



Australian Government



North  
Central  
CMA



# Rapid Flood Risk Assessment - North Central CMA Region

Marnoo

Version 2  
22/04/2020

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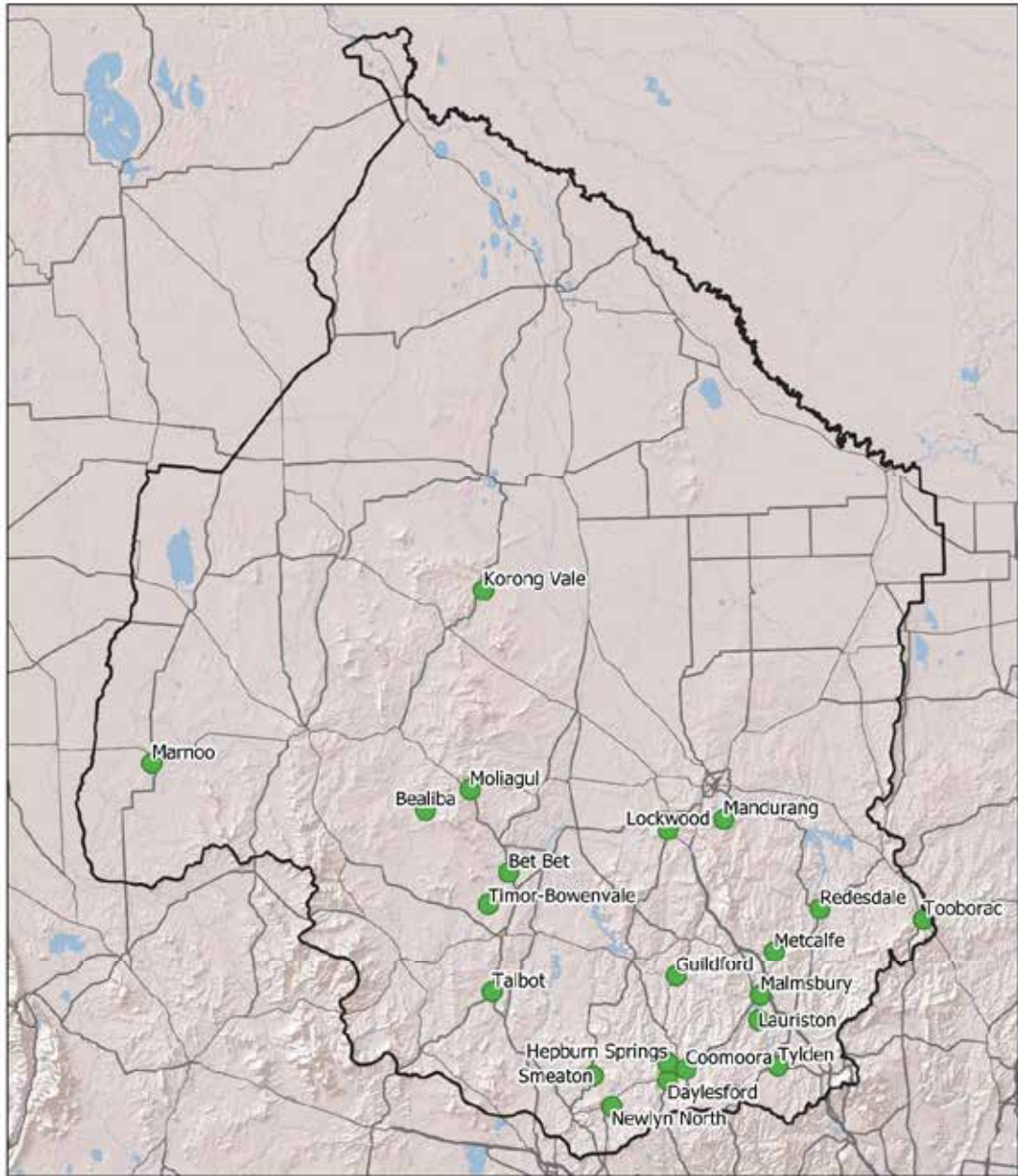
#### Acknowledgment of Country

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.



**Legend**  
 [Black outline] North Central CMA Region  
 [Grey line] State Major Road Network  
 [Green dot] Study Locations

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 Map Projection: Transverse Mercator Horizontal Datum: GDA 1994 Grid: GDA 1994 MGA Zone 54 & 30	 N	 hydrology and risk CONSULTANTS	North Central CMA Rapid Flood Risk Assessment - North Central CMA Region Study Locations	Job Number	NCC0002
				Revision	A
				Date	2019-11-13
				Reviewed By	ah
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Image Source: ESRI, 2019

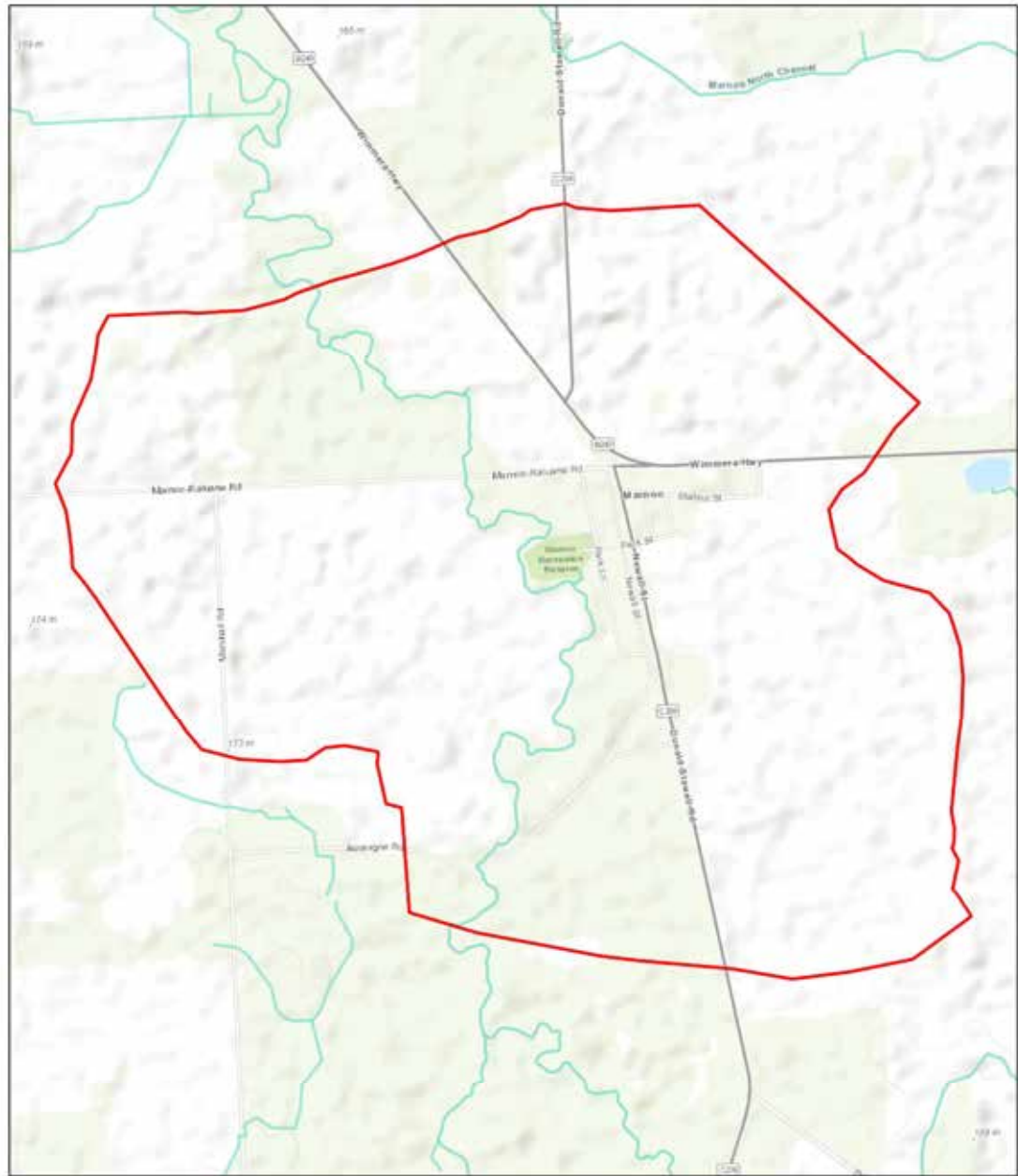
■ **Figure 1-1 Rapid Flood Risk Assessment Project Study Locations**

- **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	<b>21</b>	<b>Marnoo</b>
11	Smeaton		

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

Marnoo has a population of approximately 122 and is located in Victoria's Wimmera region, approximately 126 km west of Bendigo. Wallaloo Creek runs through the centre of the town, which has an upstream catchment area of 181 km<sup>2</sup>. The creek is reasonably well defined within the study area. The study area is shown in Figure 1-2.



**Legend**  
 Model Domain  
 Watercourse

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 Map Projection: Transverse Mercator Horizontal Datum: GDA 1994 Grid: GDA 1994 MGA Zone 58		 	North Central CMA Rapid Flood Risk Assessment - North Central CMA Region	Job Number: NCC00002 Revision: A
			Model Domain Marnoo	Date: 2019-11-19 Reviewed By: AN Study Number: 21

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■ **Figure 1-2 Marnoo 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 Donald Flood Study (GHD, 2014) which included Marnoo. 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
21	Marnoo	Donald Flood Study	160	77.6	2.1	18.8	1.1	North Grampians

### 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 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
21	Marnoo	Estimated	Culvert	Newall St Service Road
		Estimated	Culvert	Park Ln
		Council	Culverts	Three separate locations along Donald – Stawell Road
		Council	Pipe	From Newall St Service Road to River

\* For structures without details, dimensions were generally estimated based on the aerial image and street view from Google Maps in conjunction with the existing information of the structures in the area.

#### 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.

### 2.3 Previous Flood Studies

The North Central CMA provided a number of reports to provide background information for this project. The main reports relevant to this study area are listed in Table 2-3.

- **Table 2-3 Summary of flood studies**

No.	Township Name	Previous Studies
21	Marnoo	Donald Flood and Drainage Management Plan (2014), GHD



### 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.

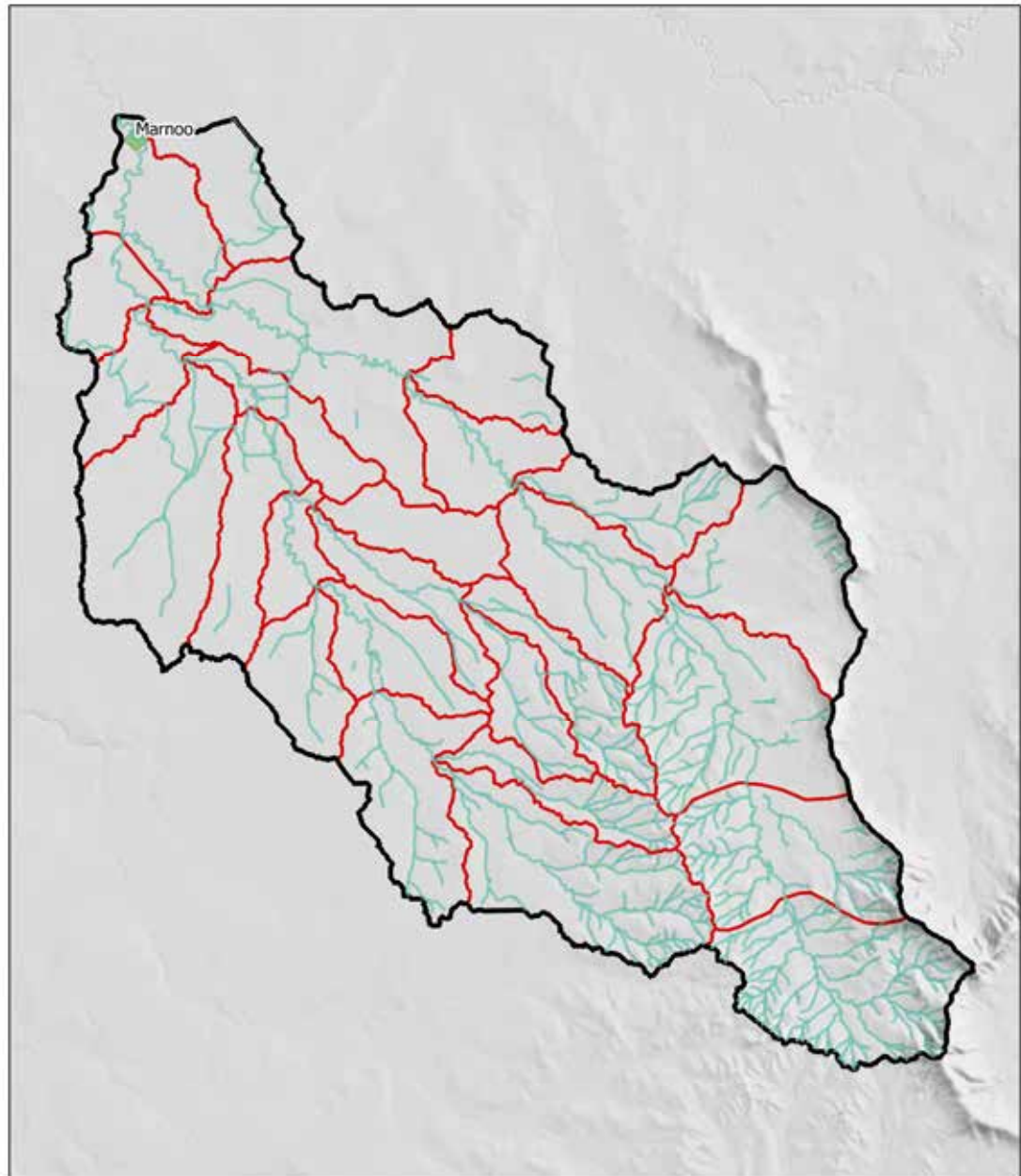
■ **Table 3-1 EIA assigned for each land use**

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 Marnoo RORB model

The RORB model established for the Donald Flood Study (GHD, 2014) had the Marnoo catchment covered by a single subarea, which was determined to be too coarse for this investigation. Therefore, a new RORB model was built, as part of this investigation, for Marnoo. The RORB model layout is shown in Figure 3-1.



**Legend**  
 Model Catchment  
 Study Area  
 RORB Subareas  
 Catchment Streams

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 Map Projection: Transverse Mercator Horizontal Datum: GDA 1994 Grid: GDA 1994 MGA Zone 54		 	North Central CMA Rapid Flood Risk Assessment - North Central CMA Region	Job Number	NCC00002
			RORB model layout Marnoo	Revision	A
				Date	2019-11-13
				Reviewed By	AN
				Study Number	21

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Image Source: Open Street Maps, 2019

■ **Figure 3-1 RORB model layout**

## 4. Design hydrology approach and inputs

### 4.1 Overview of adopted design flood approach

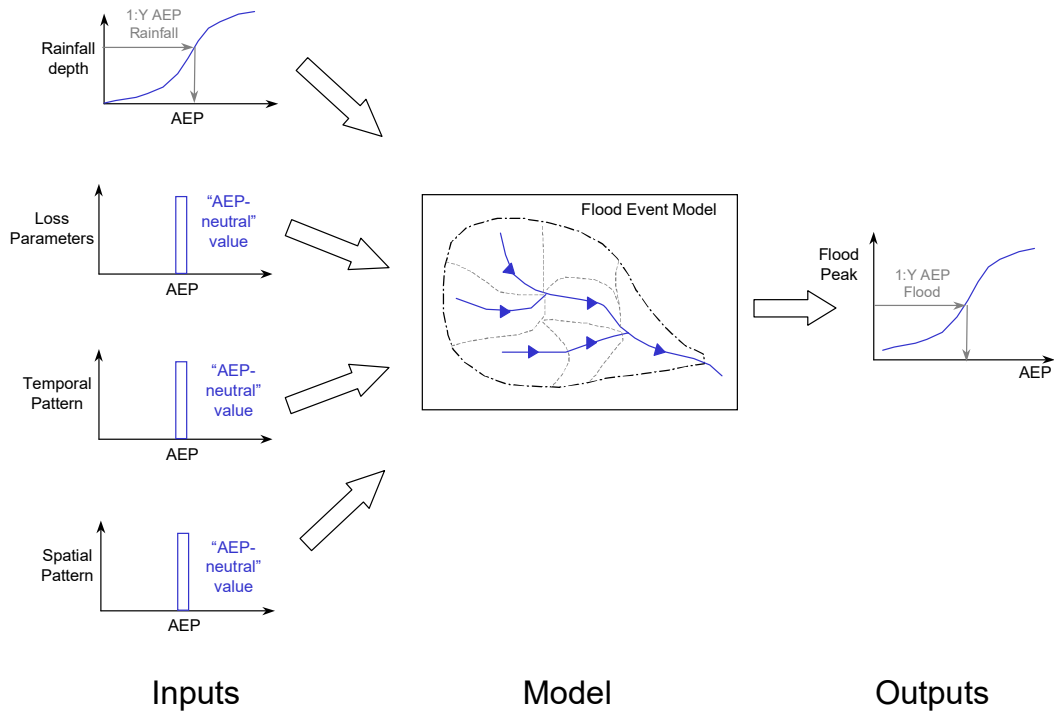
The estimation of design floods has traditionally been based on the 'design event' approach, in which all parameters other than rainfall are input as fixed, single values. This concept is illustrated in Figure 4-1 for the case where a distribution of design rainfalls is combined with fixed values of 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:

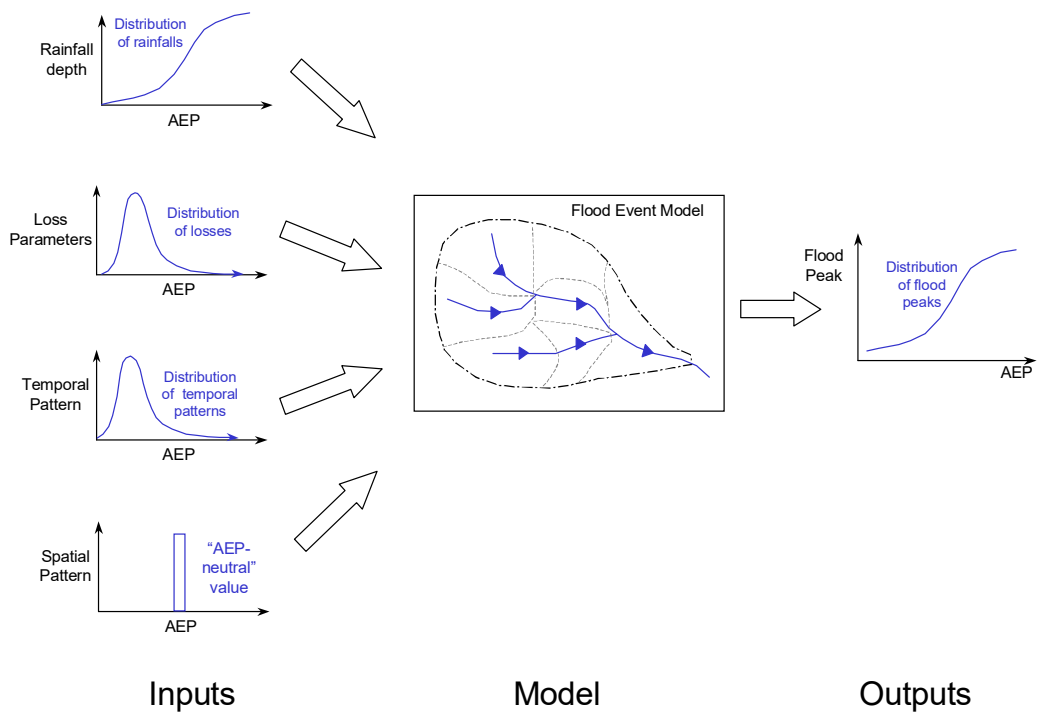
- the AEP-neutrality of some inputs can only be tested on frequent events for which independent estimates are available;
- for more extreme events, the adopted values of AEP-neutral inputs must be conditioned by physical and theoretical reasoning; and
- the treatment of more complex interactions (such 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).

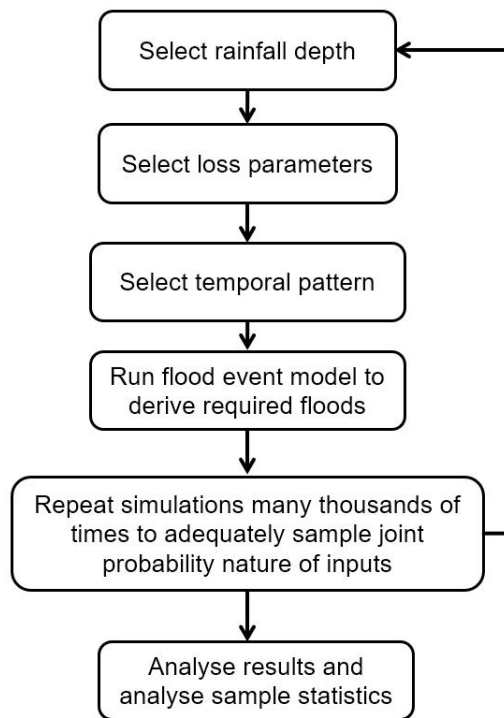


■ Figure 4-1 Schematic illustration of the design event approach



■ 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)

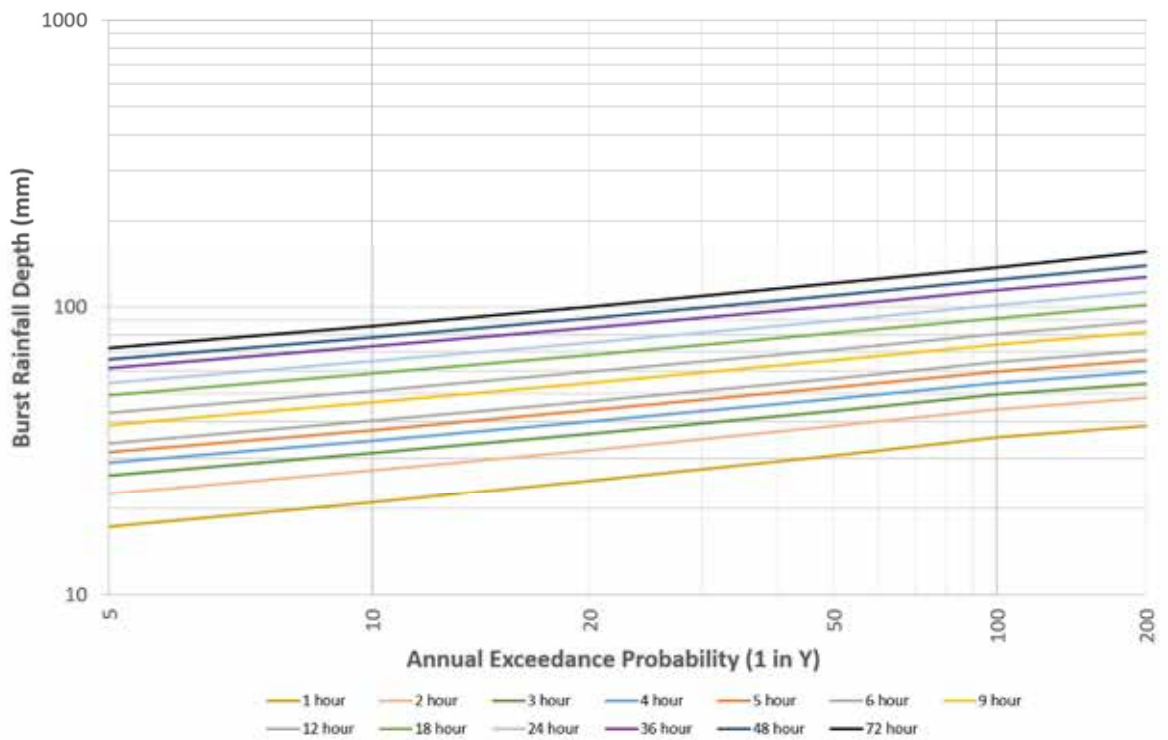
### 4.2.1 Rainfall depths

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	17	22	26	29	31	34	39	43	50	55	61	66	72
10	21	27	31	34	38	40	47	51	59	65	73	79	86

AEP (1 in Y)	1	2	3	4	5	6	9	12	18	24	36	48	72
20	25	32	36	40	44	47	54	60	68	75	85	92	101
50	31	39	44	48	53	57	65	71	81	90	101	110	121
100	35	44	50	55	60	64	74	81	92	101	114	124	138
200	39	48	54	60	65	71	82	89	102	113	127	139	156

#### 4.2.3 Spatial patterns

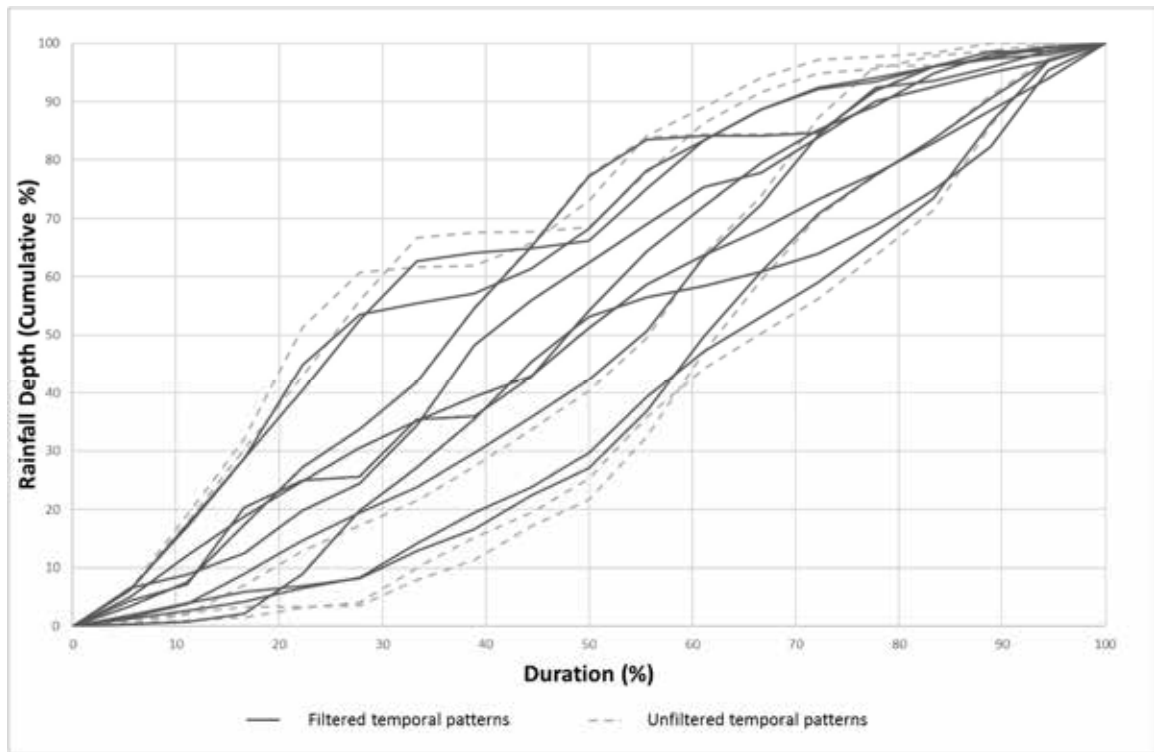
The spatial pattern for the catchment has been based on the rainfall depths from the Bureau of Meteorology, i.e. the IFD, which is recommended in ARR2019.

#### 4.2.4 Temporal patterns

For catchment areas greater than 75km<sup>2</sup> 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<sup>2</sup> 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 Scoria 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

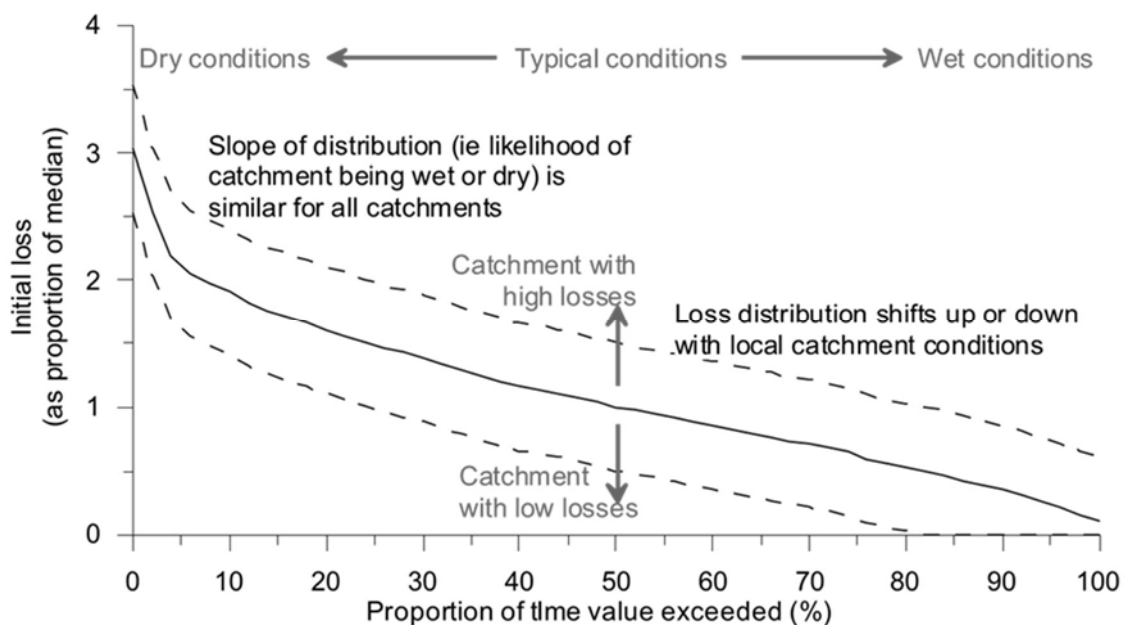
There are two key types of loss models that are typically adopted when modelling design floods:

- 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**

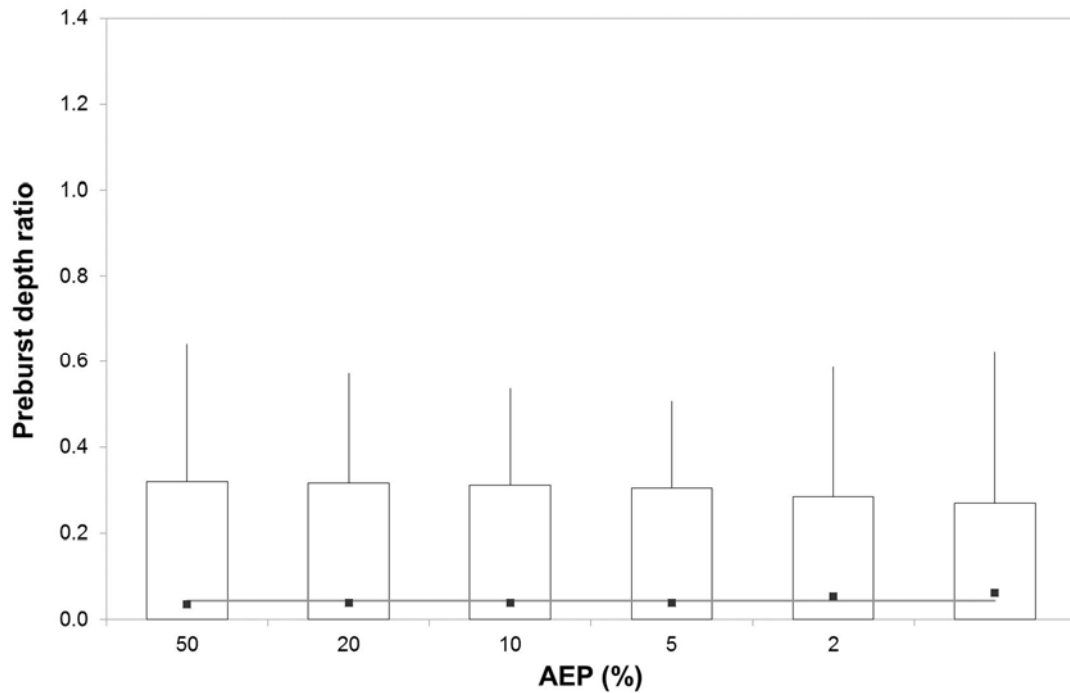
The correlation between initial losses and continuing losses is not well understood. Current practice is for initial losses to be sampled from a distribution, while the continuing loss is held constant; this approach was used for this study.

