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FLOOD RISK MANAGEMENT IN THE UPPER NEPEAN RIVER CATCHMENT, AUSTRALIA

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ABSTRACT

Flooding is a natural disaster that causes significant damage globally. Australia is prone to devastating floods. La Nina and climate change are considered to have contributed to the rise in wet weather events that occurred in Australia during 2022 (BoM, 2022). Floods across eastern Australia in February/March 2022 damaged thousands of houses, caused widespread evacuations, power outages and restricted mobility.

A scoping study for Voluntary House Raising (VHR) was conducted for a section of the Upper Nepean River floodplain that is vulnerable to mainstream riverine flooding, local catchment tributary flooding and overland flows. The scoping study was recommended by the Flood Risk Management Plan prepared for the study area, which involved the use of detailed computer flood models of catchment hydrology and floodplain hydraulics to test a range of flood mitigation measures (Camden Council, 2023).

The objective of a VHR scheme is to reduce flood damages and increase the flood resilience of the community in the study area. Eligibility criteria contained in flood risk management guidelines published by the New South Wales (NSW) Department of Planning and Environment (NSW DPE, 2023a and 2023b) were used to identify houses for inclusion in the VHR scheme. This included consideration of the location of the houses relative to floodway or high flood hazard areas, the age of the dwellings and the cost-effectiveness of raising the houses. Community consultation was also a major component of the study, which was addressed via community consultation sessions.

KEYWORDS: voluntary house raising; flood damage; floodway; flood hazard; benefit-cost.

1 INTRODUCTION

Flooding is one of the common natural disasters that causes the most damage globally. In 2022 La Nina and climate change contributed to the rise in wet weather events in Australia (BoM, 2022). In NSW alone, during flood events in February/March 2022 over 8,000 properties were inundated, over 10,000 were damaged, and over 4,000 properties were deemed uninhabitable. The cost of the floods reached $5.28 billion in insured losses from more than 233,000 claims (ICA, 2022). The direct economic cost of extreme weather events is expected to grow by 5.13 per cent each year and reach a total of about $35 billion in annual costs by 2050 (TMI, 2022).

Climate change has the potential to worsen flooding problems in some regions, while continued urbanisation of floodplains will increase potential flood damages and vulnerability (Schreider et al., 2000; Milly et al., 2002). An important challenge in sustainable floodplain management is balancing the long-term risk of increasing flood damage with the ongoing benefits that floodplains provide to both human and natural systems (Zhu et al., 2007). The severity of flood events is expected to increase significantly in the future, and if flood protection measures remain at current standards, the resulting impacts could become

unbearable for Australia, as it will be for west (web- 1). Given the complex and evolving nature of climate change, an adaptive approach is essential for managing the uncertainties surrounding flood hazards, their impacts, and associated risks.

A scoping study for a Voluntary House Raising (VHR) scheme was completed for the lower section of the Upper Nepean River Catchment, which is an area known to be vulnerable to flooding. Figure 1 shows the study area and the Upper Nepean River catchment. The Nepean River enters the study area at its southern boundary, just south-east of the township of Camden, and meanders approximately 30 km northwest before exiting the study area. The study area spans 140 km² within the Camden Local Government Area (LGA) in Western Sydney, located about 65 km from the Sydney Central Business District (CBD). It is a semi-rural area facing increasing development pressures and intensifying consequences of climate change.

Multiple flooding mechanisms affect the area, including mainstream riverine flooding, local tributary flooding, and overland flow. In 2022, the catchment experienced three significant flood events in March and July, with the July event being the most severe, corresponding to an estimated Annual Exceedance Probability (AEP) of 10% to 20%. Evacuations were required during all three events. There was a clear expression of community interest in implementing a VHR scheme following these events.

House raising has been a suitable flood resilient design strategy adopted for many homes in Queensland, Australia (QRA, 2019). The technique of constructing houses on stilts prevalent in south-east Asia and South America has been adopted in the Netherlands as well (Naga, 2021).

