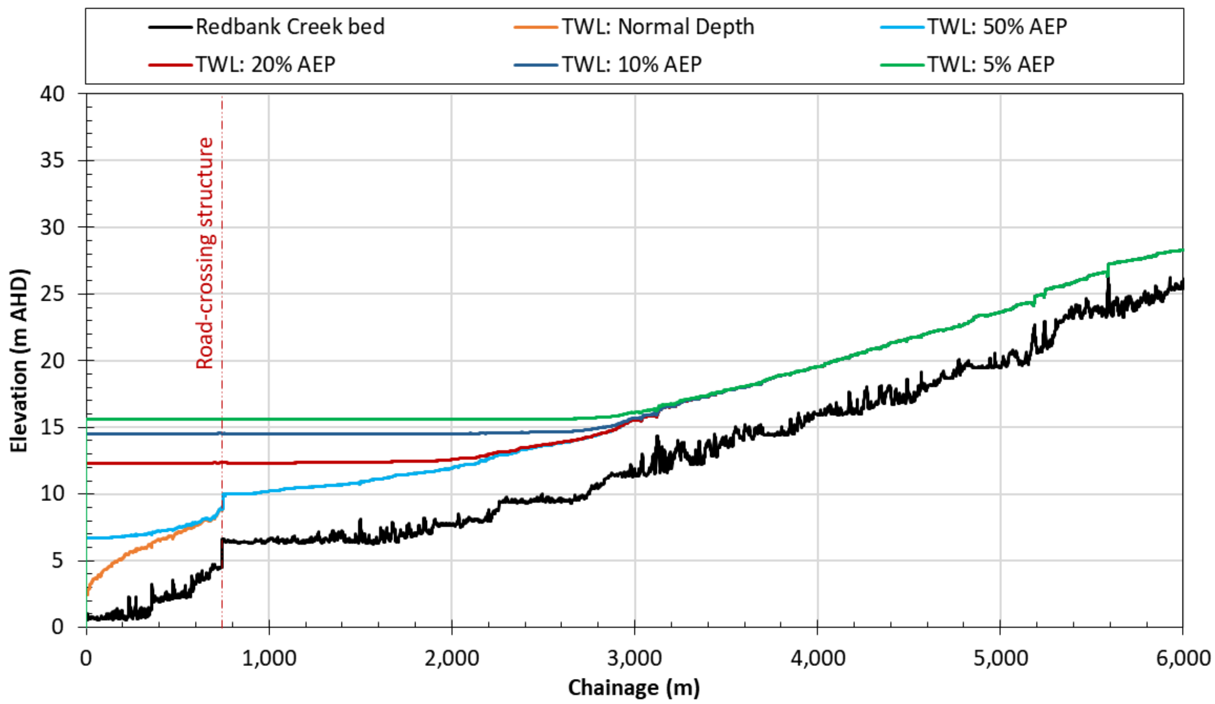

Figure 9.1 Peak water level for 1% AEP flood event with various tailwater levels along Redbank Creek (Note: the road-crossing structure is located immediately upstream of Terrace Road Bridge over Redbank Creek)

9.3 Losses sensitivity analysis

In order to analyse the influence of losses on the flood behaviour, the following scenarios were modelled for the 1% AEP event:

- No loss scenario with neither continuing losses nor initial losses in the pervious areas.
- ARR 2019 losses with 1.52 mm/hr (3.8 x 0.4 = 1.52 mm/hr) continuing losses and 50 mm initial losses in the pervious areas for the 1% AEP flood event. It is important to note that the initial loss of 30 mm and continuing loss of 2.7 mm/hr were adopted for the design event.

Each of these scenarios was modelled for all the adopted critical durations under design blockage condition and the resulting envelope of these critical durations were utilised in the assessment. The following observations can be made:

- The removal of all losses would generate increases in water levels in the order of 0.05 to 0.2 m around the township and up to 0.8 m along the creek.
- ARR 2019 losses would result in decrease in flood level by up to 0.05 to 0.10 m within the township, and by up to 0.2 m along the upstream reaches of the watercourses while

water level increases by 0.1 m along the downstream reaches of the creek.

