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HARC hydrology and risk CONSULTING

Rapid Flood Risk Assessment - North Central CMA Region

Coomoora

Version 2

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Acknowledgment of Country

We acknowledge Aboriginal Traditional Owners within the region, their rich culture and spiritual connection to Country. We also recognise and acknowledge the contribution and interest of Aboriginal people and organisations in land and natural resource management.

1. Introduction

The North Central Catchment Management Authority (CMA) commissioned HARC to undertake a rapid flood risk assessment for 21 townships in the North Central CMA region. The Rapid Flood Risk Assessments project is a joint initiative funded through the Victorian and Australian governments. The study focused on providing mapped flood extents for a range of AEPs using a range of existing and new hydrologic and hydraulic models. The rapid nature of the assessment precluded detailed, site specific studies, extensive model calibration or community engagement. The outcomes of the study were used to provide preliminary estimates of flood risk at the 21 locations, and to help identify and prioritise areas where more detailed, site specific flood studies were recommended. The study locations are shown in Figure 1-1 and the list of townships is shown in Table 1-1.

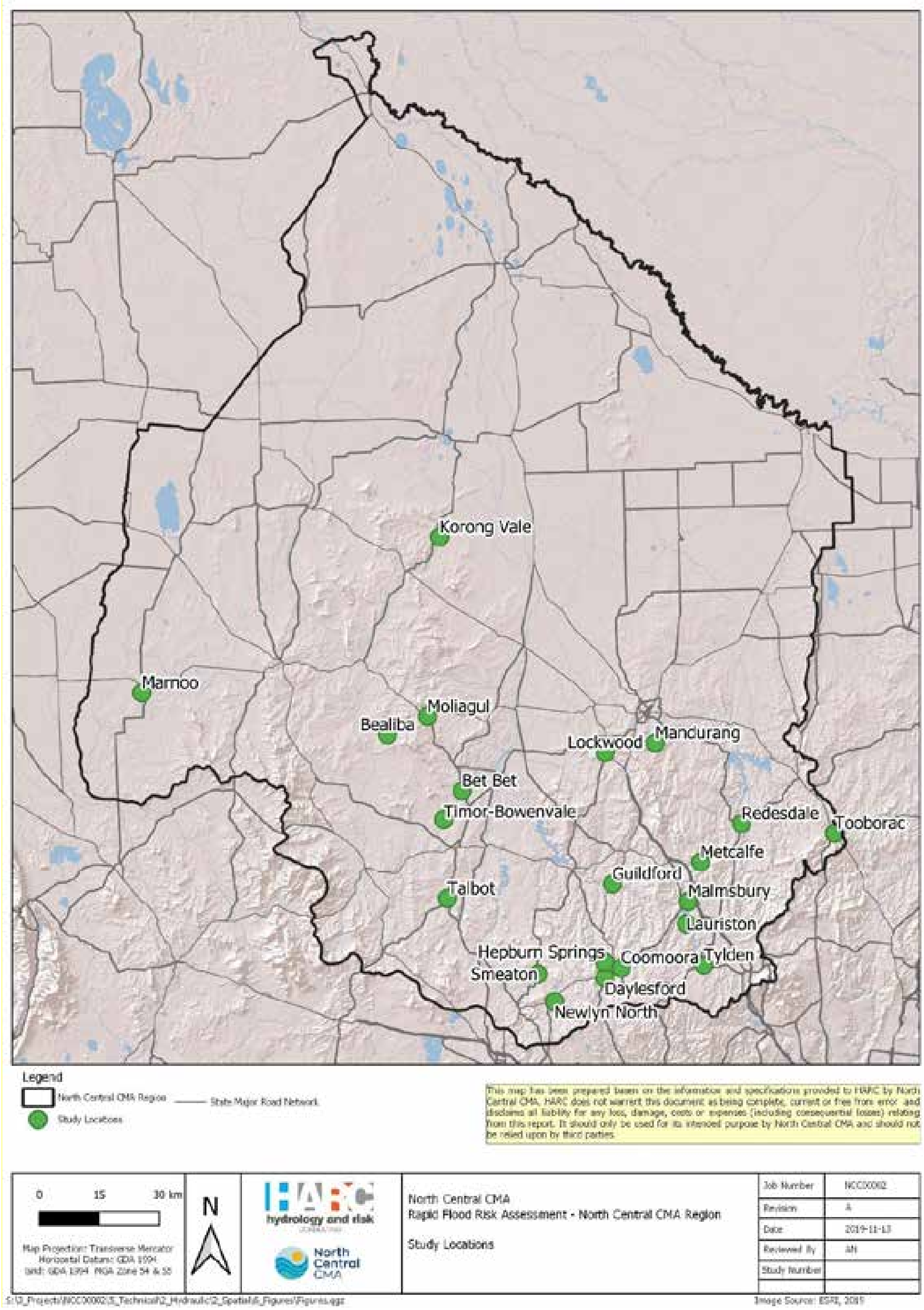


Figure 1-1 Rapid Flood Risk Assessment Project Study Locations

Table 1-1 List of Study Locations (Study Location in bold denotes the township covered in this report)

No.	Name	No.	Name
1	Lockwood	12	Daylesford
2	Mandurang	13	Hepburn Springs
3	Redesdale	14	Korong Vale
4	Moliagul	15	Malmsbury
5	Bet Bet	16	Lauriston
6	Talbot	17	Tylden
7	Bealiba	18	Tooborac
8	Timor-Bowenvale	19	Guildford
9	**Coomoora**	20	Metcalfe
10	Newlyn North	21	Marnoo
11	Smeaton		

This report documents the investigation undertaken for the study location of Coomoora.

Coomoora has a population of approximately 258 and is located approximately 41 km north-east of Ballarat. Wallaby Creek runs through the centre of the town, which has an upstream catchment area of 10 km^2. The creek channel is a small and relatively well defined with no significant tributaries joining within the study area. A map of the study area is shown in Figure 1-2.

■ **Figure 1-2 Coomoora study area**

2. Available Data

This section describes the key information used in the hydrological and hydraulic investigation.

2.1 Information Used in Hydrological Analysis

2.1.1 Previous Hydrological models

There was a RORB model set up as part of the Cairn Curran Dam: Flood Hydrology Update study (SKM, 2012) which included Coomoora. Table 2-1 summarises the key RORB parameters from the previous study.

Table 2-1 Previous RORB model summary of key parameters

No.	Study Area	Previous Study	k_c	d_{av}	$C_{0.8}$ (k_c/d_{av})	IL (mm)	CL (mm/h)	Shire
9	Coomoora	Cairn Curran Dam Hydrology	35	38.7	0.9	35	2	Hepburn

2.2 Information Used in Hydraulic Analysis

2.2.1 Hydraulic Structures

There are several hydraulic structures located within the study area. The main structures are listed in Table 2-2 and the location of these structures is shown in Figure 7-2. There may be other minor crossings within the study area but they have been assessed as likely to have little/no impact on the flood extents. The North Central CMA approached three organisations to provide information on their bridges and culverts. The three organisations were:

- VicRoads;
- VicTrack; and
- Council

Table 2-2 Summary of hydraulic structures for consideration

No.	Township Name	Source	Structure Type	Description
9	Coomoora	VicRoads	Bridge	Daylesford-Malmsbury Rd (SN9297)

2.2.2 Topographic Data

To undertake detailed hydraulic modelling requires high quality ground surface information. For this study, aerial captured ground survey, LIDAR, was supplied by North Central CMA. The LIDAR was used to generate a Digital Elevation Model (DEM) of the study area. This LIDAR covered the whole model extent. Further information on the LiDAR dataset used for this study is provided in Section 7.1.

3. Hydrologic model development

A rainfall runoff model (RORB) was established for the catchment, terminating at the study area downstream boundary (refer to Figure 1-2). RORB (Laurenson, Mein and Nathan, 2010) is a general runoff and streamflow routing program that is used to calculate flood hydrographs from rainfall and other channel inputs. It subtracts losses from rainfall to determine rainfall excess and routes this through catchment storages to produce streamflow hydrographs at points of interest. The model is spatially distributed, non-linear, and applicable to both rural and urban catchments. It makes provision for both temporal and areal spatial distribution of rainfall as well as losses, and can model flows at any number of points throughout a catchment (including upstream and downstream of reservoirs). RORB also has the capacity to use a Monte-Carlo approach to produce design flood estimates that incorporate the joint probability of several factors that influence flood characteristics.

In general terms, development of a RORB model entails sub-dividing the catchment into a series of subareas to suit the catchment topography and other features such as the location of gauging stations and storage locations.

Four different types of reaches can be defined in RORB, each having different properties and different relative delay times. The reach types are identified as natural, excavated but unlined, lined channel or pipe and drowned reaches. Drowned reaches were used within reservoir water bodies; natural reaches were used for all other reaches. Excavated and lined channel reaches are normally only applied in urbanised areas and hence were not used in this study.

Impervious fractions are required for each sub-area. For rural areas the impervious fraction was assumed to be zero. For any areas within a dam or reservoir water body, an impervious fraction was calculated based on the percentage of the sub-area that would be inundated. The RORB model also includes some urban areas. The total impervious area (TIA) was estimated for the urban areas using aerial photography and land use information. The Victorian Land Use Information System (VLUIS) dataset was used to define the land use. Because not all impervious areas are well connected to the drainage network (i.e. they flow onto pervious parts of the catchment), the effective impervious area (EIA) is less than the TIA. ARR2019 (Book 5, Chapter 5, Hill and Thomson, 2015) and Phillips et al. (2014) have consolidated the recommended industry practice for estimating EIA and loss parameters for the pervious portion of urban catchments. Phillips et al. (2014) analysed eight catchments and concluded that EIA is typically 55 to 65% of the TIA. ARR2019 recommends an EIA/TIA ratio of 60%. For the RORB model the TIA fraction was multiplied by 0.6 to estimate EIA. The EIA assigned to each land use is shown in Table 3-1.

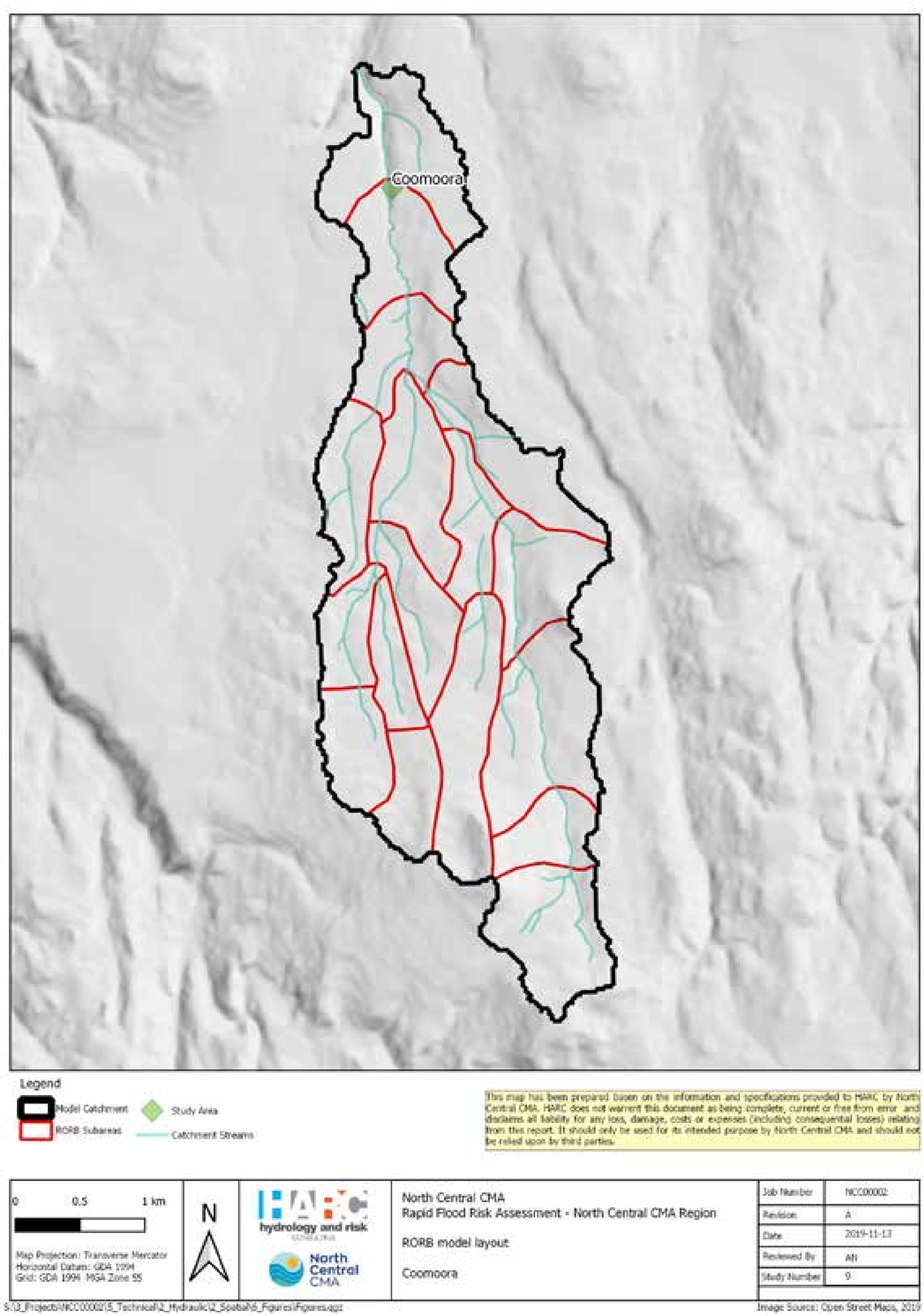
Table 3-1 EIA assigned for each land use

Land Use Type	EIA
Residential areas – high density	0.45
Residential areas – low density	0.12
Industrial/commercial – low density	0.54

Land Use Type	EIA
Open space or waterway – minimal vegetation	0.0
Open space or waterway – moderate vegetation	0.0
Open space or waterway – heavy vegetation	0.0
Paved roads/car park/driveways	0.6
Railway line	0.6
Grass reserves/floodway (regularly mowed)	0.0
Rural floodplains in clear paddocks	0.0
Forested (heavy stand of timber)	0.0
Dam/Reservoir body of water	1.0

3.1 Coomoora RORB model

The RORB model established for the Cairn Curran Dam: Flood Hydrology Update (SKM, 2010) had the Coomoora catchment covered with a single subarea, which was considered too coarse for this investigation. Therefore, a new RORB model was built, as part of this investigation, for Coomoora. The RORB model layout is shown in Figure 3-1.



■ **Figure 3-1 RORB model layout**

4. Design hydrology approach and inputs

4.1 Overview of adopted design flood approach

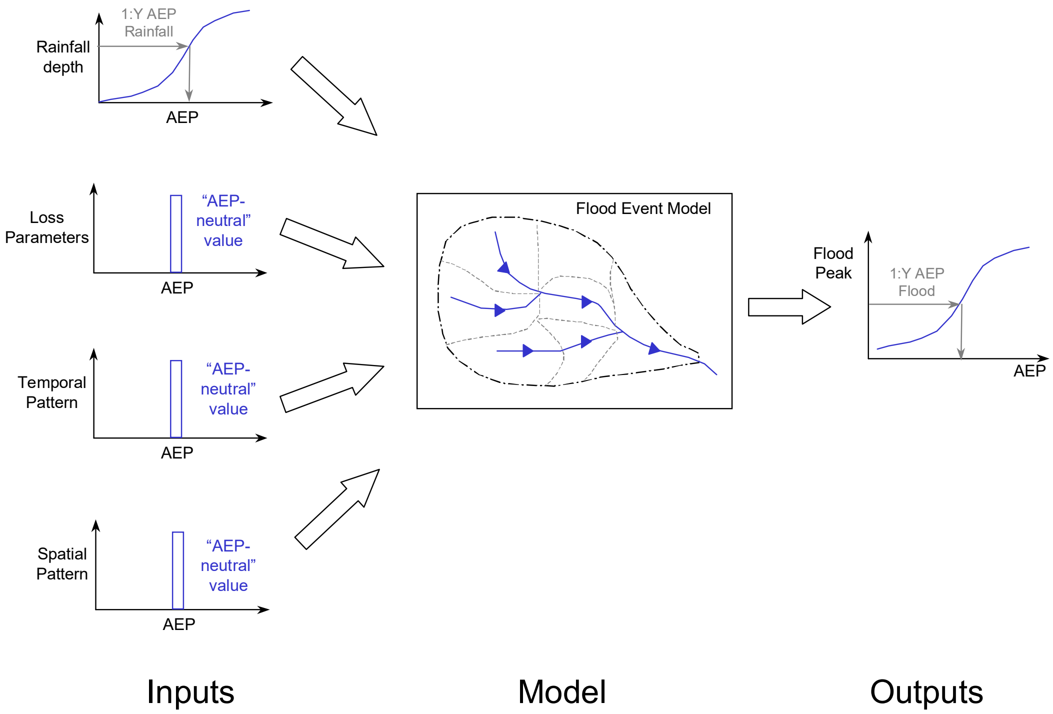
The estimation of design floods has traditionally been based on the ‘design event‘ approach, in which all parameters other than rainfall are input as fixed, single values. This concept is illustrated in Figure 4-1 for the case where a distribution of design rainfalls is combined with fixed values of losses, rainfall temporal patterns and spatial patterns. Considerable effort is made to ensure that the single values of the adopted parameters are ’AEP-neutral‘, that is, they are selected with the objective of ensuring that the resulting flood has the same annual exceedance probability as its causative rainfall.