VHR is a flood risk management tool that involves elevating a dwelling above the minimum flood design level or relocating it to higher ground within the same lot (NSW DPE, 2023b). It is effective in reducing the frequency of flood-related property damage and associated social and psychological impacts on residents. However, VHR should be implemented as part of a broader floodplain risk management strategy for an area, as it does not address all hazards, such as risk to life. Following the development of a Scoping Study, the implementation of a VHR scheme is partially funded by the NSW Government, which currently covers up to two-thirds of the cost through local councils (NSW DPE, 2023b).

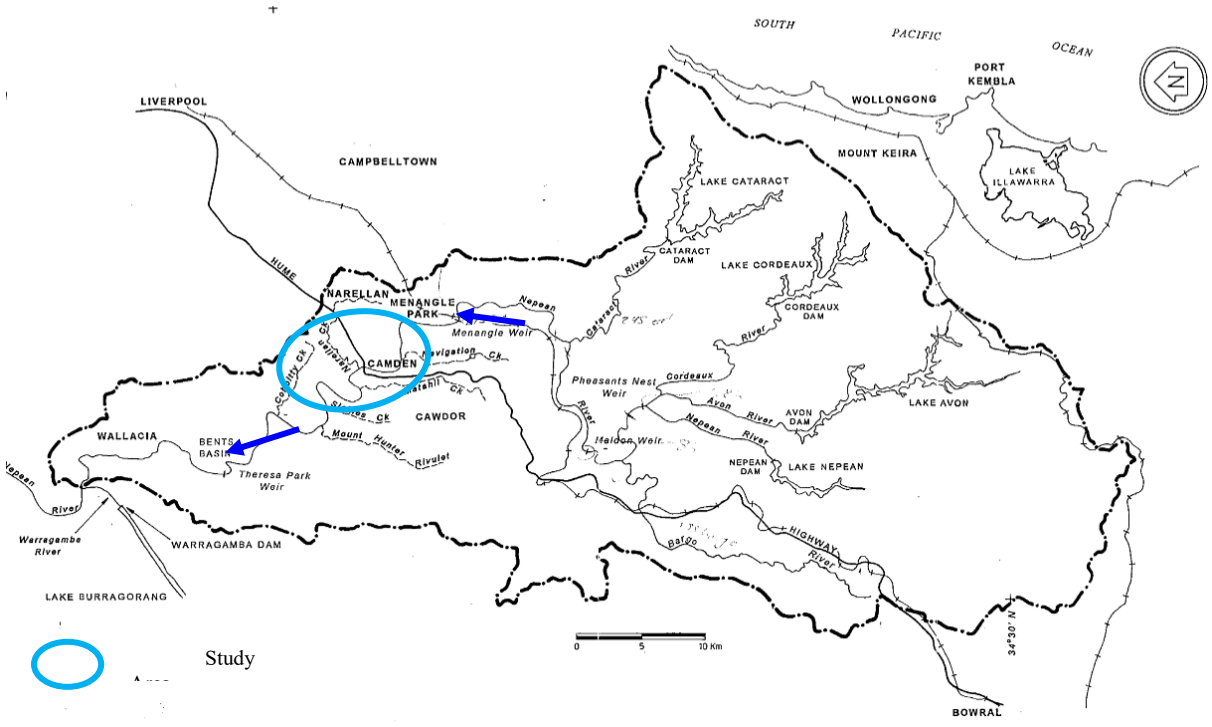

Figure 1: Study area relative to the Upper Nepean River Catchment

2 BACKGROUND

Historic flood data indicates that flood events between the 0.5 EY (Exceedances per Year) / 39.35% Annual Exceedance Probability (AEP) and 20% AEP have occurred in the study area during the past two decades. The most significant flood on record was a 0.5% AEP (1-in-200-year) event that occurred in 1873. Inundation of the Camden CBD starts to occur from the 0.5 EY event, with full inundation occurring during the 20% AEP and larger events.