- These results are consistent with expectations, as losses can have a significant impact on model results. It is important to note that realistic loss estimates have been adopted for this study based on the Hawkesbury Nepean River Flood Study (2024).

9.4 Roughness sensitivity analysis

In order to analyse the influence of hydraulic roughness on the flood behaviour, the following scenarios were modelled for the 1% AEP flood event:

- Low roughness scenario with roughness reduced by 20%.
- High roughness scenario with roughness increased by 20%.

Each of these scenarios was modelled for all adopted critical durations with design blockage conditions and the resulting envelope of these critical durations was utilised in the assessment. The following observations can be made:

- Increase in roughness by 20% may increase water levels by up to 0.25 m along the watercourses but has a lesser impact on the flood levels within the North Richmond township with increases of up to 0.07 m. It is noted that some areas are subject to decreases in flood level by up to 0.05 m. These areas are typically located in basins and other storage areas due to upstream flows taking longer to reach the storage area and giving it more time to drain.
- Similarly, decrease in roughness by 20% may decrease water levels by up to 0.25 m along the watercourses but has a lesser impact on the flood levels within the North Richmond township with decreases of up to 0.07 m. It is noted that some areas are subject to increases in flood level by up to 0.05 m. These areas are typically located in basins and other storage areas due to upstream flows reaching the storage area faster and giving it less time to drain.
- These results are consistent with expectations, as roughness can have a significant impact on model results. Roughness values adopted in this study are based on the best available data.

9.5 Blockage sensitivity analysis

In order to analyse the influence of blockage on the flood behaviour, the following scenarios were modelled for the 1% AEP event:

- No blockage scenario. These scenarios assumed that all the cross-drainage structures, pits and pipes were free of blockages.
- Double design blockage scenario. These scenarios consider double the design blockage assigned to cross-drainage structures, pits and pipes.

Based on the results of this analysis, the following observations can be made:

- The double blockage scenario can lead to water level increases of up to 0.2 m within the North Richmond township, with some localised areas experiencing even higher water levels. These local increases are typically located along main drainage channels and upstream of major culverts, where the reduced capacity for drainage leads to an accumulation of water. Conversely, this scenario may cause decreases of up to 0.02 m in water levels along Redbank Creek, especially north of Pansy Crescent. This reduction is attributed to a greater volume of water that remains undrained in the system.

- The no blockage scenario may result in localised variations in water levels of up to 0.10 m. Certain areas, particularly upstream of major culverts / pipes may experience reduced water levels, while areas downstream of major structures could experience increases in water levels, especially along Redbank Creek north of Pansy Crescent. These changes are attributed to the enhanced drainage capacity, allowing a greater volume of water to flow through the system.
- These results are consistent with expectations, as blockage can have a significant impact on model results. It is important to note that realistic blockage estimates have been adopted for this study and that the sensitivity tests are unrealistic examples for comparison purposes only.

9.6 Model validation

A preliminary model validation was undertaken utilising the information provided by the community during the community consultation. The model's performance was evaluated against the flooding that occurred in the Redbank Creek catchment during the March 2022 event. This event was triggered by rainfall between 10:00 AM on 28 February 2022 to 22:00 PM on 8 March 2022.

To replicate this event, a 5-minute interval rainfall dataset from North Richmond STP gauge (No. 563069), as presented in **Figure 9.2**, was used. Additionally, 15-minute interval water level recordings from the Hawkesbury River at North Richmond (No. 212200) were incorporated as the downstream boundary condition, also referenced in **Figure 9.2**.