This approach suffers from the limitations that:

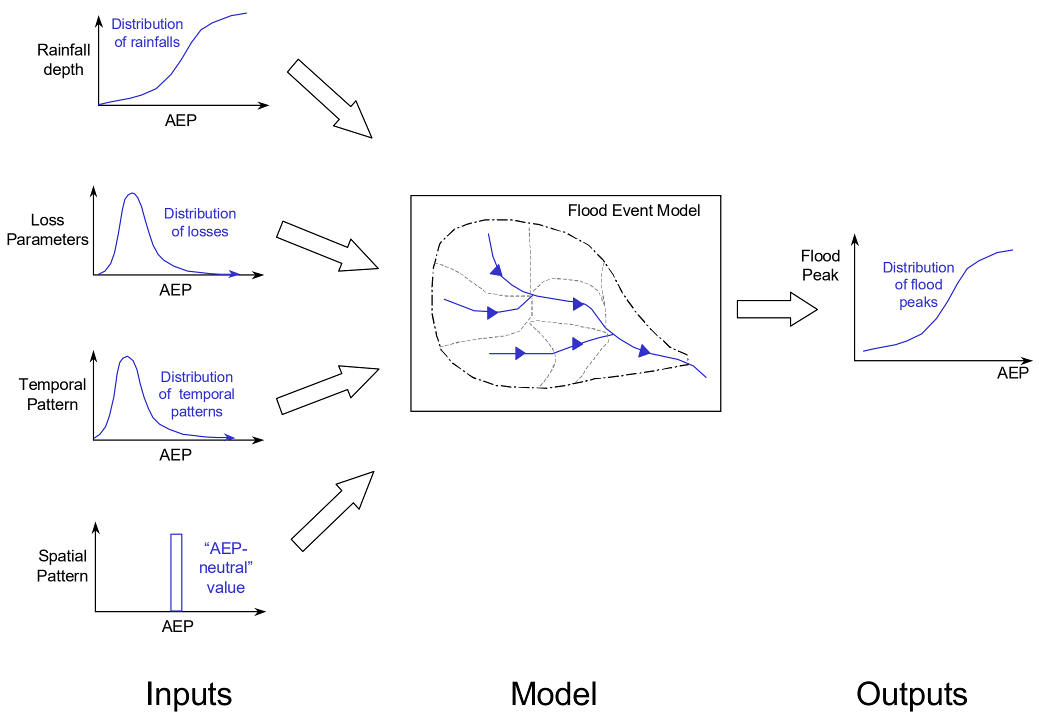
- the AEP-neutrality of some inputs can only be tested on frequent events for which independent estimates are available;
- for more extreme events, the adopted values of AEP-neutral inputs must be conditioned by physical and theoretical reasoning; and
- the treatment of more complex interactions (such as the variability in rainfall spatial and temporal pattern) becomes rapidly more complex and less easy to defend.

Joint probability techniques offer an improvement to the traditional design event method. These techniques recognise that any design flood characteristics (e.g. peak flow) could result from a variety of combinations of flood producing factors, rather than from a single combination. For example, the same peak flood could result from a moderate storm on a saturated catchment, or a large storm on a dry catchment. In probabilistic terms, a 1 in 100 AEP flood could be the result of a 1 in 50 AEP rainfall on a very wet catchment, or a 1 in 200 AEP rainfall on a dry catchment. Joint probability approaches attempt to mimic ‘mother nature’ in that the influence of the key probability distributed inputs are explicitly considered, thereby providing a more realistic representation of the flood generation processes.

The application of joint probability approaches to flood estimation is widely acknowledged to be a more thorough and defensible approach to design flood estimation than the design event approach in Australian practice, and has been incorporated in the 2019 version of Australian Rainfall and Runoff (Ball et al., 2019).



▪ **Figure 4-1 Schematic illustration of the design event approach**



▪ **Figure 4-2 Schematic illustration of the joint probability approach**

The joint probability framework adopted for the study was developed by Nathan et al (2002, 2003) and is summarised in Figure 4-3. In essence the approach involves undertaking numerous model simulations, where the model inputs are sampled from non-parametric distributions that are based either on readily available design information or on the results of recent research. For those study areas where reservoir starting water level is applicable, the level in the storage is also sampled.

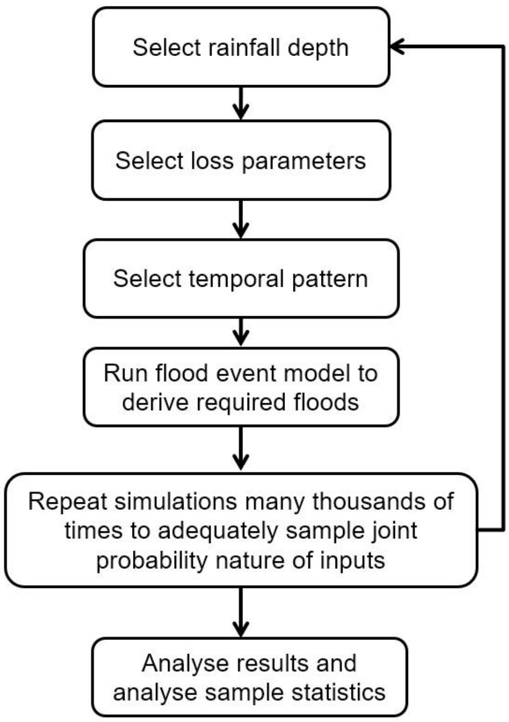


Figure 4-3 Overview of adopted joint probability framework

In developing the joint probability framework particular attention was given to ensuring that the model inputs and the manner in which they were incorporated was consistent with ARR (Ball et al., 2019). The following briefly describes the main inputs, and how they will relate to establishing design information.

Select rainfall depth. Rainfall depths were stochastically sampled from the cumulative distribution of rainfall depths.

Select storm losses. Storm initial losses were stochastically sampled from a nonparametric distribution that was determined from the analysis of a large number of catchments across Australia (Hill et al., 2014). The limited number of investigations that have explored the correlation between initial and continuing loss values have concluded that there is little systematic dependence between the two. There is little information regarding the correlation between initial and continuing loss rates, and since antecedent conditions have most influence on initial loss rates, in this study the continuing loss rates will be held constant. Current practice is for initial losses to be sampled from a distribution, while the continuing loss is held constant; this approach was used for the design flood modelling.

Select temporal pattern. Temporal patterns were randomly selected from a sample of temporal patterns relevant to the catchment area and duration of the storm. The temporal patterns in the data hub were derived from large historic storms that have been observed in the region.

Monte-Carlo simulation. Simulations were undertaken using a stratified sampling approach in which the sampling procedure focuses selectively on the probabilistic range of interest. Thus, rather than undertake many millions of simulations in order to estimate an event with, say, a 1 in 100 probability of exceedance, a reduced number of simulations were undertaken over a specified number of probability intervals. In this study, the rainfall frequency curve was divided into 100 intervals uniformly spaced over the standardised normal probability domain, and 250 simulations were taken within each division. Thus, a total of 25,000 simulations were undertaken to derive the frequency curve corresponding to each storm duration considered. This approach accounts for the natural variability inherent in floods. Monte Carlo techniques are grounded in, and consistent with, the principle that “no two floods are ever the same”.

The key advantage of the Monte Carlo approach is that it reduces uncertainty by accounting for variability. The results of a Monte Carlo analysis are presented as median peak flow estimates rather than single hydrographs, however it must be remembered that the natural variability of the key inputs is built into these median estimates. The median peak flows are not biased one way or the other by selection of a single arbitrary rainfall temporal or spatial pattern. Using the technique described above hydrographs were produced for the 20%, 10%, 5%, 2%, 1% and 0.5% AEP events.

In the context of a rapid flood risk assessment the estimation of the magnitude of the PMF was based on the regional prediction equation described in Nathan et al. (1994).

4.2 Overview of design flood hydrology inputs

Design inputs were produced in accordance with ARR2019. Inputs include:

- Rainfall depths (IFD - BOM),
- Areal reduction factors (Data hub),
- Spatial patterns (Rainfall depths over the catchment – based on IFD)
- Temporal patterns (Rainfall depths over time – Data hub)
- Losses (ARR guidance)
- Pre-burst (Data hub)
- Baseflow (ARR guidance)

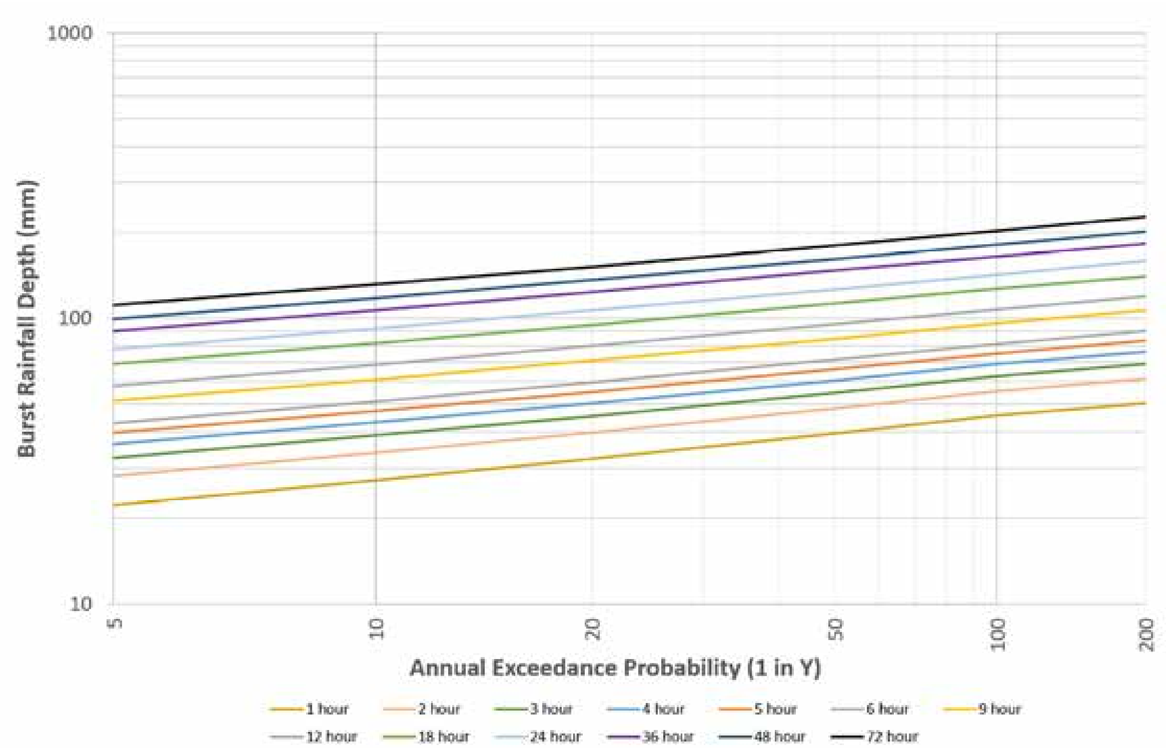
4.2.1 Rainfall depths

Catchment average point design rainfall depths for burst durations between 1 and 72 hours, and AEPs from 1 in 5 to 1 in 200, were taken from the Bureau of Meteorology (2016) (http://www.bom.gov.au/water/designRainfalls/revised-ifd/).

4.2.2 Areal reduction factors

The point rainfall estimates were converted to areal values using the ARR2019 areal reduction factors (Jordan et al, 2016) extracted from the ARR Data Hub. Conceptually, these factors account for the fact that larger catchments are less likely to experience high intensity storms over the whole catchment.

A summary of the complete, catchment average areally reduced design rainfall depths adopted are shown in Figure 4-4 and Table 4-1.



- **Figure 4-4 Adopted design rainfall depths**
- **Table 4-1 Adopted design rainfall depths**

AEP (1 in Y)	1	2	3	4	5	6	9	12	18	24	36	48	72
5	22	28	33	36	40	43	51	58	69	78	91	99	111
10	27	34	39	43	47	51	61	69	82	92	107	118	132

AEP (1 in Y)	1	2	3	4	5	6	9	12	18	24	36	48	72
20	32	40	46	50	55	60	71	80	95	107	124	136	152
50	40	48	55	61	66	72	85	95	113	126	147	161	180
100	46	56	63	69	75	82	96	108	127	142	165	182	203
200	51	61	69	76	84	91	107	120	141	159	183	201	227

4.2.3 Spatial patterns

The spatial pattern for the catchment has been based on the rainfall depths from the Bureau of Meteorology, i.e. the IFD, which is recommended in ARR2019.

4.2.4 Temporal patterns

For catchment areas greater than 75km^2 ARR recommends the use of the sample of areal temporal patterns available from the ARR data hub (Geoscience Australia, 2019) for long durations (greater than 24 hours). The derivation of these patterns is discussed in ARR 2019 (Ball et al., 2019). For the shorter duration storms, the sample of temporal patterns derived by Jordan et al (2005) was used. For catchment areas less than 75km^2 ARR recommends the use of ARR data hub (Geoscience Australia, 2019) point patterns.

Before the temporal patterns were used, they required some filtering to remove embedded bursts. An embedded burst is a sub-period of rainfall within a given temporal pattern that has a rarer AEP than the actual burst itself. The method described by Scorah et al. (2016) was used to smooth out the embedded bursts. As an example, Figure 4-5 shows the 24 hour design temporal patterns, before and after embedded bursts are removed.

All temporal patterns in the sets used for sampling were given equal probability of selection in the Monte Carlo simulation.