#### 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 10<sup>th</sup>, 25<sup>th</sup>, 50<sup>th</sup>, 75<sup>th</sup> and 90<sup>th</sup> 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 initially taken from the Donald Flood Study (GHD, 2014). 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 Donald Flood Study (GHD, 2014) was calibrated to three events i.e. October 1996, September 2010 and December 2010. The RORB model was also verified to a flood frequency curve (FFC) at Avon River @ Wimmera Highway (415220), Richardson River @ Carrs Plain (415226) and Richardson River @ Donald (415257).

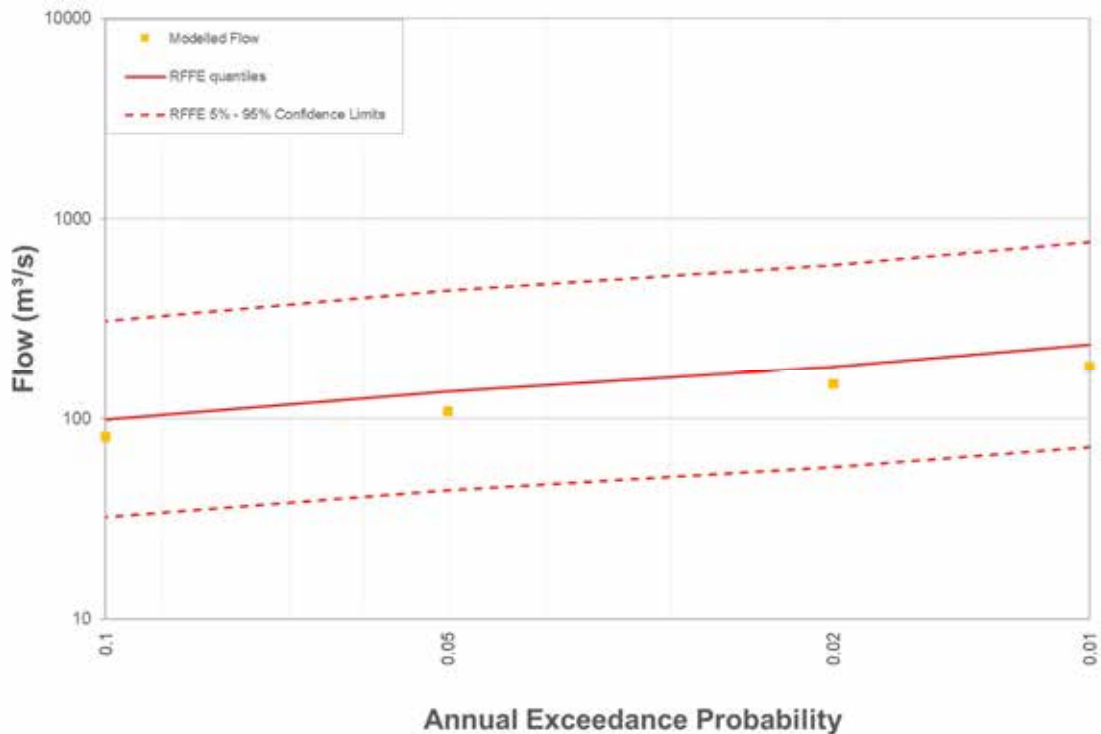
Initially when the results using the parameters from the Donald Flood Study (GHD, 2014) were compared to the RFFE (refer to Section 5.2) the modelled flow estimates were low compared to the RFFE. The closest gauge used in the Donald Flood Study (GHD, 2014) was the Richardson River @ Carrs Plain which, as noted at the time, produced lower flows than the FFC. Therefore, for this investigation a lower  $k_c/d_{av}$  ratio was adopted which was taken as the expected value i.e. 1.25 from Pearse et al. (2002) so a better verification could be achieved to the RFFE. The design losses of 18.8 mm and 1.1 mm/hr from the Donald Flood Study were adopted. Table 5-1 summarises the RORB parameters adapted for Marnoo.

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

Parameter	Value
$k_c$	25.6
$d_{av}$	20.5
$C_{0.8} (k_c/d_{av})$	1.25
$m$	0.8
IL (mm)	18.8
CL (mm/hr)	1.1

### 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 matches the RFFE reasonably well.



■ Figure 5-1 Verification results compared to RFFE

### 5.3 Comparison to regional parameters

The results 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).

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

Where  $A$  is the area in  $\text{km}^2$ .

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

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

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  $k_c$  values – regional estimates**

Location	Area (km <sup>2</sup> )	$k_c$ (equation 1)	$k_c$ (equation 2)			$k_c$ (adopted)
			Expected	High	Low	
Marnoo	180	14.4	25.6	42.4	15.3	25.6

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)
Marnoo	30.0	3.5	18.8	1.1

## 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 Marnoo**

AEP (1 in Y)	Peak Flow (m <sup>3</sup> /s)	Critical Duration (hours)
5	55.9	24.0
10	81.6	18.0
20	111.2	18.0
50	149.2	18.0
100	176.8	12.0
200	215.8	12.0

### 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.

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

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

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

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

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

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

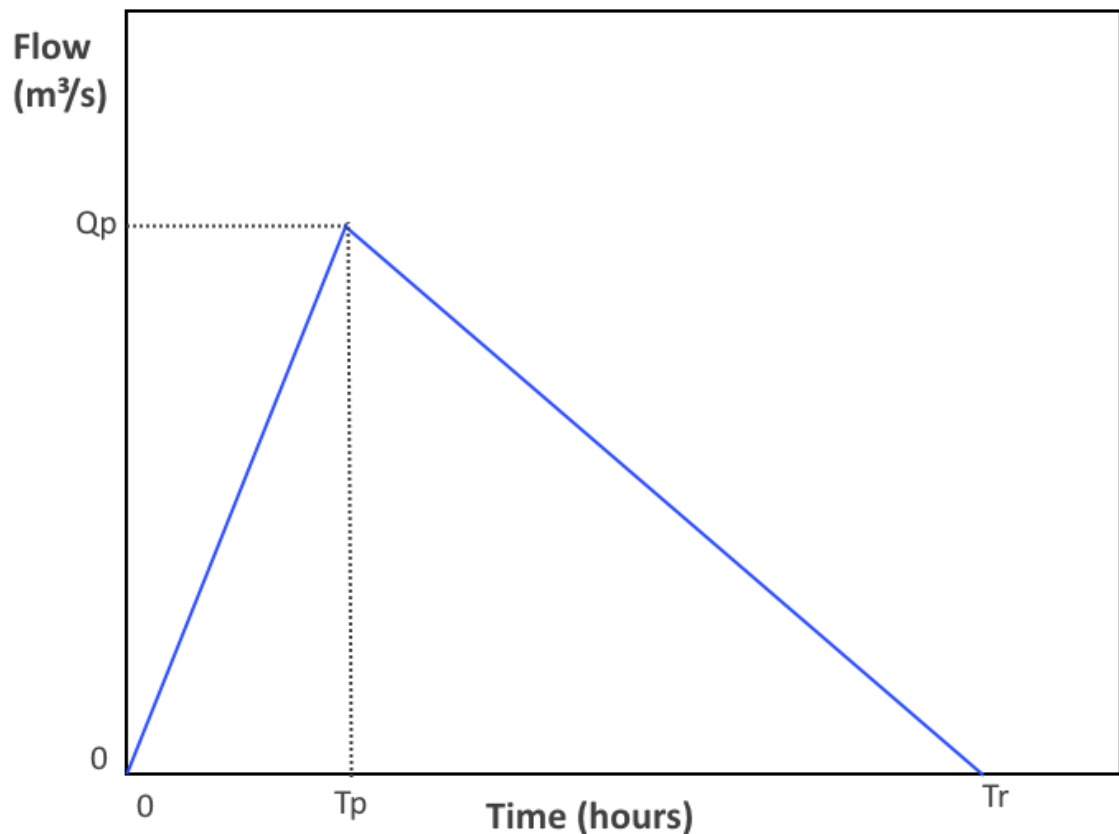
$A$  is catchment area ( $km^2$ )

$V$  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.



■ **Figure 6-1 - Characteristics of 'triangular' PMF - source: Nathan et al. (1994)**

The peak PMF flow was estimated to be 3168 m<sup>3</sup>/s.

### 6.3 Climate change and sensitivity analysis

An important aspect of any hydrological modelling is the undertaking of appropriate sensitivity testing. Sensitivity testing helps to understand the influence of key parameters and the model schematisation on the result. The Monte Carlo framework accounts for the key inputs which influence flows (i.e. temporal patterns and losses) and incorporates these into flow estimates. In this way the Monte Carlo analysis already takes into account the impact of the natural variability of the key parameters. However, an important aspect to consider is the impact of climate change on the design flow estimates.

ARR2019 offers interim advice on estimation of the increase in design rainfall intensities associated with a range of climate change scenarios. The chapter in ARR2019 on climate change uses output from the Climate Futures web tool developed by the CSIRO. Climate change projections are focussed on Natural Resource Management (NRM) 'clusters'. "Projected changes from Global Climate Models (GCMs) can be explored for 14 20-year periods and the four Representative



Concentration Pathways (RCPs) for greenhouse gas and aerosol concentrations that were used to drive the GCMs. The RCPs are designated as 2.6, 4.5, 6.0 and 8.5, and are named according to radiative forcing values ( $W m^{-2}$ ) in the year 2100 relative to pre-industrial values" (ARR, 2019). ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated in the Data Hub to the values that can be found on the climate change in Australia website.

ARR2019 considers a six step process to incorporate climate change risks into decisions involving the estimation of design flood characteristics. The six steps are:

Step 1 – set the effective service life or planning horizon

Step 2 – set the flood design standard

Step 3 – consider the purpose and nature of the asset or activity and consequence of its failure

Step 4 – carry out a climate change risk screening analysis

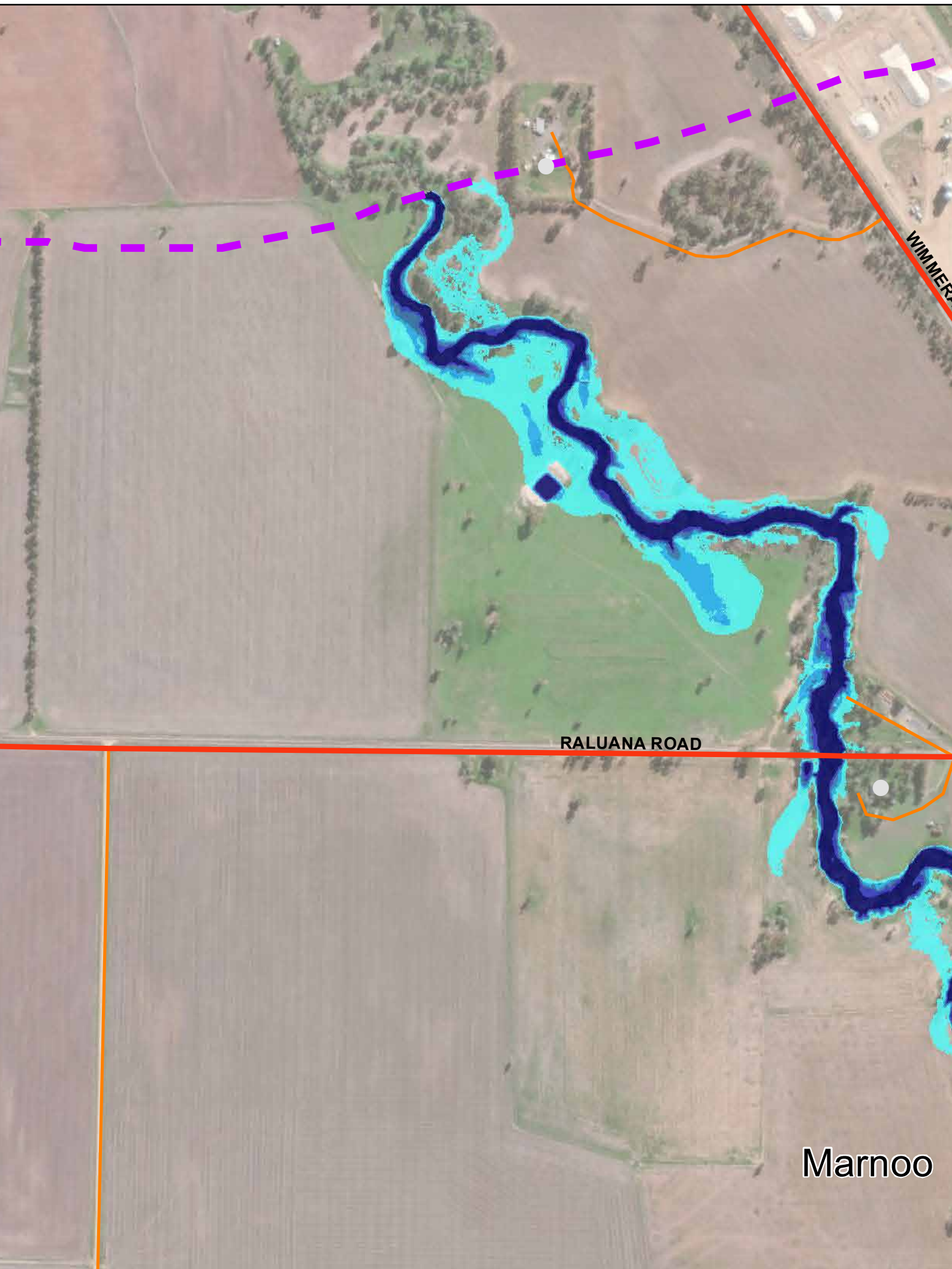
Step 5- consider climate change projections and their consequences

Step 6 – consider statutory requirements.

For this study the service life was considered to be long term (step 1). The design standard is notionally 1 in 100 AEP for this investigation (step 2). The consequence of failure is considered to be high, as from ARR2019 "this category generally relates to high value assets, or assets of significant economic or welfare importance" (step 3). For step 4 it has been assumed that climate change is a "significant issue for the facility of interest" (ARR2019) therefore this is rated as medium/high. From ARR2019 "in reaching Step 5, the minimum basis for design should be the low greenhouse gas and aerosol concentration pathway RCP4.5 and the maximum GCM consensus case indicated by the Climate Futures web tool for the NRM cluster of interest". "Where the additional expense can be justified on socioeconomic and environmental grounds, the maximum consensus case for the high concentration pathway RCP8.5 should also be considered". Step 6 from ARR2019 states that "if statutory requirements relating to climate change are in place, adopt the changed design. Otherwise, carry out an economic analysis (e.g. cost-benefit or cost effectiveness analysis, or multi-attribute utility theory) of potential changes in flood-related design requirements and make an informed decision on how to proceed". An economic analysis is beyond the scope of this study therefore, the results of the impacts of climate change on rainfall intensities for an RCP of 4.5 are recommended for adoption for this study. However, the results from RCP 8.5 have also been provided for completeness.

The study area is located in the 'Southern Slopes Mainland' NRM 'cluster'. Considering a planning horizon out to 2090 and a RCP of 4.5 then the Data Hub indicates a 9.2% increase in the design rainfall intensities and for a RCP of 8.5 a 20.2% increase in the design rainfall intensities.



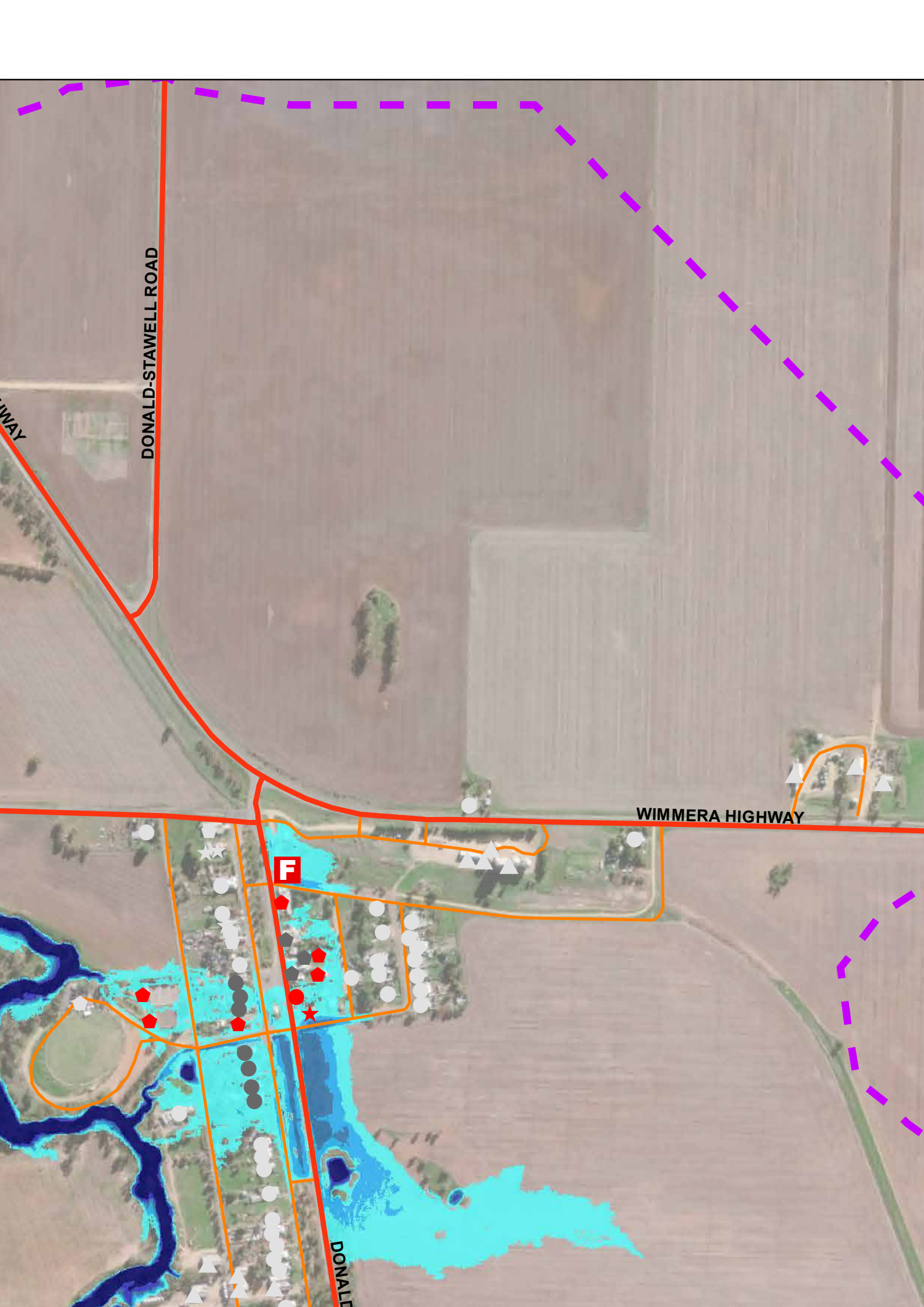


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#### 7.4 Hydraulic structures

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.

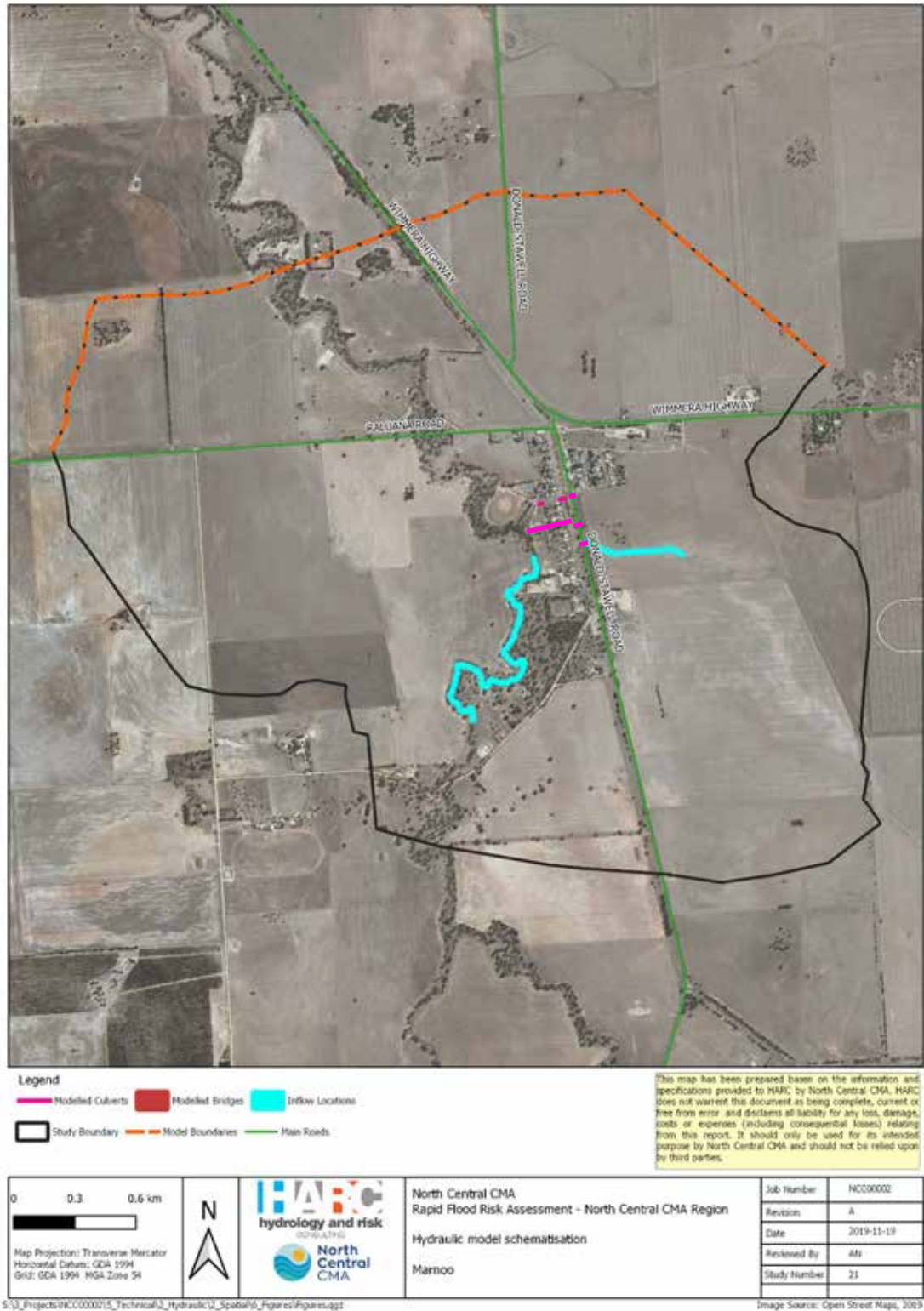
The results of the Monte Carlo analysis are presented as peak flow estimates rather than single hydrographs, with the natural variability of the key inputs built into the estimates. The peak flows are not biased one way or the other by selection of a single arbitrary rainfall temporal or spatial pattern. 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 1% 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
21-5-1	1 in 5 year Depth Map	21-5-4	1 in 5 year Hazard Map
21-10-1	1 in 10 year Depth Map	21-10-4	1 in 10 year Hazard Map
21-20-1	1 in 20 year Depth Map	21-20-4	1 in 20 year Hazard Map
21-50-1	1 in 50 year Depth Map	21-50-4	1 in 50 year Hazard Map
21-100-1	1 in 100 year Depth Map	21-100-4	1 in 100 year Hazard Map
21-200-1	1 in 200 year Depth Map	21-200-4	1 in 200 year Hazard Map
21-PMF-1	PMF Depth Map	21-PMF-4	PMF Hazard Map
21-5-2	1 in 5 year Depth x Velocity Map	21-5-5	1 in 5 year Velocity Map
21-10-2	1 in 10 year Depth x Velocity Map	21-10-5	1 in 10 year Velocity Map
21-20-2	1 in 20 year Depth x Velocity Map	21-20-5	1 in 20 year Velocity Map
21-50-2	1 in 50 year Depth x Velocity Map	21-50-5	1 in 50 year Velocity Map
21-100-2	1 in 100 year Depth x Velocity Map	21-100-5	1 in 100 year Velocity Map
21-200-2	1 in 200 year Depth x Velocity Map	21-200-5	1 in 200 year Velocity Map
21-PMF-2	PMF Depth x Velocity Map	21-PMF-5	PMF Velocity Map
21-5-3	1 in 5 year Elevation Map		
21-10-3	1 in 10 year Elevation Map		
21-20-3	1 in 20 year Elevation Map		
21-50-3	1 in 50 year Elevation Map		
21-100-3	1 in 100 year Elevation Map		
21-200-3	1 in 200 year Elevation Map		
21-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 Raluana Road (mAHD)	Impact
5	145.4	Donald-Stawell Road overtopped. 19 properties are inundated within the township
10	145.8	Additional property is inundated within the township
20	146.2	Three additional properties are inundated within the township
50	146.5	Three additional properties are inundated within the township
100	146.6	Additional industrial property is inundated near Park Lane
200	146.8	One additional property is inundated within the township



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■ **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	8	0	0	1	9	1	0	0	0	0	0
10	9	0	0	1	9	1	0	0	0	0	0
20	12	0	0	1	9	1	0	0	0	0	0
50	14	0	0	1	10	1	0	0	0	0	0
100	14	1	0	1	10	1	0	0	0	0	0
200	14	1	0	2	10	1	0	0	0	0	0

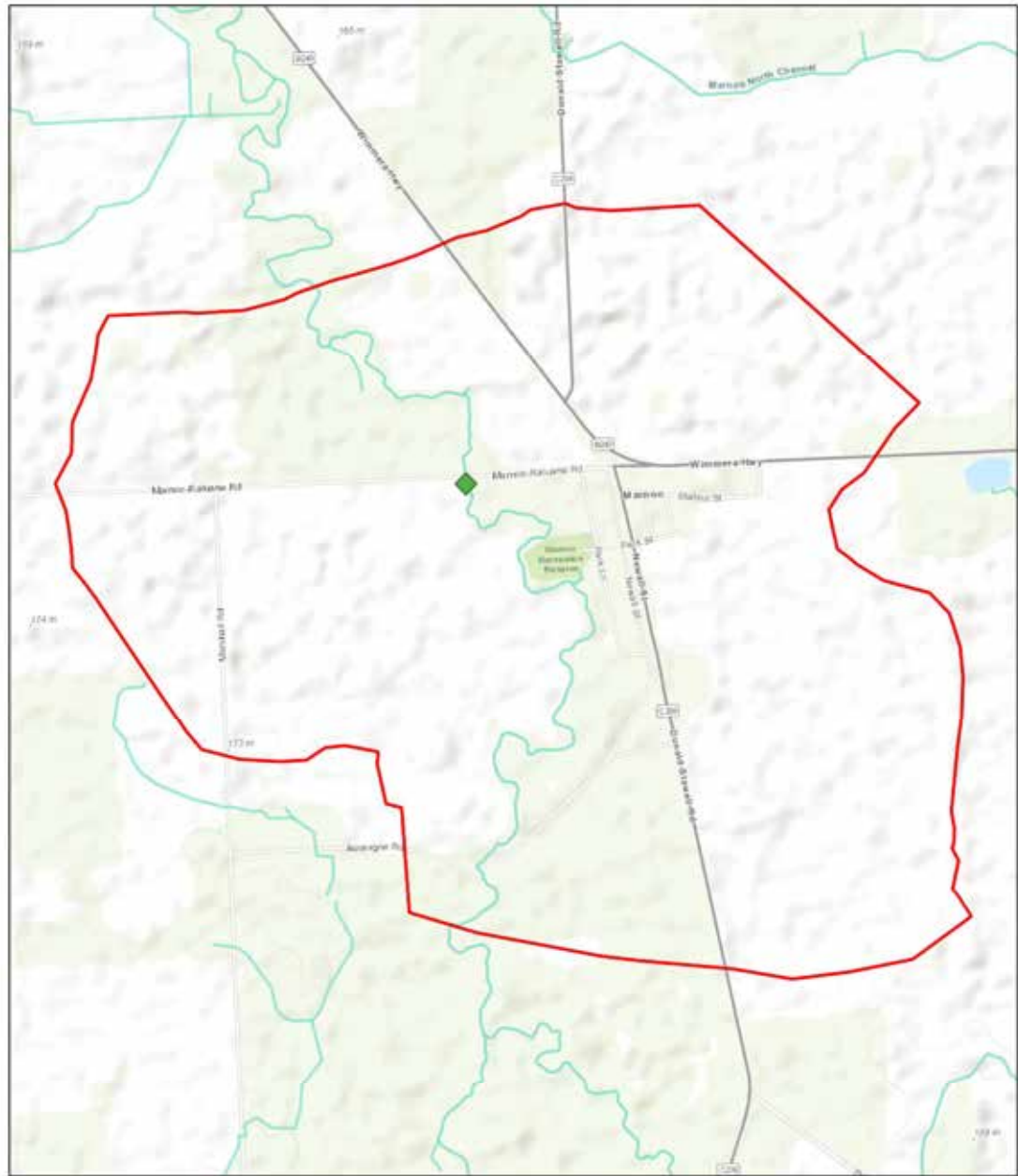
■ **Table 8-4 Summary of over floor flooding\***

AEP (1 in Y)	Residential	Industrial	Agriculture	Public	Commercial	Fire	Aged Care	Education	Hospital	Police	Caravan / Camp Ground
5	1	0	0	1	6	0	0	0	0	0	0
10	1	0	0	1	6	1	0	0	0	0	0
20	1	0	0	1	6	1	0	0	0	0	0
50	2	0	0	1	7	1	0	0	0	0	0
100	4	0	0	1	7	1	0	0	0	0	0
200	5	0	0	1	7	1	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	Raluana Road	0	0
	Donald-Stawell Road	0.1	6
10	Raluana Road	0	0
	Donald-Stawell Road	0.1	10
20	Raluana Road	0	0
	Donald-Stawell Road	0.1	11
50	Raluana Road	0.1	20
	Donald-Stawell Road	0.1	14
100	Raluana Road	0.1	21
	Donald-Stawell Road	0.1	11
200	Raluana Road	0.2	24
	Donald-Stawell Road	0.1	12



**Legend**  
 Model Domain  
— Watercourse  
◆ Reporting Locations

This map has been prepared based on the information and specifications provided to HARC by North Central CMA. HARC does not warrant this document as being complete, current or free from error and disclaims all liability for any loss, damage, costs or expenses (including consequential losses) relating from this report. It should only be used for its intended purpose by North Central CMA and should not be relied upon by third parties.