Figure 2 illustrates the extent of flooding in the Camden CBD during the July 2022 flood, which was estimated to be between a 20% and 10% AEP event. Several other locations within the study area exhibit similar flood behaviour.

During mainstream 1% AEP flooding and the Probable Maximum Flood (PMF), the maximum flood depths at properties in Camden reach up to 9 and 11 meters, respectively (Camden Council, 2023). Most roads get cut in frequent flood events and hence emergency management and evacuation are difficult (Camden Council, 2023). Due to the combination of high flood depths and velocities, most of the floodplain within the study area is classified as high hazard (Camden Council, 2023). The extent of nominated high-risk areas is even larger, as many regions become inaccessible during floods, further complicating emergency response. Additionally, land situated outside the Flood Planning Area (defined as the 1% AEP flood level plus freeboard) but within the PMF extent is considered to carry residual risk, which also requires targeted emergency management planning (Camden Council, 2023).

The study area is considered highly sensitive to climate change impacts. For Representative Concentration Pathway (RCP) 4.5, which is approximately equivalent to 10% increase in 1% AEP rainfall intensity, the flood level increases in the study area would vary from 0.5m to 1.5m (Camden Council, 2023).

Figure 2: Camden CBD during the July 2022 flood

3 STUDY OBJECTIVES

The primary objective of this study was to assess the implementation of Voluntary House Raising (VHR) as a suitable flood risk mitigation measure for the study area. A scoping study was initiated to

evaluate the feasibility of VHR and to develop a VHR Scheme aimed at reducing flood damages and enhancing community resilience, thereby contributing to broader flood risk management efforts across New South Wales (NSW DPE, 2023b). This work was partially funded by the NSW Government.

Residential properties with over floor flooding in the 5% AEP event were identified for VHR as a high-priority property modification measure in the Nepean River Floodplain Risk Management Study and Plan (Plan). The assessment was based on a Multi Criteria Assessment, with the scoring based on a triple bottom line approach, incorporating economic, social and environmental criteria (Camden Council, 2023). The scoping study is required to define the scheme's scope, estimated costs, and prioritise properties before seeking funding for implementation (NSW DPE, 2023b).

4 METHODOLOGY

The following criteria were adopted in the identification and eligibility assessment of houses for VHR, as outlined in the NSW Guidelines for Voluntary House Raising Schemes (NSW DPE, 2023b)

1. The full range of flood events are to be considered in the damages assessment of each property.
2. Floodway areas in the 1% AEP event are to be excluded, which denote areas of high flood conveyance as part of hydraulic category (flood function) mapping.
3. VHR is to be limited to low hazard areas, which means that dwellings are not to be in high hazard areas (H5 to H6 classification as per Australian Rainfall & Runoff 2019).
4. The effectiveness as an ongoing maintenance requirement to address risk to life, such as those based around supporting self-evacuation in response to directions from the State Emergency Service. The Local Flood Plan must be communicated to the residents and complied with.
5. Assessment of the suitability of individual houses for raising, including building age, whether houses are of slab-on-ground or brick construction.
6. Cost-effectiveness of the VHR Scheme (benefit-cost ratio) measured across the full range of floods with the aim to generate positive financial returns from reduced damage relative to costs.
7. Viability of the scope and scale of the VHR Scheme and how the Scheme will be prioritized.

Support of the affected community for VHR as determined through consultation with affected property owners. All above criteria were considered. The benefit-cost ratio (BCR) for each dwelling was calculated and used to prioritise properties for raising. Consultation with landowners was completed during the study. A VHR implementation plan was prepared, comprising information on the number of properties targeted, the estimated cost of house raising, and the priority ranking based on the benefit-cost ratio for each property.