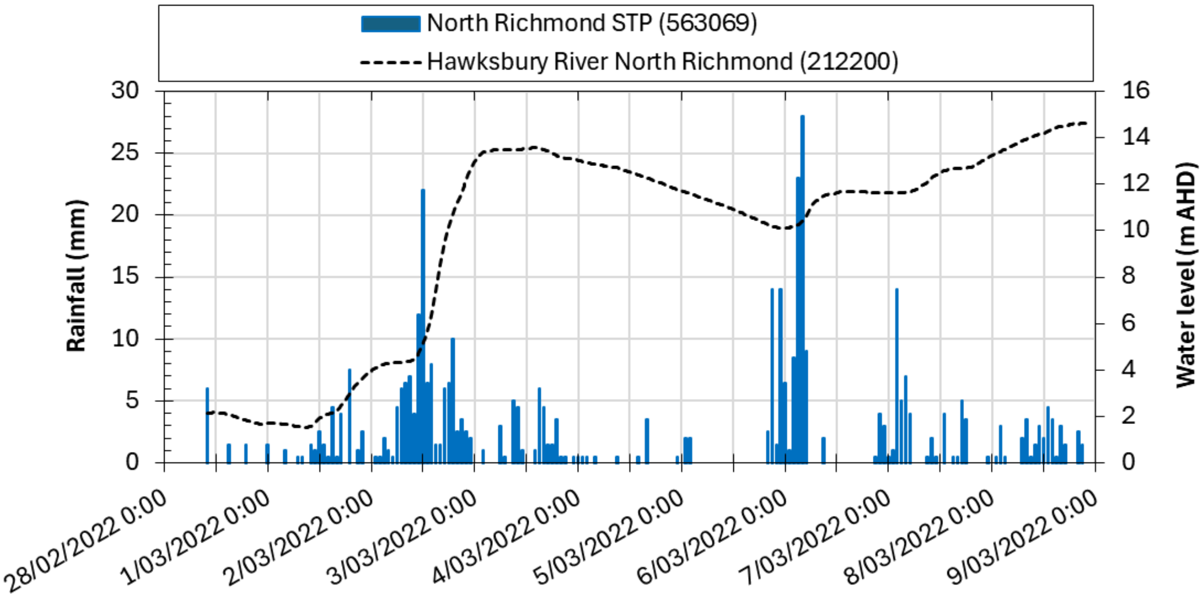

Figure 9.2 March 2022 event time-series

The modelled outputs for the March 2022 event are provided in **Appendix D**. **Figure 6.1** shows that floodwaters overtopped the banks of Redbank Creek, inundated the backyards of adjacent properties along the creek. However, floodwaters did not reach the dwellings, which is consistent with the model's projections (**Appendix D.8)**. The results indicate that while properties near the creek are susceptible to flooding, dwelling inundation would likely only occur during more extreme events. **Appendix D.8** and **Appendix D.9** present peak flood depths and peak flow velocities. These results show that flood depths reached up to 5.6 m, with flow velocities surpassing 1.5 m/s, in sections of the creek adjacent to residential backyards. These results align with community observations, including anecdotal evidence such as photos and videos.

Model validation highlighted several key findings, as outlined below:

- Residents along Redbank Creek reported flooding in their backyards only, which aligns with the model results as only rare events may lead to above floor flooding. Many respondents identified Redbank Creek as the primary source of flooding, with floodwaters rising in the Creek which is observed in the model results.
- Several respondents described flood depths exceeding 3 m in the creek, aligning with the model's results for flood levels in the creek.

Overall, the preliminary model validation exercise confirms that the flood model provides a reliable representation of flood behaviour under existing catchment conditions, with observed flood impacts largely consistent with model predictions.

10 Flood modelling results

10.1 Flood modelling description

The 1D / 2D TUFLOW hydraulic model was run for events including the 20%, 10%, 5%, 2%, 1%, 1 in 200, 1 in 500, 1 in 1,000, 1 in 2,000 and 1 in 5,000 AEPs and PMF events. Multiple durations and temporal patterns were modelled for all the events, per **Table 7.6.** Therefore, model results from representative critical durations are available for the majority of the catchment, and also consider areas acting as detention basins (with longer critical durations). An envelope of the peak results from these durations and temporal patterns was produced to represent the flooding for each event.