<p>0 350 700 m</p> <p>Map Projection: Transverse Mercator Horizontal Datum: GDA 1994 Grid: GDA 1994 MGA Zone 58</p>	<p>N</p>	 	<p>North Central CMA Rapid Flood Risk Assessment - North Central CMA Region</p> <p>Reporting Location Marnoo</p>	<table border="1" style="border-collapse: collapse; font-size: small;"> <tr><td>Job Number</td><td>NCC00002</td></tr> <tr><td>Revision</td><td>A</td></tr> <tr><td>Date</td><td>2019-11-19</td></tr> <tr><td>Reviewed By</td><td>AM</td></tr> <tr><td>Study Number</td><td>21</td></tr> </table>	Job Number	NCC00002	Revision	A	Date	2019-11-19	Reviewed By	AM	Study Number	21
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Image Source: Open Street Maps, 2019

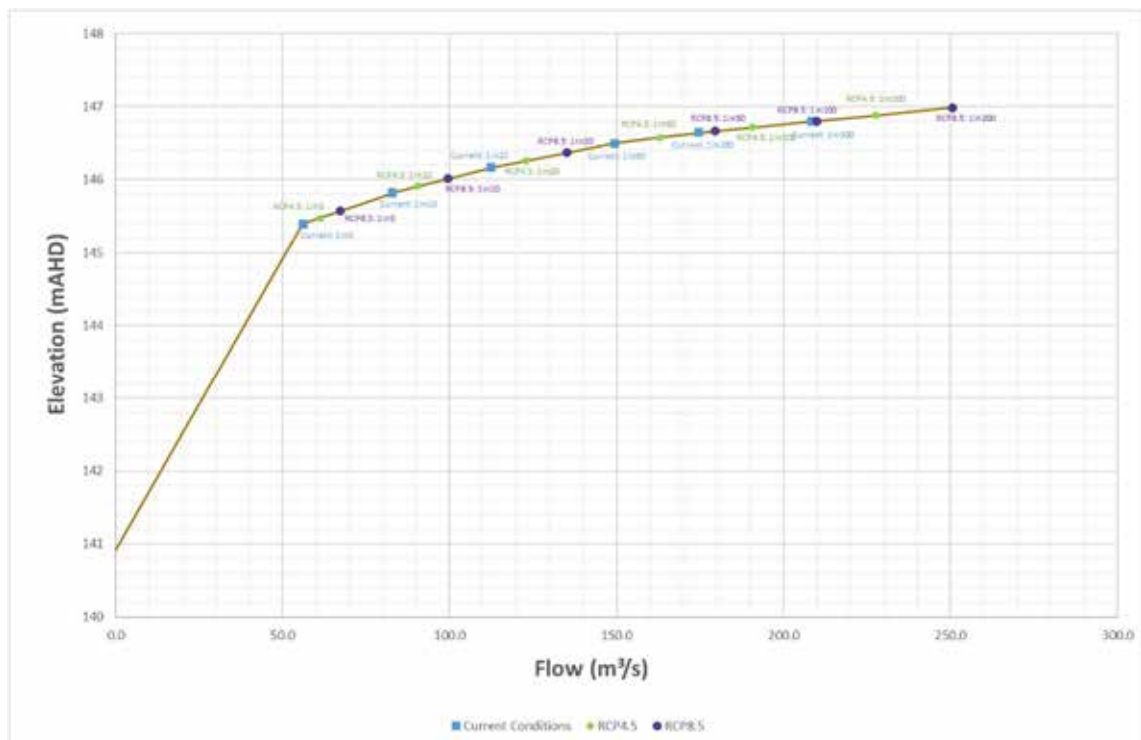
■ **Figure 8-1 Climate change assessment reporting location**

### 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 peak flow estimates

AEP (1 in Y)	Current Climate – Peak Flow (m <sup>3</sup> /s)	Climate Change – Peak Flow (m <sup>3</sup> /s)	
		RCP 4.5	RCP 8.5
5	56.0	61.1	67.3
10	82.8	90.4	99.6
20	112.5	122.8	135.2
50	149.4	163.1	179.5
100	174.6	190.7	209.9
200	208.4	227.6	250.5



- 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 5
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:

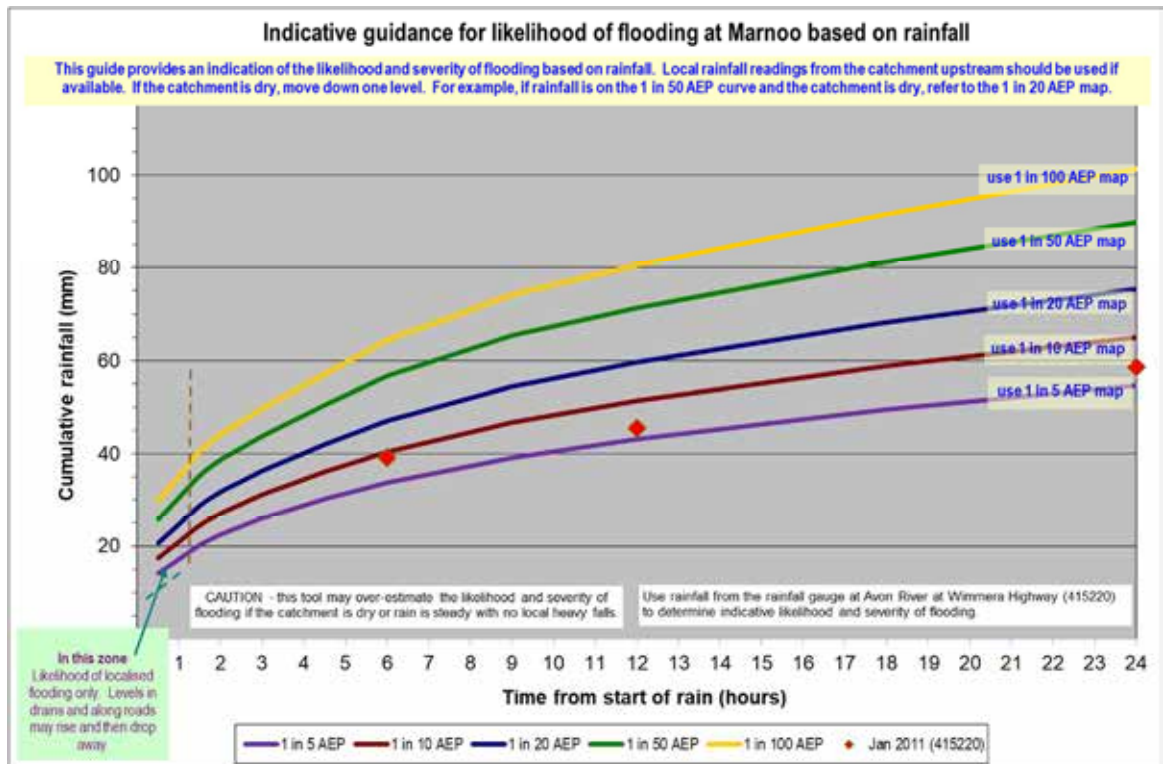
- Interpreting relevant flood related intelligence and consequence information from the mapping and modelling including typical flood travel times, rates of rise, etc;
- Identifying properties, roads and other community assets (e.g. essential infrastructure and services, high risk facilities, emergency 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 Avon River at Wimmera Highway (415220). 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 Lockwood.

Rainfall recorded at Avon River at Wimmera Highway (415220) was used to develop the quick look tool. As the data being used comes from a rain gauge that is outside the Lockwood 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.

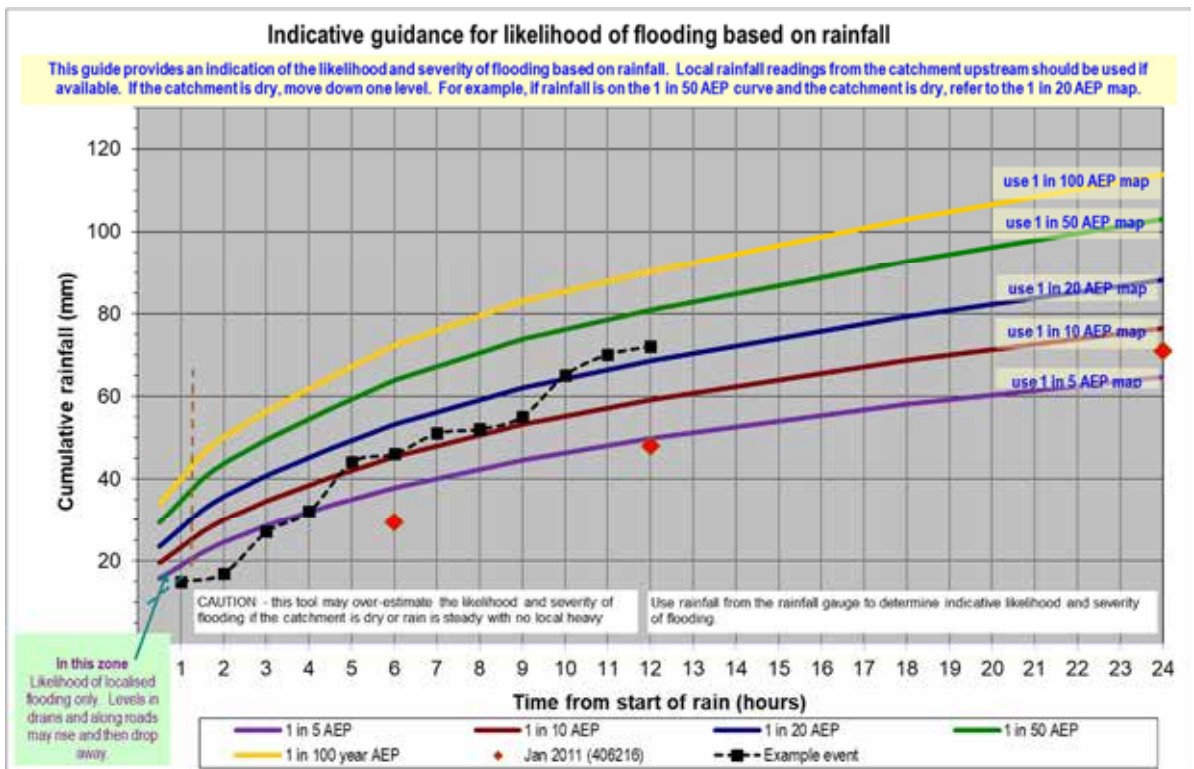
Note that in cases where the tool has not been used from the start of rain (i.e. from early in the event), data should be either picked up from the start of the event or the first data plotted should include an estimate of how much rain has fallen and the time over which it has fallen. If this is not 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<sup>1</sup>, moderate<sup>2</sup> and major<sup>3</sup> flood (as defined by the BoM). The minor, moderate and major flood has been based on the flood impacts. For Marnoo the 1 in 5, 10 and 20 AEP has been adopted for the minor, moderate and major flood respectively.

## 8.7 Sensitivity Analysis

In consultation with the North Central CMA only a sub-set of the hydraulic models was re-run for the sensitivity analysis as, in general, an increase in Manning's roughness values results in monotonic increases in flood levels providing limited information. The choice of the six study areas was discussed with the North Central CMA and the areas chosen were based on the areas with the highest number of properties affected by flooding. Marnoo was one of the study areas chosen. Table 8-9 shows the adopted Manning's n along with Manning's n used for the sensitivity analysis. For the sensitivity analysis only the 1% AEP was rerun. The difference in extent and levels from the sensitivity analysis is presented in Figure 8-5. Table 8-10 summarises the impact on the number of buildings flooded and the number of properties that are inundated above floor.

### ■ Table 8-9 Manning's n values for different land use types

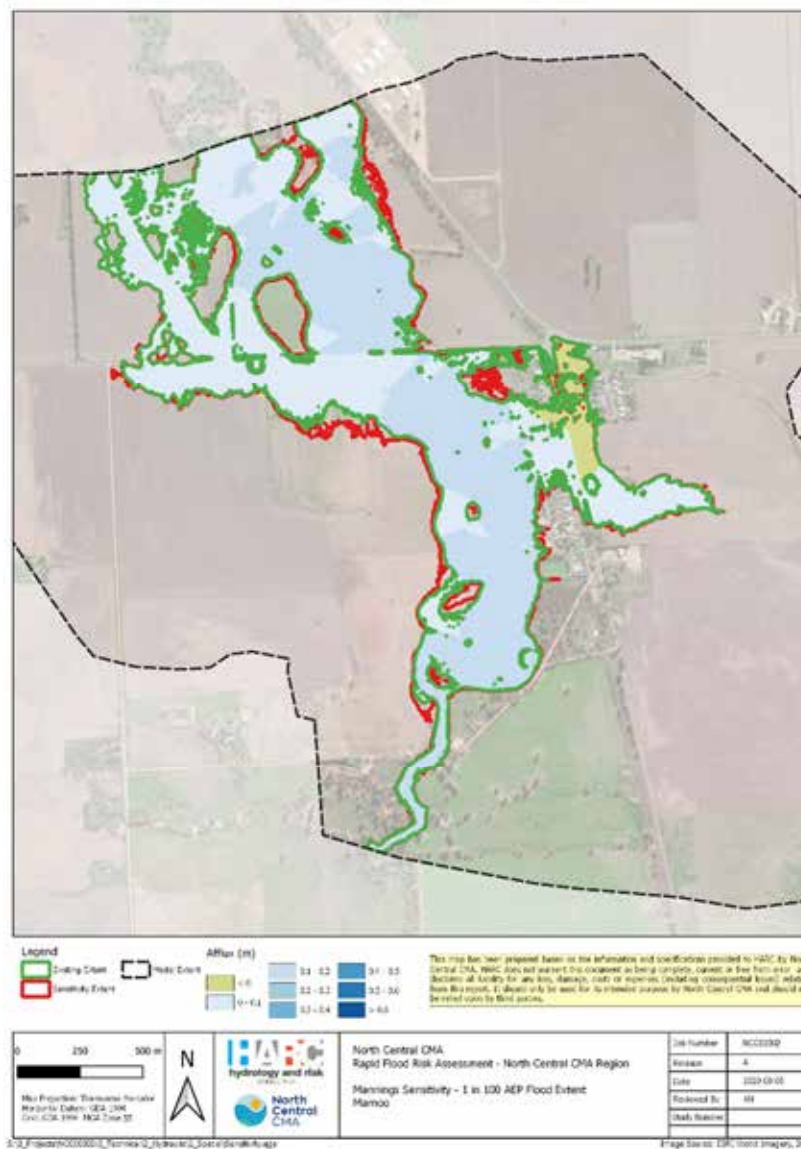
Land Use Type	Manning's n adopted	Manning's n sensitivity analysis
Residential areas – urban high density (building and parcel combined)	0.35	0.50
Residential areas – rural high density (building and parcel combined)	0.15	0.20
Industrial/commercial or large buildings	0.30	0.50
Residential areas – rural low density (parcel only or large blocks with house)	0.05	0.07
Open space or waterway – minimal vegetation	0.04	0.05
Open space or waterway – moderate vegetation	0.06	0.07
Open space or waterway – heavy vegetation	0.095	0.12
Paved roads/car park/driveways	0.025	0.03

<sup>1</sup> 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.

<sup>2</sup> 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

<sup>3</sup> 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

Land Use Type	Manning's n adopted	Manning's n sensitivity analysis
Grass reserves/floodway (regularly mowed)	0.035	0.05
Rural floodplains in clear paddocks	0.05	0.07
Forested (heavy stand of timber)	0.12	0.20
Dam/Reservoir body of water	0.035	0.04



■ Figure 8-5 Manning's n sensitivity analysis result

■ **Table 8-10 Summary of number of buildings flooded – sensitivity analysis**

AEP (1 in Y)	Number of Building Inundated		Above Floor Flooding	
	Adopted	Sensitivity Analysis	Adopted	Sensitivity Analysis
100	27	28	13	16

Table 8-10 show that the results are somewhat sensitive to the Manning's n values with 1 additional building inundated and 3 additional buildings experiencing over floor flooding.

## 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 Marnoo 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 – Marnoo**

Category	Comment	Rating
RORB model set up	RORB model established for Marnoo catchment. Adequate sub-area division for larger catchment. However, additional local catchment sub-division recommended if more detailed local flows are required.	Yellow
RORB model parameters	Based on a calibrated and verified model however for a larger catchment.	Yellow
Currency of hydrology	All inputs are based on ARR2019	Green
Topographic data	LIDAR available for entire study area	Green
Manning's n	Generally OK but was based on VLUIS	Green
Modelling of key structures	Both culverts explicitly modelled however based on estimated data.	Yellow
TUFLOW model set up	Cell size adequately represents waterway and boundary conditions modelled appropriately.	Green
TUFLOW parameters	TUFLOW parameters have not been calibrated or verified to recorded flood levels.	Yellow

## 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 accurately. 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.



## 12. References

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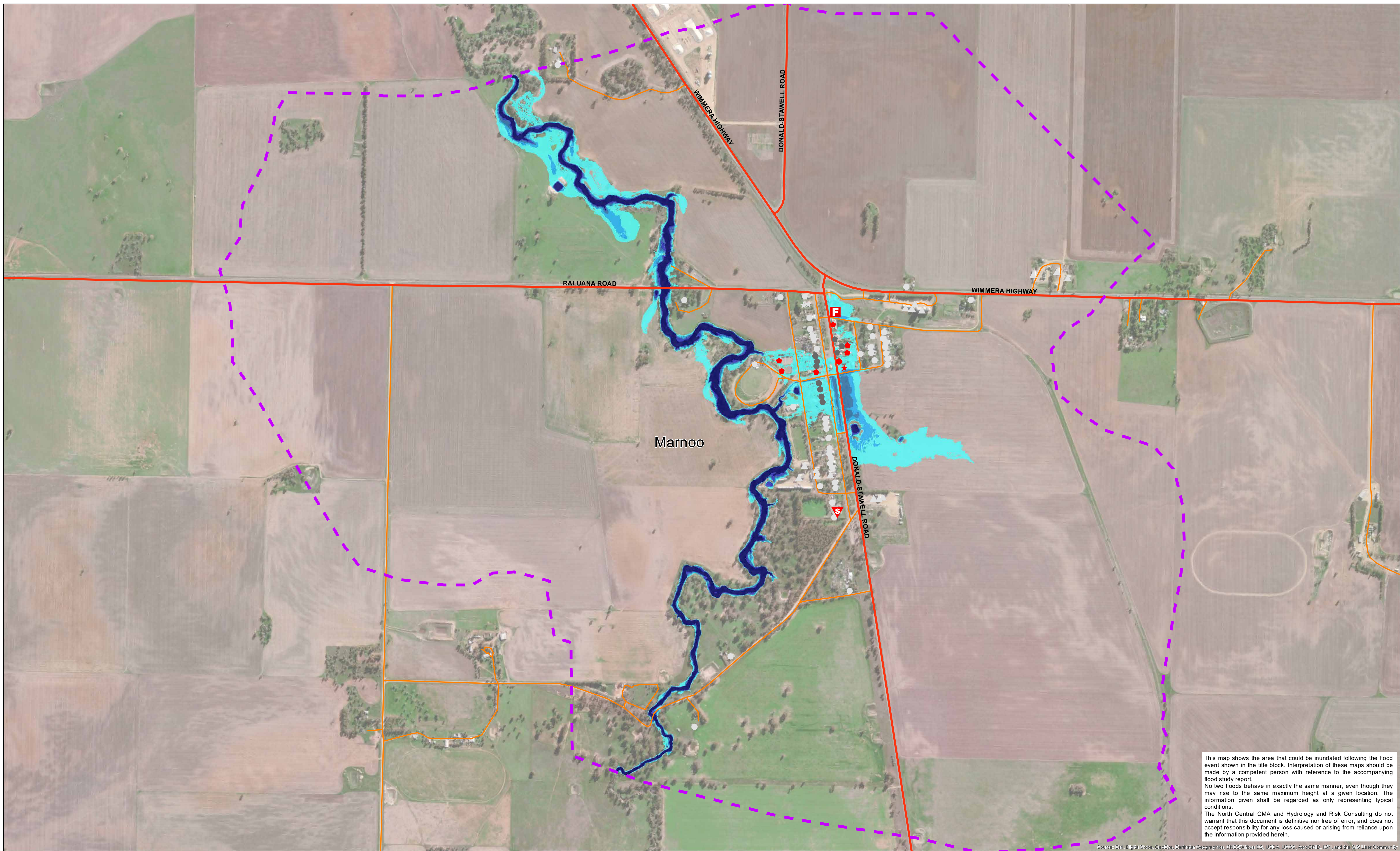
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Scorah M, Hill P, Lang S and Nathan R (2016), Addressing embedded bursts in design storms for flood hydrology. Water, Infrastructure and the Environment: Proceedings of the 56th New Zealand Hydrological Society Conference and the 37th Hydrology and Water Resources Symposium, Queenstown, New Zealand. New Zealand Hydrological Society and Engineers Australia.

## 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.

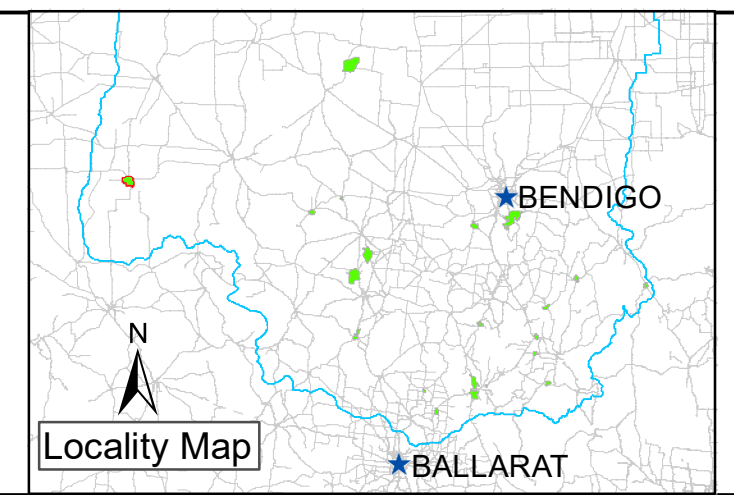
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.

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\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

CFA/MFB Fire Station	Main Road	<b>Building Classification</b>	<b>Max Depth (m)</b>
Police Station	Tertiary Road	Residential	< 0.3
Hospital	Railway Line	Commercial	0.3 - 0.5
School/College	Flood Model Extent	Industrial	0.5 - 0.8
Nursing Home/Aged Care		Public	0.8 - 1.2
Caravan Park		not inundated	> 1.2
		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 DEPTH (m)**

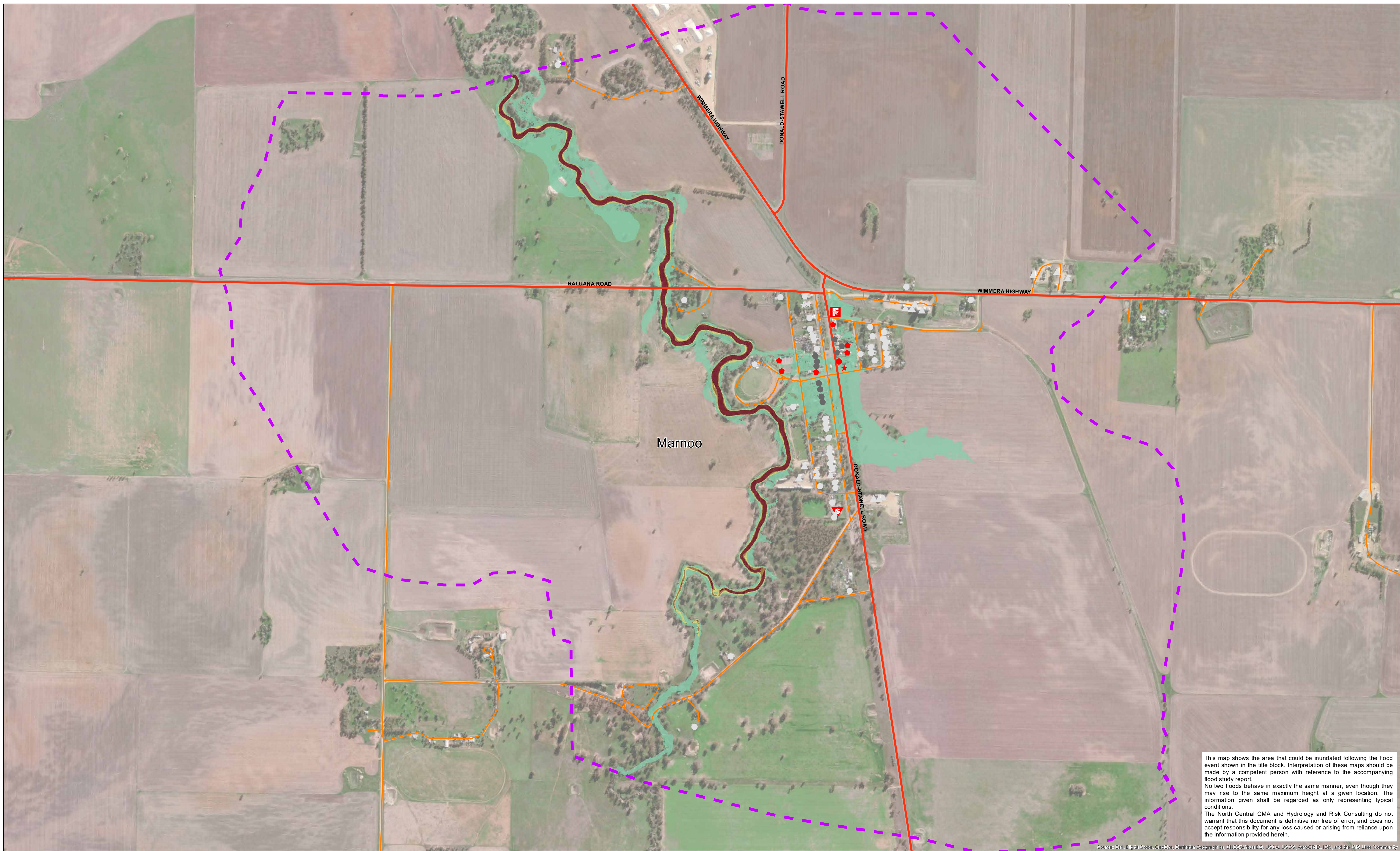
**Marnoo - 20% AEP Flood Event**

0 200 400 600 800  
Meters

Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 25/02/2020	Map No.: 21 - 5 - 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.

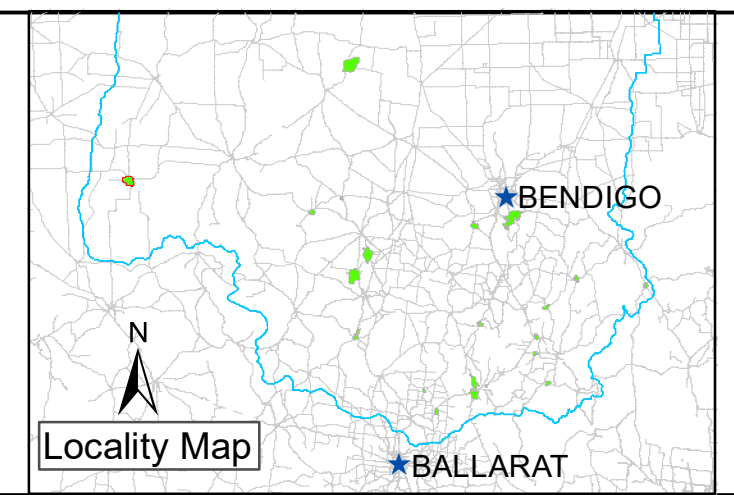
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.

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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VxDmaxMGA54.m  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

	CFAMFB Fire Station		Main Road	<b>Building Classification</b> ● Residential ● Commercial ▲ Industrial ★ Public <b>Building Inundation</b> ■ not inundated ■ inundated (without floor level survey) ■ below floor level (with floor level survey) ■ above floor level (with floor level survey)
	Police Station		Tertiary Road	
	Hospital		Railway Line	
	School/College		Flood Model Extent	
	Nursing Home/Aged Care			<b>Max V x D (m<sup>2</sup>/s)</b> < 0.4 0.4 - 0.8 0.8 - 1.2 > 1.2
	Carvaran Park			



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 (m<sup>2</sup>/s)

**Marnoo - 20% AEP Flood Event**

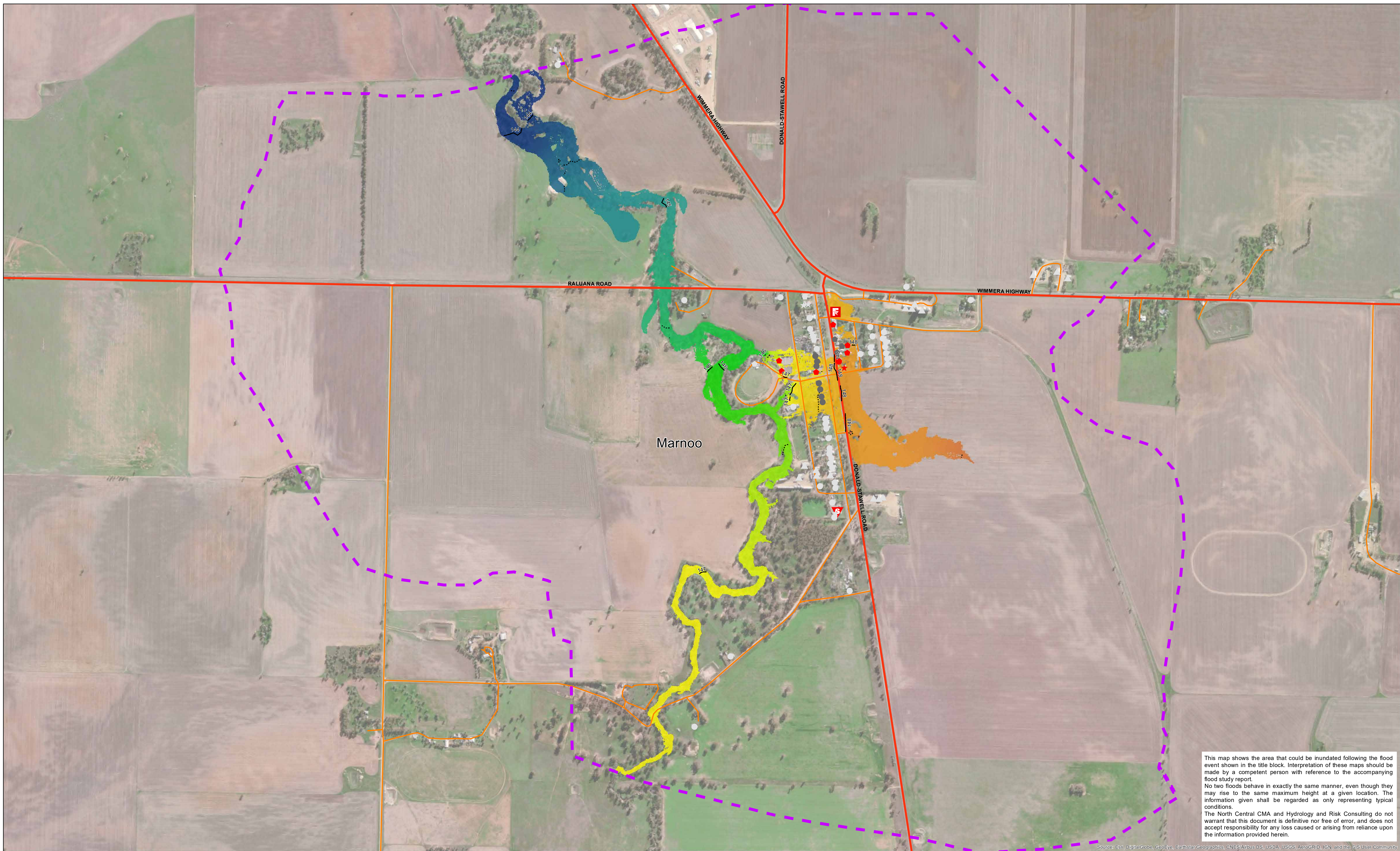
0 200 400 600 800  
Meters

N

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 25/02/2020	Map No.: 21 - 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.