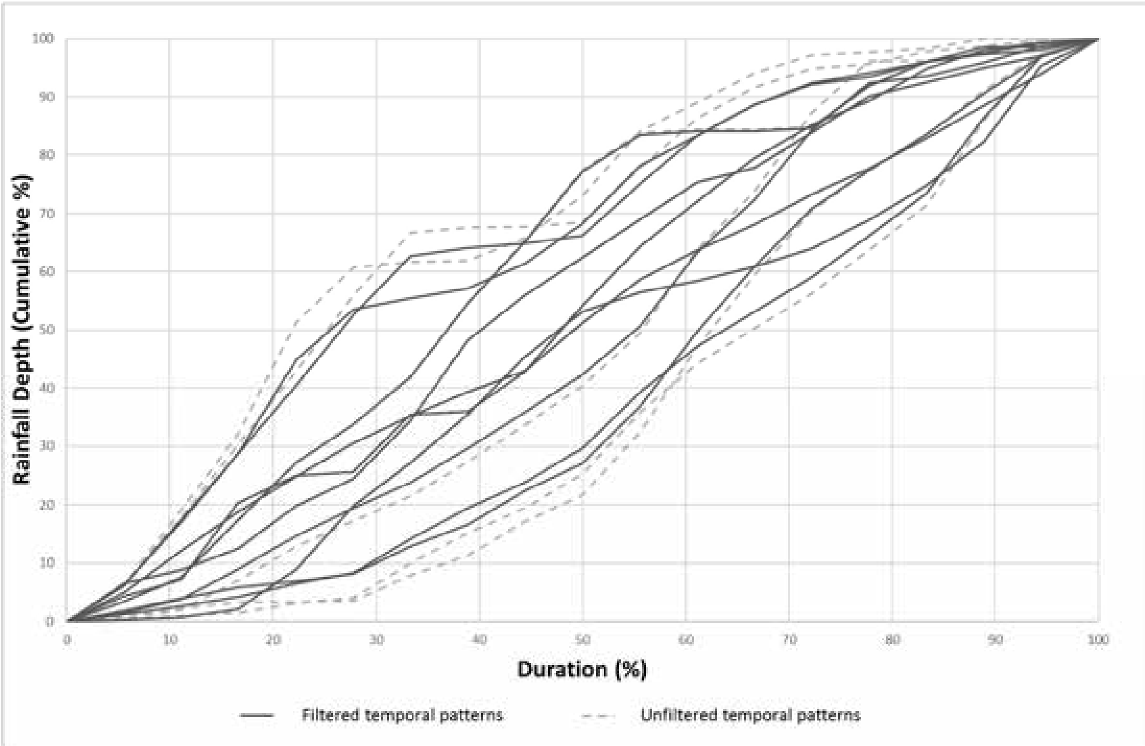


Figure 4-5 24-hour design temporal patterns before filtering and after filtering to remove embedded bursts

4.2.5 Losses

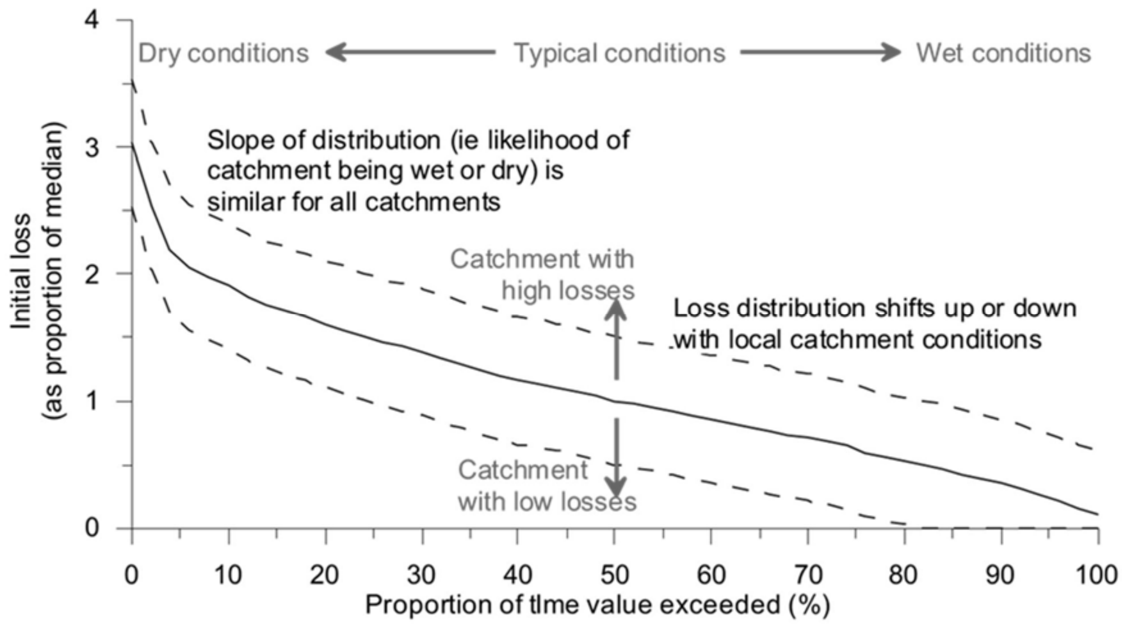
There are two key types of loss models that are typically adopted when modelling design floods:

- Initial loss/continuing loss
- Initial loss/proportional loss

Investigations by Hill et al. (2014) as part of the ARR 2019 revision were inconclusive as to which loss model works best. Even for catchments where one of the loss models performed better for a majority of events, there were still some events for which the other approach was better. Similarly, there was no obvious relationship between the relative performance of the loss models and hydro-climatic or catchment characteristics.

The advice in ARR is that the initial loss/continuing loss model is most suitable for design flood modelling, because it can be used to estimate flood peaks and volumes for all AEPs. In contrast, it is often difficult to derive unbiased estimates of flood quantiles using the initial loss/proportional loss model over the same range of AEPs. The initial loss/proportional loss model underestimates peak flows for extreme floods if the proportional loss is not varied appropriately with AEP; and to date there is little evidence about how proportional loss varies with AEP. Therefore, for this study an initial loss/continuing loss model was adopted.

The shape of the initial loss distribution used in the design flood modelling was derived by Hill et al. (2014) from flood modelling results for a large number of catchments across Australia. Hill et al. (2014) developed a non-dimensional distribution of initial loss values for each catchment, by representing initial losses as a proportion of the median loss. This allowed the distributions of initial losses across different catchments to be directly compared. The standardised distributions exhibited a high degree of consistency, and suggested that while the magnitude of initial losses may vary between different catchments, the shape of the distribution does not. That is, while it may be expected that typical loss rates vary from one catchment to another, the likelihood of a catchment being in a relatively dry or wet state is similar for all catchments. The adopted distribution of initial loss is shown in Figure 4-6.



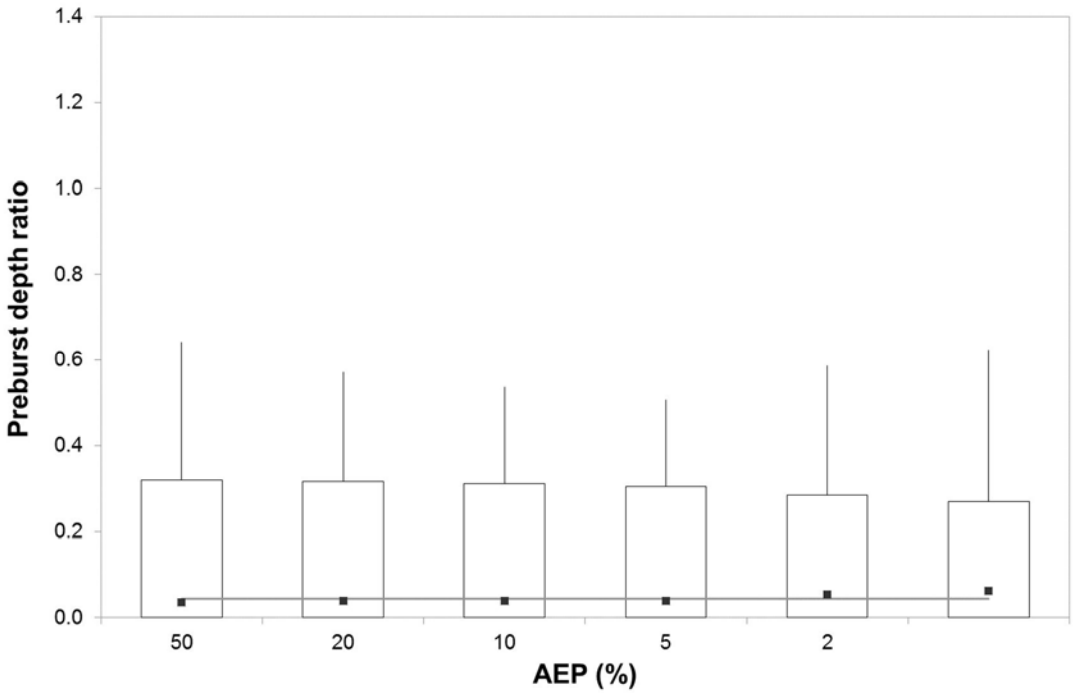
- **Figure 4-6 Cumulative probability distribution of initial loss**

The correlation between initial losses and continuing losses is not well understood. Current practice is for initial losses to be sampled from a distribution, while the continuing loss is held constant; this approach was used for this study.

4.2.6 Pre-burst rainfall depths and temporal patterns

Estimates of the percentage of burst depth of rainfall antecedent to the main burst were taken from the ARR data hub (Geoscience Australia, 2019). The data hub provides a distribution of pre-burst depths by duration and AEP. The median pre-burst depths for each duration was compared across AEPs, and for the purpose of design flood modelling, it was decided that adopting an average of the median for each duration was appropriate (Figure 4-7).

Although the ARR data hub provides pre-burst depths, it does not contain information regarding the temporal patterns. Therefore, temporal patterns of rainfall antecedent to the main burst were taken from Minty and Meighen (1999) and applied to burst durations of 12 hours and longer (Minty and Meighen, 1999). For the shorter durations, the pre-burst patterns from Jordan et al (2005) were applied.



- **Figure 4-7 Pre-burst rainfall depths – 6 hour burst – shown as a ratio of burst depth, using a box plot of the 10th, 25th, 50th, 75th and 90th percentiles. The grey line shows the adopted value for the design flood modelling; this is the average of the median values across the available AEPs.**

4.2.7 Baseflow

As RORB only estimates the surface runoff, baseflow needs to be added. For baseflow, regional estimates were used. From the ARR data hub the peak factor was extracted. The baseflow peak factor is applied to the estimated surface runoff peak flow to give the value of peak baseflow for a 10% AEP event. ARR 2019 provides a scaling factor to be applied to the 10% AEP baseflow peak factor to determine the baseflow peak factor for events of various AEPs.

A frequency distribution of baseflow with AEP was estimated by using the Regional Flood Frequency Estimation (RFFE - refer to Section 5) distribution. This provided the frequency distribution for baseflow under the peak of the annual maxima flood events.

5. Hydrologic model verification

5.1 Adopted parameters

For the RORB model the routing parameters (m and k_c), initial loss (IL) and continuing loss were taken from the Cairn Curran Dam: Flood Hydrology Update (SKM, 2012). For the routing parameter, k_c, the ratio of k_c/d_{av} was used to ensure that the same routing was applied to the RORB model established for the study area as per the previous model. McMahon and Muller (1983) showed that k_c is directly proportional to d_{av}, where d_{av} is the weighted average flow distance to the catchment outlet (this is calculated automatically in the RORB model). Therefore, a way to measure the similarity of two different RORB models is to compare k_c/d_{av}.

The RORB model established for the Cairn Curran Dam: Flood Hydrology Update (SKM, 2012) was calibrated to three events i.e. September 2010, November 2010 and January 2011. The RORB model was also verified to a flood frequency curve (FFC) at Loddon River @ Newstead (407215).

As the RORB model established for the Cairn Curran Dam: Flood Hydrology Update (SKM, 2012) was calibrated and verified to a local gauged at-site flood frequency, this gives some confidence that the parameters adopted for this investigation are representative of the catchment characteristics. Table 5-1 summarises the RORB parameters adopted for Coomoora.

Table 5-1 Summary of key parameters adopted for the RORB model

Parameter	Value
k_c	3.8
d_{av}	4.2
$C_{0.8}$ (k_c/d_{av})	0.91
m	0.8
IL (mm)	35.0
CL (mm/hr)	2.0

5.2 Verification to the Regional Flood Frequency Estimation Model

To gain additional confidence in the parameters adopted, the RORB model results were compared to the Regional Flood Frequency Estimation Model (RFFE) which was developed as part of ARR2019. The RFFE was used as a guide only with more confidence given to the calibration/verification process undertaken for the individual catchment. Figure 5-1 shows the RFFE compared to the RORB model results using the parameters shown in Table 5-1. Figure 5-1 shows that the RORB model is higher than the RFFE but well within the confidence limits.

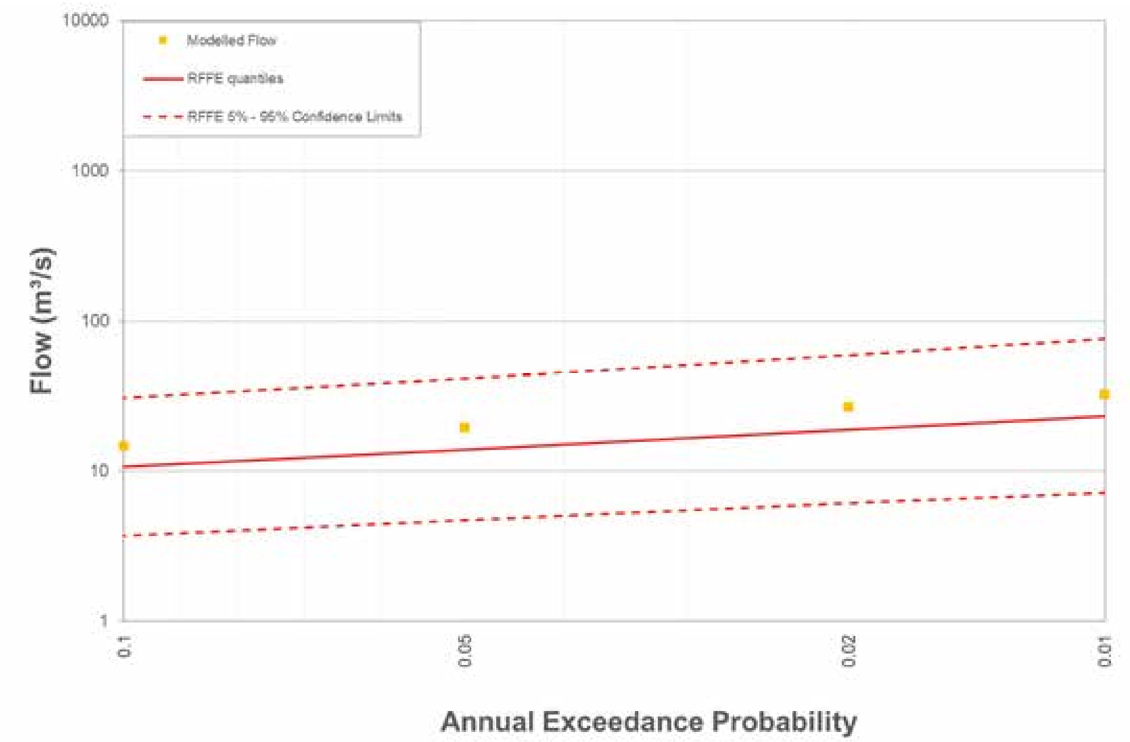


Figure 5-1 Verification results compared to RFFE

5.3 Comparison to regional parameters

As mentioned in Section 5.1 the choice of k_c for the Coomoora catchment was based on the calibration result from the Cairn Curran Dam: Flood Hydrology Update (SKM, 2012) however, the results from the calibration were compared to a number of regional estimates.

For Victorian regions with a mean annual rainfall of less than 800 mm k_c is estimated using equation 1 from ARR 2016 (Hansen et al, 1986).

$$k_c = 0.49\, A^{0.65} \qquad (1)$$

Where A is the area in km^2.

The k_c value from calibration was also compared to another regional estimate by Pearse et. al. (2002). Pearse et. al. (2002) analysed a large database of routing parameters collated by the CRC for Catchment Hydrology and derived a prediction equation applicable to Victoria. The d_{av} for the catchment was used to predict the k_c value where k_c is directly proportional to d_{av} giving equation 2

$$k_c = C\, d_{av} \qquad (2)$$

Where C is a characteristic of the catchment independent of the scale or size of the catchment and d_{av} is the weighted average flow distance to the catchment outlet (this is calculated automatically in the RORB model).

Pearse et al. (2002) also gave an expected value and one standard deviation (High and Low).

Table 5-2 provides a summary of the regional estimates along with the adopted value. Table 5-2 shows the k_c based on the calibration event undertaken in the Cairn Curran Hydrology (SKM, 2012) is in line with the regional estimates.

- **Table 5-2 k_c values – regional estimates**

Location	Area (km^2)	k_c (equation 1)	k_c (equation 2)			k_c (adopted)
			Expected	High	Low	
Coomoora	10	2.2	5.3	8.7	3.2	3.8

The ARR2019 data hub provides some regional estimates of losses. The regional losses are to only be used as a guide as ARR2019 clearly states it is always desirable to reconcile design values with independent flood frequency estimates where possible. Table 5-3 shows the regional estimates along with the adopted values. Table 5-3 shows that the adopted losses are different to the regional estimates highlighting the need to verify the model, where possible.

- **Table 5-3 Loss values – regional estimates**

Location	Regional		Adopted	
	IL (mm)	CL (mm/h)	IL (mm)	CL (mm/h)
Coomoora	26.0	4.2	35.0	2.0

6. Design flood hydrology

6.1 Design flows for the 20% to 0.5% AEP events

The RORB model was run in the joint probability framework, with the design inputs and the adopted routing parameters, initial and continuing losses to generate design flood frequency curves and inflow hydrographs.

In order to generate hydrographs the RORB model was run in the joint probability framework described in Section 4.1, with the design inputs summarised in Section 4.2 and the adopted parameters summarised in Section 5.

The joint probability framework provides a peak flow, whereas the hydraulic model requires a set of hydrographs. The results of the Monte Carlo analysis are presented as median peak flow estimates rather than single hydrographs, with the natural variability of the key inputs built into the median estimates. The median peak flows are not biased one way or the other by selection of a single arbitrary rainfall temporal or spatial pattern. Hydrographs were chosen from the set of Monte Carlo results that best matched the median peak flows and were an unbiased transformation from input rainfall AEP to flood AEP.