1.1 4.1 Assessment of Flood Behaviour

Flood model results from the Nepean River FRMSP (2023) were used to describe the flood behaviour at the study area, including flood extents, hydraulic category and hazard mapping to address the criteria listed in the NSW Guidelines (NSW DPE, 2023b). An XP-RAFTS hydrologic model and 1D/2D TUFLOW hydraulic model were developed for the study area and calibrated to four historical flood events. The models were used to define flood behaviour for the 0.5 EY (Exceedances per Year), 20% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP and 0.2% AEP events and PMF.

Table 1 identifies the number of properties within the study area that are affected by flooding for the full range of events. In the 5% AEP event, 190 properties will be flooded, including 147 inundated above floor level, of which 108 are residential properties (Camden Council, 2023).

Table 1: Flood affectation for full range of design flood events (Camden Council, 2023)

Flood event	Properties with over floor flooding	Properties with over floor flooding (residential only)	Properties with over ground flooding
0.5 EY (Exceedances	6	5	10

per Year) or 39.35% AEP			
20% AEP	13	11	18
5% AEP	147	**108**	190
1% AEP	271	**200**	347
0.5% AEP	361	283	454
0.2% AEP	519	431	629
PMF	2306	2071	2505

The flood model results were used for hydraulic category and hazard mapping and the calculation of Average Annual Damages (AAD) (Camden Council, 2023, 2025).

1.2 4.2 Stage 1 - Dwelling Eligibility Assessment

The first stage of investigations involved a desktop assessment of the 108 dwellings affected by over floor flooding in the 5% AEP flood against the VHR eligibility criteria. The following information was considered.

- Hydraulic category (flood function) mapping for the 1% AEP event to identify floodway, flood storage and flood fringe areas (NSW DPE, 2023a).
- Flood hazard mapping for the 1% AEP event to classify the hazard at each property from H1 to H6. The Australian Rainfall and Runoff flood hazard curves provided in Figure 3 were used for hazard mapping (Camden Council, 2023).
- Construction age to confirm whether houses were built before or after 1986. The NSW State Flood Prone Land Policy came in to force in 1986 and the dwellings built after 1986 are not eligible for VHR funding (NSW DPE, 2023b).
- Dwelling construction type: whether slab-on-ground, weatherboard, fibro, brick, etc.