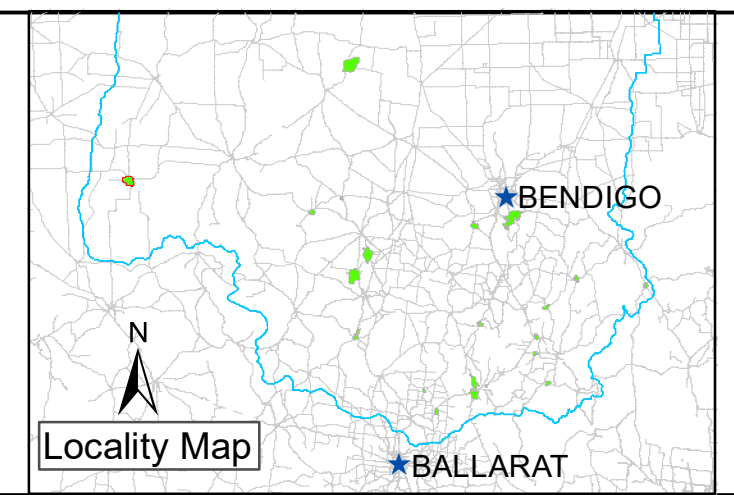
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.

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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HmaxMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

	CFAMFB Fire Station		Main Road	<b>Building Classification</b> Residential Commercial Industrial Public	<b>Max WSE (mAHD) Marnoo</b> <b>Value</b>  High : 149 Low : 144
	Police Station		Tertiary Road		
	Hospital		Railway Line	<b>Building Inundation</b> not inundated inundated (without floor level survey) below floor level (with floor level survey) above floor level (with floor level survey)	
	School/College		Flood Model Extent		
	Nursing Home/Aged Care		Contour (1m)		
	Carvaran Park		Contour (0.5m)		



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North Central CMA Project Manager : N. TRELOAR	

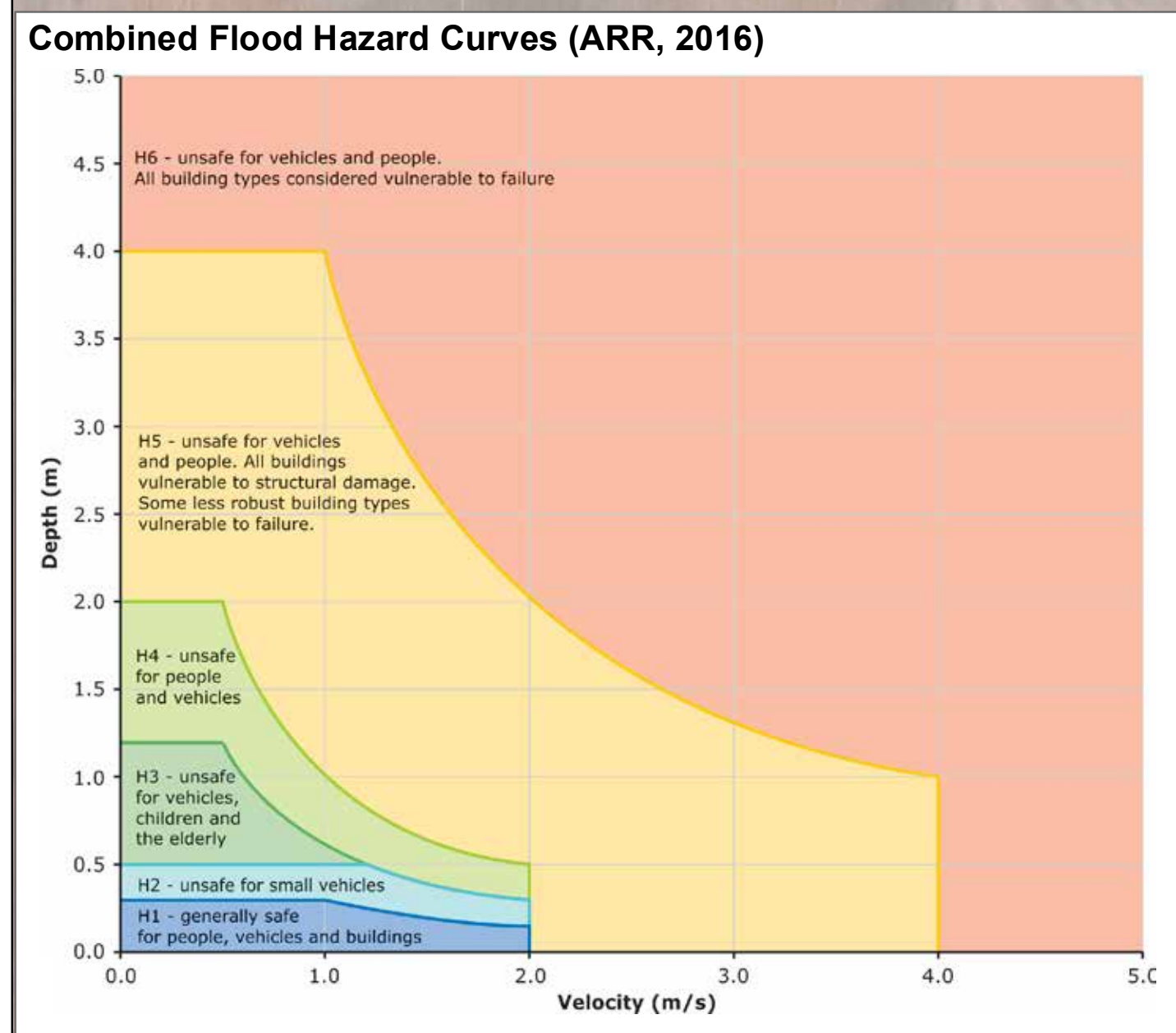
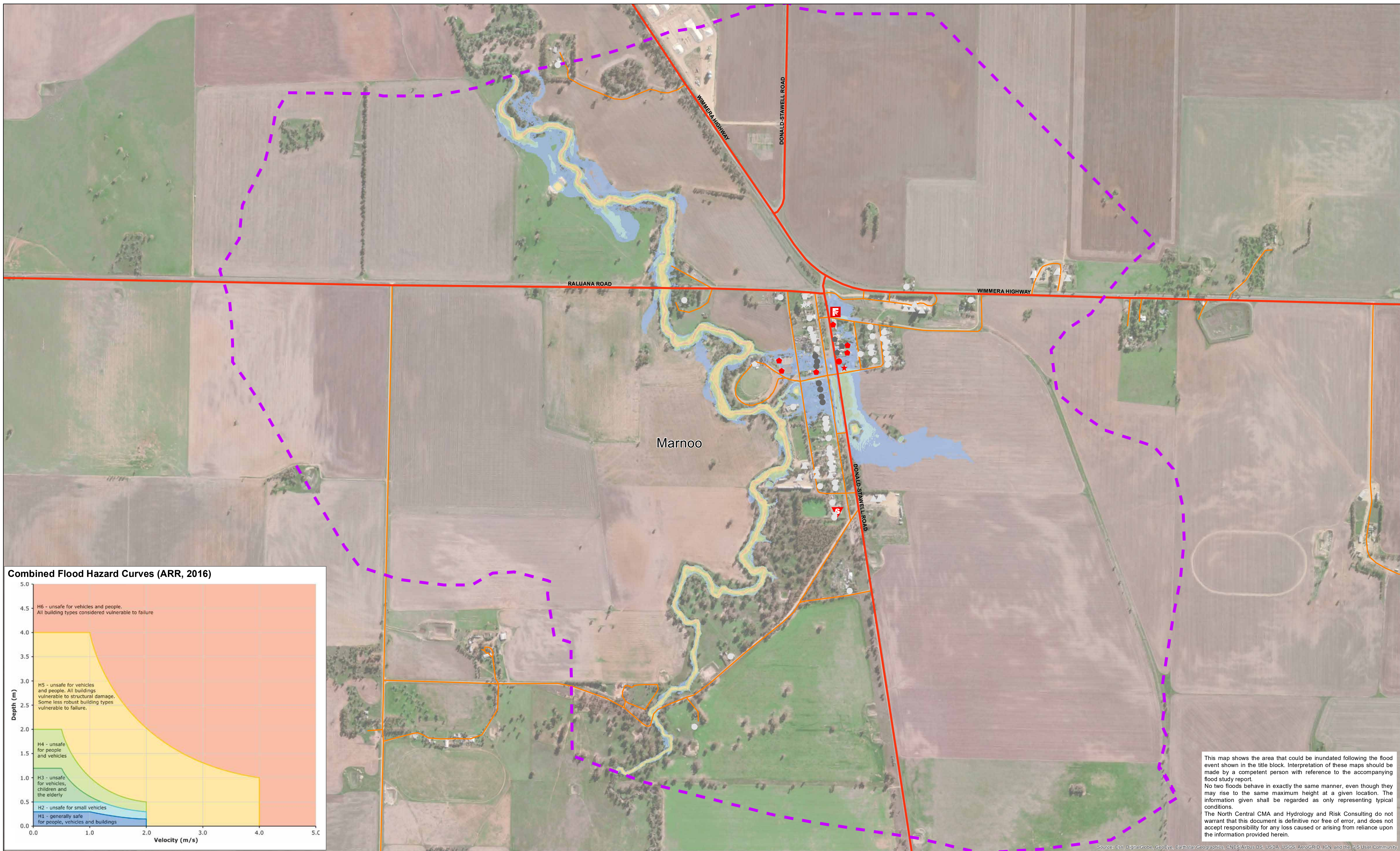
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
 MAXIMUM WATER LEVEL (mAHD)

**Marnoo - 20% AEP Flood Event**

Scale: 1:7,000 when printed @ A1  
 Date: 26/02/2020  
 Map No.: 21 - 5 - 3

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54





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.

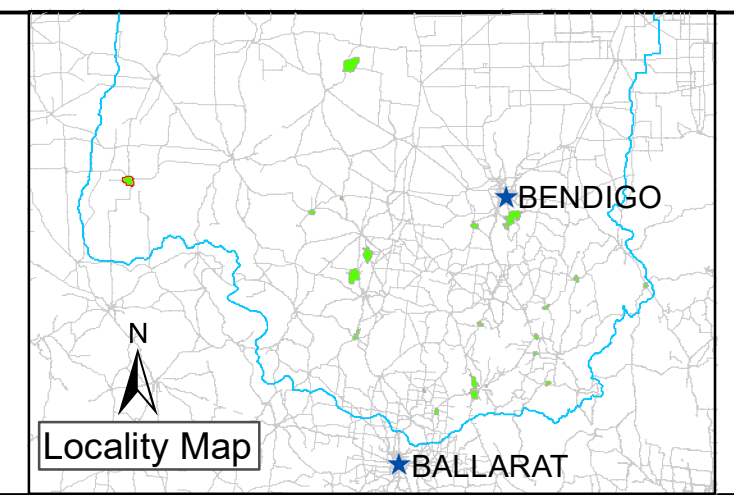
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.

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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HazardsMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

CFAMFB Fire Station	Main Road	<b>Building Classification</b>
Police Station	Tertiary Road	Residential
Hospital	Railway Line	Commercial
School/College	Flood Model Extent	Industrial
Nursing Home/Aged Care		Public
Caravan Park		<b>Building Inundation</b>
		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
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Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

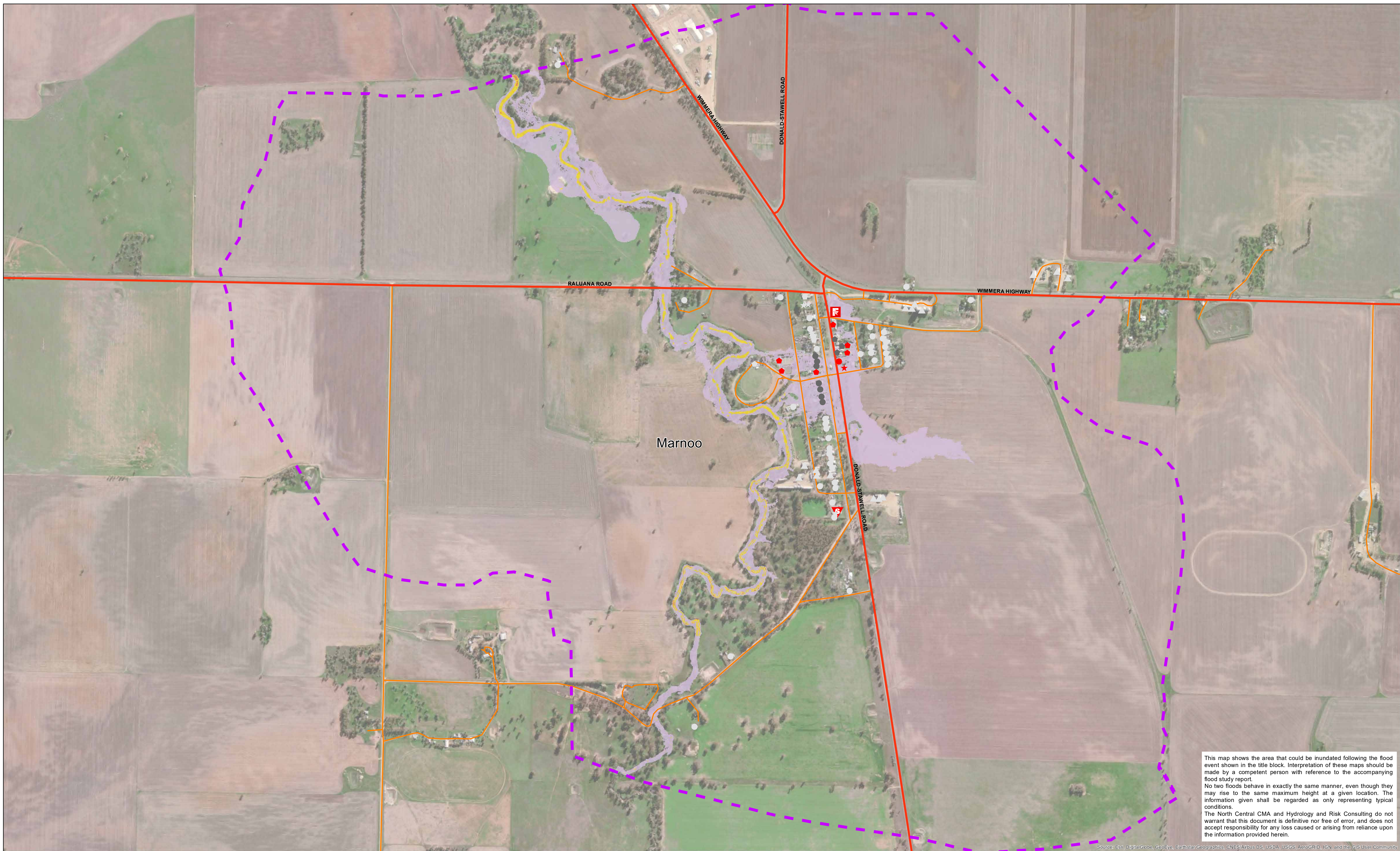
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
 MAXIMUM HAZARD

**Marnoo - 20% AEP Flood Event**

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 26/02/2020	Map No.: 21 - 5 - 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.

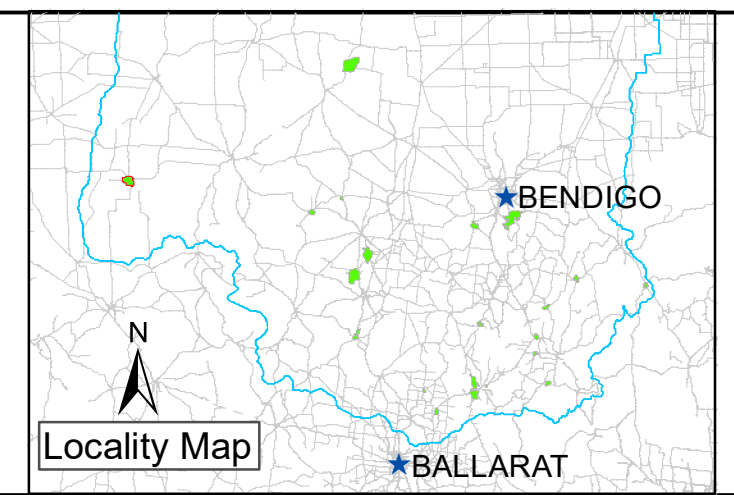
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.

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\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

CFAMFB Fire Station	Main Road	<b>Building Classification</b>	< 1
Police Station	Tertiary Road	Residential	1 - 2
Hospital	Railway Line	Commercial	2 - 3
School/College	Flood Model Extent	Industrial	> 3
Nursing Home/Aged Care		Public	
Carvaran Park		<b>Building Inundation</b>	
		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	

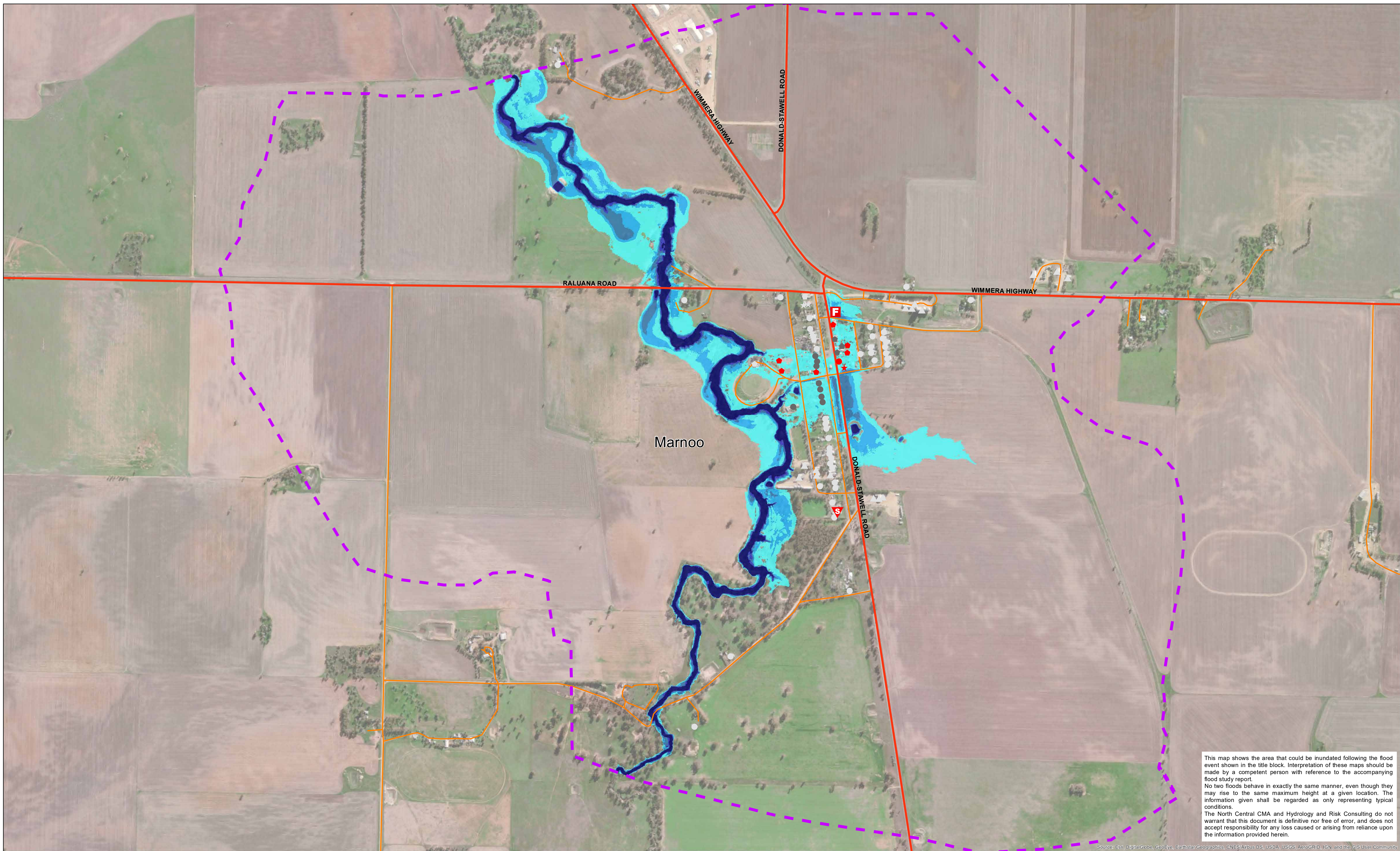
**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT**  
**MAXIMUM VELOCITY (m/s)**

**Marnoo - 20% AEP Flood Event**

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 25/02/2020	Map No.: 21 - 5 - 5





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.

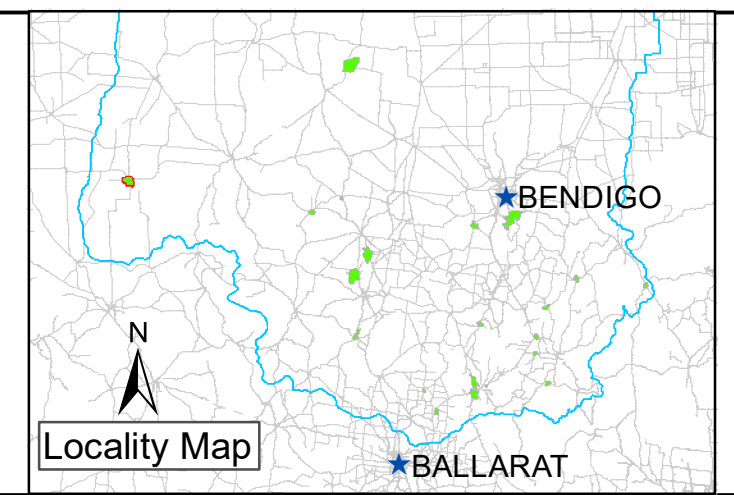
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.

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\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

CFA/MFB Fire Station	Main Road	<b>Building Classification</b>	<b>Max Depth (m)</b>
Police Station	Tertiary Road	● Residential	< 0.3
Hospital	Railway Line	● Commercial	0.3 - 0.5
School/College	Flood Model Extent	▲ Industrial	0.5 - 0.8
Nursing Home/Aged Care		★ Public	0.8 - 1.2
Caravan Park		■ not inundated	> 1.2
		■ 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
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Project Manager: A. NORTHFIELD	
Project No.: NCC00002	
North Central CMA Project Manager: N. TRELOAR	

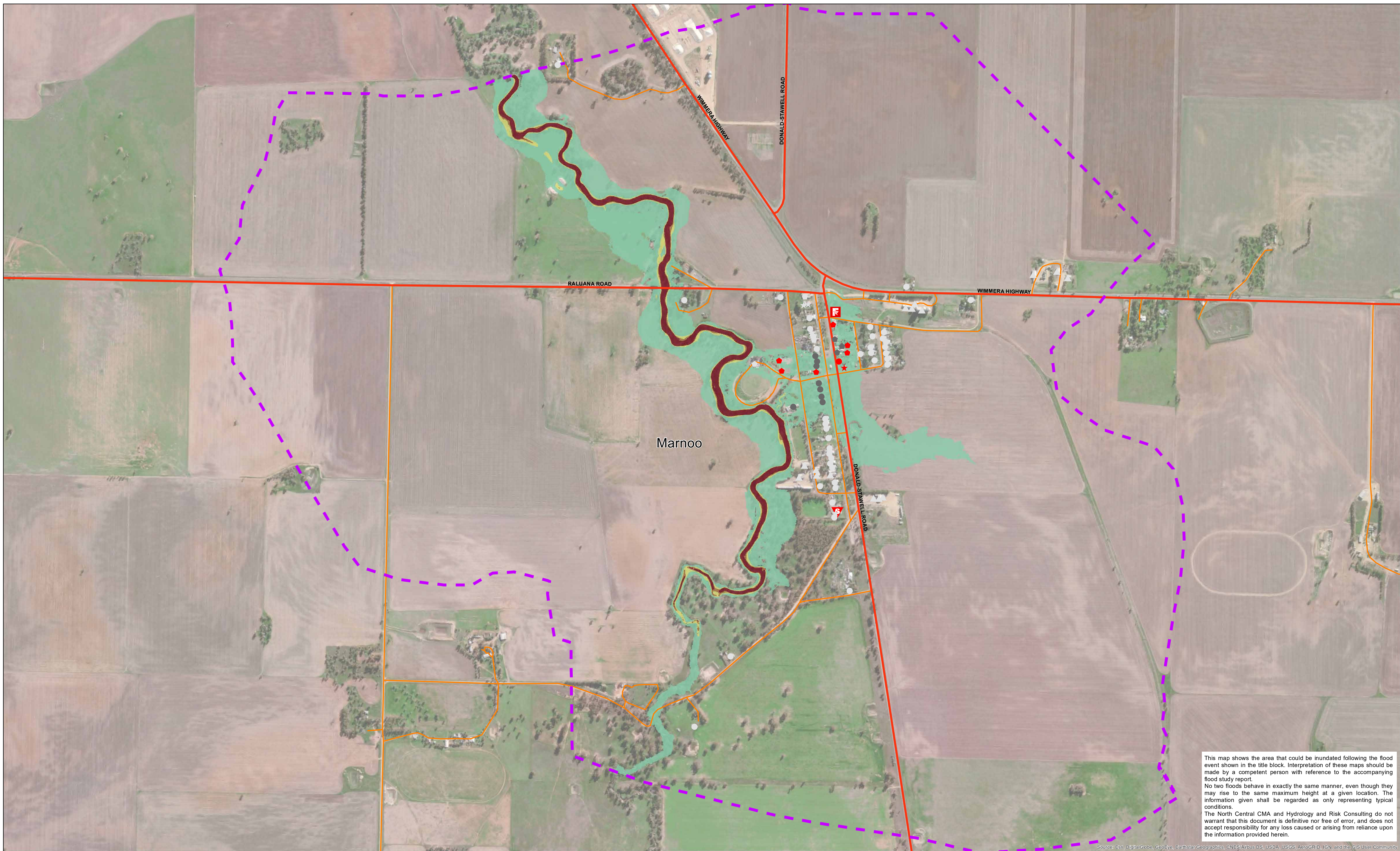
**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT**  
**MAXIMUM DEPTH (m)**

**Marnoo - 10% AEP Flood Event**

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 25/02/2020	Map No.: 21 - 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.

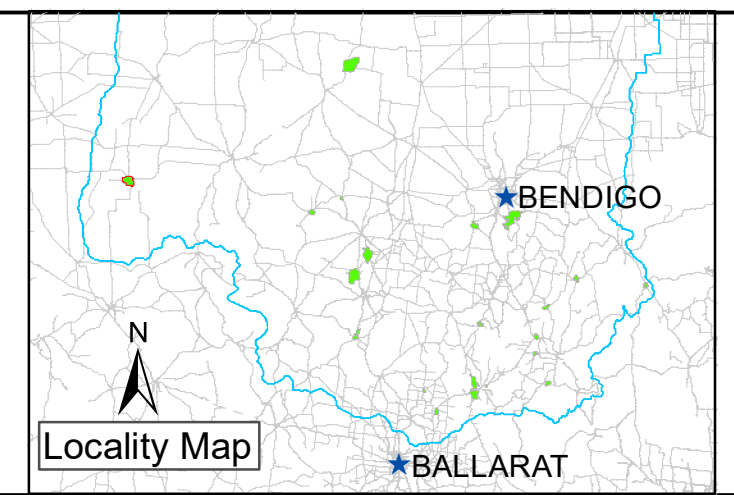
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.

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\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VxDmaxMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

CFAM/FB Fire Station	Main Road	<b>Building Classification</b>	<b>Max V x D (m<sup>2</sup>/s)</b>
Police Station	Tertiary Road	● Residential	< 0.4
Hospital	Railway Line	● Commercial	0.4 - 0.8
School/College	Flood Model Extent	▲ Industrial	0.8 - 1.2
Nursing Home/Aged Care		★ Public	> 1.2
Carvaran Park		■ 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	

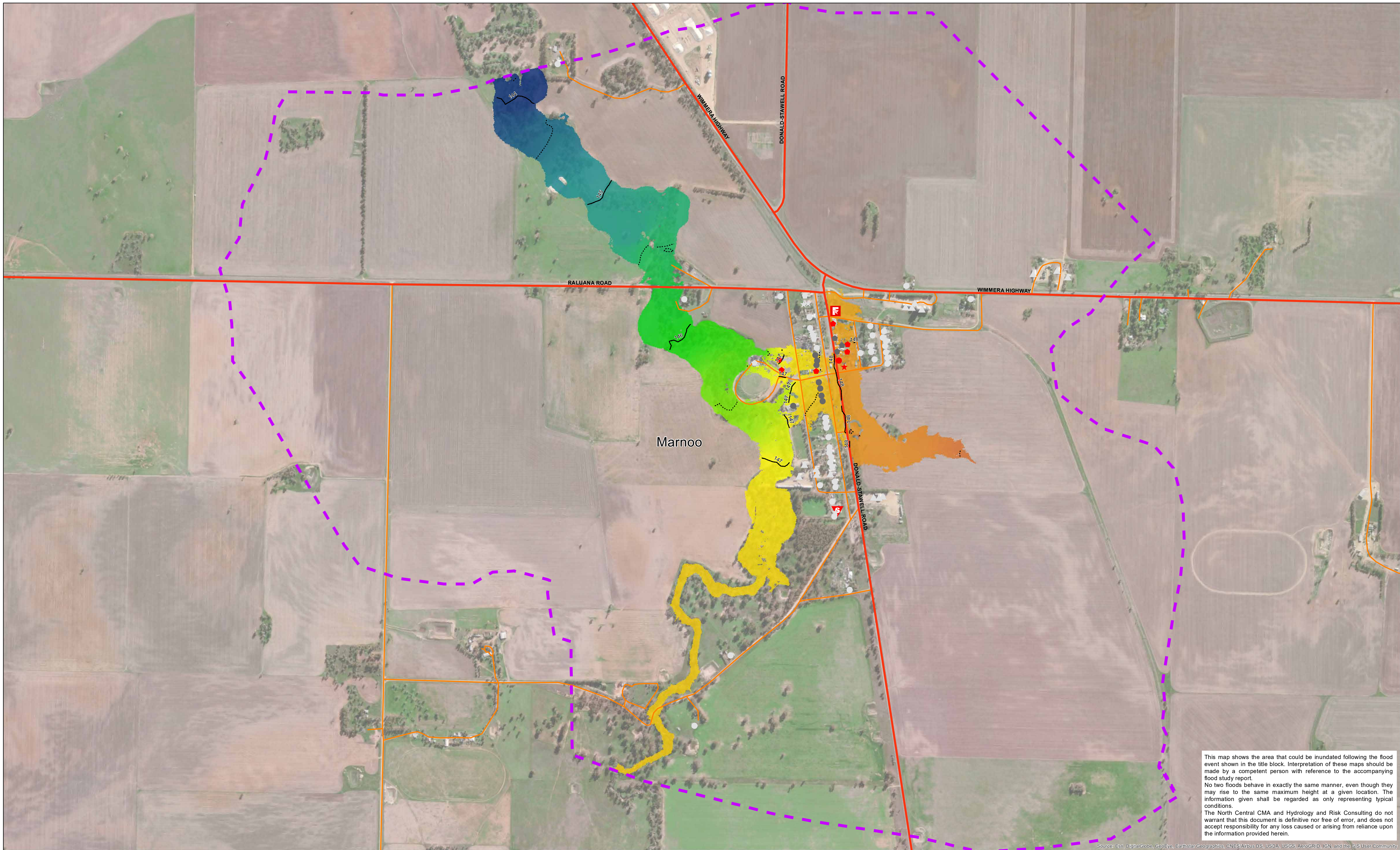
**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT**  
 MAXIMUM V x D (m<sup>2</sup>/s)

**Marnoo - 10% AEP Flood Event**

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 25/02/2020	Map No.: 21 - 10 - 2





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.