For the hydraulic model hydrographs were extracted at key locations within the study area. Table 6-1 shows the peak flows at downstream end of the study area from the event centred over the entire catchment.

Table 6-1 Summary of modelled peak flow estimates for Coomoora

AEP (1 in Y)	Peak Flow (m^3/s)	Critical Duration (hours)
5	10.6	12.0
10	13.9	12.0
20	17.6	6.0
50	24.4	6.0
100	31.5	6.0
200	39.0	6.0

6.2 PMF estimate

As mentioned earlier in the context of a rapid flood risk assessment the estimation of the magnitude of the PMF was based on the regional prediction equation described in Nathan et al. (1994). Nathan et al. (1994) looked at 56 sites across South-Eastern Australia and developed a series of equations to estimate the peak, volume and time to peak of a PMF.

Nathan et al. (1994) estimates of the PMF magnitude are based on the catchment area using the following equations.

$$Q_p = 129.1 * A^{0.616} \qquad (1)$$

$V = 497.7 * A^{0.984}$ (2)

$T_p = 1.066 * 10^{-4} * A^{-1.057} * V^{1.446}$ (3)

And from a mass balance taking Equations (1) and (2).

$T_r = \frac{V}{1.8 * Q_p}$ (4)

Where: Q_p is peak flow (m^3/s);

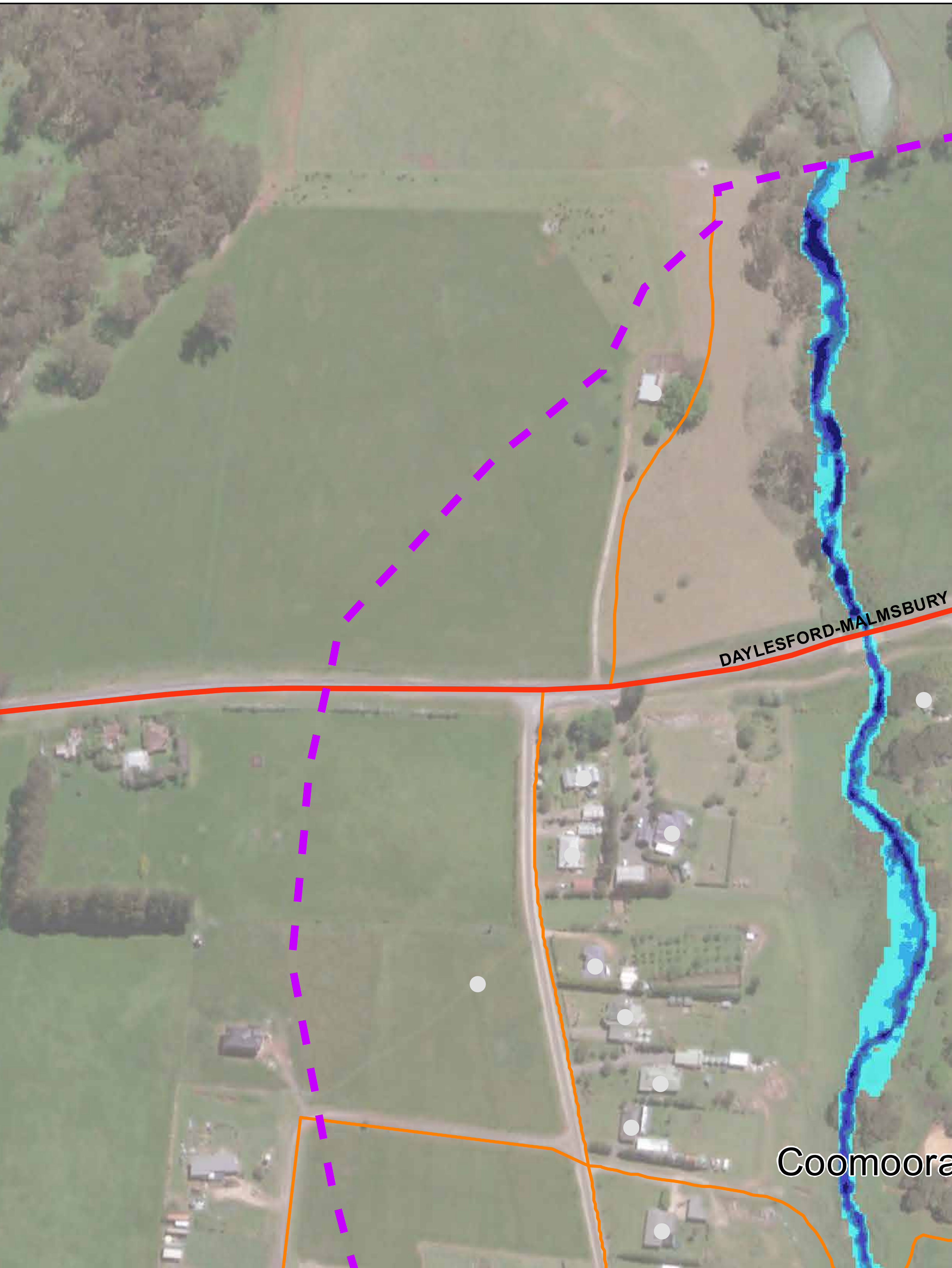
A is catchment area (km^2)

V is the Volume of the hydrograph (ML)

T_p is the time to peak flow (hours)

T_r is the total time of the hydrograph (hours)

Each of these characteristics has been used to determine a 'triangular' PMF hydrograph. Figure 6-1 illustrates the characteristics of the 'triangular' PMF hydrograph.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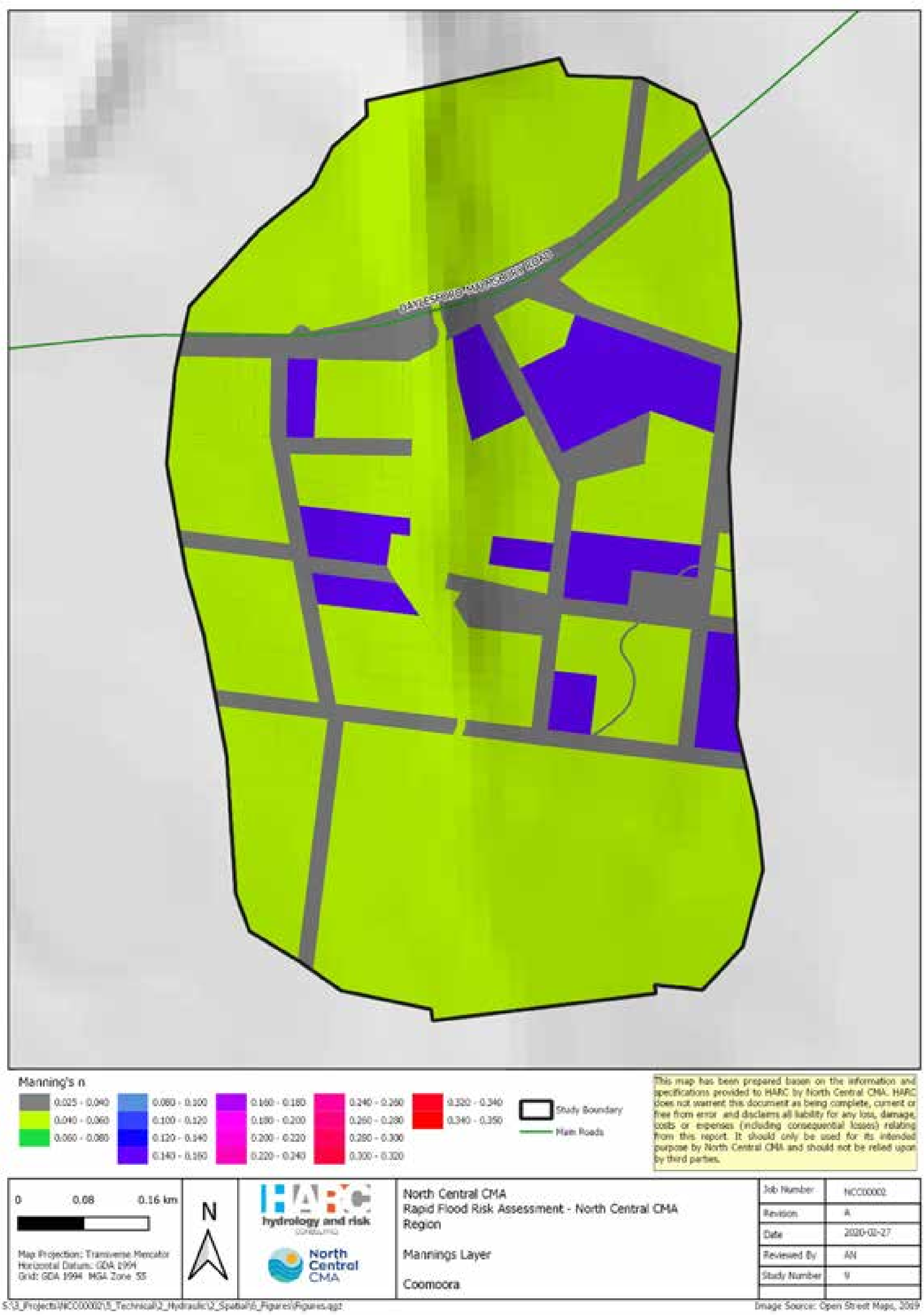
n categories were selected to be in line with the values provided by ARR2019. No calibration of the hydraulic models was undertaken for this project.

Table 7-1 Manning's n values for different land use types

Land Use Type	Manning's n adopted
Residential areas – urban high density (building and parcel combined)	0.35
Residential areas – rural high density (building and parcel combined)	0.15
Industrial/commercial or large buildings	0.30
Residential areas – rural low density (parcel only or large blocks with house)	0.05
Open space or waterway – minimal vegetation	0.04
Open space or waterway – moderate vegetation	0.06
Open space or waterway – heavy vegetation	0.095
Paved roads/car park/driveways	0.025
Railway line	0.05
Grass reserves/floodway (regularly mowed)	0.035
Rural floodplains in clear paddocks	0.05
Forested (heavy stand of timber)	0.12
Dam/Reservoir body of water	0.035



- **Figure 7-1 Surface roughness distribution**

7.4 Hydraulic structures

Table 2-2 lists the culverts/bridges that were entered into the model. Bridges were represented using a layered flow constriction and culverts in 1D.

Bridge structures were modelled with the appropriate losses derived from Waterway Design: A Guide to the Hydraulic Design of Bridges, Culverts and Floodways (Austroads, 1994). The layered flow constrictions used to model these bridges allows for typical bridge characteristics such as deck height and thickness, pier shape and width and blockages associated with guard or hand rails to be directly incorporated into the 2D domain. The details of these were extracted from supplied plans. Where plans were not available the losses and dimensions were estimated based on typical bridge configurations and loss parameters.

The 1D elements were dynamically linked to the 2D domain. Details of the culverts were extracted from supplied plans, details provided by Council or the North Central CMA.

7.5 Inflows

The inflows to the hydraulic model were taken from the RORB model, as discussed in Section 6 and modelled in TUFLOW as two-dimensional source area polygons distributing the inflow over the polygon. The polygons were located along the waterways within the study area.

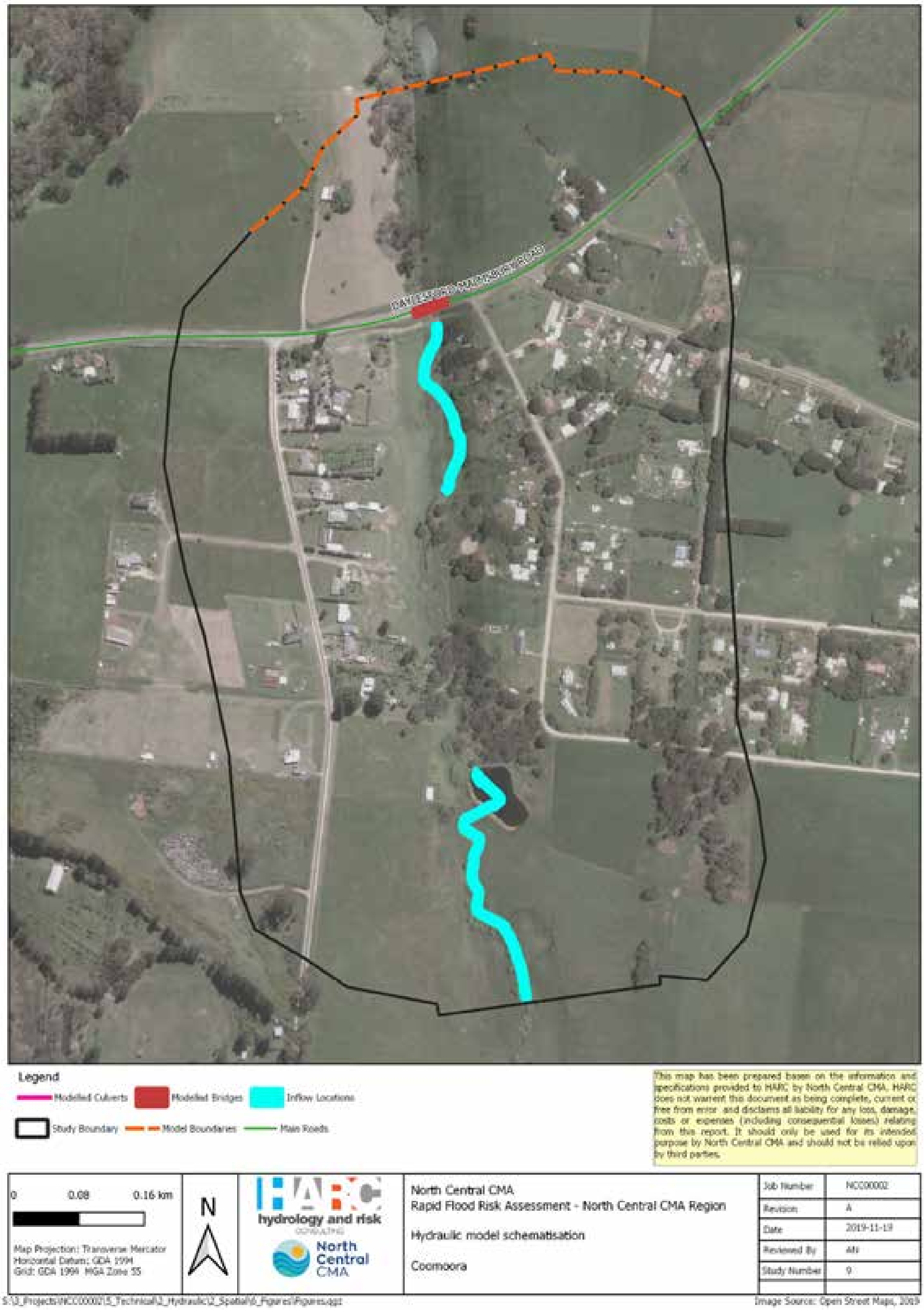
The results of the Monte Carlo analysis are presented as peak flow estimates rather than single hydrographs, with the natural variability of the key inputs built into the estimates. The peak flows are not biased one way or the other by selection of a single arbitrary rainfall temporal or spatial pattern. The hydrographs entered into the hydraulic model were chosen from the suite of runs from the Monte Carlo analysis such that the single hydrographs matched the peak flows.

7.6 Downstream boundary

The downstream boundary condition was entered as a normal depth relationship with a slope of 7% based on the LIDAR data.

A schematisation of the hydraulic model is found in Figure 7-2.

All the hydraulic models were run for the 1 in 5, 10, 20, 50, 100 and 200 AEP and PMF events, for the critical durations identified in Table 6-1.



■ **Figure 7-2 Hydraulic model schematisation**

8. Flood Risk Assessment

8.1 Flood Mapping

Flood maps showing flood level, depth, velocity and hazard (depth x velocity) have been produced for the 1 in 5, 10, 20, 50, 100 and 200 AEP event along with the PMF. The flood maps are shown in Appendix A.

Table 8-1 shows the flood map reference numbers that correspond to the maps in Appendix A.