10.2 Flood mapping

10.2.1 Mapping filtering

The flood extents were filtered to remove shallow depths areas generated by the direct rainfall methodology. The filtering criteria used to retain relevant areas including the following conditions:

- Depth > 0.10 m; OR
- Depth > 0.05 m AND Velocity × Depth > 0.025 m^2/s; OR
- Velocity > 2 m/s.

Following application of the above criteria, "puddles" smaller than 100 m^2 were also excluded from the flood extent. These filtering criteria are informed by recent studies completed along the NSW coastline such as the Coastal Lagoons Catchments Overland Flood Study for Central Coast Council and the Racecourse Creek Flood Study and Option Assessment for MidCoast Council. Consultation was also undertaken with DCCEEW.

As part of the present study, a sensitivity analysis was undertaken to assess the impact of removing various puddle sizes from the flood maps. During this process, the aforementioned filtering criteria were applied, and puddles of different sizes were systematically excluded. The analysis estimated the volume of the water within the study area, as summarised in **Table 10.1.**

Table 10.1 Summary of estimated volume of water and impact of puddle removal

Puddle sizes were removed	Flood / Water Volume (m^3)	% Removed
0	1,236,053	-
< 50 m^2	1,232,997	-0.25%
< 100 m^2	1,230,567	-0.44%
< 250 m^2	1,225,312	-0.87%

The table above reveals that the removal of puddles with areas less than 50, 100 and 250 m^2 resulted in reductions in volume of water of 0.25%, 0.44% and 0.87%, respectively. Given the minimal impact on the overall water volume within the study area, excluding puddles smaller than 100 m^2 was confirmed as a reasonable approach with Council and DCCEEW.

Further sensitivity analysis was conducted to assess the impact of Velocity × Depth value on the extent of flooding. This sensitivity analysis assessed the following conditions:

- **Baseline condition:**
  - Depth > 0.10 m; OR
  - Depth > 0.05 m AND Velocity × Depth > 0.025 m^2/s; OR
  - Velocity > 2 m/s.
- **Scenario A:**
  - Depth > 0.10 m; OR
  - Depth > 0.05 m AND Velocity × Depth > 0.05 m^2/s; OR
  - Velocity > 2 m/s.
- **Scenario B:**
  - Depth > 0.10 m; OR
  - Depth > 0.05 m AND Velocity × Depth > 0.10 m^2/s; OR
  - Velocity > 2 m/s.
- **Scenario C:**
  - Depth > 0.10 m; OR
  - Velocity > 2 m/s.

Following application of each of the above criteria, "puddles" smaller than 100 m^2 were also excluded from the flood extent. **Figure 10.1** illustrates the extent of flooding for the 1% AEP event, incorporating various map filtering criteria based on Velocity x Depth (m^2/s), ranging from a baseline of 0.025 m^2/s to 0.1 m^2/s, along with an unrestricted scenario. The analysis revealed that applying a Velocity × Depth threshold greater than 0.025 m^2/s resulted in a continuous flow path across the study area, while the other scenarios produced discontinuous flow paths and additional puddles. Therefore, it appeared that Velocity × Depth > 0.025 m^2/s is the most appropriate threshold for overland flooding map filtering, aligning with the Coastal Lagoons Catchments Overland Flood Study for Central Coast Council and the Racecourse Creek Flood Study and Option Assessment for MidCoast Council.

Figure 10.1

Map filtering criteria sensitivity for the 1% AEP event

Legend

- Study area
- Baseline condition
- Scenario A
- Scenario B
- Scenario C

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10.2.2 Flood maps

Flood mapping presenting the peak flood level, peak flood depth and peak flood velocity envelops of each event is provided in **Appendix E** . These results are further discussed in the following section.