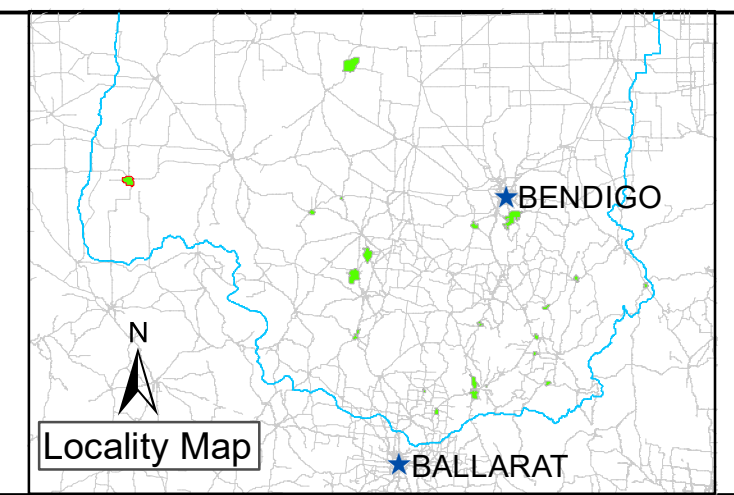
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.

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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HmaxMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

	CFAMFB Fire Station		Main Road	<b>Building Classification</b>	 High : 149 Low : 144
	Police Station		Tertiary Road		
	Hospital		Railway Line		Commercial
	School/College		Flood Model Extent		Industrial
	Nursing Home/Aged Care		Contour (1m)		Public
	Carvaran Park		Contour (0.5m)		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 WATER LEVEL (mAHD)**

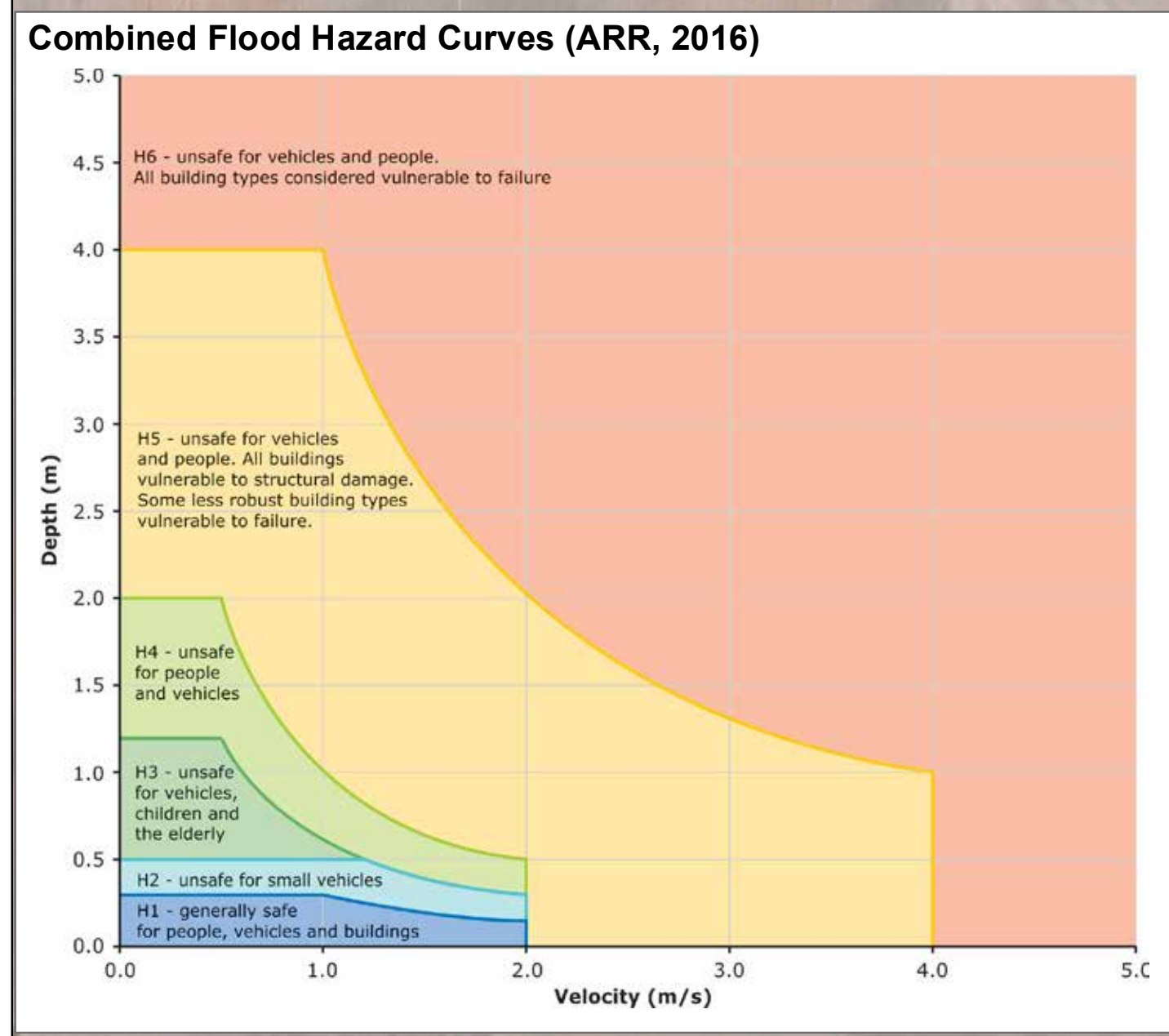
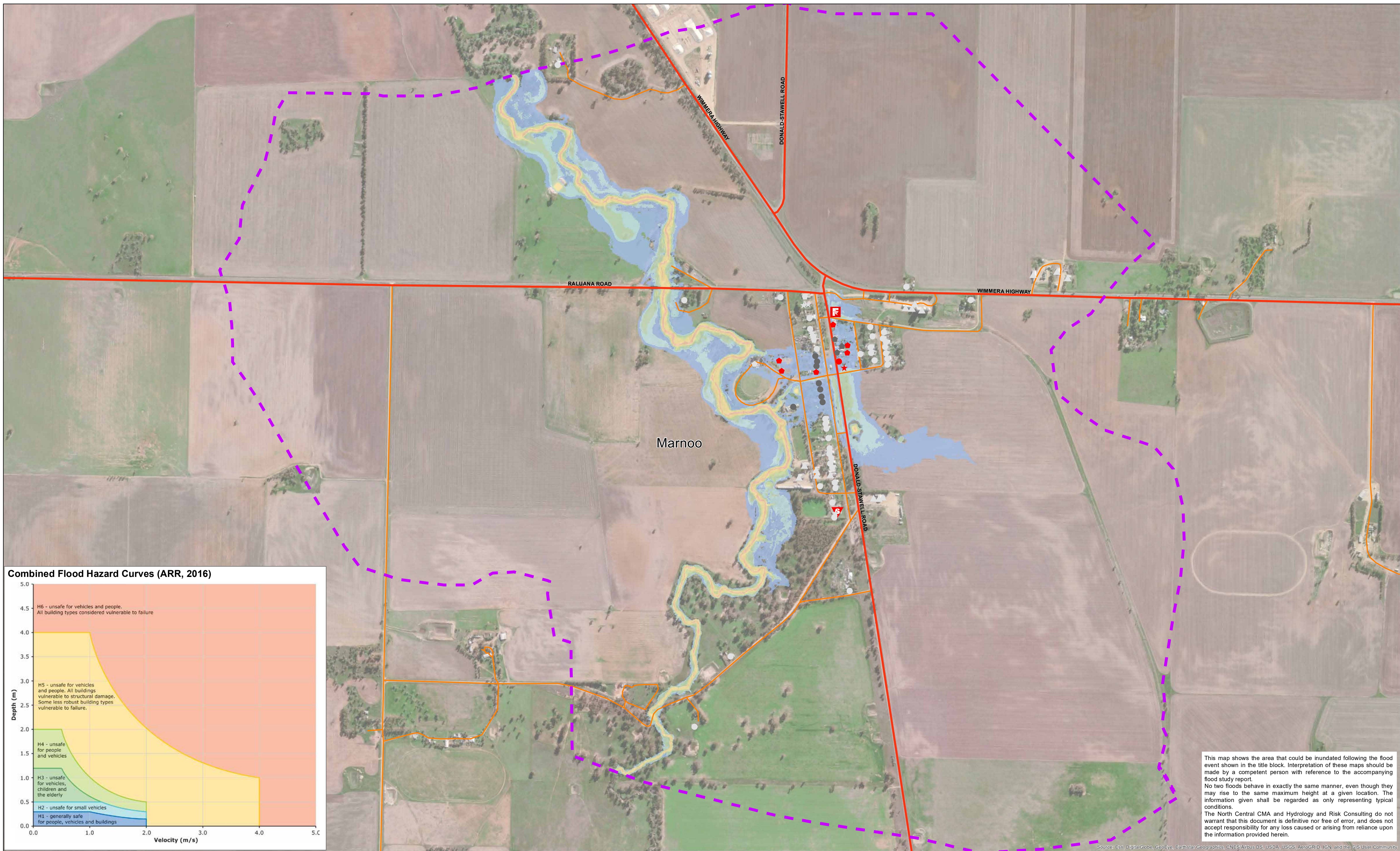
**Marnoo - 10% AEP Flood Event**

Meters

Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 26/02/2020	Map No.: 21 - 10 - 3





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.

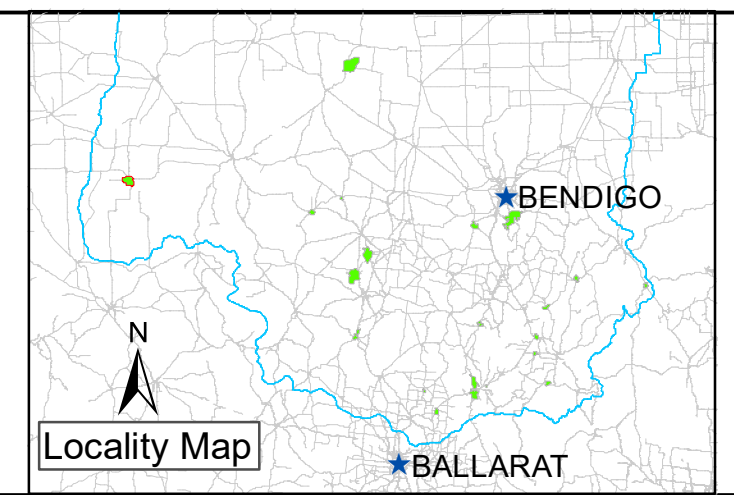
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.

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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HazardsMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

CFAM/FB Fire Station	Main Road	<b>Building Classification</b>
Police Station	Tertiary Road	Residential
Hospital	Railway Line	Commercial
School/College	Flood Model Extent	Industrial
Nursing Home/Aged Care		Public
Caravan Park		<b>Building Inundation</b>
		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	

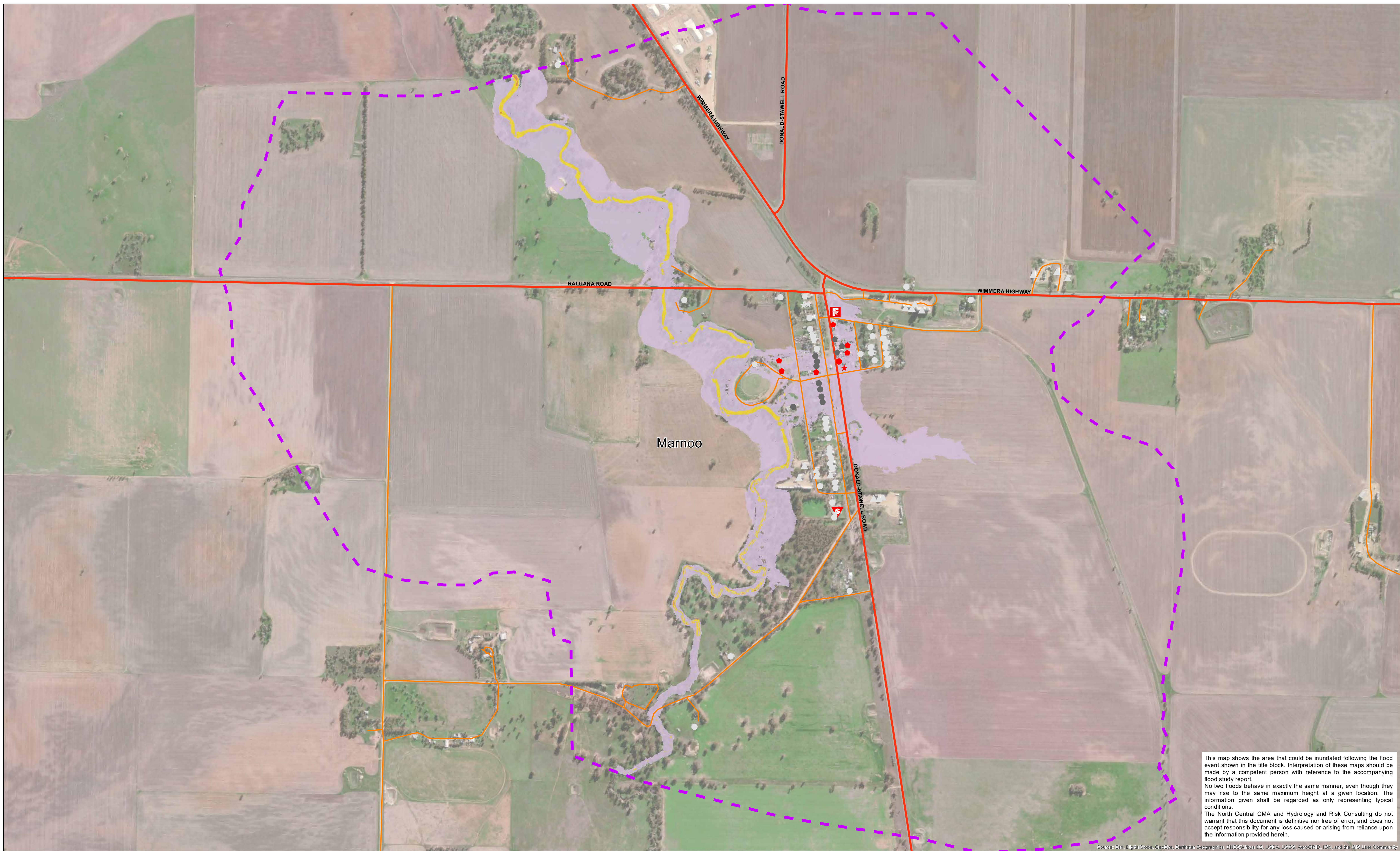
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
 MAXIMUM HAZARD

**Marnoo - 10% AEP Flood Event**

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 26/02/2020	Map No.: 21 - 10 - 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.

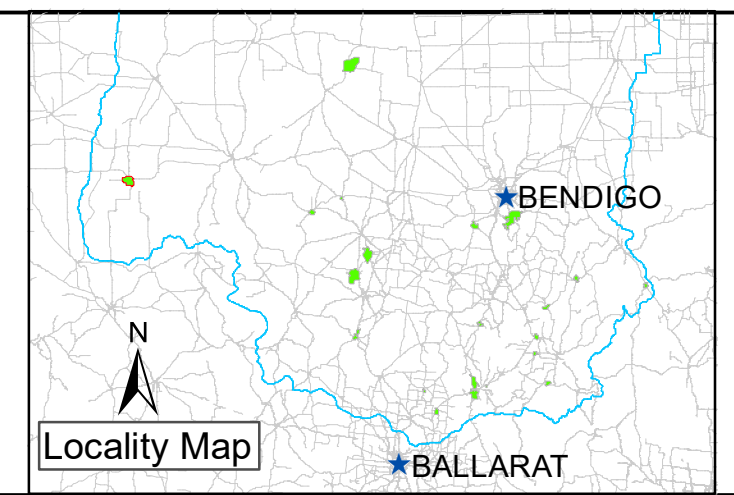
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.

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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

	CFAMFB Fire Station		Main Road	<b>Building Classification</b>		< 1
	Police Station		Tertiary Road			1 - 2
	Hospital		Railway Line			2 - 3
	School/College		Flood Model Extent			> 3
	Nursing Home/Aged Care					
	Carvaran Park			<b>Building Inundation</b>		



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)**

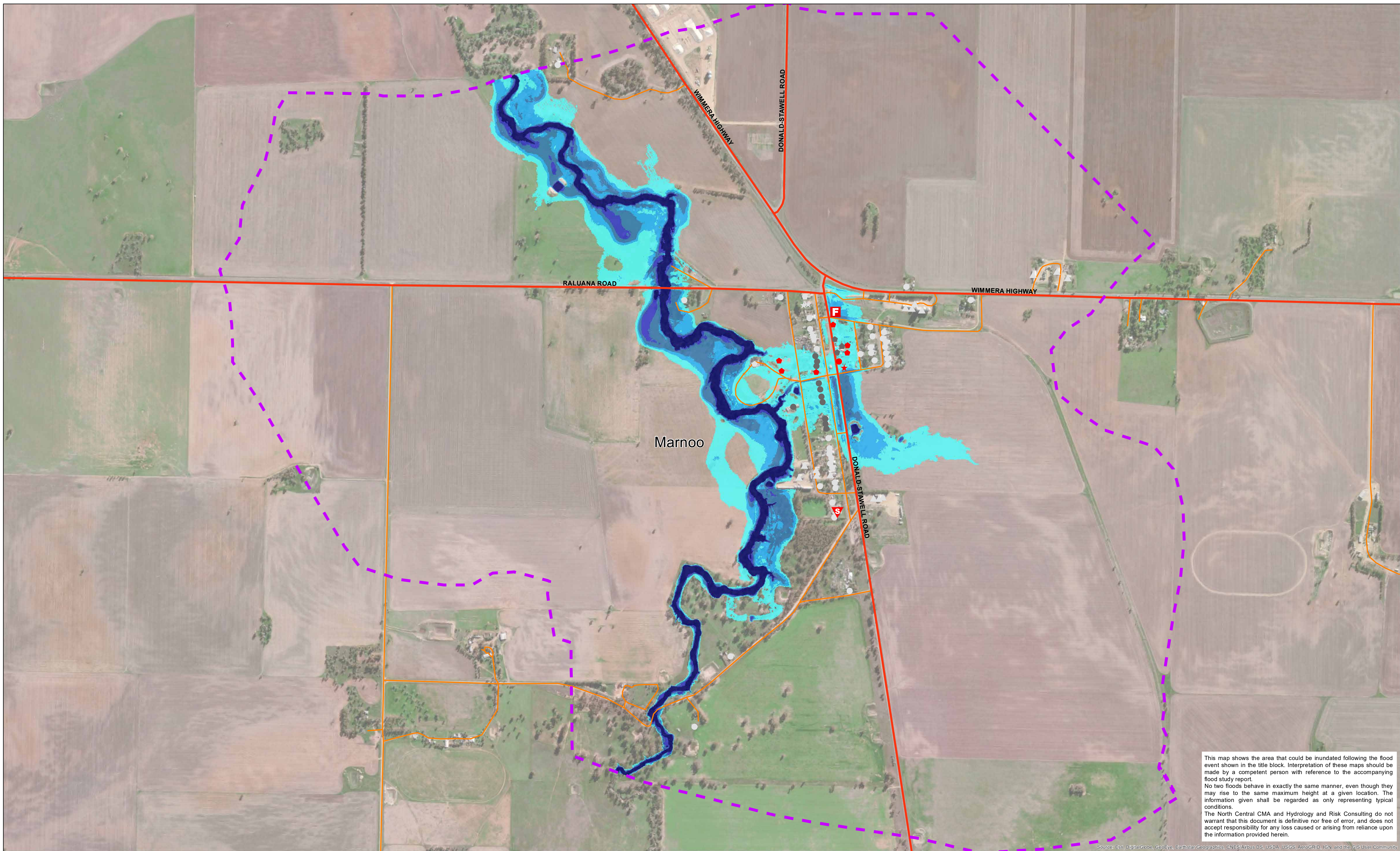
**Marnoo - 10% AEP Flood Event**

0 200 400 600 800  
Meters

Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 25/02/2020	Map No.: 21 - 10 - 5





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.

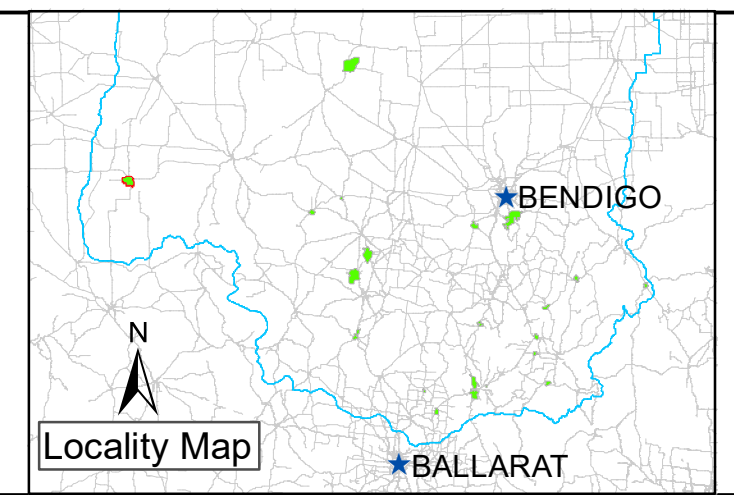
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.

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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

CFA/MFB Fire Station	Main Road	<b>Building Classification</b>	<b>Max Depth (m)</b>
Police Station	Tertiary Road	Residential	< 0.3
Hospital	Railway Line	Commercial	0.3 - 0.5
School/College	Flood Model Extent	Industrial	0.5 - 0.8
Nursing Home/Aged Care		Public	0.8 - 1.2
Caravan Park		not inundated	> 1.2
		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	

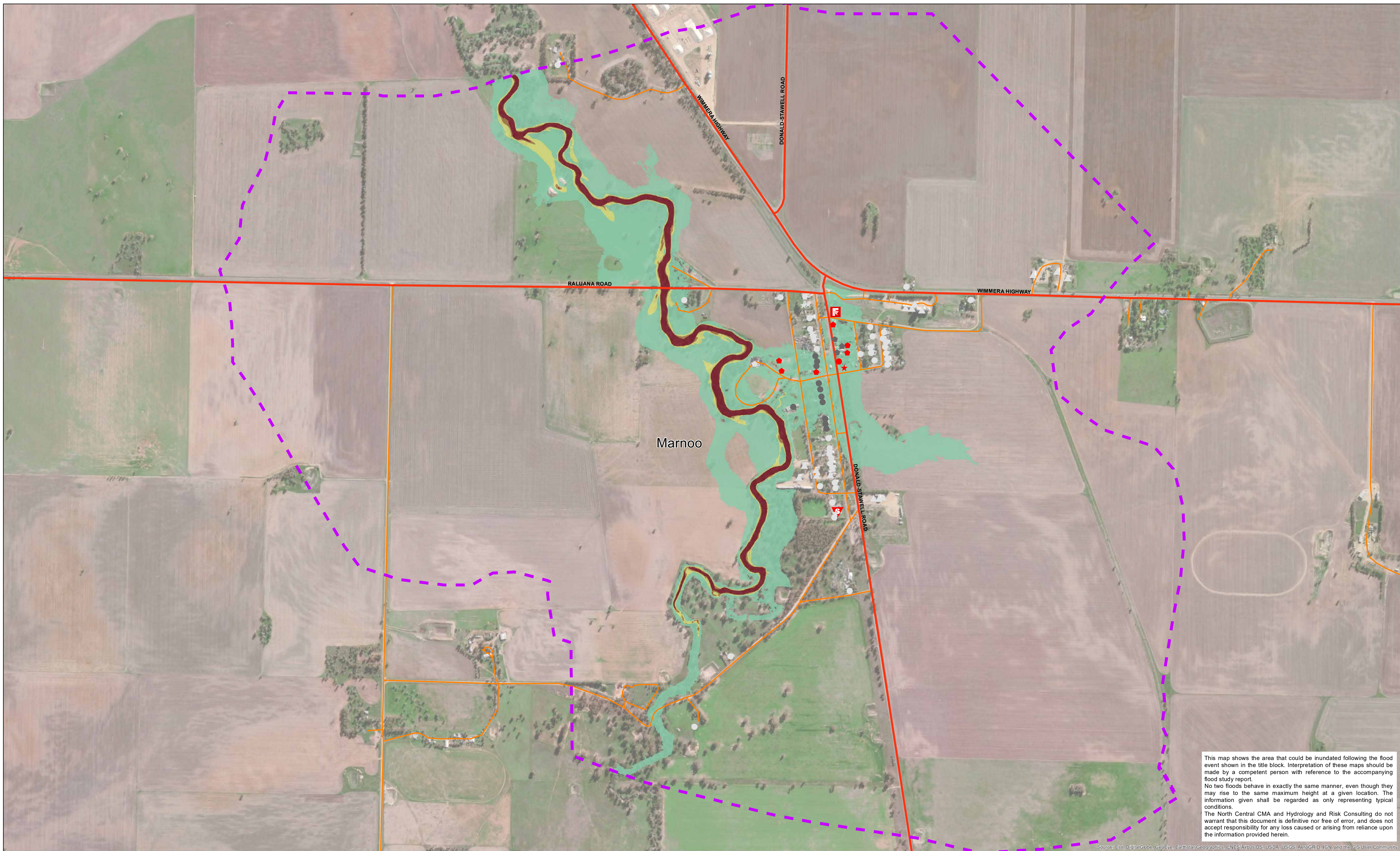
**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT**  
**MAXIMUM DEPTH (m)**

**Marnoo - 5% AEP Flood Event**

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 25/02/2020	Map No.: 21 - 20 - 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.

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.

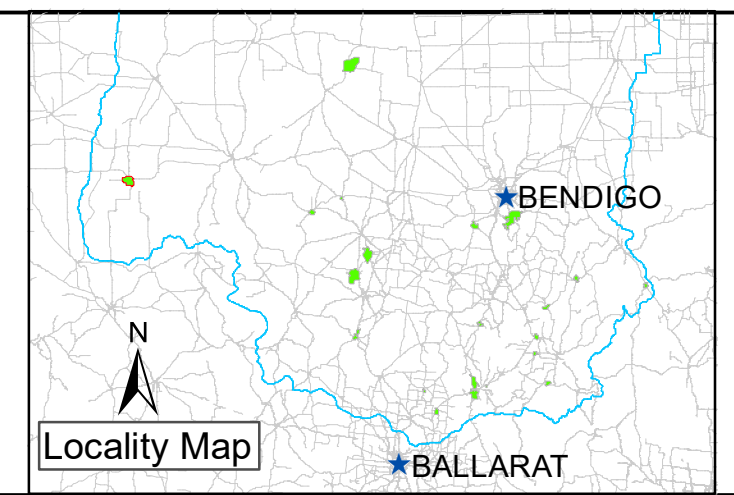
The North Central CMA and Hydrology and Risk Consulting do not warrant that this document is definitive nor free of error, and does not accept responsibility for any loss caused or arising from reliance upon the information provided herein.

Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VxDmaxMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

	CFM/FB Fire Station		Main Road	<b>Building Classification</b> ● Residential ● Commercial ▲ Industrial ★ Public <b>Building Inundation</b> ■ not inundated ■ inundated (without floor level survey) ■ below floor level (with floor level survey) ■ above floor level (with floor level survey)
	Police Station		Tertiary Road	
	Hospital		Railway Line	
	School/College		Flood Model Extent	
	Nursing Home/Aged Care			
	Carveran Park			

<b>Max V x D (m²/s)</b>		< 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	

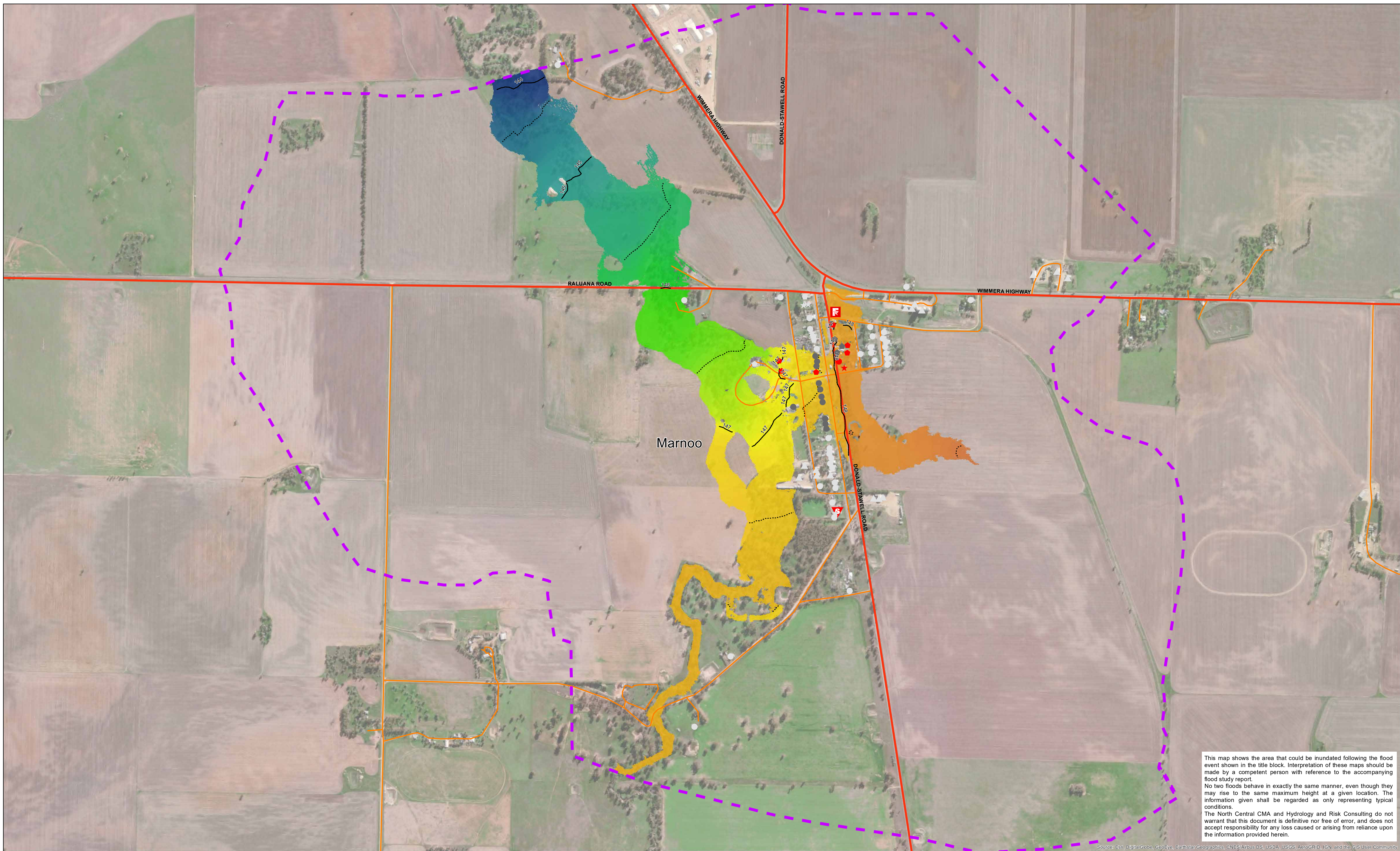
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
 MAXIMUM V x D (m²/s)

**Marnoo - 5% AEP Flood Event**

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 25/02/2020	Map No.: 21 - 20 - 2





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.

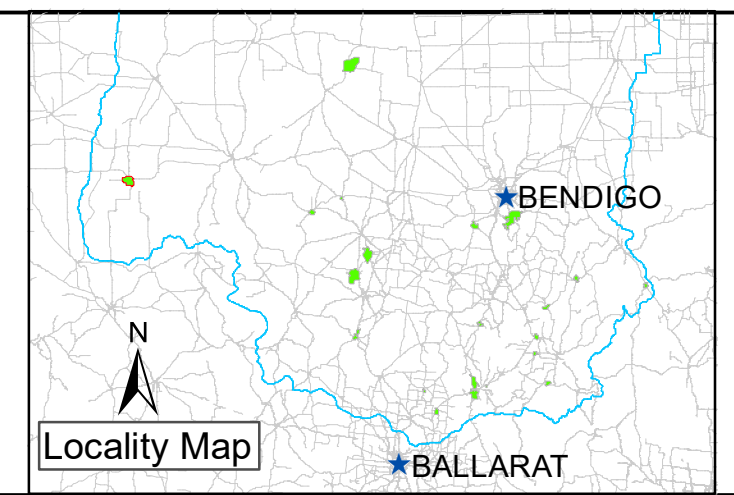
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.