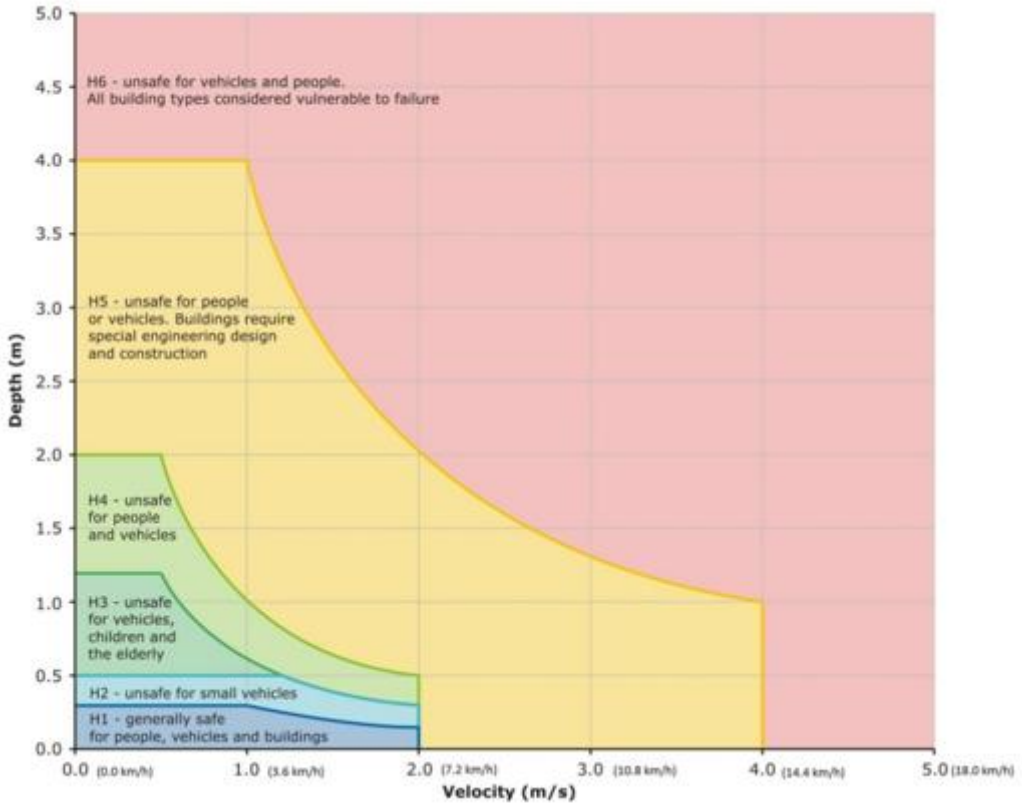

Figure 3: Flood Hazard Vulnerability Curves (Source: AEMI 2013)

1.3 4.3 Stage 2 - Benefit-Cost Assessment

After identifying the dwellings eligible for the VHR scheme, the next step was to calculate the BCR for voluntary house raising by comparing the Net Present Value (NPV) of the flood damage reduction over the lifespan of the works against the cost of the house raising works.

The proposed house raising of eligible dwellings would involve raising the existing floor level to the Flood Planning Level (FPL), which aligns with Councils Flood Risk Management Policy for habitable floor levels and the requirements listed in the Flood Risk Management Measures, MM01 (DPE, 2023a). The FPL is the 1% AEP flood level plus a freeboard of 500mm. An Average Annual Damages (AAD) calculation was completed for each dwelling under both scenarios; existing conditions and raised conditions. The cost of house raising works was estimated according to information provided by local builders specialising in house raising (Camden Council, 2025).

The NPV of the costs and benefits accounts for the value of all future costs and benefits over the entire life (50 years) of an investment discounted (7%) to the present. The BCR for house raising works at each property was calculated as the NPV of the AAD reduction divided by the NPV of the house raising costs. The BCR results were used to rank properties in the VHR scheme.

1.4 4.4Community Consultation

The Nepean River FRMSP, incorporating the recommended Voluntary House Raising (VHR), was publicly exhibited in 2023.

After completion of the Stage 1 investigations, a drop-in session was held to inform homeowners of eligible dwellings, address questions, and gather feedback. Key concerns included exclusion of high-risk properties, construction-related issues such as asbestos removal, services relocation, temporary accommodation, builders' reliability, and potential impacts on neighbouring properties due to overland flow. One-on-one follow-ups were conducted with the affected homeowners expressing the most support or interest in the VHR scheme. Ongoing updates were provided to the Camden Flood Risk Management Committee. A VHR Implementation Plan was subsequently developed and publicly exhibited as part of the draft Scoping Study, accompanied by general and property-specific information sheets for residents (Camden Council, 2025).

5 RESULTS AND DISCUSSION

Of the 108 properties inundated in the 5% AEP flood, only 16 were determined to be outside of both the 1% AEP high flood hazard areas (H5 or H6 classification) and the 1% AEP floodway. However, none of those 16 properties met the construction type and/or construction date eligibility criteria. Accordingly, the Scoping Study was extended to include investigation of properties inundated with over floor flooding in the 1% AEP flood.

There are an additional 92 dwellings inundated in the 1% AEP event (Table 1, Figure 4), which were assessed according to the same eligibility criteria outlined in Section 4 above.