The flood extents due to a range of Hawkesbury River flooding mechanism were derived from the Hawkesbury-Nepean River Flood Study (Rhelm and Catchment Simulation Solutions, 2024) and were added to the peak flood depth maps. This integration allows to differentiate areas where flooding from Redbank Creek or overland flooding predominates from area where riverine flooding due to Hawkesbury River flooding predominates.

11 Consequences of flooding on the community

This section outlines the effects of flooding on the community. To grasp the impact of flooding, it is essential to analyse the flood behaviour within the catchment and identify key problem areas. Following this, the consequences of flooding, including road closures and damage can be evaluated and more details are provided in this section.

11.1 Flood behaviour

Flow within the study area is mostly contained within Redbank Creek and the main drainage channel through the township. Key flood-prone areas are highlighted below, noting that the described impacts are based on flooding that affects the floor level of buildings on properties:

- Properties located at the northern end of William Street, Elizabeth Street, Susella Crescent, Merrick Place and O'Dea Place are impacted from the 1 in 500 AEP event; however, road access may be affected by events as frequent as the 20% AEP event;
- A few properties along the northern side of Flannery Avenue are impacted from the 1 in 200 AEP event; however, their access may be affected by event as frequent as a 5 AEP event;
- A few properties at the north-west corner of Pansy Crescent are impacted by events as frequent as the 10% AEP event;
- Properties located along the main drainage channel between Pecks and Elizabeth Streets are affected due to 1 in 5,000 AEP and PMF events. For events up to and including the 1 in 2000 AEP event, flow is mostly contained within the main drainage channel.
- A few properties located between Stephen and Pecks Streets are impacted by events as frequent as the 10% AEP event.
- Properties situated between Tyne Crescent, Stephen Street and the northern end of Yvonne Place are impacted by events as frequent as the 5% AEP event.
- A secondary overland flow path was observed through the North Richmond township, from the sag point along Enfield Avenue through to a few properties towards the southern end of Monti Place, continuing towards the intersection of Charles and Elizabeth Streets. These areas are impacted by events as frequent as the 10% AEP event;
- Properties located at the southernmost corner of Tyne Crescent are impacted by events as frequent as the 5% AEP event;
- A few properties located at the north-east corner of the intersection of Charles and William Streets are impacted by events as frequent as the 5% AEP event;
- Properties near the intersection of Charles and Elizabeth Streets are impacted by floods as frequent as the 5% AEP event such as the North Richmond Community Centre.

11.2 Flood damage assessment

11.2.1 Flood damage categories

A preliminary flood damage assessment has been conducted to evaluate the economic impacts of flooding. Economic impacts can be categorised as tangible or intangible. According to the Flood Risk Management Manual (DPE, 2023a), flood damages are categorised as follows:

- Tangible Damages: Those that can be readily assigned a monetary value and measured
  - Direct Damages: Losses incurred from floodwaters wetting goods and possessions.
  - Indirect Damages: Financial losses related to the flood, including lost wages and increased expenses for cleanup and recovery efforts.
- Intangible Damages: Involve effects that are challenging to quantify financially, these may include:
  - Increased emotional stress and mental health issues resulting from the flooding.
  - Loss of personal items such as photographs and documents, contributing to feelings of grief.
  - Financial strain from replacing damaged possessions.
  - Disruption to family life due to temporary relocation, school changes, and increased commuting times.

This assessment primarily focuses on direct tangible damages to properties, including residential, commercial, industrial, and public buildings. Other potential damages, such as those to infrastructure (e.g., roads and bridges), are not included due to the absence of a clear methodology for quantification.

While the damage assessment provides insight into the magnitude of flooding issues, its utility for absolute economic evaluation is limited. Nonetheless, it serves as a valuable foundation for quantifying the benefits of mitigation strategies, allowing for a comparison of the reduction in tangible property damages against implementation costs. Additional assessments of tangible infrastructure damages and intangible impacts are incorporated into the multi-criteria analysis during the option investigation process. The methodology for this damage assessment adheres to the latest guidelines and is summarised below.