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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HmaxMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

CFAMFB Fire Station	Main Road	<b>Building Classification</b>	<b>Max WSE (mAHD) Marnoo</b>
Police Station	Tertiary Road	Residential	High : 149
Hospital	Railway Line	Commercial	Low : 144
School/College	Flood Model Extent	Industrial	
Nursing Home/Aged Care	Contour (1m)	Public	
Carvaran Park	Contour (0.5m)	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 WATER LEVEL (mAHD)**

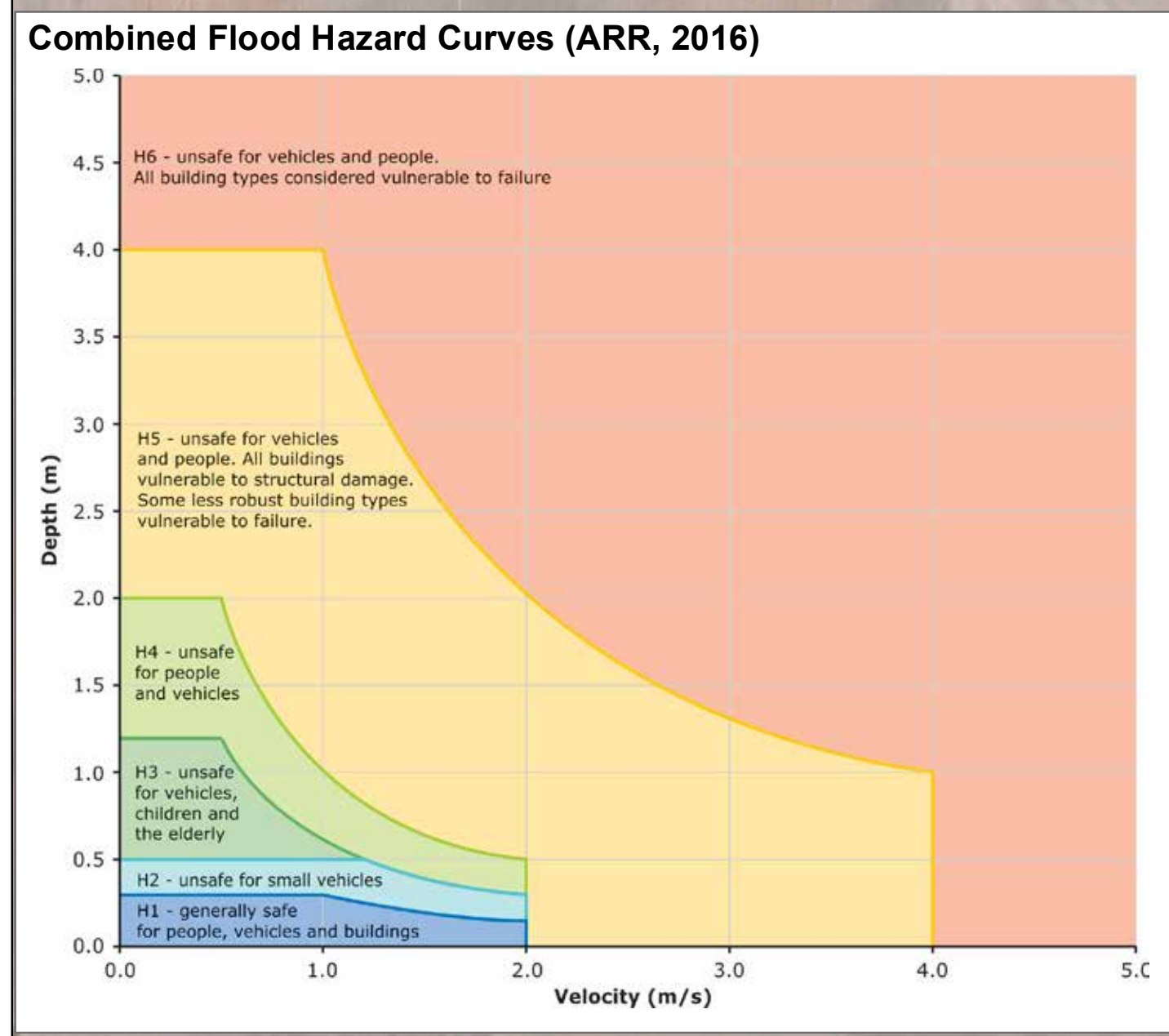
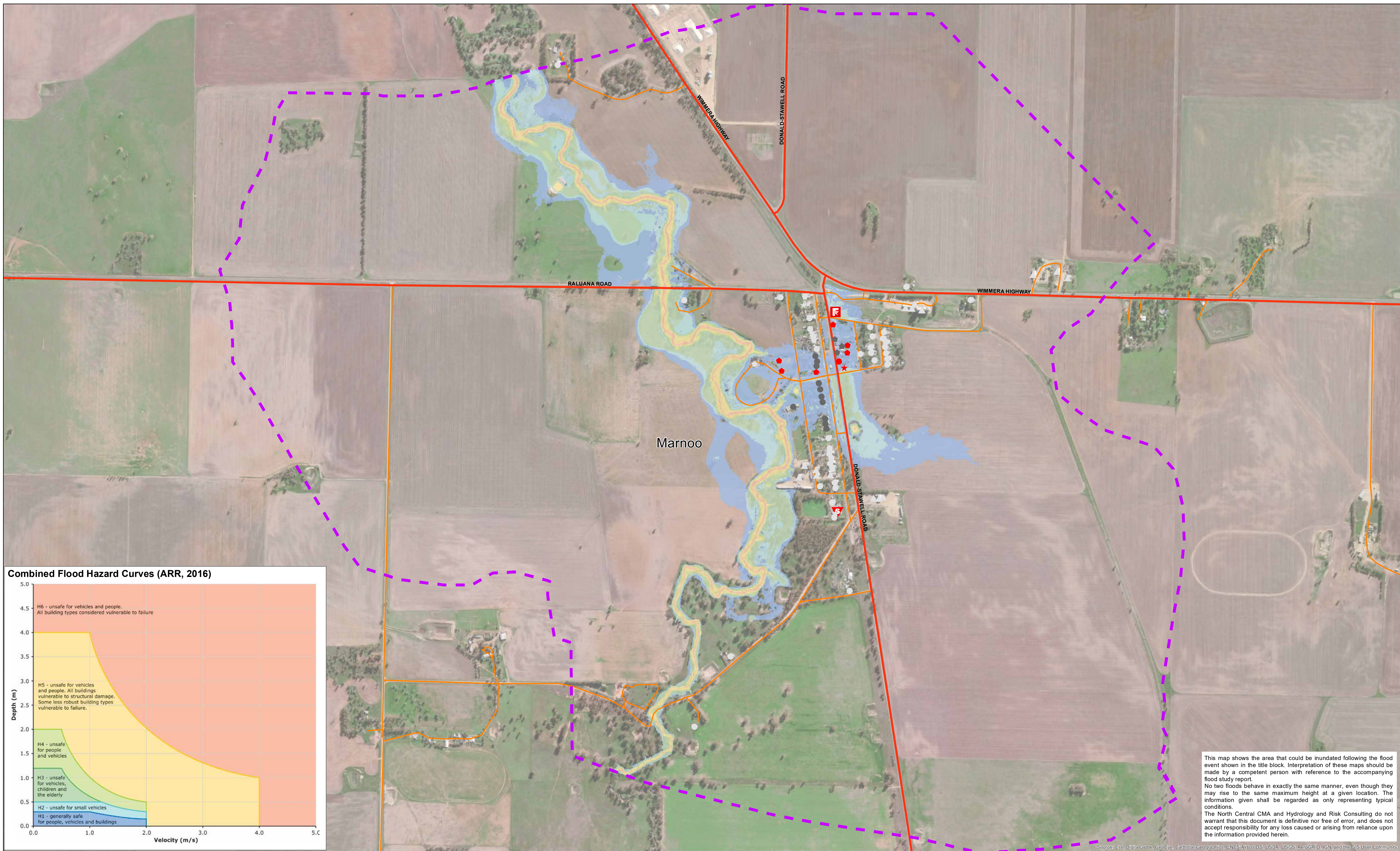
**Marnoo - 5% AEP Flood Event**

0 200 400 600 800  
Meters

Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 26/02/2020	Map No.: 21 - 20 - 3





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.

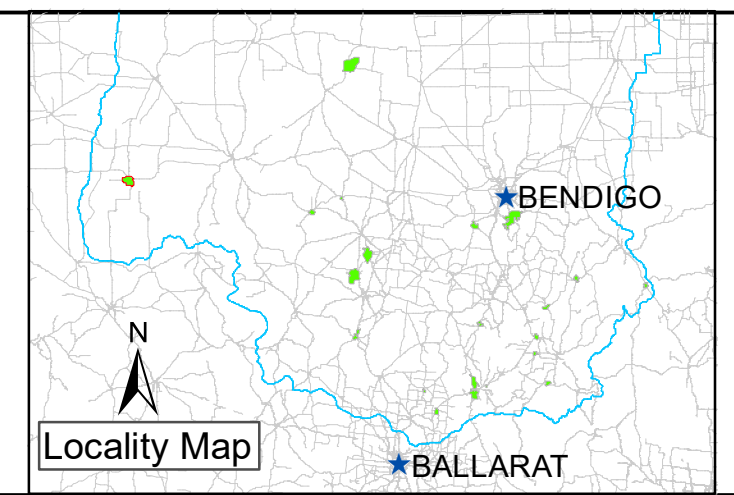
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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HazardsMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

CFAMFB Fire Station	Main Road	<b>Building Classification</b>
Police Station	Tertiary Road	Residential
Hospital	Railway Line	Commercial
School/College	Flood Model Extent	Industrial
Nursing Home/Aged Care		Public
Caravan Park		<b>Building Inundation</b>
		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	

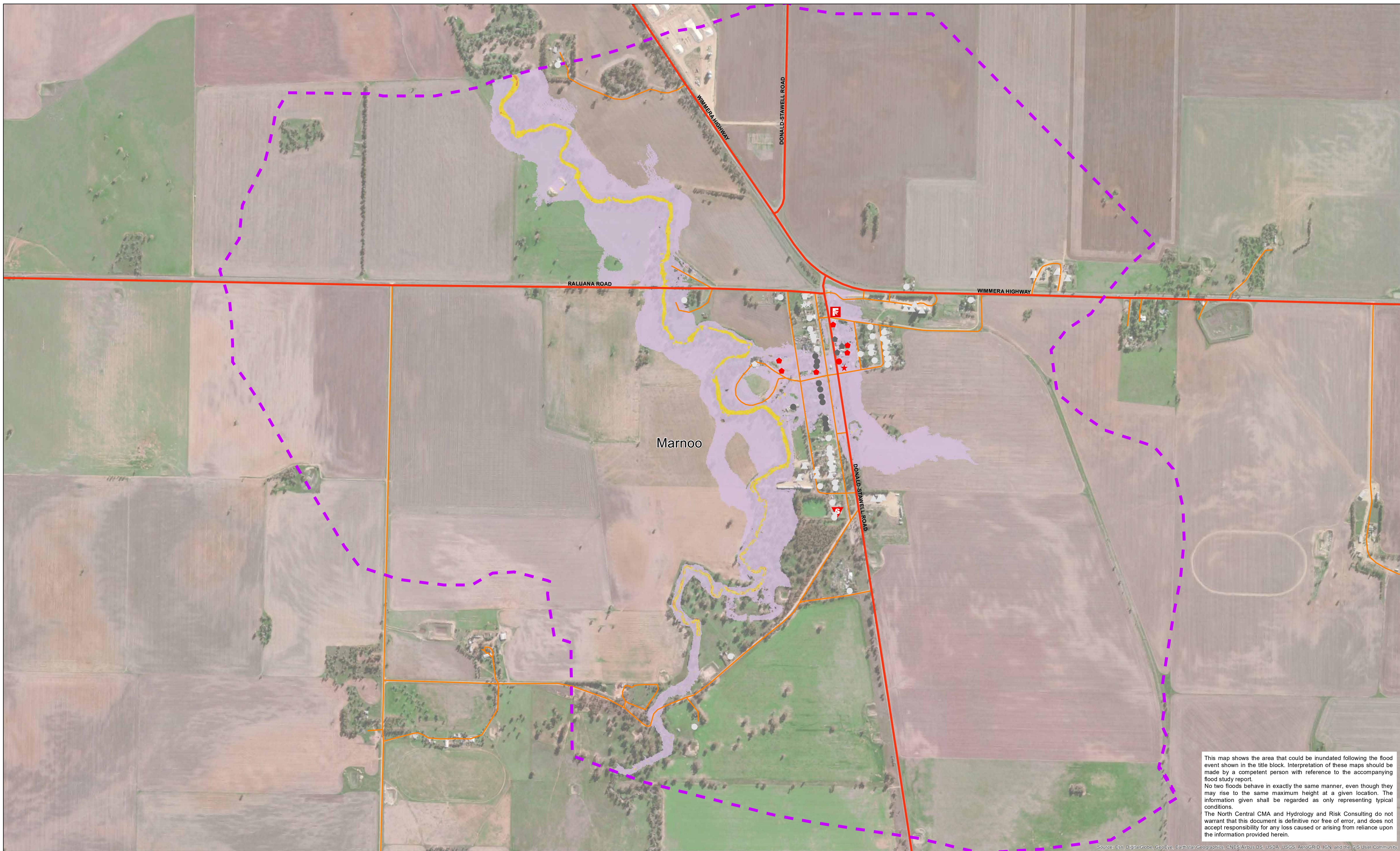
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
 MAXIMUM HAZARD

**Marnoo - 5% AEP Flood Event**

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 26/02/2020	Map No.: 21 - 20 - 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.

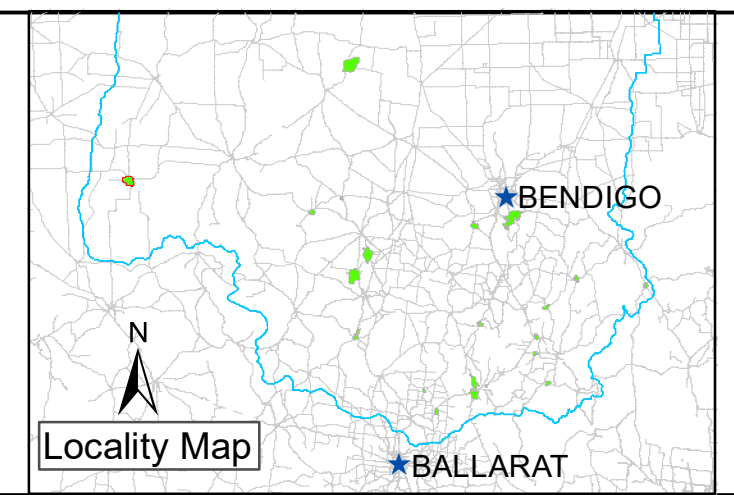
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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

CFA/MFB Fire Station	Main Road	<b>Building Classification</b>	< 1
Police Station	Tertiary Road	Residential	1 - 2
Hospital	Railway Line	Commercial	2 - 3
School/College	Flood Model Extent	Industrial	> 3
Nursing Home/Aged Care		Public	
Carvaran Park		<b>Building Inundation</b>	
		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	

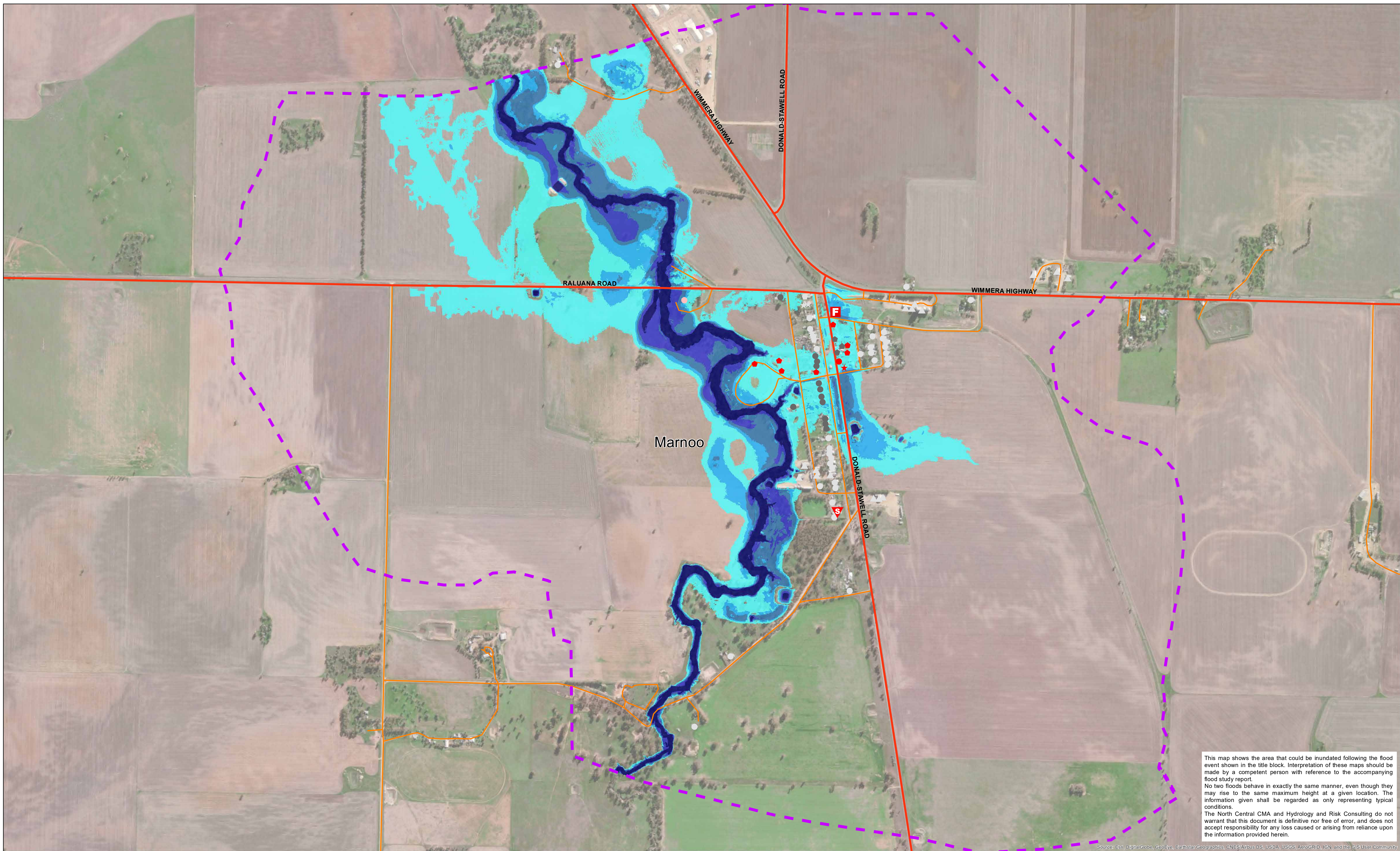
**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT**  
**MAXIMUM VELOCITY (m/s)**

**Marnoo - 5% AEP Flood Event**

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 25/02/2020	Map No.: 21 - 20 - 5





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.

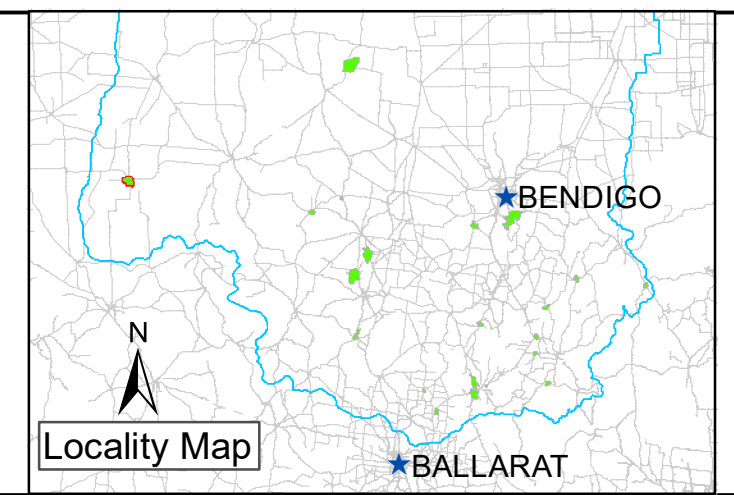
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.

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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

CFA/MFB Fire Station	Main Road	<b>Building Classification</b>	<b>Max Depth (m)</b>
Police Station	Tertiary Road	● Residential	< 0.3
Hospital	Railway Line	● Commercial	0.3 - 0.5
School/College	Flood Model Extent	▲ Industrial	0.5 - 0.8
Nursing Home/Aged Care		★ Public	0.8 - 1.2
Caravan Park		■ not inundated	> 1.2
		■ 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	

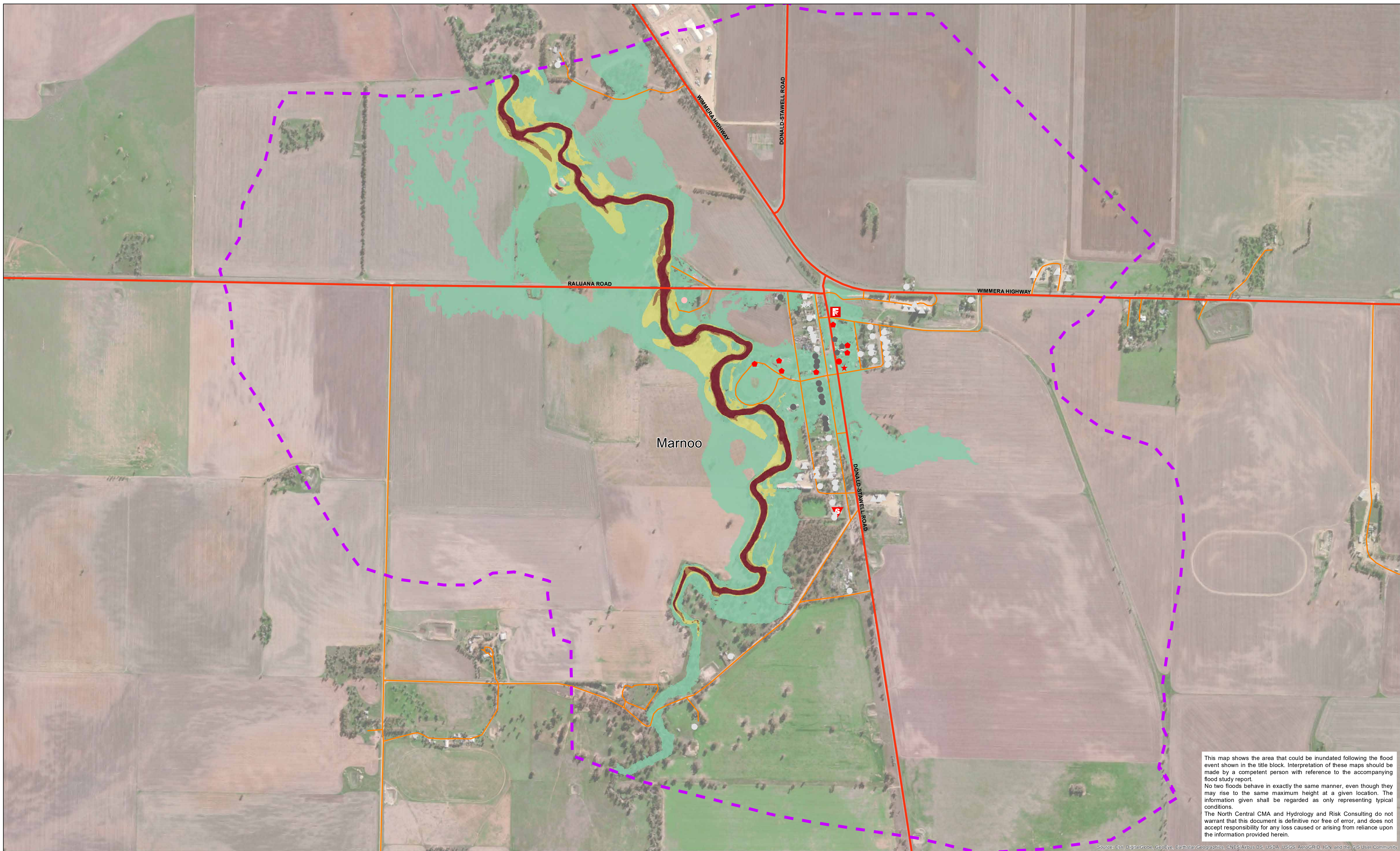
**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT**  
**MAXIMUM DEPTH (m)**

**Marnoo - 2% AEP Flood Event**

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 25/02/2020	Map No.: 21 - 50 - 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.

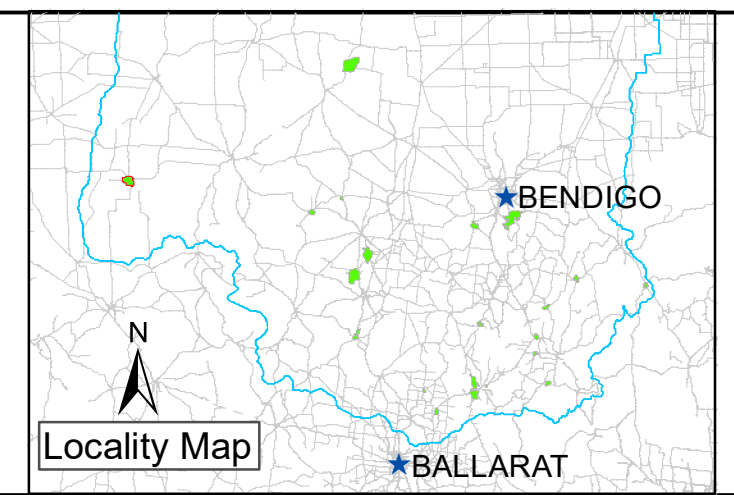
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.

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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VxDmaxMGA54.m  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

	CFM/MFB Fire Station		Main Road	<b>Building Classification</b> ● Residential ● Commercial ▲ Industrial ★ Public <b>Building Inundation</b> ■ not inundated ■ inundated (without floor level survey) ■ below floor level (with floor level survey) ■ above floor level (with floor level survey)
	Police Station		Tertiary Road	
	Hospital		Railway Line	
	School/College		Flood Model Extent	
	Nursing Home/Aged Care			
	Caravan Park			



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 (m<sup>2</sup>/s)

**Marnoo - 2% AEP Flood Event**

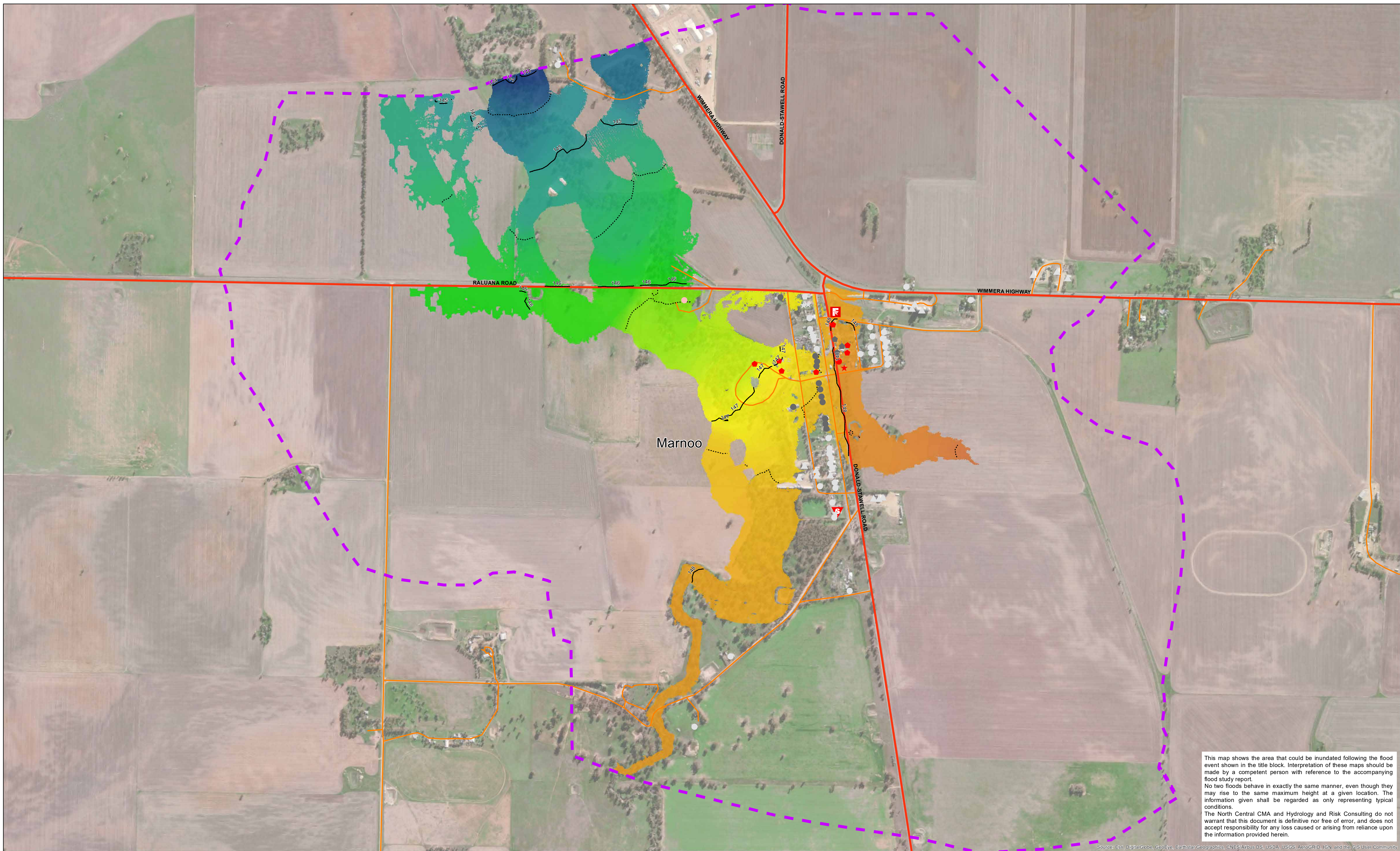
Scale: 1:7,000  
when printed @ A1

Date: 25/02/2020

Map No.: 21 - 50 - 2

Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 54





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.

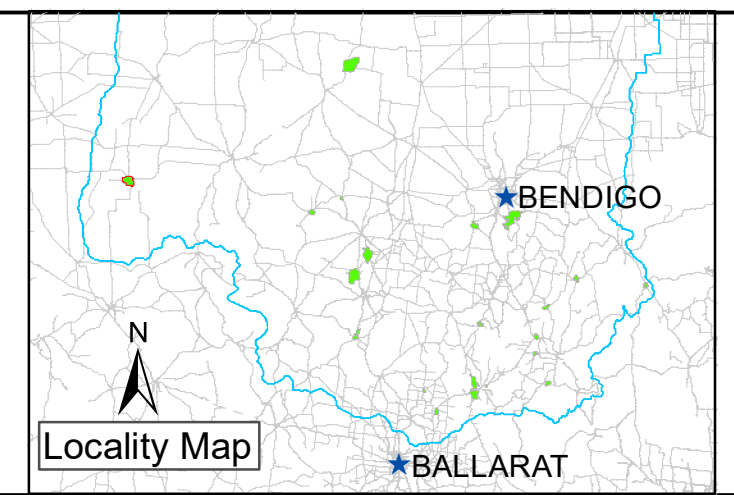
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.