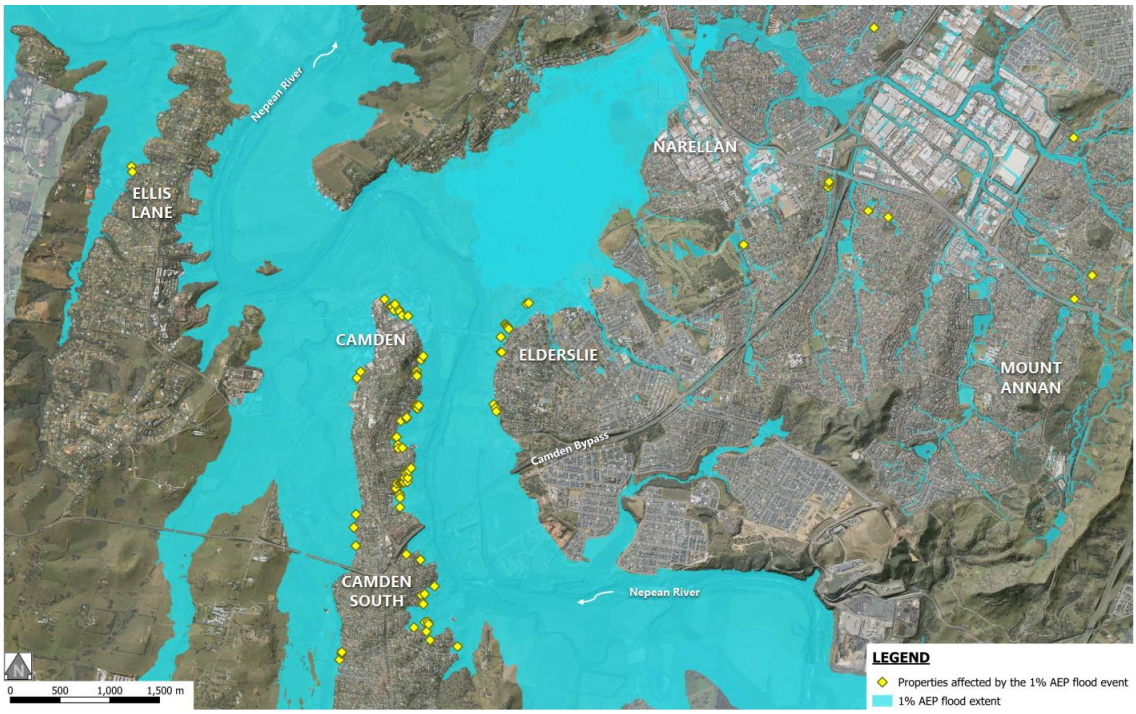

Figure 4: Additional dwellings inundated in the 1% AEP event considered for voluntary house raising

Of the 92 dwellings, an initial assessment showed that 28 dwellings met the flood hazard and floodway eligibility criteria. Based on construction type and the date of construction, a residual of 19 eligible dwellings were taken through to the Stage 2 benefit-cost investigations (Figure 5).