Table 8-1 Flood maps reference table

Map Number	Map Name	Map Number	Map Name
9-5-1	1 in 5 year Depth Map	9-5-4	1 in 5 year Hazard Map
9-10-1	1 in 10 year Depth Map	9-10-4	1 in 10 year Hazard Map
9-20-1	1 in 20 year Depth Map	9-20-4	1 in 20 year Hazard Map
9-50-1	1 in 50 year Depth Map	9-50-4	1 in 50 year Hazard Map
9-100-1	1 in 100 year Depth Map	9-100-4	1 in 100 year Hazard Map
9-200-1	1 in 200 year Depth Map	9-200-4	1 in 200 year Hazard Map
9-PMF-1	PMF Depth Map	9-PMF-4	PMF Hazard Map
9-5-2	1 in 5 year Depth x Velocity Map	9-5-5	1 in 5 year Velocity Map
9-10-2	1 in 10 year Depth x Velocity Map	9-10-5	1 in 10 year Velocity Map
9-20-2	1 in 20 year Depth x Velocity Map	9-20-5	1 in 20 year Velocity Map
9-50-2	1 in 50 year Depth x Velocity Map	9-50-5	1 in 50 year Velocity Map
9-100-2	1 in 100 year Depth x Velocity Map	9-100-5	1 in 100 year Velocity Map
9-200-2	1 in 200 year Depth x Velocity Map	9-200-5	1 in 200 year Velocity Map
9-PMF-2	PMF Depth x Velocity Map	9-PMF-5	PMF Velocity Map
9-5-3	1 in 5 year Elevation Map		
9-10-3	1 in 10 year Elevation Map		
9-20-3	1 in 20 year Elevation Map		
9-50-3	1 in 50 year Elevation Map		
9-100-3	1 in 100 year Elevation Map		
9-200-3	1 in 200 year Elevation Map		
9-PMF-3	PMF Elevation Map		

8.2 Flood behaviour and impact of flooding

The following section summarises the impact of flooding. Table 8-2 provides a summary of the water level at the location shown in Figure 8-1 along with the main impacts for each AEP. Table 8-3 is a summary of the number of properties that are inundated for each AEP event. Table 8-4 is a summary of the number of properties that are inundated above floor for each AEP event. Table 8-5 is a summary of the main roads that are overtopped.

Table 8-2 Summary of impacts of flooding

AEP (1 in Y)	Water level upstream of Daylesford-Malmsbury Road (mAHD)	Impact
5	575.5	No buildings are inundated
10	575.6	No buildings are inundated
20	575.8	No buildings are inundated
50	576.1	No buildings are inundated
100	576.2	No buildings are inundated
200	576.4	No buildings are inundated

Table 8-3 Summary of property inundation

AEP (1 in Y)	Residential	Industrial	Agriculture	Public	Commercial	Fire	Aged Care	Education	Hospital	Police	Caravan / Camp Ground
5	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0	0
200	0	0	0	0	0	0	0	0	0	0	0

Table 8-4 Summary of over floor flooding*

AEP (1 in Y)	Residential	Industrial	Agriculture	Public	Commercial	Fire	Aged Care	Education	Hospital	Police	Caravan / Camp Ground
5	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	0
100	0	0	0	0	0	0	0	0	0	0	0
200	0	0	0	0	0	0	0	0	0	0	0

* Note the floor levels have assumed to be 300 mm above the natural surface level for those buildings without surveyed floor levels

Table 8-5 Summary of road Inundation

AEP (1 in Y)	Roads impacted by flooding	Maximum depth over road (m)	Duration of inundation (hours)
5	Daylesford-Malmsbury Road	0.0	0
10	Daylesford-Malmsbury Road	0.0	0
20	Daylesford-Malmsbury Road	0.0	0
50	Daylesford-Malmsbury Road	0.0	0
100	Daylesford-Malmsbury Road	0.0	0
200	Daylesford-Malmsbury Road	0.0	0

■ **Figure 8-1 Reporting location**

8.3 Climate change

The increase in flows due to climate change was discussed in Section 6.3. To present the sensitivity of flood levels to changes resulting from climate change a rating curve of flow and water level at a key location within the study area is shown in Figure 8-2. Figure 8-1 shows the location of the rating curve and Table 8-6 the flows. The flow for the current conditions shown in Table 8-6 was taken from the TUFLOW model. The climate change flows were derived by multiplying the current climate peak flows by the percentages as discussed in Section 6.3 . The rating curve shows the water level that corresponds to a peak flow under existing climate conditions as well as the corresponding water level under climate change conditions (RCP 4.5 and 8.5).

Table 8-6 Climate change flow

AEP (1 in Y)	Current Climate – Peak Flow (m³/s)	Climate Change – Peak Flow (m³/s)	
		RCP 4.5	RCP 8.5
5	10.8	11.8	13.0
10	14.9	16.2	17.9
20	18.9	20.6	22.7
50	26.7	29.1	32.1
100	33.1	36.2	39.8
200	40.2	44.0	48.4

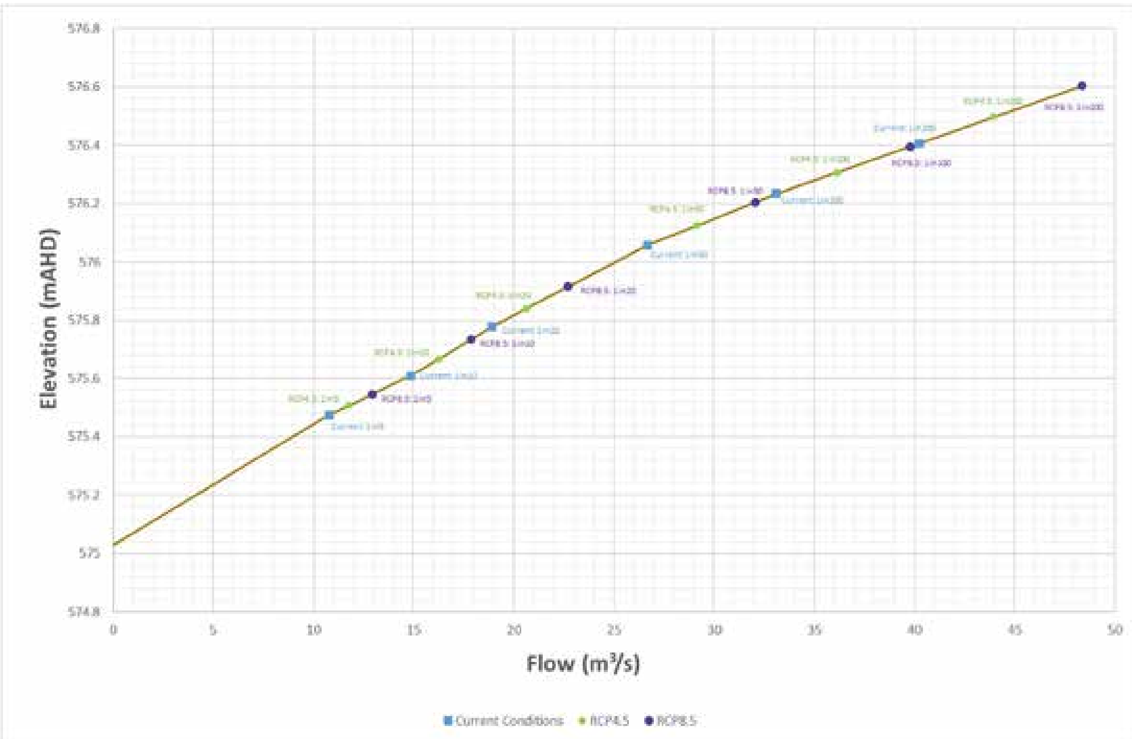


Figure 8-2 Estimated changes in peak water level associated with climate change

Table 8-7 shows which AEP map to consider adopting under various climate change scenarios. Note that the results have been based on the flows shown in Table 8-6 and rounded to the nearest AEP.

Table 8-7 Map to consider adopting under various climate change scenarios

Current AEP	Event Map to consider adopting under various climate change scenarios	
	RCP4.5	RCP8.5
1 in 5	1 in 5	1 in 10
1 in 10	1 in 10	1 in 20
1 in 20	1 in 20	1 in 50
1 in 50	1 in 50	1 in 100
1 in 100	1 in 100	1 in 200

8.4 Flood Intelligence Information

Results from this investigation have been used to update the MFEPs with key information. This has included:

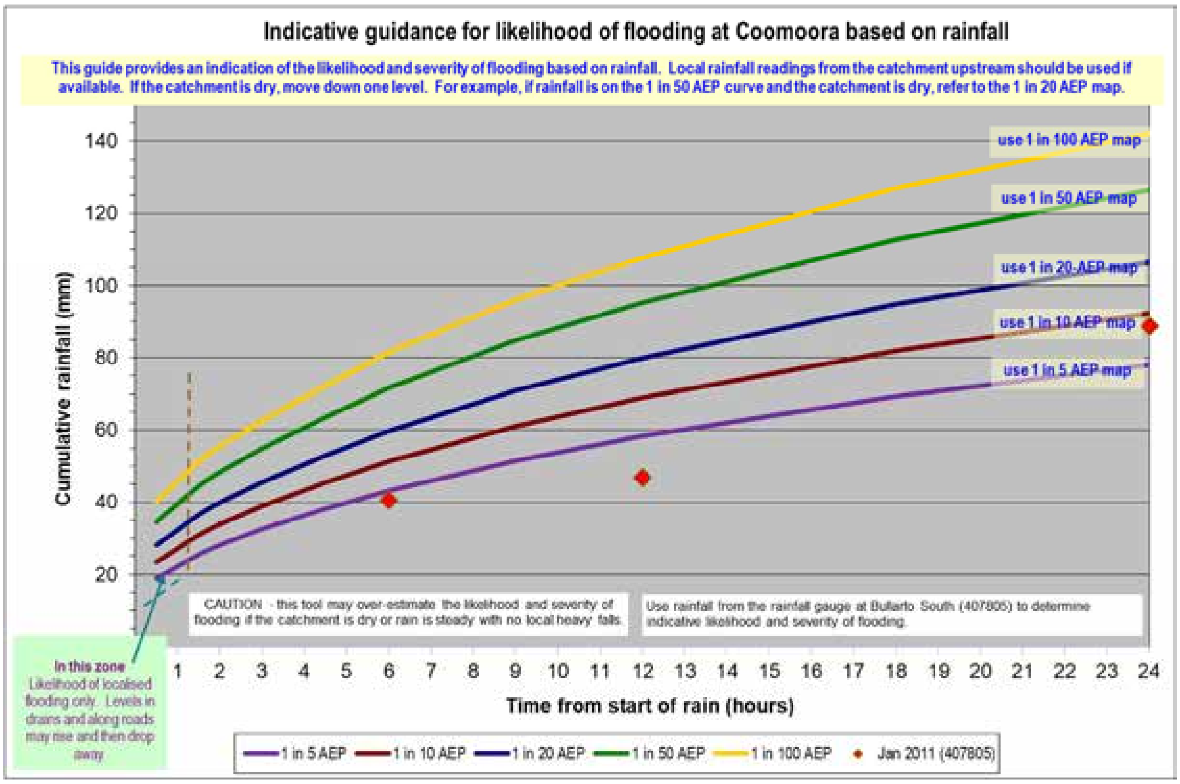
- Interpreting relevant flood related intelligence and consequence information from the mapping and modelling including typical flood travel times, rates of rise, etc;
- Identifying properties, roads and other community assets (e.g. essential infrastructure and services, high risk facilities, emergency service properties, low points in roads, etc.) affected by flooding;
- Identifying likely isolations and shrinking islands;
- Identifying areas of probable high flood risk / high hazard;
- Building flood intelligence tables; and
- Extracting catchment descriptions and flooding chronology from project deliverables.

8.5 Developing Indicative Quick Look Flood / No-Flood Tools

Using the results of the hydrologic and hydraulic modelling work, an indicative quick look flood / no-flood assessment tool has been developed for the study area.

The tool is aimed at providing a rapid indication of whether flooding is likely with some lead time. It is intended to be indicative only and will not provide a forecast of expected flood depth. The tool is designed to be linked to the mapping and intelligence produced by this project and in that way provides an indication of likely consequences.

The tool is driven by rainfall recorded at Bullarto South (407805). IFD data from this location has been compared to the study area specific IFD data. Adjusted rainfall depths were then plotted against time to produce the tool as shown in Figure 8-3.



- **Figure 8-3 Quick look tool**

8.5.1 Guidance on the use of the Quick Look Flood / No flood Tool

8.5.1.1 In the lead up to a flood

The quick look indicative flood / no-flood tool provided in Figure 8-3 gives guidance on the likelihood and severity of expected flooding at Coomoora.

Rainfall recorded at Bullarto South (407805) was used to develop the quick look tool. As the data being used comes from a rain gauge that is outside the Coomoora catchment, the tool may not perform to expectations in severe thunderstorm situations and / or when there is locally heavy rainfall embedded in more general rain. In such situations, rainfalls recorded more locally are likely to drive a more accurate indication of flooding and likely severity.

Unless there are unusual circumstances, actions as per the Flood Intelligence Card in the MFEP should be initiated as soon as the tool suggests flooding is likely. Response can be escalated if the tool indicates an increase in the expected severity of flooding.

8.5.1.2 During a flood - using the quick look tool

Plot cumulative rainfall depth against elapsed time on a copy of the tool. Do not start using the tool until rainfall exceeds approximately 2 mm an hour (i.e. ignore early drizzle or very light rain).

At each time step, after plotting the cumulative rainfall, assess the likelihood and expected severity of flooding from the curves. Some degree of judgement is required to determine if the quick look tool is providing an answer that is in line with expected outcomes. When plotted rainfall data crosses a curve on Figure 8-3 this indicates that flooding of around that severity is possible.

If the catchment is dry, it would generally be appropriate to step down one level. For example, if the rainfall plot is on the 1 in 50 AEP curve and the catchment is dry, refer to the 1 in 20 AEP map and associated consequences listed in the flood intelligence card available in the MFEP. The exception to this would be if there was very heavy rain on a dry catchment. In that circumstance, adopt a cautious approach and do not step down a level.

If the catchment is dry and / or rain extends over more than 12 hours, the quick look tool will tend to over-estimate the likelihood of flooding.

8.5.1.3 After a flood – updating the tool

After a flood event, plot the event rainfall depth (with date) on the quick look tool. At the same time, include an overview of the event, along with commentary on antecedent conditions and other relevant information, in the relevant Appendix of the MFEP.

8.5.1.4 Example use of the quick look tool

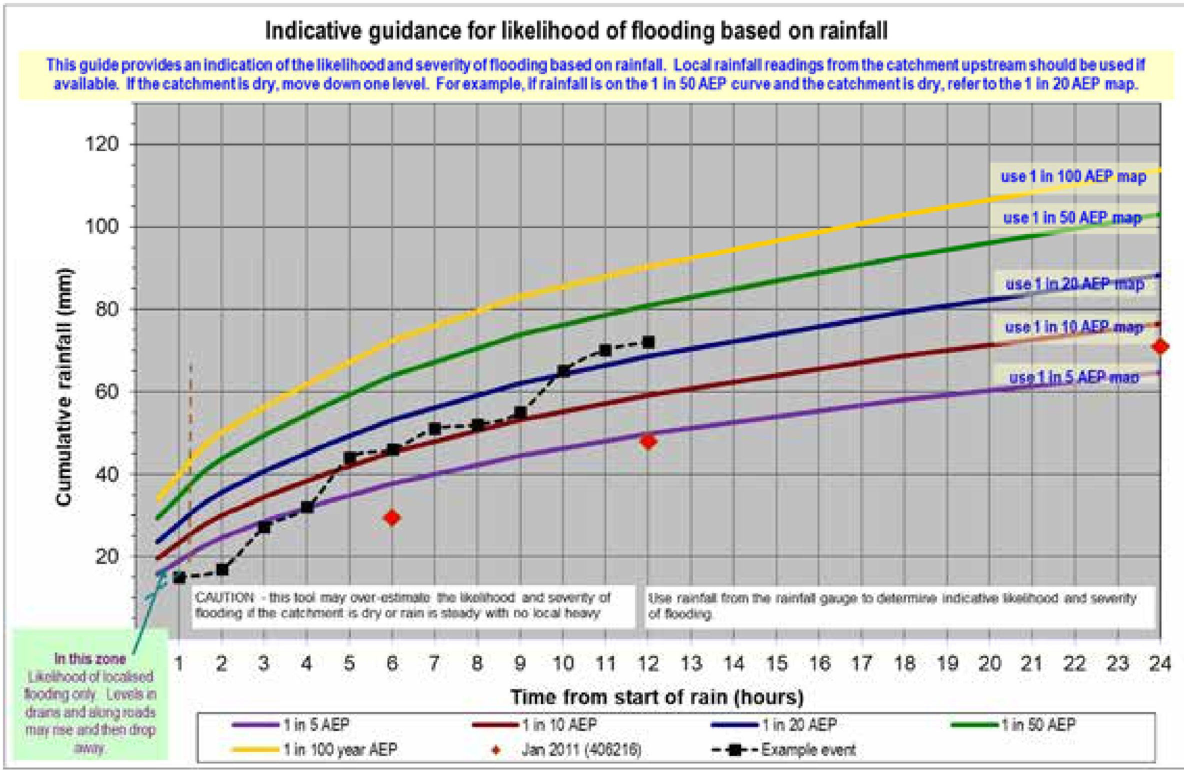
The section below is a fictitious example of how to use the quick look tool. Table 8-7 shows the rainfall depths recorded at the rain gauge and the action to take on the basis of the recorded rainfall. Figure 8-4 shows the fictitious example plotted up on the quick look tool.