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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HmaxMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

	CFM/MFB Fire Station		Main Road	<b>Building Classification</b> Residential Commercial Industrial Public	<b>Max WSE (mAHD) Marnoo</b> <b>Value</b>  High : 149 Low : 144
	Police Station		Tertiary Road		
	Hospital		Railway Line	<b>Building Inundation</b> not inundated inundated (without floor level survey) below floor level (with floor level survey) above floor level (with floor level survey)	
	School/College		Flood Model Extent		
	Nursing Home/Aged Care		Contour (1m)		
	Carvaran Park		Contour (0.5m)		



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)**

**Marnoo - 2% AEP Flood Event**

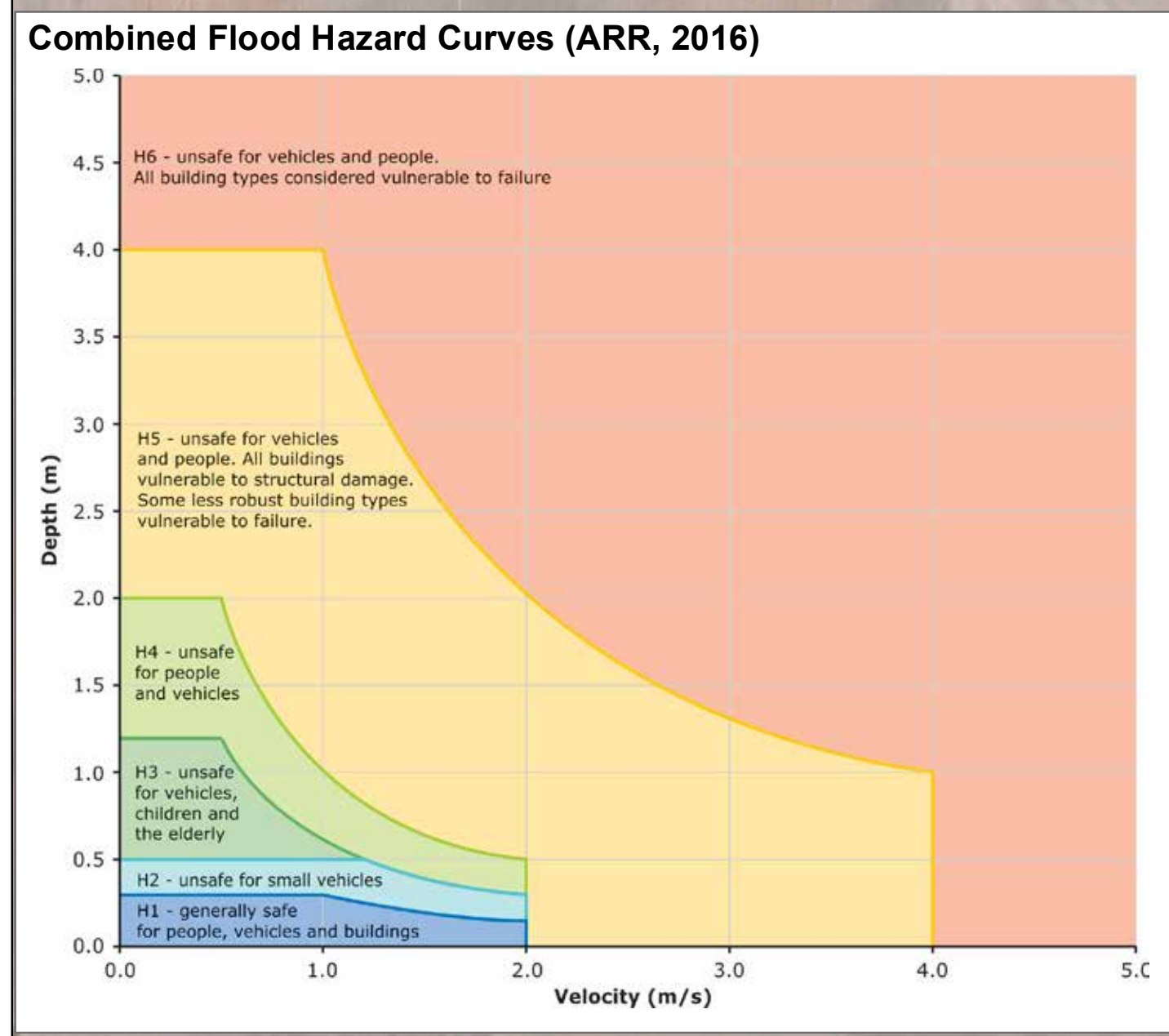
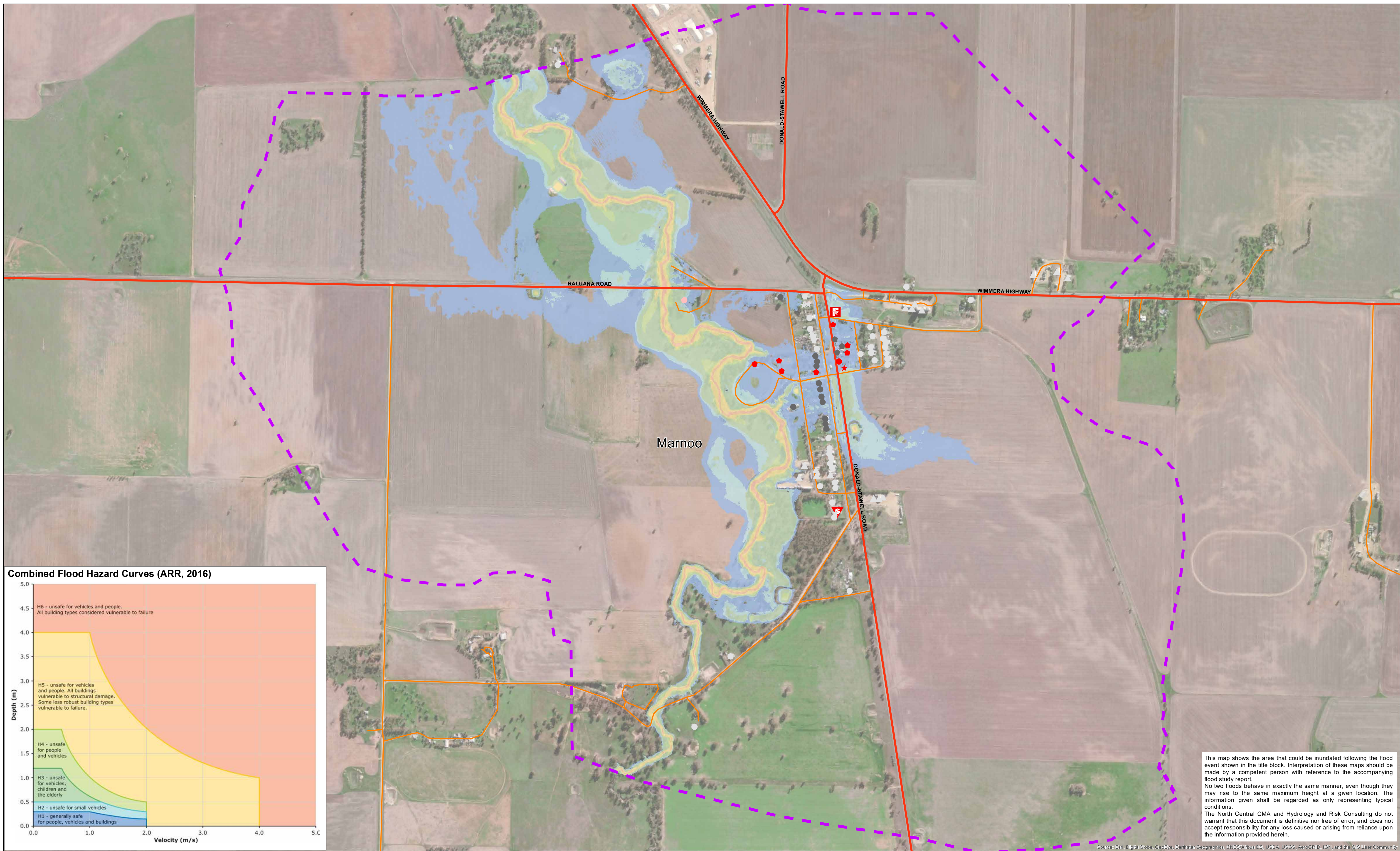
0 200 400 600 800  
Meters

N

Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 26/02/2020	Map No.: 21 - 50 - 3





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.

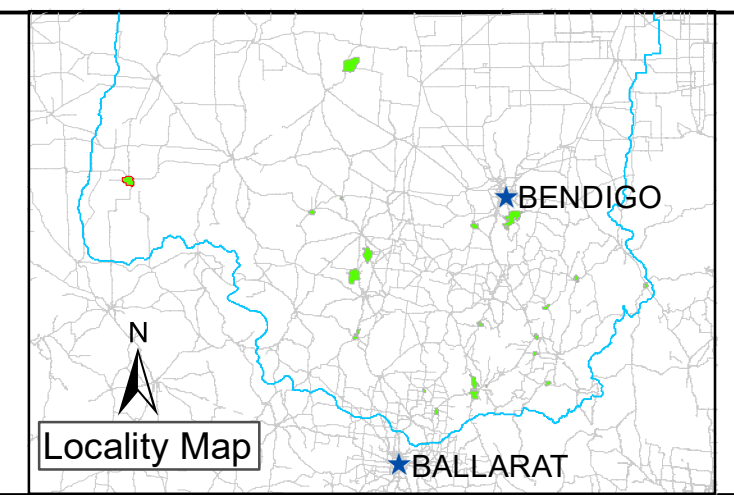
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.

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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HazardsMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

CFAMFB Fire Station	Main Road	Residential
Police Station	Tertiary Road	Commercial
Hospital	Railway Line	Industrial
School/College	Flood Model Extent	Public
Nursing Home/Aged Care		<b>Building Inundation</b>
Caravan Park		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	

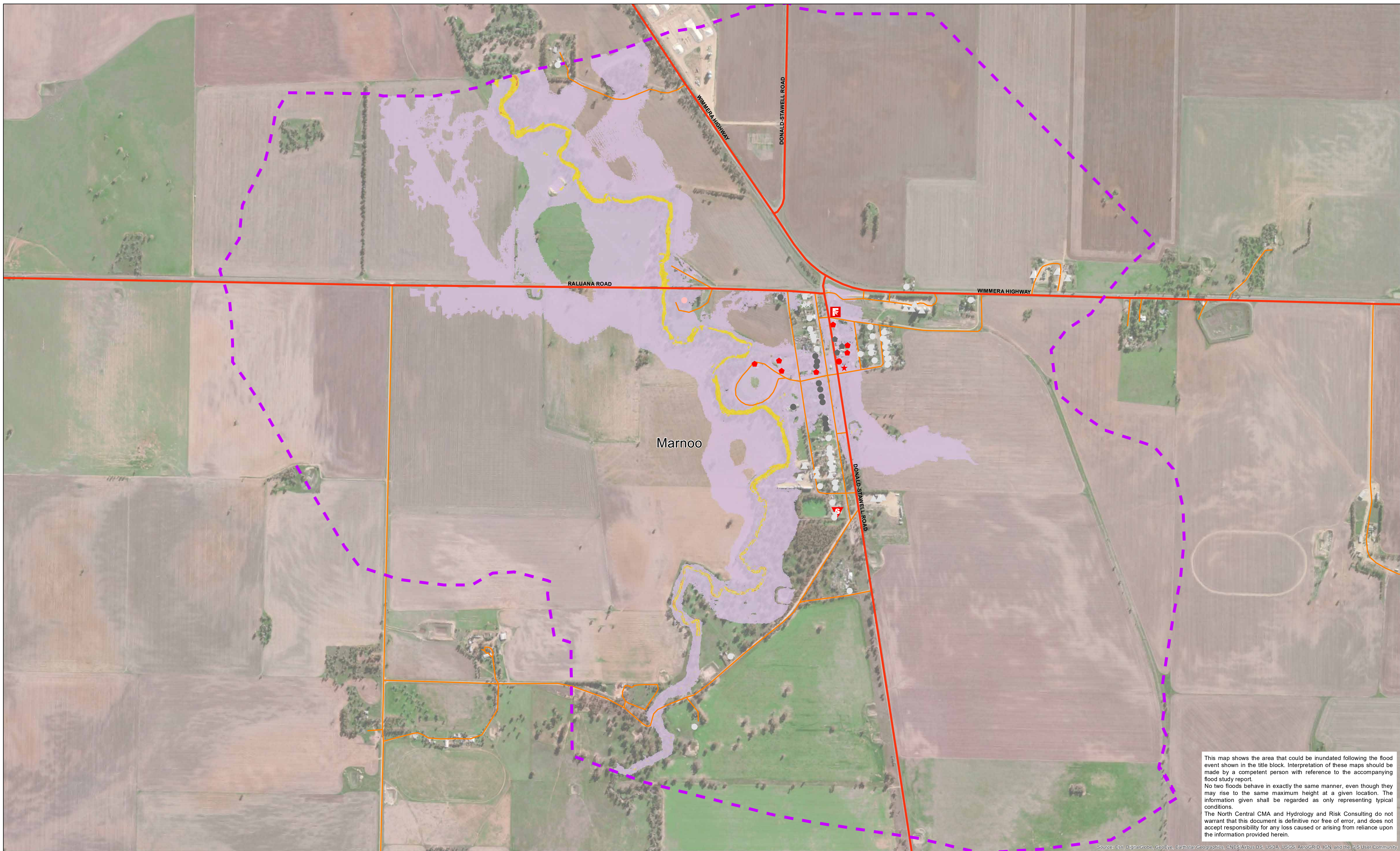
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
 MAXIMUM HAZARD

**Marnoo - 2% AEP Flood Event**

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 26/02/2020	Map No.: 21 - 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.

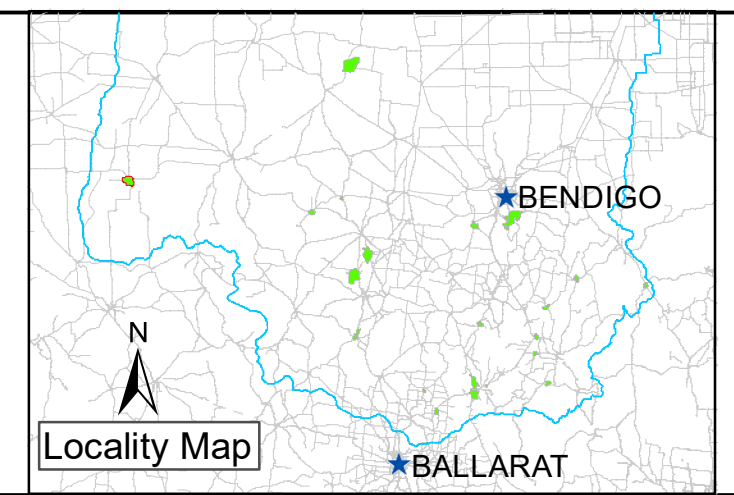
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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

	CFAMFB Fire Station		Main Road	<b>Building Classification</b>		< 1
	Police Station		Tertiary Road			1 - 2
	Hospital		Railway Line			2 - 3
	School/College		Flood Model Extent			> 3
	Nursing Home/Aged Care					
	Carvaran Park			<b>Building Inundation</b>		



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

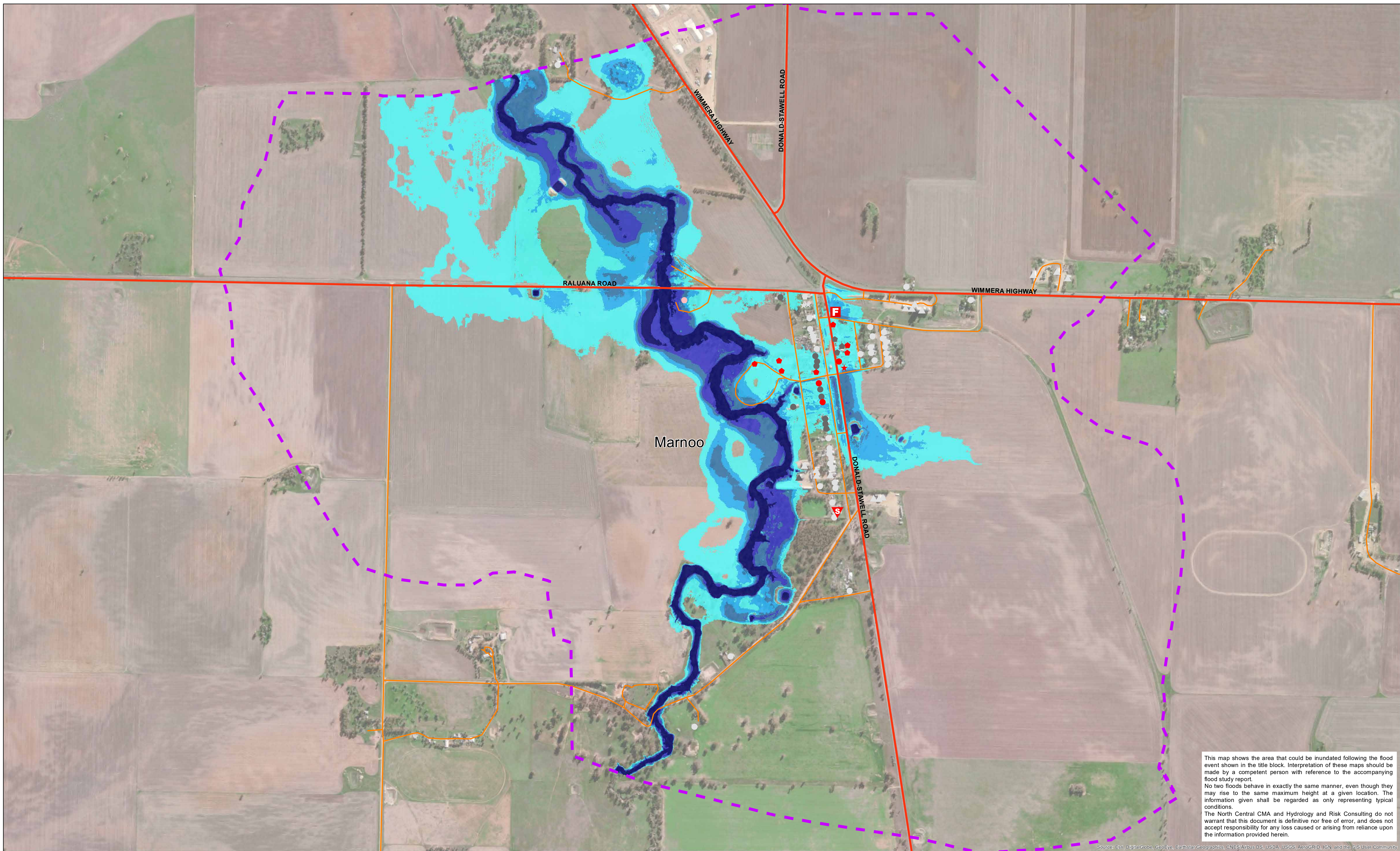
**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT**  
 MAXIMUM VELOCITY (m/s)

**Marnoo - 2% AEP Flood Event**

Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 25/02/2020	Map No.: 21 - 50 - 5





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.

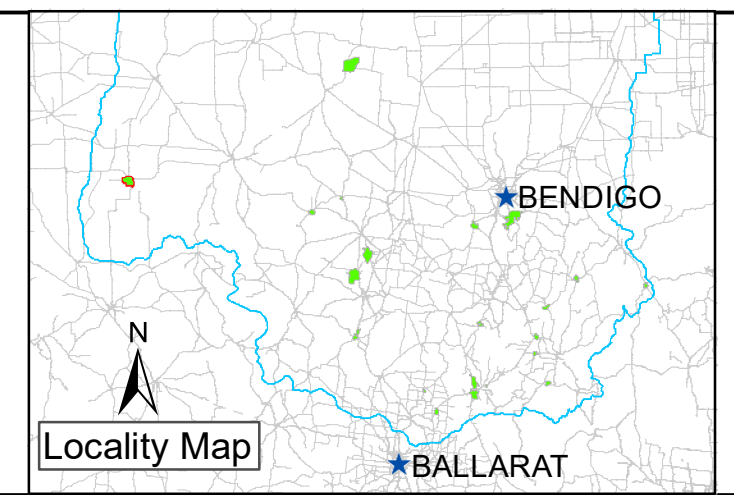
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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

CFA/MFB Fire Station	Main Road	<b>Building Classification</b>	<b>Max Depth (m)</b>
Police Station	Tertiary Road	Residential	< 0.3
Hospital	Railway Line	Commercial	0.3 - 0.5
School/College	Flood Model Extent	Industrial	0.5 - 0.8
Nursing Home/Aged Care		Public	0.8 - 1.2
Caravan Park		not inundated	> 1.2
		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 DEPTH (m)

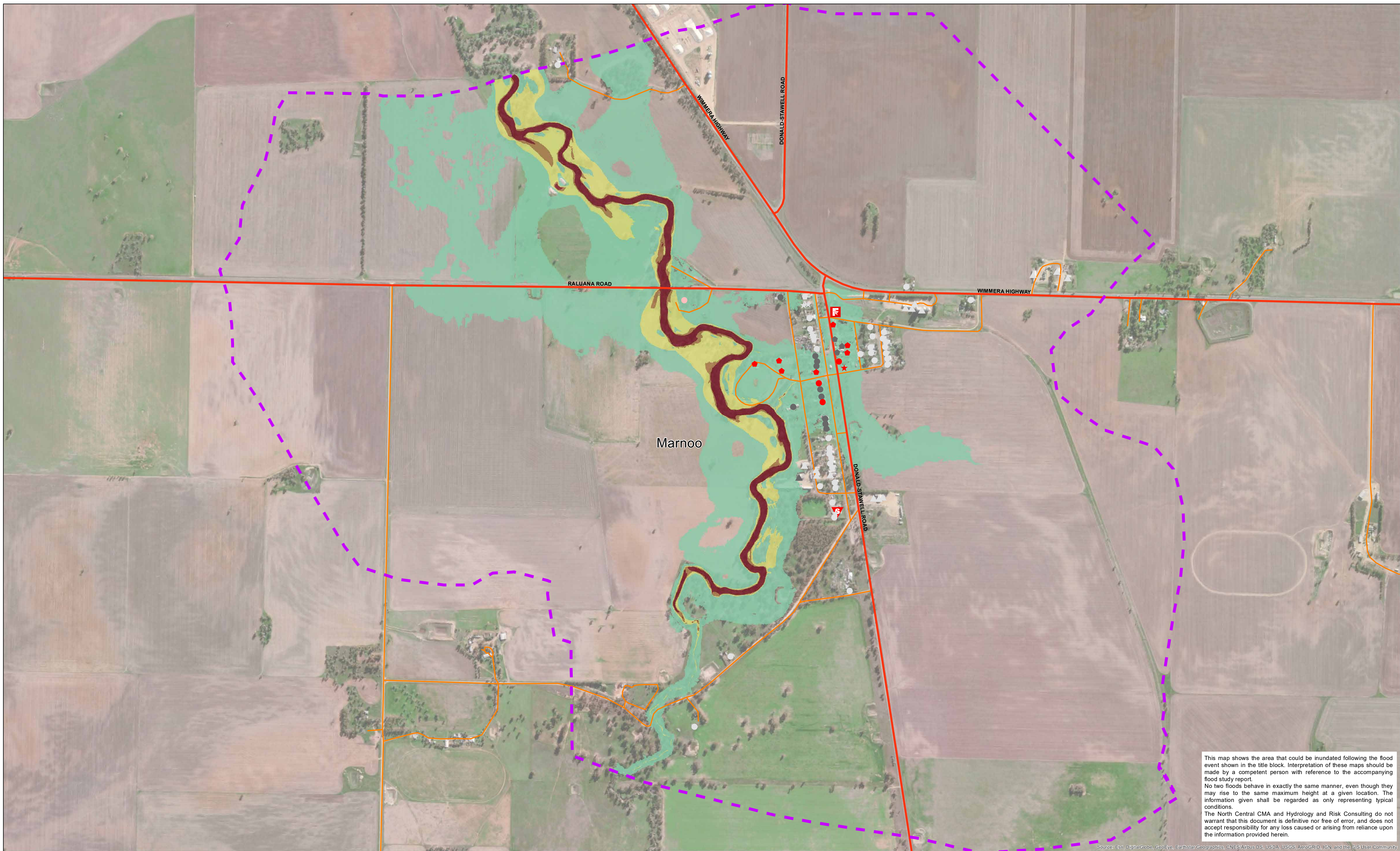
**Marnoo - 1% AEP Flood Event**

0 200 400 600 800  
Meters

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 25/02/2020	Map No.: 21 - 100 - 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.

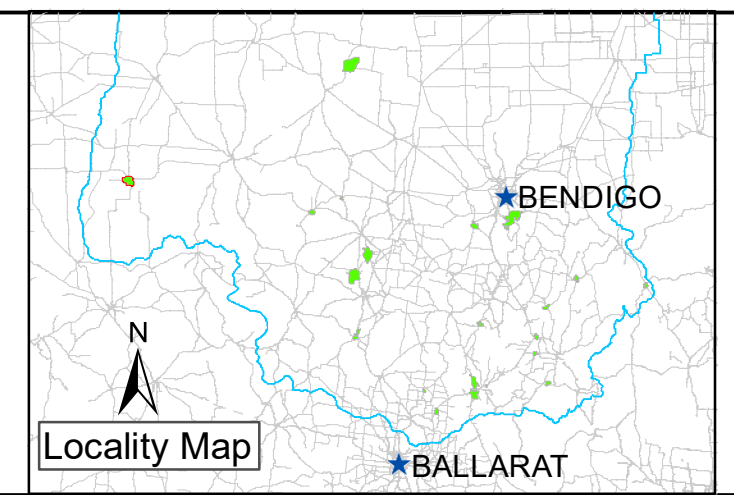
No two floods behave in exactly the same manner, even though they may rise to the same maximum height at a given location. The information given shall be regarded as only representing typical conditions.

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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VxDmaxMGA54.m  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

	CFA/MFB Fire Station		Main Road	<b>Building Classification</b> ● Residential ● Commercial ▲ Industrial ★ Public <b>Building Inundation</b> ■ not inundated ■ inundated (without floor level survey) ■ below floor level (with floor level survey) ■ above floor level (with floor level survey)
	Police Station		Tertiary Road	
	Hospital		Railway Line	
	School/College		Flood Model Extent	
	Nursing Home/Aged Care			<b>Max V x D (m²/s)</b> < 0.4 0.4 - 0.8 0.8 - 1.2 > 1.2
	Caravan Park			



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)

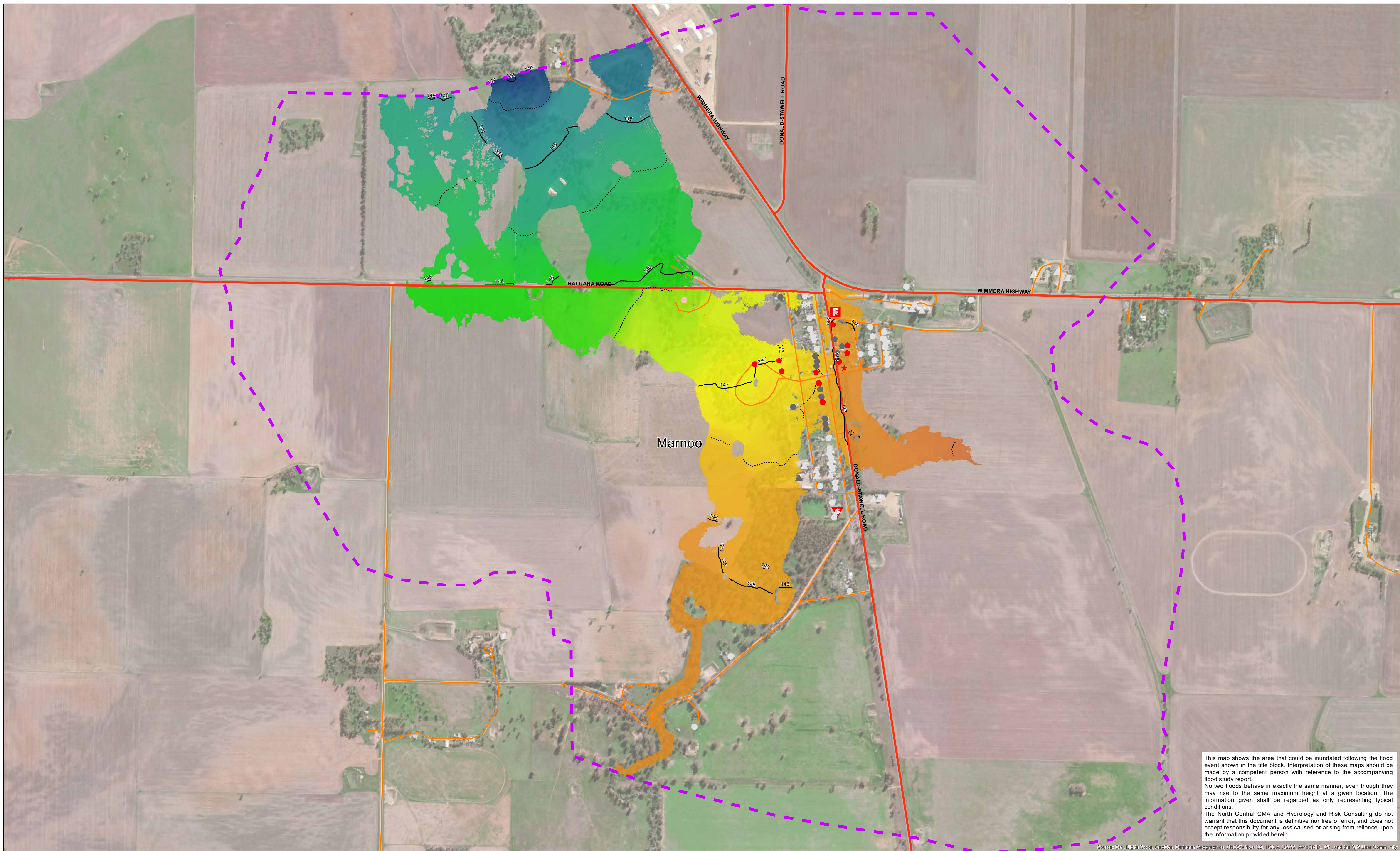
**Marnoo - 1% AEP Flood Event**

0 200 400 600 800  
Meters

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 25/02/2020	Map No.: 21 - 100 - 2





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.