11.2.2 Assessment methodology

The flood damages assessment methodology is presented below:

- **Establish design flood modelling results** for the 20%, 10%, 5%, 1%, 1 in 200, 1 in 500, 1 in 1,000, 1 in 2,000, 1 in 5,000 AEPs and the PMF events. Flood modelling results are derived from the models established for the Redbank Creek catchment area, and are based on an envelope of overland and creek flooding for various critical durations / temporal patterns;

- **Obtain floor level data** (refer to **Section 11.2.3**);
- **Determine the peak flood depth** that would occur at each property during each design flood event;
- **Apply damage curves** derived from the Excel template version DT01-v1.02 developed as part of Flood risk management manual: the management of flood liable land (the manual) and its supporting toolkit (NSW DPE, 2023) to relate the depth of flooding to a monetary cost in each design flood event;
- **Calculate the Average Annual Damages (AAD):** The AAD represents the estimated tangible damages sustained every year (on average), over a long period of time.

Note that the results are not an indicator of individual flood risk exposure, but part of a regional assessment of flood risk. Furthermore, the purpose of the damages assessment is not to calculate the actual damage that would be incurred in a flood, but to form a basis of comparison with other flood prone communities throughout NSW, and a baseline against which future mitigation options can be assessed.

Considering that the Excel template version DT01-v1.02 is constrained by up to 10 events; a preliminary damage assessment was undertaken revealing a linear trend among 1 in 500, 1 in 1,000 and 1 in 2,000 AEP events. It appeared that discarding the 1 in 1,000 AEP event would not cause a significant change in the trend; therefore, the 1 in 1,000 AEP event was excluded from the damage assessment.

11.2.3 Floor level database

The preliminary flood damages assessment is based on the depth of flooding that occurs above and below the floor level of each property in the PMF extent. A desktop study was undertaken determining a total of 5250 buildings located within the present study area including 5093 residential and 157 non-residential building. For non-residential buildings, aerial photographs, available DEM data and Google Street View were used to identify the number of steps to the entrance; however, in case of invisibility of the entrance zero steps were assumed. Given the absence of detailed floor level survey dataset, a blanket approach of assuming two steps (2 * 0.15 m = 0.30 m) was adopted to represent the floor level of residential properties excluding the residential properties within the senior housing area. Google Street view revealed that, the assumption of zero steps was reasonable to represent the floor level of the majority of the residential buildings within the seniors housing area. Also, a blanket approach of assuming one step was employed to represent the floor level of school buildings. It is noted that each building was analysed separately and some properties such as schools may include multiple buildings. Outlines of the building were estimated from the available aerial imagery. It is also noted that some buildings are spreading over multiple lots and some lots include multiple buildings. The maximum water level encroaching the building outline was adopted as the building flood level to be used in the damage calculation for each event. It is recommended to undertake a thorough site inspection as part of a future Floodplain Risk Management Study and Plan (FRMS&P) for a detailed damage assessment.

11.2.4 Flood damage assessment results

Table 11.1, **Table 11.2** and **Table 11.3** present the flood damages results for the Redbank Creek catchment area and are divided into residential damages, commercial / industrial damages, damages to public buildings and the total combined damages. The spread of the AAD across the Redbank Creek catchment is illustrated in **Appendix F** .

In addition, a sensitivity analysis was carried out demonstrating the crucial role of the number of steps on estimating the AAD, tabulated in **Table 11.4**. It was observed that increasing by one step resulted in a decrease in AAD of up to 62% while decreasing the number of steps by one resulted in an increase in AAD of up to 96%. These results indicate a high degree of sensitivity of the damages estimates to the assumed building floor levels and highlight the importance of undertaking a floor level survey prior to assessing management options in the future Floodplain Risk Management Study and Plan stages.