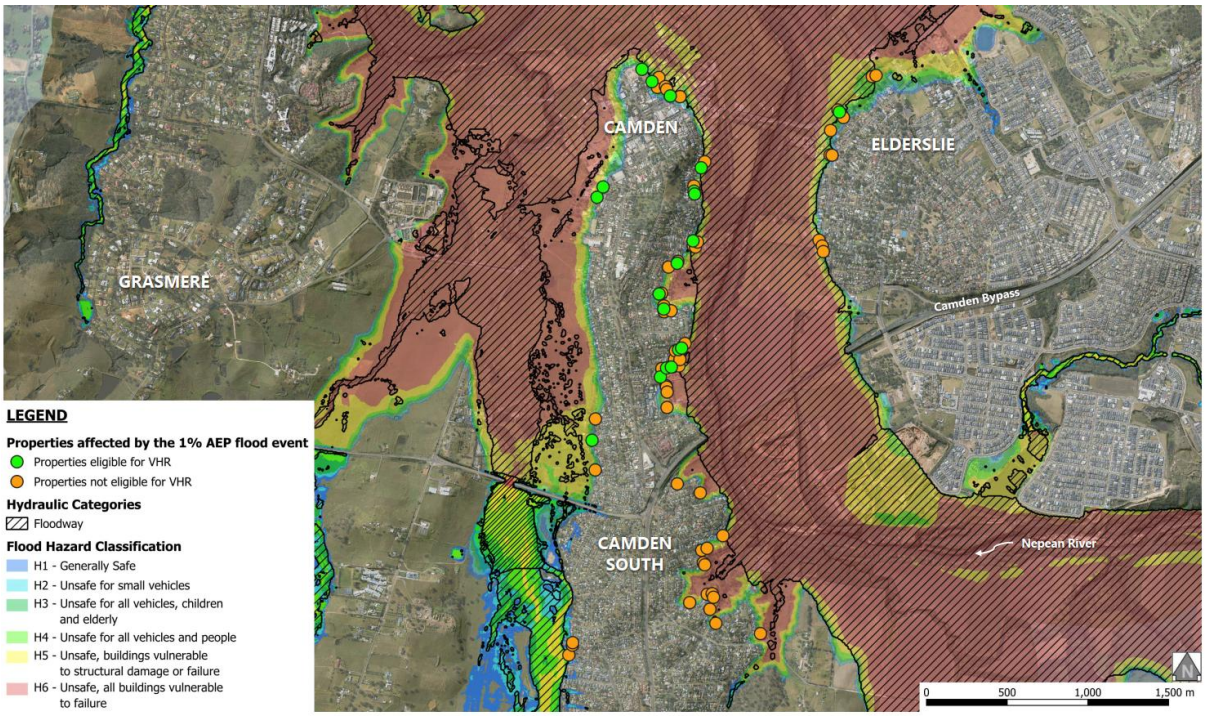

Figure 5: Final set of 19 dwellings assessed as part of Stage 2 investigations

The house raising required for the 19 dwellings would range between 0.7 and 2.0 metres. The assessment showed that dwelling floor areas ranged from 126 m² to 305 m², with the median house size being about 150 m². The reduction in AAD at each house (i.e., the benefit) was estimated to be between $2,700 to $9,400, with the average reduction being about $4,300. The total AAD reduction afforded by raising all 19 dwellings was estimated to be about $81,500.

The adopted cost rates for house raising were applied to each dwelling based on the estimated house floor area, which yielded total raising costs between $128,000 and $275,000 per dwelling. The total cost for all 19 dwellings was estimated to be $3.3M.

The NPV of the reduction in AAD due to house raising was calculated to range between $40,000 and $139,000 per property. The NPV of the total AAD reduction across all 19 properties was estimated to be about $1.2M.

The Benefit-Cost Ratio (BCR) for house raising works at each property was calculated as the NPV of the AAD reduction divided by the NPV of the house raising costs. The BCRs for individual dwellings range from 0.3 to 0.5, with the overall BCR for all dwellings in the scheme estimated to be about 0.4.

6 CONCLUSION

The VHR Scoping Study for Camden determined that 19 dwellings affected in the 1% AEP flood meet the VHR eligibility criteria, are of appropriate construction type, and are therefore recommended for inclusion in the proposed VHR Scheme. Dwellings were prioritised according to the benefit-cost ratio of the raising works at each property, which ranged between 0.3 and 05. Community consultation played a vital role in the study, providing valuable insights into local concerns and practical considerations essential for the successful completion of future VHR activities.

It was determined that dwellings affected in the 5% AEP flood would not be eligible for house raising, primarily due to being located in floodway and/or high flood hazard areas, or otherwise not being of suitable construction age or type. These properties were therefore recommended for consideration under a future Voluntary House Purchase (VHP) Scheme. A VHP Scheme would operate under a different set of eligibility criteria and may be more appropriate for addressing the flood risk in these high hazard areas. VHP is a risk management strategy involving the voluntary purchase of flood-prone properties to permanently remove people from high-risk areas, with the land typically cleared and rezoned for flood-compatible use (DCCEEW, 2024).

7 ACKNOWLEDGEMENTS

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