Note that in cases where the tool has not been used from the start of rain (i.e. from early in the event), data should be either picked up from the start of the event or the first data plotted should include an estimate of how much rain has fallen and the time over which it has fallen. If this is not done, the tool will likely under-estimate likely flood severity.

- **Table 8-8 Rainfall depths for example use of tool**

Time (hours)	Rainfall Depth (mm)	Action
0	1	Ignore
1	2	Ignore
3	2	Ignore
4	1	Ignore
5	15	Plot as 15 mm at 1 hour
6	2	Plot as 17 mm at 2 hours
7	10	Plot as 27 mm at 3 hours
8	5	Plot as 32 mm at 4 hours Indicates it may be a 5-year (20% AEP) event
9	12	Plot as 44 mm at 5 hours Indicates it may be a 10-year (10% AEP) event Start planning for a 10% AEP event

Time (hours)	Rainfall Depth (mm)	Action
10	2	Plot as 46 mm at 6 hours More confident that a 10% AEP event is likely
11	5	Plot as 51 mm at 7 hours
12	1	Plot as 52 mm at 8 hours
13	3	Plot as 55 mm at 9 hours
14	10	Plot as 65 mm at 10 hours Indicates it may be a 20-year (5% AEP) event.
15	5	Plot as 70 mm at 11 hours More confident that a 5% AEP event is likely
16	2	Plot as 72 mm at 12 hours



■ **Figure 8-4 Quick look tool example**

8.6 Flood classification – Bureau of Meteorology

Electronic maps have been produced for the minor[1], moderate[2] and major[3] flood (as defined by the BoM). The minor, moderate and major flood has been based on the flood impacts. For Coomoora the 1 in 10, 20 and 50 AEP has been adopted for the minor, moderate and major flood respectively. Note however, for Coomoora no buildings or roads are affected from the modelling undertaken.

[1] Minor Flooding - Causes inconvenience. Low-lying areas next to water courses are inundated. Minor roads may be closed and low-level bridges submerged. In urban areas inundation may affect some backyards and buildings below the floor level as well as bicycle and pedestrian paths. In rural areas removal of stock and equipment may be required.

[2] Moderate Flooding - In addition to minor flooding, the area of inundation is more substantial. Main traffic routes may be affected. Some buildings may be affected above the floor level. Evacuation of flood affected areas may be required. In rural areas removal of stock is required

[3] Major Flooding – In addition to moderate flooding, extensive rural areas and/or urban areas are inundated. Many buildings may be affected above the floor level. Properties and towns are likely to be isolated and major rail and traffic routes closed. Evacuation of flood affected areas may be required. Utility services may be impacted

9. Summary of rating of key areas

The following section provides a summary rating of each of the key areas of the project. The rating is subjective but has been rated against current standards and industry best practice for undertaking detailed flood studies.

The intention is that this will enable the North Central CMA to easily identify the areas where additional caution may need to be applied when using the information from this investigation for making decisions on flooding issues. In addition it will identify the areas of additional investigation, should a more detailed study be undertaken in the future.

Table 9-1 shows a summary of the rating for Coomoora where green is considered to be good, orange is OK and red is poor. Below is a summary of the main considerations given to each aspect of the study:

- *RORB model set up*. Adequacy of sub-area division, reach types, impervious fractions
- *RORB model parameters*. Has the RORB model been calibrated and/or verified to streamflow gauge information
- *Currency of hydrology*. Rated based on whether the hydrology used in the study is consistent with current practice and data sets.
- *Topographic data*. Typically will be rated orange or red if LiDAR data is not available and if the state wide DEM is required for use.
- *Manning's n*. Has land use been represented with appropriate values
- *Modelling of key structures*. Reflects whether the model was attempted to incorporate key hydraulic structures within the inundation zone and to what degree.
- *TUFLOW model set up.* Considers such aspects as does the cell size capture key features and the boundary conditions.
- *TUFLOW parameters*. Has the TUFLOW model been calibrated and/or verified to recorded flood levels.

Table 9-1 Summary of review – Coomoora

Category	Comment	Rating
RORB model set up	RORB model set up for Coomoora catchment.	
RORB model parameters	Based on a calibrated and verified model of a much larger catchment.	
Currency of hydrology	All inputs are based on ARR2019	
Topographic data	LIDAR available for entire study area	
Manning's n	Generally OK but was based on VLUIS	
Modelling of key structures	Bridges explicitly modelled. Reasonable data was available	
TUFLOW model set up	Cell size adequately represents waterway and boundary conditions modelled appropriately.	
TUFLOW parameters	TUFLOW parameters have not been calibrated or verified to recorded flood levels.	

10. Limitations

Any information provided by the Bureau of Meteorology, Geoscience Australia as well as published methodologies (e.g. Australian Rainfall and Runoff) cannot be guaranteed to be free of errors.

The hydrological parameters rely on the previous calibration and verification undertaken for each of the RORB models. Therefore, the accuracy of this will vary depending on the information available to calibrate the models. However, any calibration and verification of the models to streamflow information will most likely be better than just relying on regional parameter estimates.

The proposed methodology for the PMF estimate is preliminary in nature. Other, more detailed techniques are available in which to estimate the PMF. However, for this investigation a preliminary assessment has been considered to be appropriate.

The analysis has relied heavily on the supplied LIDAR terrain data. For this investigation no survey will be undertaken to independently check the terrain data.

For the hydraulic model the intention is that the waterways are represented by 4-5 cells. Where a waterway is less eight metres wide it will be represented by less than the 4-5 cells which could mean that the waterway is not fully represented.

The Manning's roughness adopted for the study areas utilising the VLUIS dataset. As the VLUIS is a state wide dataset there may be some areas that have either been developed since the VLUIS was established or not captured accuracy. Whilst, basic checks have been undertaken to pick up any large errors in assigned land use there may still be some lot scale differences in land use which may not be picked up.

As the hydraulic model was not calibrated to surveyed flood levels the Manning's n values listed in Table 7-1 may not necessarily represent the roughness values accurately.

As mentioned in Section 6.3 the ARR2019 approach to climate change has a number of limitations, including the fact that it does not provide a means to account for potential increases in rainfall losses under a drying climate.

The quick look flood / no flood tools may be replaced where more detailed investigations are undertaken in the future.

11. Conclusion

This project forms part of the Rapid Flood Risk Assessment for the North Central CMA region. Outputs from the assessment will assist the North Central CMA to meet a range of business requirements. Outputs can be used to assist in flood related controls, develop flood intelligence products, inform emergency response planning and assist in the preparation of community flood awareness and education products.

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Appendix A Maps

This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_DmaxMGA55.mxd
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

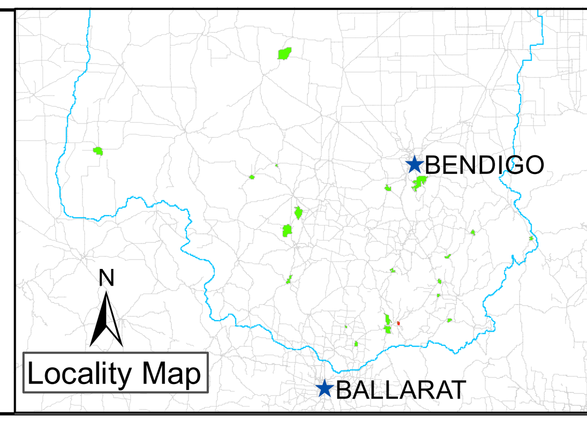
Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification
- Residential
- Commercial
- Industrial
- Public

Building Inundation
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max Depth (m)
- < 0.3
- 0.3 - 0.5
- 0.5 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM DEPTH (m)

Coomoora - 20% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - 5 - 1

hydrology and risk CONSULTING
North Central CMA
VICTORIA State Government
Australian Government

Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_VxDmaxMGA55.m

Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

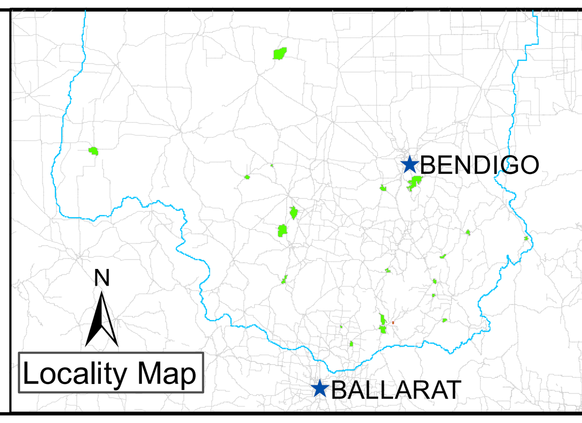
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max V x D (m²/s)

- < 0.4
- 0.4 - 0.8
- 0.8 - 1.2
- > 1.2



Locality Map

Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager : N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM V x D (m²/s)

Coomoora - 20% AEP Flood Event

0 200
Meters

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - 5 - 2

hydrology and risk CONSULTING
VICTORIA State Government
North Central CMA
Australian Government

This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.
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Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_HmaxMGA55.mxd
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

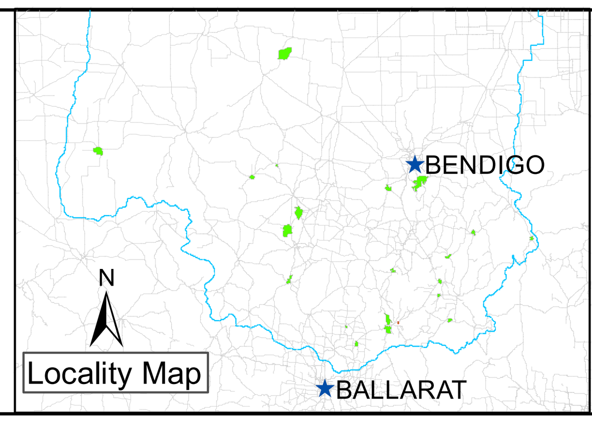
Legend

- F CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- N Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)
- Contour (0.5m)

Building Classification
- Residential
- Commercial
- Industrial
- Public

Building Inundation
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max WSE (mAHD) Coomoora
Value
High : 592
Low : 563



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager : N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM WATER LEVEL (mAHD)

Coomoora - 20% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	27/02/2020	9 - 5 - 3

hydrology and risk CONSULTING
VICTORIA State Government
North Central CMA
Australian Government

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Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_HazardsMGA55.m
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend

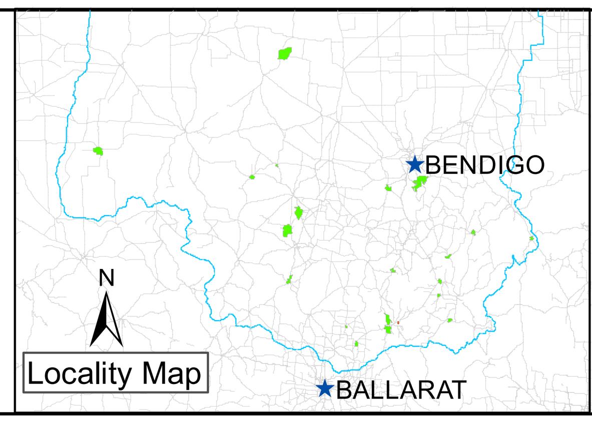
- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM HAZARD

Coomoora - 20% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - 5 - 4

hydrology and risk CONSULTING
VICTORIA State Government
North Central CMA
Australian Government

This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.
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Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_VmaxMGA55.mxd
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

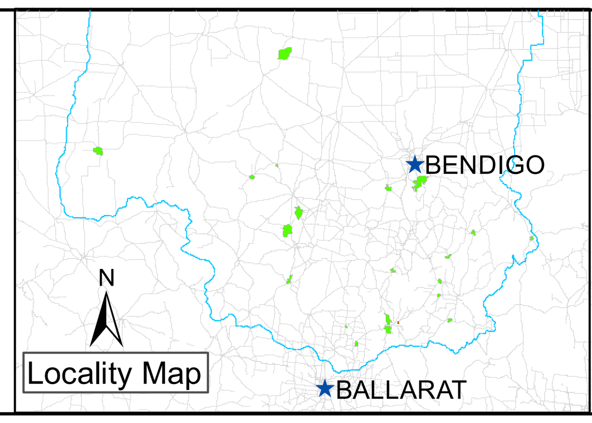
Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification
- Residential
- Commercial
- Industrial
- Public

Building Inundation
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max Velocity (m/s)
- < 1
- 1 - 2
- 2 - 3
- > 3



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager : N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM VELOCITY (m/s)

Coomoora - 20% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale: 1:2,600 when printed @ A1

Date: 25/02/2020

Map No.: 9 - 5 - 5

hydrology and risk

North Central CMA

VICTORIA State Government

Australian Government

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Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_DmaxMGA55.mxd

Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

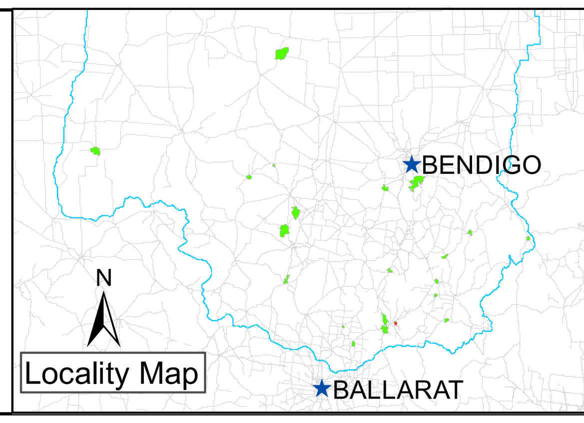
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max Depth (m)

- < 0.3
- 0.3 - 0.5
- 0.5 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM DEPTH (m)

Coomoora - 10% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - 10 - 1

This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.
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Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_VxDmaxMGA55.m
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

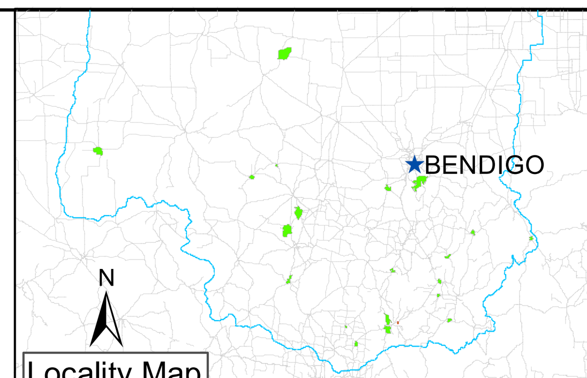
Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification
- Residential
- Commercial
- Industrial
- Public

Building Inundation
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max V x D (m²/s)
- < 0.4
- 0.4 - 0.8
- 0.8 - 1.2
- > 1.2



Locality Map

Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager : N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM V x D (m²/s)

Coomoora - 10% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - 10 - 2

HARC hydrology and risk CONSULTING
VICTORIA State Government
North Central CMA
Australian Government

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Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_HmaxMGA55.mxd
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend

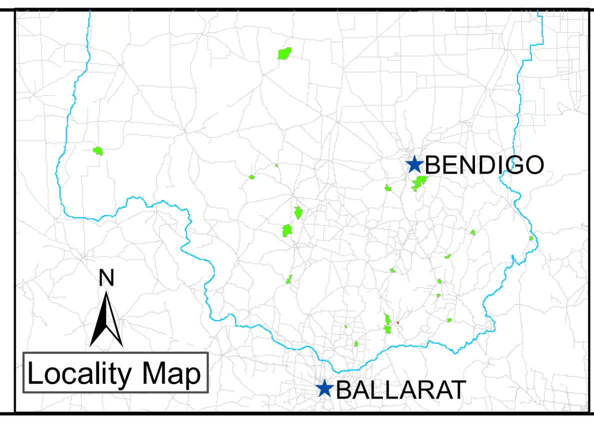
- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)
- Contour (0.5m)

Building Classification
- Residential
- Commercial
- Industrial
- Public

Building Inundation
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max WSE (mAHD) Coomoora

Value
High : 592
Low : 563



Locality Map

Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager : N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM WATER LEVEL (mAHD)

Coomoora - 10% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	27/02/2020	9 - 10 - 3

hydrology and risk CONSULTING
VICTORIA State Government
North Central CMA
Australian Government

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Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

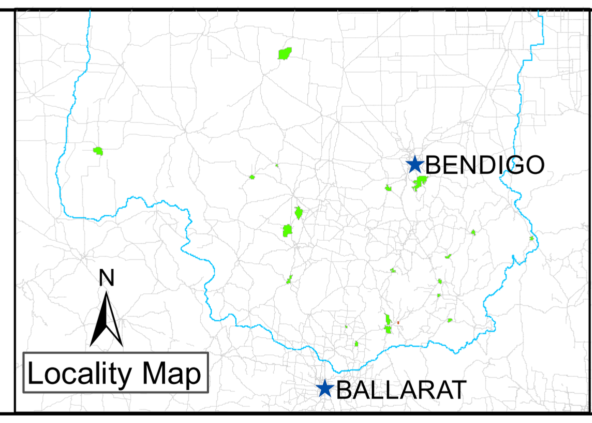
Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_HazardsMGA55.m
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification
- Residential
- Commercial
- Industrial
- Public

Building Inundation
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Locality Map

Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager : N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM HAZARD

Coomoora - 10% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - 10 - 4

hydrology and risk CONSULTING
VICTORIA State Government
North Central CMA
Australian Government

Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_VmaxMGA55.mxd

Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

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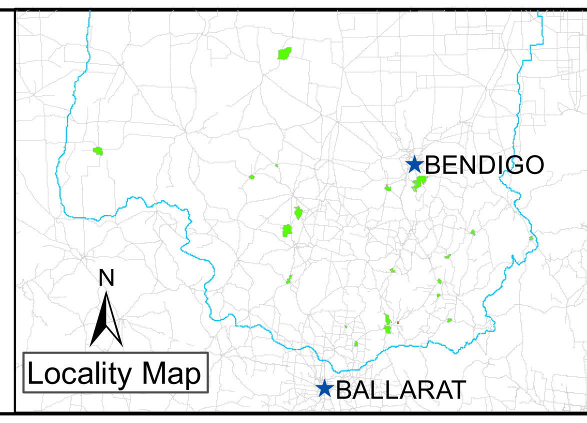
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max Velocity (m/s)

- < 1
- 1 - 2
- 2 - 3
- > 3



Locality Map

Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM VELOCITY (m/s)

Coomoora - 10% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - 10 - 5

hydrology and risk
VICTORIA State Government
North Central CMA
Australian Government

Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_DmaxMGA55.mxd

Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

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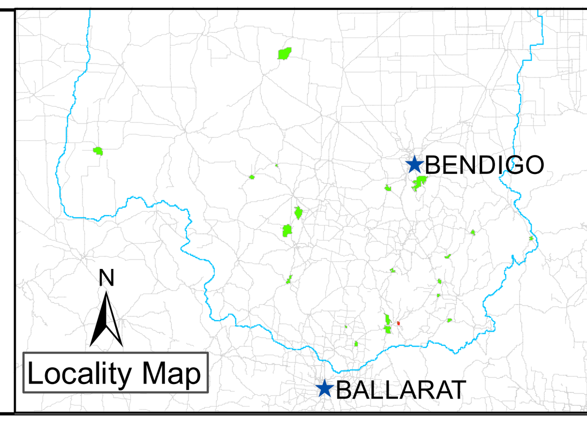
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max Depth (m)

- < 0.3
- 0.3 - 0.5
- 0.5 - 0.8
- 0.8 - 1.2
- > 1.2



Locality Map

Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager : N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM DEPTH (m)

Coomoora - 5% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - 20 - 1

HARC hydrology and risk CONSULTING
VICTORIA State Government
North Central CMA
Australian Government

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Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_VxDmaxMGA55.m
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

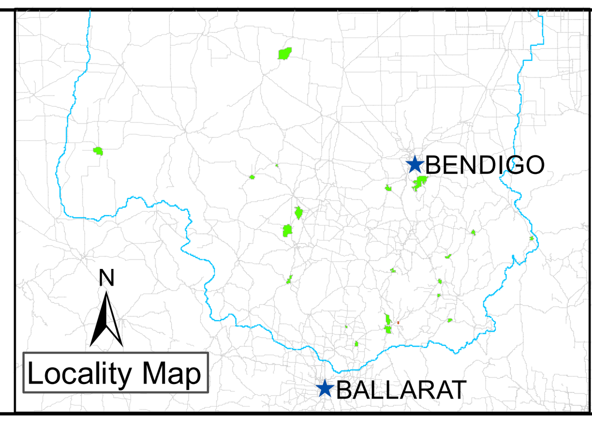
Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification
- Residential
- Commercial
- Industrial
- Public

Building Inundation
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max V x D (m²/s)
- < 0.4
- 0.4 - 0.8
- 0.8 - 1.2
- > 1.2



Locality Map

Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM V x D (m²/s)

Coomoora - 5% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - 20 - 2

HARC hydrology and risk CONSULTING
VICTORIA State Government
North Central CMA
Australian Government

Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_HmaxMGA55.mxd

Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)
- Contour (0.5m)

Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

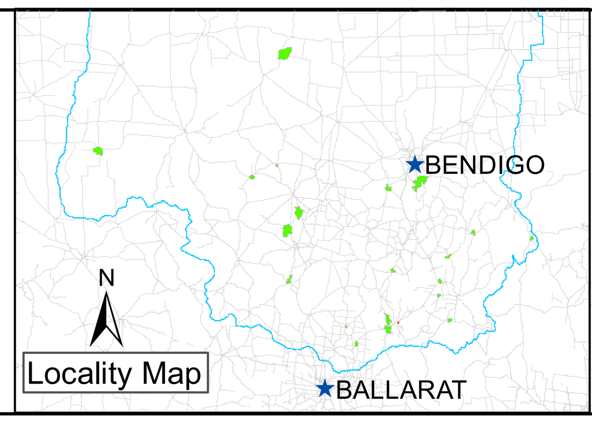
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max WSE (mAHD) Coomoora

Value

High : 592

Low : 563



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM WATER LEVEL (mAHD)

Coomoora - 5% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	27/02/2020	9 - 20 - 3

hydrology and risk CONSULTING

VICTORIA State Government

North Central CMA

Australian Government

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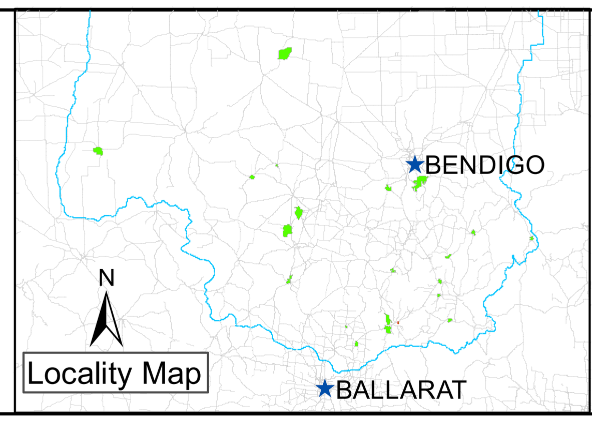
Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_HazardsMGA55.m
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification
- Residential
- Commercial
- Industrial
- Public

Building Inundation
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager : N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM HAZARD

Coomoora - 5% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - 20 - 4

HARC hydrology and risk CONSULTING
VICTORIA State Government
North Central CMA
Australian Government

Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_VmaxMGA55.mxd

Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

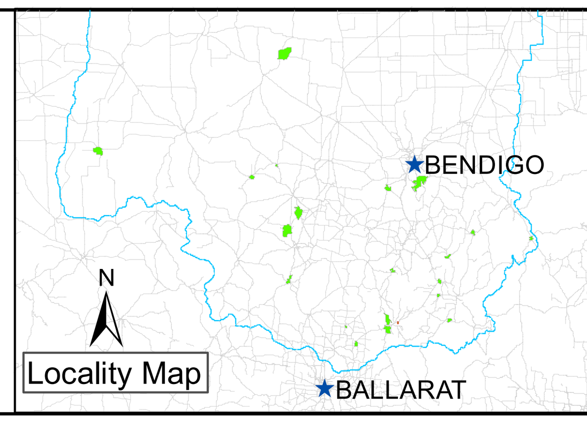
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max Velocity (m/s)

- < 1
- 1 - 2
- 2 - 3
- > 3



Locality Map

Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager : N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM VELOCITY (m/s)

Coomoora - 5% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - 20 - 5

hydrology and risk

VICTORIA State Government

North Central CMA

Australian Government

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Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_DmaxMGA55.mxd
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

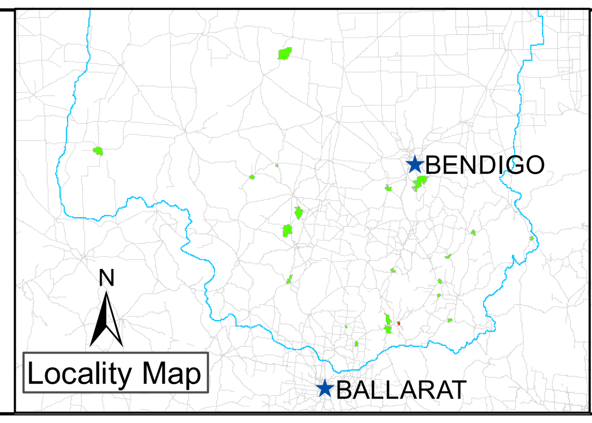
Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification
- Residential
- Commercial
- Industrial
- Public

Building Inundation
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max Depth (m)
- < 0.3
- 0.3 - 0.5
- 0.5 - 0.8
- 0.8 - 1.2
- > 1.2



Locality Map

Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM DEPTH (m)

Coomoora - 2% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - 50 - 1

Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_VxDmaxMGA55.m

Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

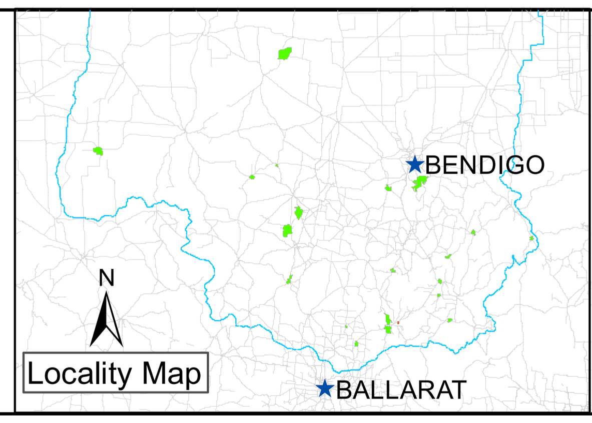
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max V x D (m²/s)

- < 0.4
- 0.4 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager : N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM V x D (m²/s)

Coomoora - 2% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - 50 - 2

hydrology and risk CONSULTING

State Government

North Central CMA

Australian Government

This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.
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Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_HmaxMGA55.mxd
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

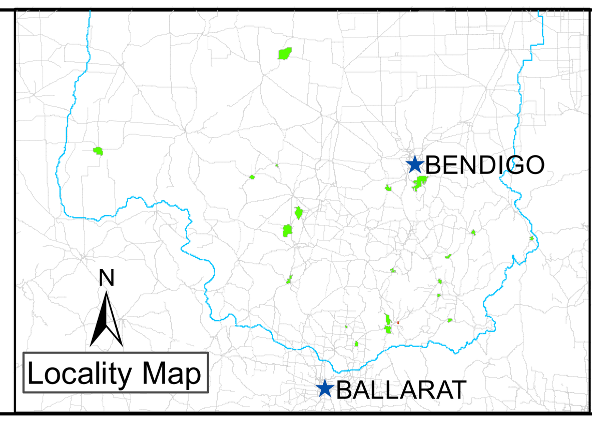
Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)
- Contour (0.5m)

Building Classification
- Residential
- Commercial
- Industrial
- Public

Building Inundation
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max WSE (mAHD) Coomoora
Value
High : 592
Low : 563



Locality Map

Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager : N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM WATER LEVEL (mAHD)

Coomoora - 2% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	27/02/2020	9 - 50 - 3

HARC hydrology and risk consulting
VICTORIA State Government
North Central CMA
Australian Government

This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.
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Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_HazardsMGA55.m

Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend

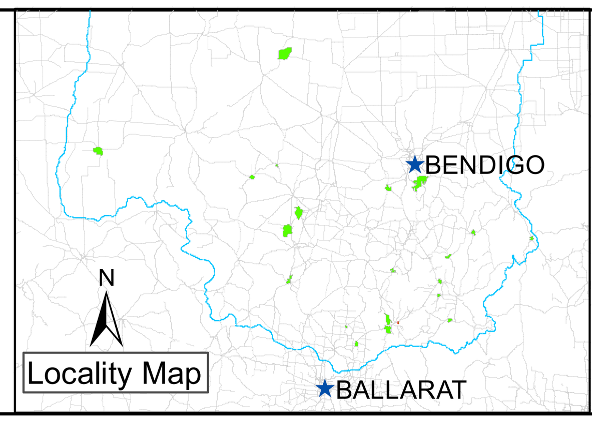
- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM HAZARD

Coomoora - 2% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - 50 - 4

This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.
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Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_VmaxMGA55.mxd
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

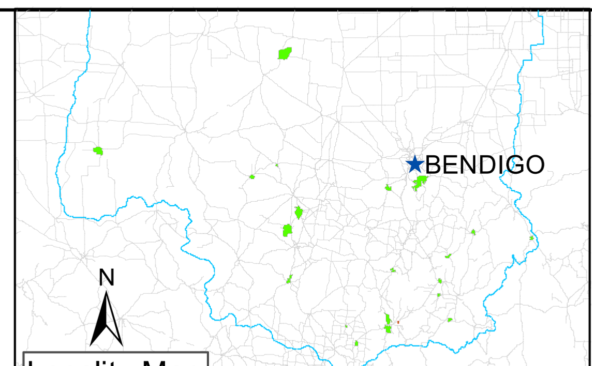
Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification
- Residential
- Commercial
- Industrial
- Public

Building Inundation
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max Velocity (m/s)
- < 1
- 1 - 2
- 2 - 3
- > 3



Locality Map

Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM VELOCITY (m/s)

Coomoora - 2% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - 50 - 5

HARC hydrology and risk
VICTORIA State Government
North Central CMA
Australian Government

This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.

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Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_DmaxMGA55.mxd

Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

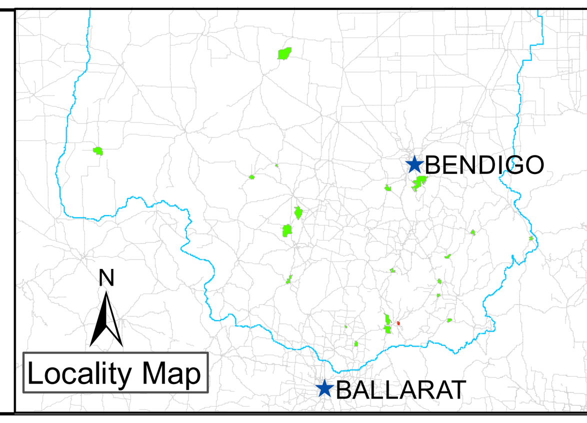
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max Depth (m)

- < 0.3
- 0.3 - 0.5
- 0.5 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager : N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM DEPTH (m)

Coomoora - 1% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - 100 - 1

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Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_VxDmaxMGA55.m
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

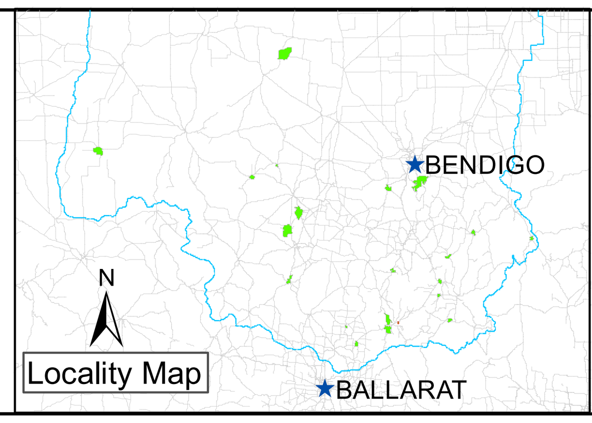
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max V x D (m²/s)

- < 0.4
- 0.4 - 0.8
- 0.8 - 1.2
- > 1.2



Locality Map

Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM V x D (m²/s)

Coomoora - 1% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - 100 - 2

hydrology and risk CONSULTING

VICTORIA State Government

North Central CMA

Australian Government

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Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_HmaxMGA55.mxd
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)
- Contour (0.5m)

Building Classification
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- Industrial
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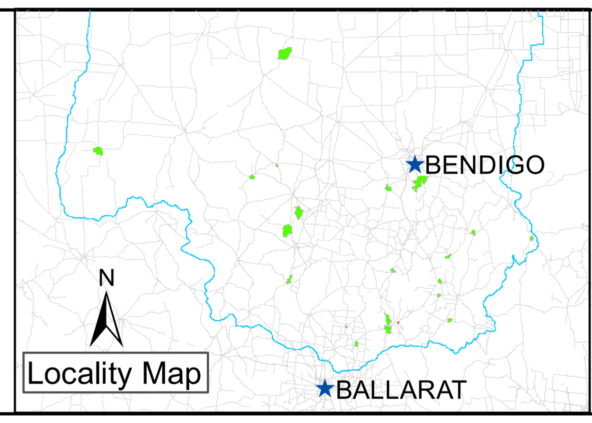
Building Inundation
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max WSE (mAHD) Coomoora

Value

High : 592

Low : 563



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager : N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM WATER LEVEL (mAHD)

Coomoora - 1% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	27/02/2020	9 - 100 - 3

hydrology and risk CONSULTING
VICTORIA State Government
North Central CMA
Australian Government

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Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_HazardsMGA55.m

Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

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Building Inundation

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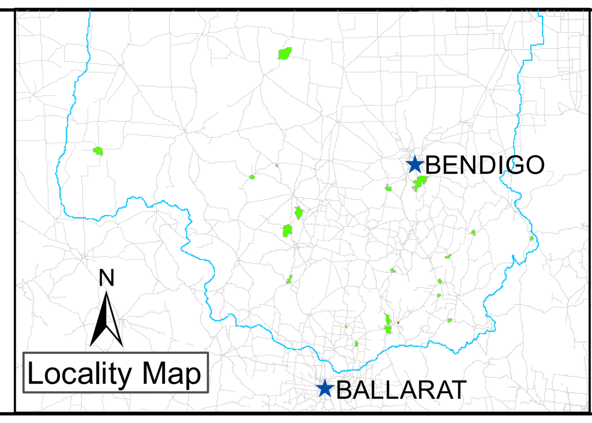
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Locality Map

Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM HAZARD

Coomoora - 1% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - 100 - 4

hydrology and risk CONSULTING
VICTORIA State Government
North Central CMA
Australian Government

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Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_VmaxMGA55.mxd
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

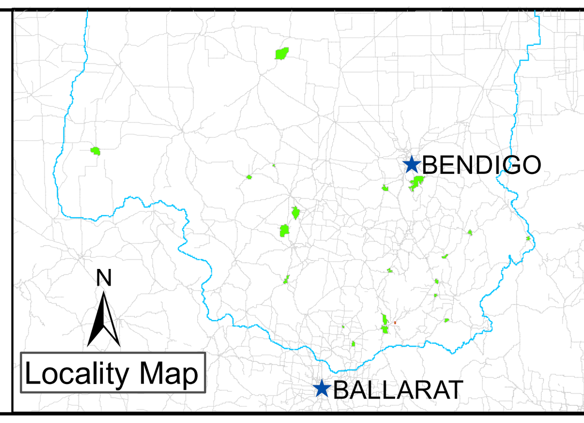
Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification
- Residential
- Commercial
- Industrial
- Public

Building Inundation
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max Velocity (m/s)
- < 1
- 1 - 2
- 2 - 3
- > 3



Locality Map

Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager : N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM VELOCITY (m/s)

Coomoora - 1% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - 100 - 5

HARC hydrology and risk
VICTORIA State Government
North Central CMA
Australian Government

Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_DmaxMGA55.mxd

Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

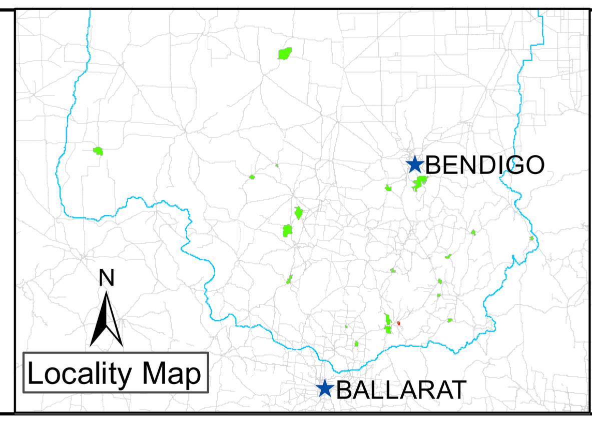
- Residential
- Commercial
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max Depth (m)

- < 0.3
- 0.3 - 0.5
- 0.5 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM DEPTH (m)

Coomoora - 0.5% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - 200 - 1

hydrology and risk CONSULTING

North Central CMA

VICTORIA State Government

Australian Government

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Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_VxDmaxMGA55.m
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

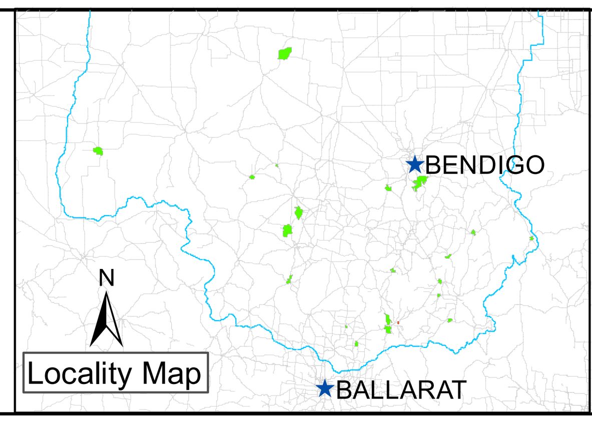
Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification
- Residential
- Commercial
- Industrial
- Public

Building Inundation
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max V x D (m²/s)
- < 0.4
- 0.4 - 0.8
- 0.8 - 1.2
- > 1.2



Locality Map

Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager : N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM V x D (m²/s)

Coomoora - 0.5% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - 200 - 2

hydrology and risk CONSULTING
VICTORIA State Government
North Central CMA
Australian Government

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Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_HmaxMGA55.mxd
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)
- Contour (0.5m)

Building Classification
- Residential
- Commercial
- Industrial
- Public

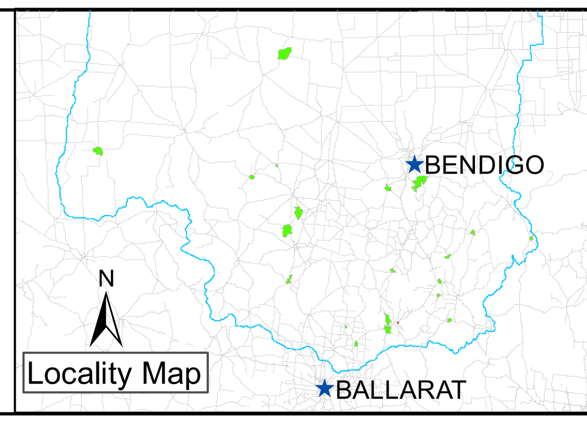
Building Inundation
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max WSE (mAHD) Coomoora

Value

High : 592

Low : 563



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager : N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM WATER LEVEL (mAHD)

Coomoora - 0.5% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	27/02/2020	9 - 200 - 3

HARC hydrology and risk CONSULTING
VICTORIA State Government
North Central CMA
Australian Government

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Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

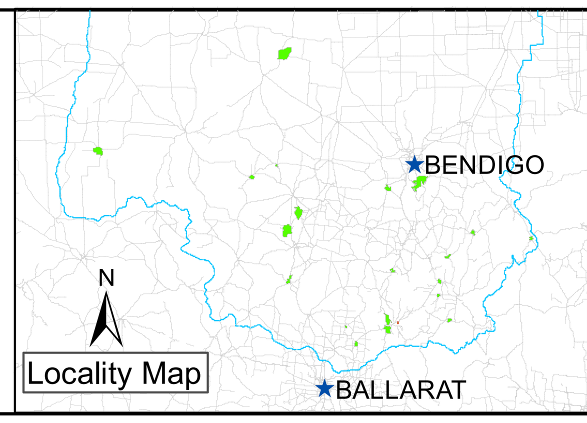
Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_HazardsMGA55.m
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification
- Residential
- Commercial
- Industrial
- Public

Building Inundation
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Locality Map

Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM HAZARD

Coomoora - 0.5% AEP Flood Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - 200 - 4

HARC hydrology and risk CONSULTING
North Central CMA
VICTORIA State Government
Australian Government

Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_VmaxMGA55.mxd

Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

- Residential
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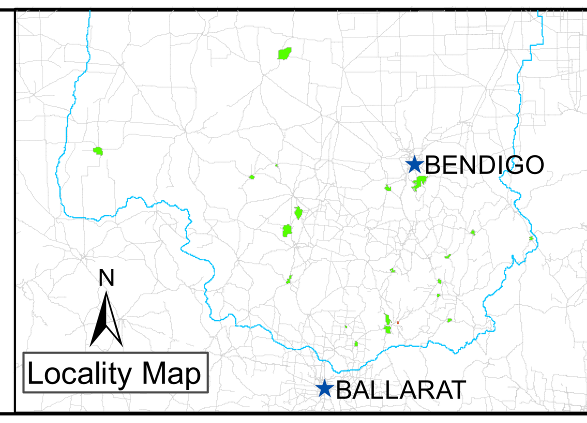
- Industrial
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max Velocity (m/s)

- < 1
- 1 - 2
- 2 - 3
- > 3



Locality Map

Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager : N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM VELOCITY (m/s)

Coomoora - 0.5% AEP Flood Event

0 — 200 Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - 200 - 5

hydrology and risk

VICTORIA State Government

North Central CMA

Australian Government

This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.
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Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_DmaxMGA55.mxd
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification
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- Industrial
- Public

Building Inundation
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- inundated (without floor level survey)
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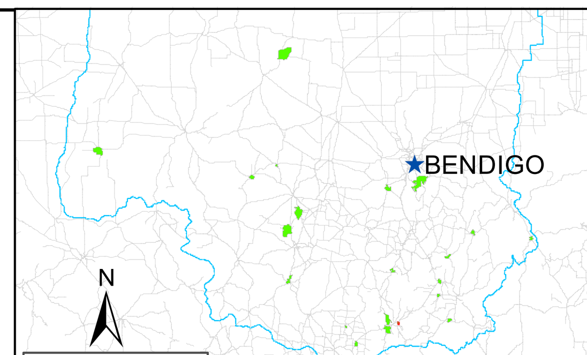
- above floor level (with floor level survey)

Max Depth (m)
- < 0.3
- 0.3 - 0.5
- 0.5 - 0.8
- 0.8 - 1.2
- > 1.2



Locality Map

Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager : N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM DEPTH (m)

Coomoora - PMF Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - PMF - 1

HARC hydrology and risk CONSULTING
VICTORIA State Government
North Central CMA
Australian Government

Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_VxDmaxMGA55.m

Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
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- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

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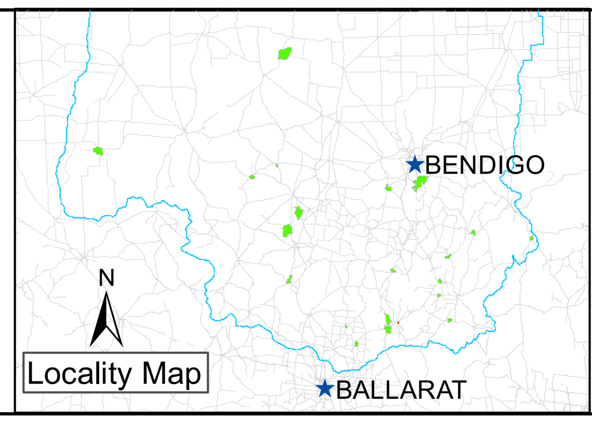
- Public

Building Inundation

- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max V x D (m²/s)

- < 0.4
- 0.4 - 0.8
- 0.8 - 1.2
- > 1.2



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager : N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM V x D (m²/s)

Coomoora - PMF Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - PMF - 2

HARC hydrology and risk CONSULTING

VICTORIA State Government

North Central CMA

Australian Government

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Data Location: S:\3_Projects\NCC00002\5_Technical\3_Mapping\NCC00002_InundationMapping_Datadrivenpages_HmaxMGA55.mxd
Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park
- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent
- Contour (1m)
- Contour (0.5m)

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- Public

Building Inundation
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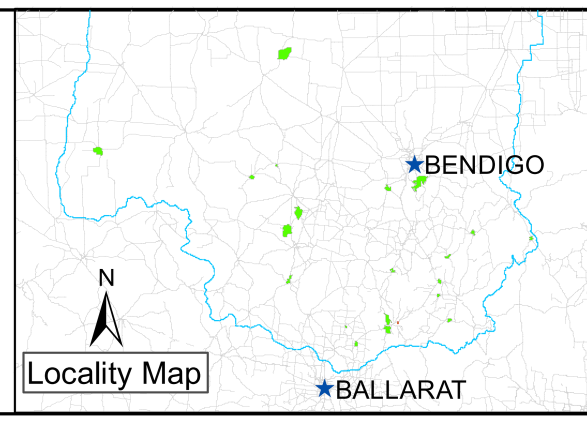
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max WSE (mAHD) Coomoora

Value

High : 592

Low : 563



Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM WATER LEVEL (mAHD)

Coomoora - PMF Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	27/02/2020	9 - PMF - 3

HARC hydrology and risk CONSULTING
VICTORIA State Government
North Central CMA
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Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
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- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification

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Building Inundation

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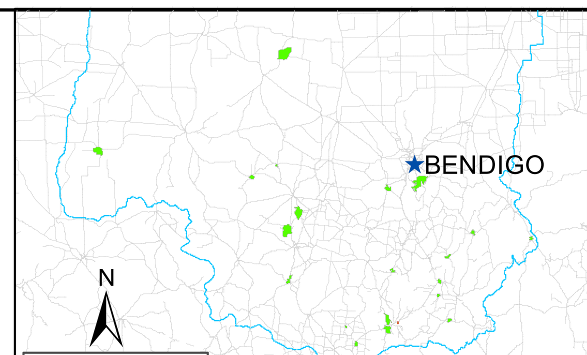
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)



Locality Map

Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM HAZARD

Coomoora - PMF Event

0 — 200 Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - PMF - 4

HARC hydrology and risk consulting
VICTORIA State Government
North Central CMA
Australian Government

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Roads Layer: Vicmap; Imagery: ESRI ; Geoscape Polygons: Navigate, PSMA Australia,

Legend

- CFA/MFB Fire Station
- Police Station
- Hospital
- School/College
- Nursing Home/Aged Care
- Carvaran Park

- Main Road
- Tertiary Road
- Railway Line
- Flood Model Extent

Building Classification
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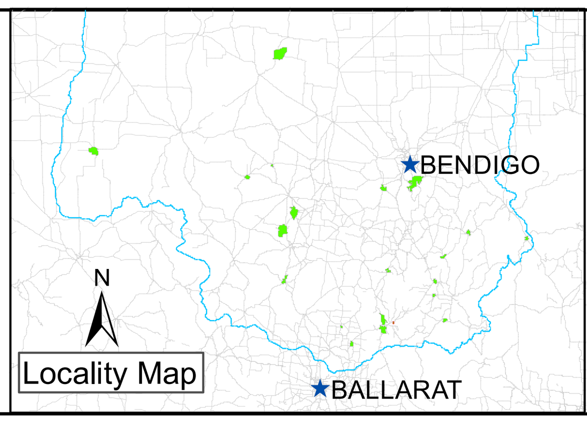
- Industrial
- Public

Building Inundation
- not inundated
- inundated (without floor level survey)
- below floor level (with floor level survey)
- above floor level (with floor level survey)

Max Velocity (m/s)
- < 1
- 1 - 2
- 2 - 3
- > 3



Locality Map

Drawn: A. SHEN	Project Director: D. STEPHENS
Checked: T. CRAIG	
Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager : N. TRELOAR	

NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT
MAXIMUM VELOCITY (m/s)

Coomoora - PMF Event

0 200
Meters

N

Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Scale:	Date:	Map No.:
1:2,600 when printed @ A1	25/02/2020	9 - PMF - 5

HARC hydrology and risk
VICTORIA State Government
North Central CMA
Australian Government