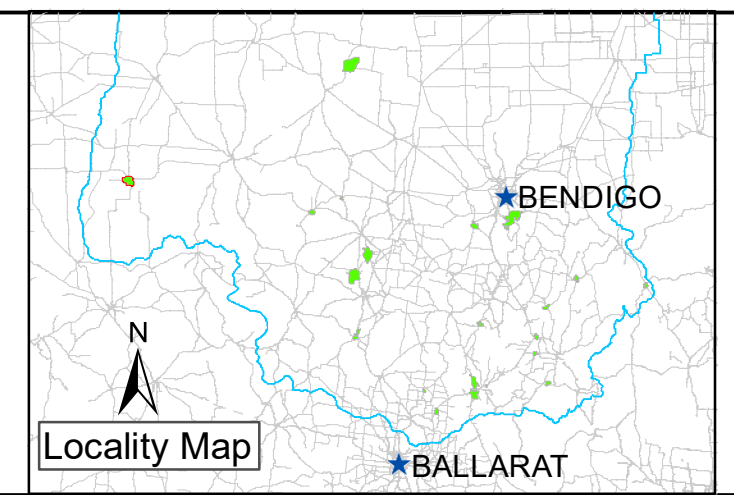
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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HmaxMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

CFAMFB Fire Station	Main Road	<b>Building Classification</b>	<b>Max WSE (mAHd) Marnoo</b>
Police Station	Tertiary Road	Residential	Value
Hospital	Railway Line	Commercial	High : 149
School/College	Flood Model Extent	Industrial	Low : 144
Nursing Home/Aged Care	Contour (1m)	Public	
Caravan Park	Contour (0.5m)	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	

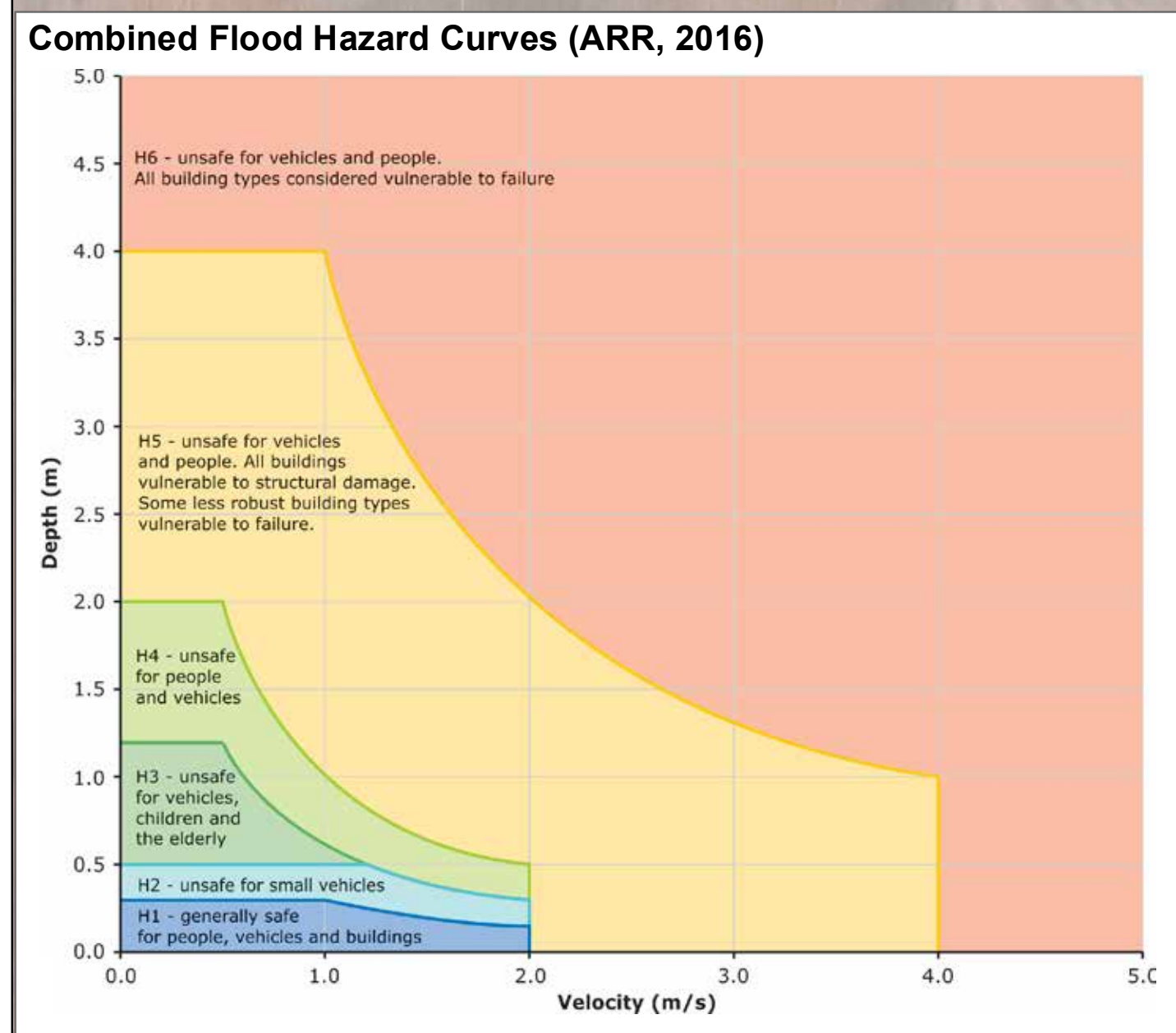
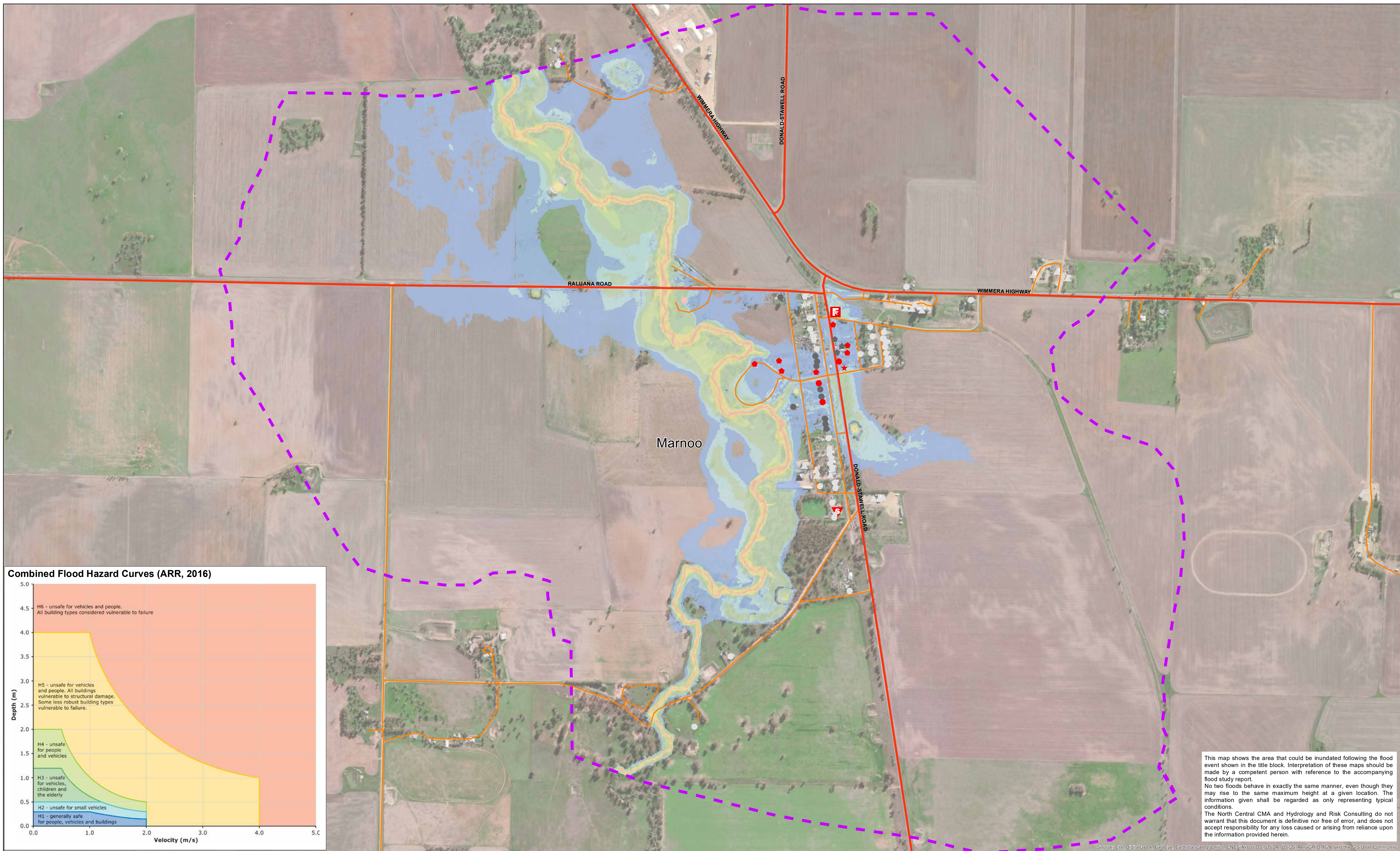
**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT**  
**MAXIMUM WATER LEVEL (mAHd)**

**Marnoo - 1% AEP Flood Event**

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 26/02/2020	Map No.: 21 - 100 - 3





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.

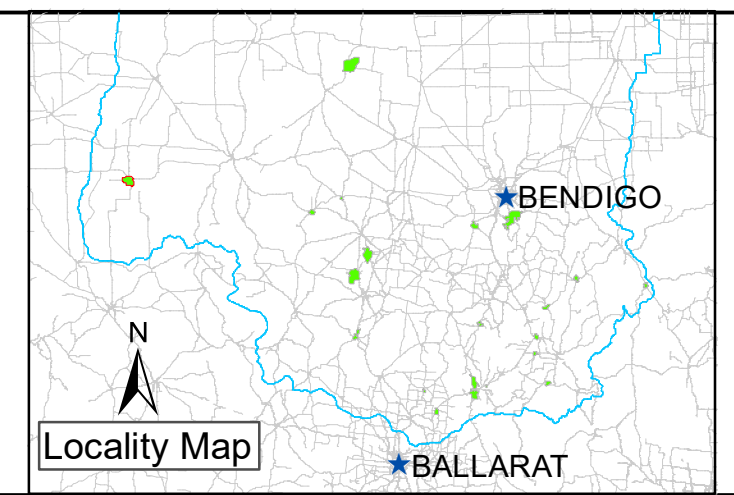
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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HazardsMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

CFAM/FB Fire Station	Main Road	<b>Building Classification</b>
Police Station	Tertiary Road	Residential
Hospital	Railway Line	Commercial
School/College	Flood Model Extent	Industrial
Nursing Home/Aged Care		Public
Caravan Park		<b>Building Inundation</b>
		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	

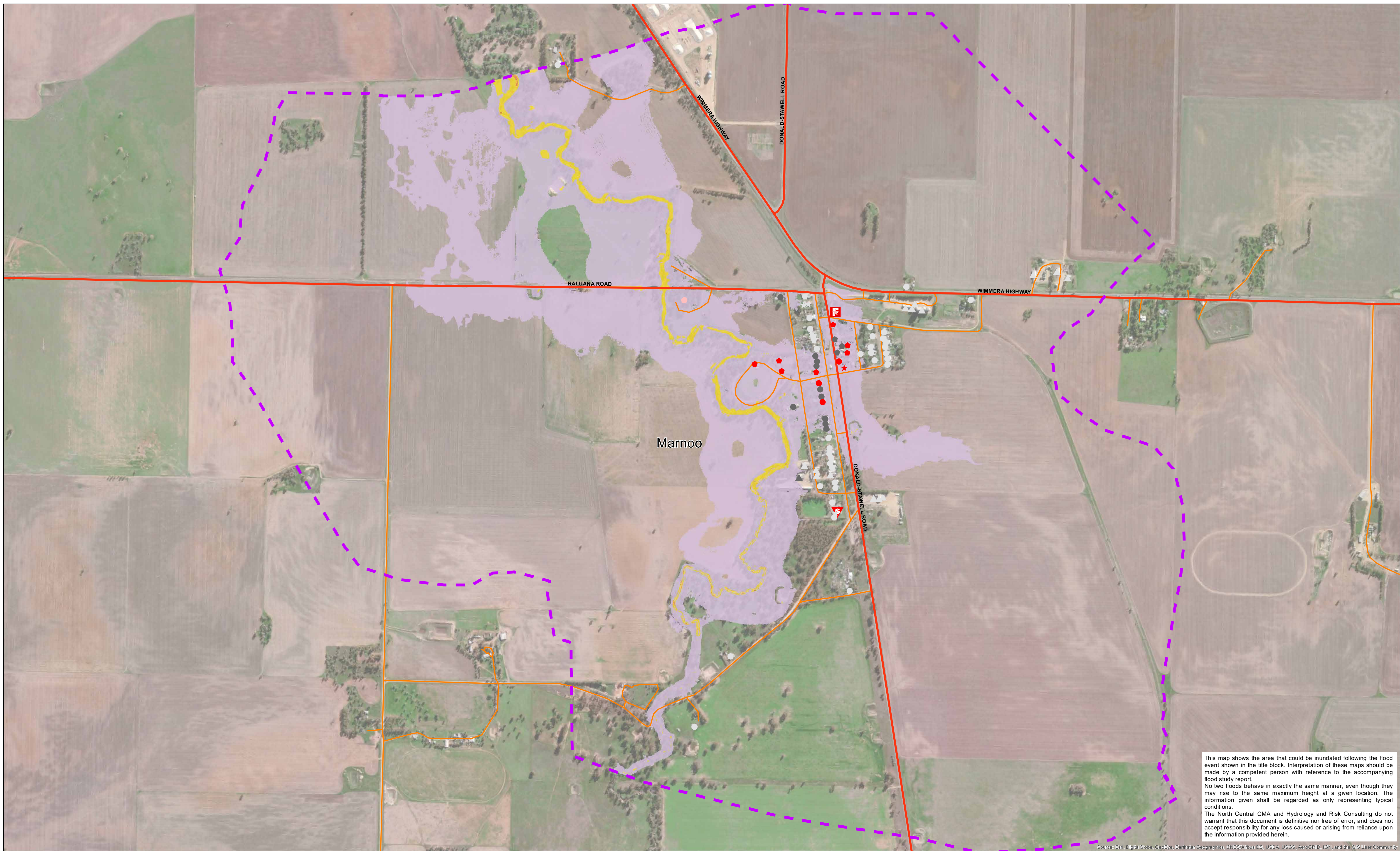
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
 MAXIMUM HAZARD

**Marnoo - 1% AEP Flood Event**

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 26/02/2020	Map No.: 21 - 100 - 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.

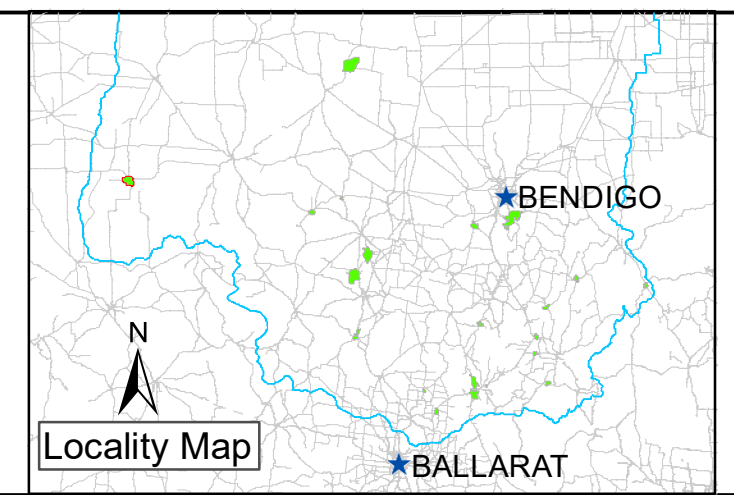
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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

	CFAMFB Fire Station		Main Road	<b>Building Classification</b>		< 1
	Police Station		Tertiary Road			1 - 2
	Hospital		Railway Line			2 - 3
	School/College		Flood Model Extent			> 3
	Nursing Home/Aged Care					
	Carvaran Park			<b>Building Inundation</b>		



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

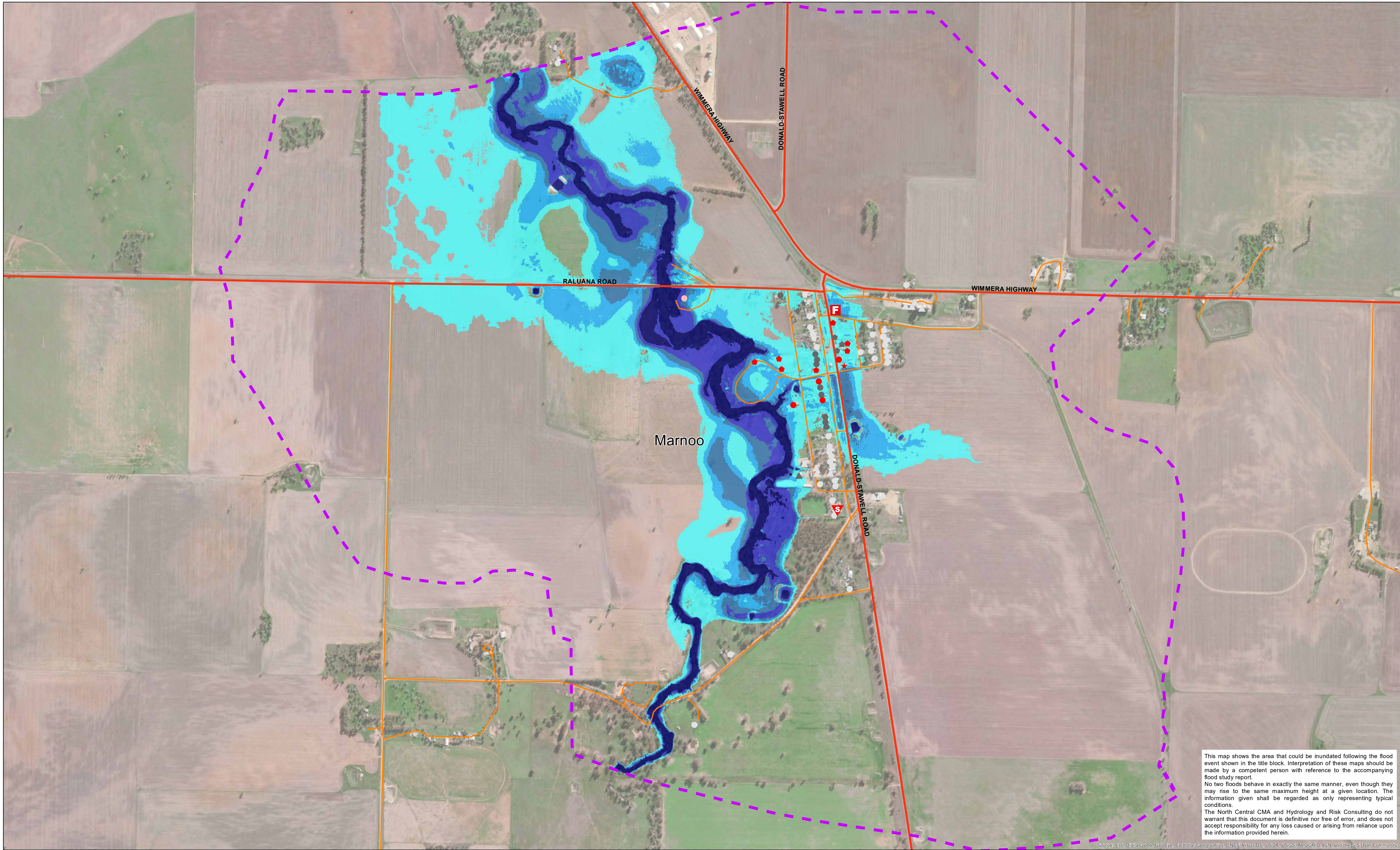
**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT**  
**MAXIMUM VELOCITY (m/s)**

**Marnoo - 1% AEP Flood Event**

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 25/02/2020	Map No.: 21 - 100 - 5





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.

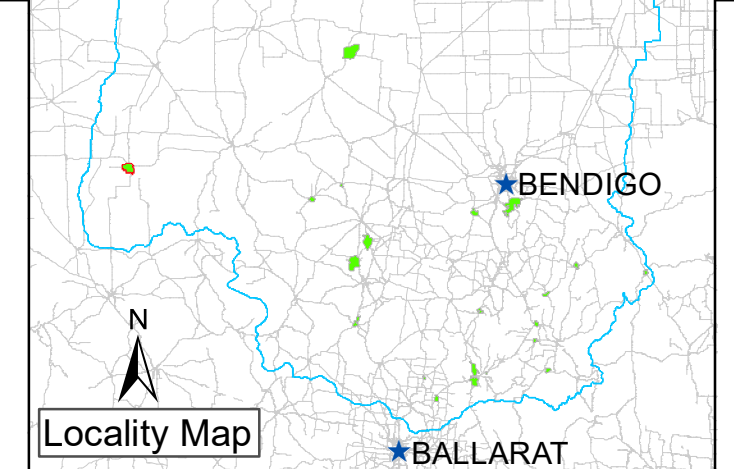
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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

CFA/MFB Fire Station	Main Road	<b>Building Classification</b>	<b>Max Depth (m)</b>
Police Station	Tertiary Road	Residential	< 0.3
Hospital	Railway Line	Commercial	0.3 - 0.5
School/College	Flood Model Extent	Industrial	0.5 - 0.8
Nursing Home/Aged Care		Public	0.8 - 1.2
Caravan Park		not inundated	> 1.2
		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	

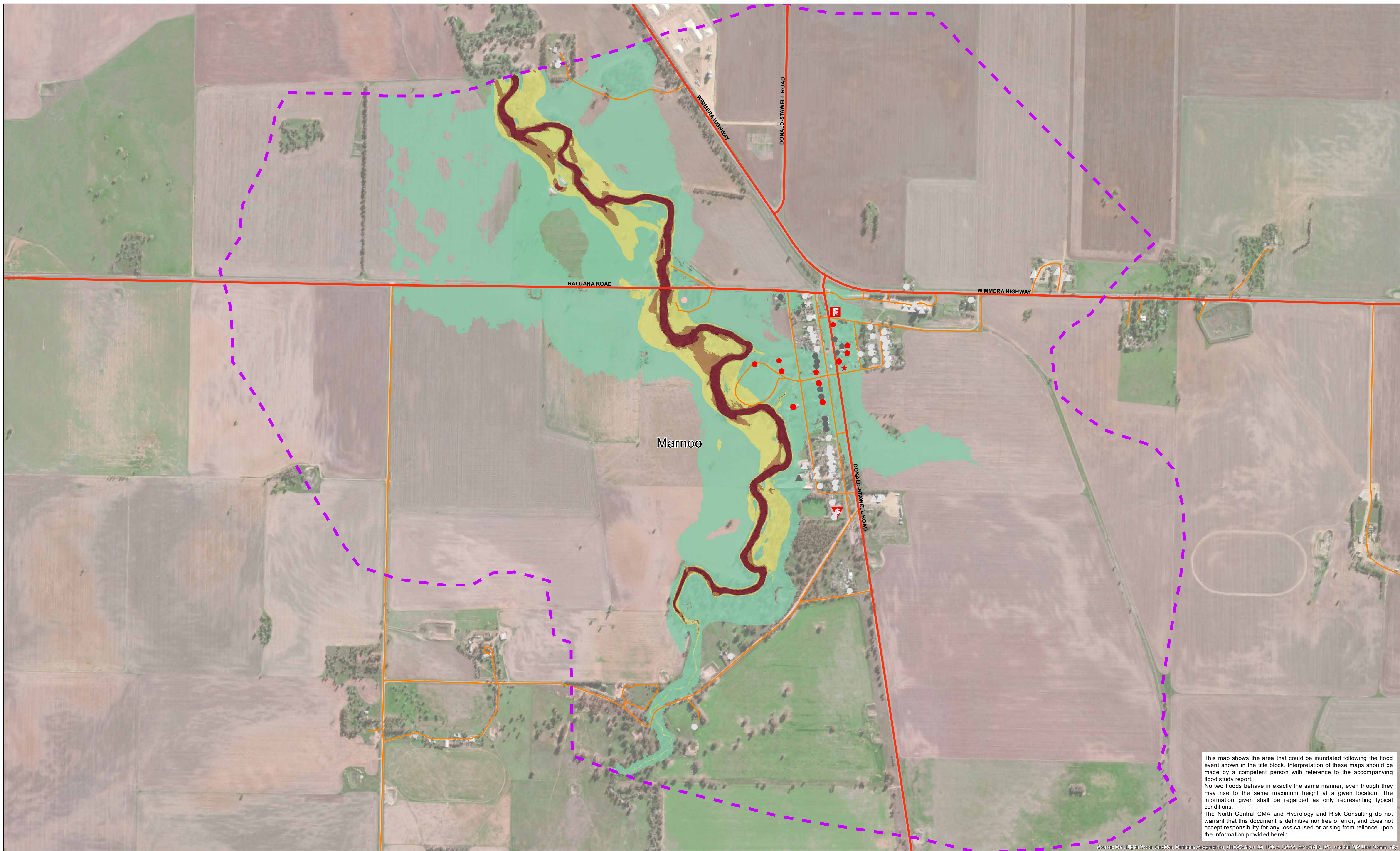
**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT**  
**MAXIMUM DEPTH (m)**

**Marnoo - 0.5% AEP Flood Event**

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 25/02/2020	Map No.: 21 - 200 - 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.

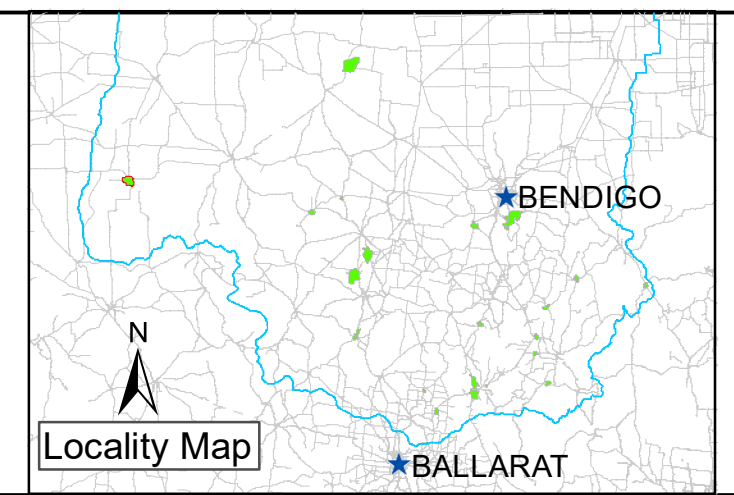
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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VxDmaxMGA54.m  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

CFAMFB Fire Station	Main Road	<b>Building Classification</b>	<b>Max V x D (m<sup>2</sup>/s)</b>
Police Station	Tertiary Road	Residential	<math>< 0.4</math>
Hospital	Railway Line	Commercial	<math>0.4 - 0.8</math>
School/College	Flood Model Extent	Industrial	<math>0.8 - 1.2</math>
Nursing Home/Aged Care		Public	> 1.2
Carvaran Park		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	

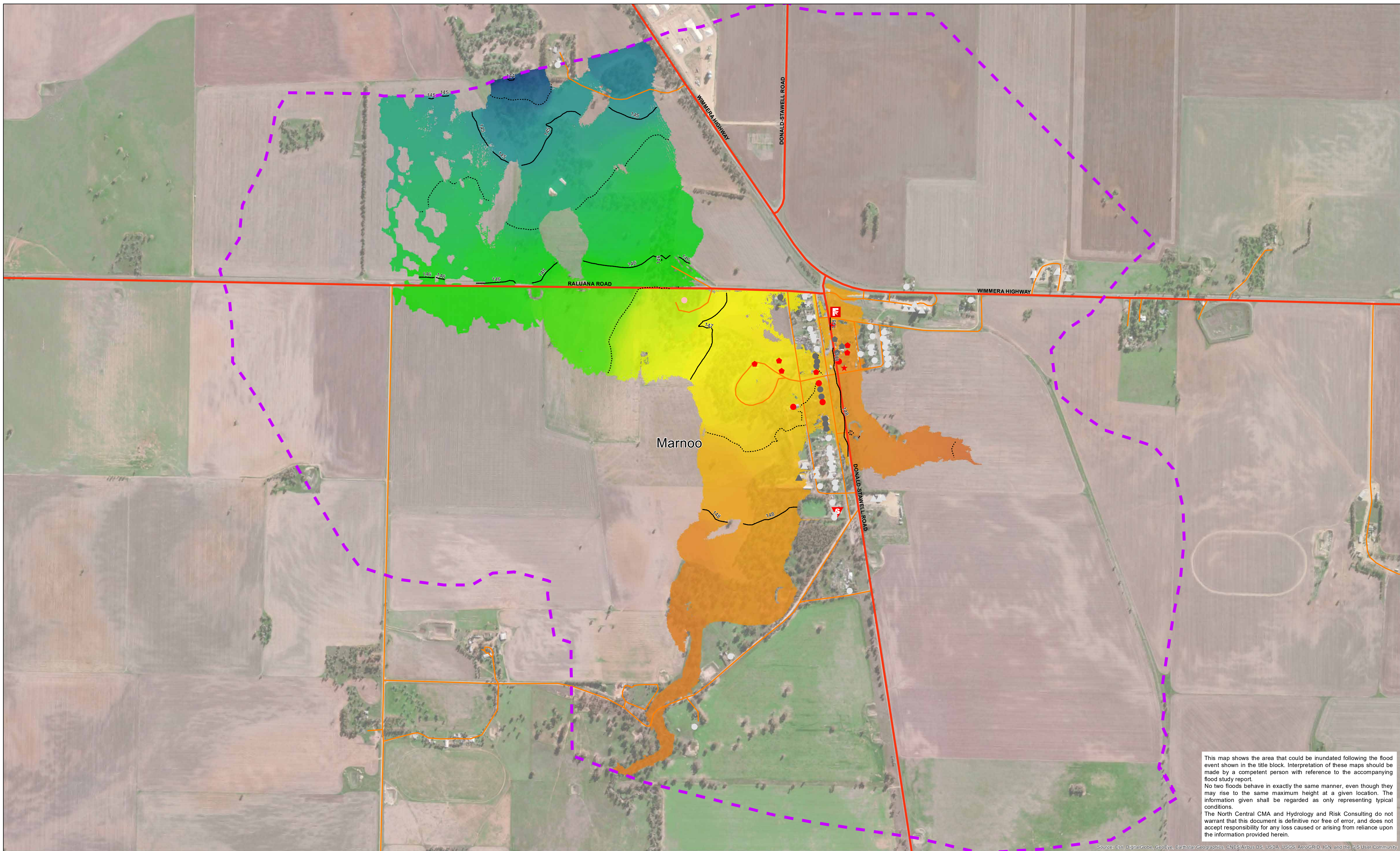
NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT  
 MAXIMUM V x D (m<sup>2</sup>/s)

**Marnoo - 0.5% AEP Flood Event**

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 25/02/2020	Map No.: 21 - 200 - 2





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.

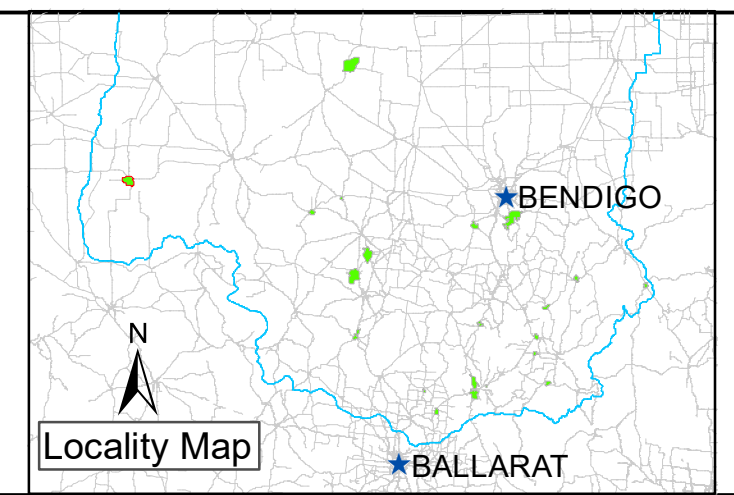
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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HmaxMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

	CFM/MFB Fire Station		Main Road	<b>Building Classification</b> Residential Commercial Industrial Public	<b>Max WSE (mAHD) Marnoo</b> <b>Value</b>  High : 149 Low : 144
	Police Station		Tertiary Road		
	Hospital		Railway Line	<b>Building Inundation</b> not inundated inundated (without floor level survey) below floor level (with floor level survey) above floor level (with floor level survey)	
	School/College		Flood Model Extent		
	Nursing Home/Aged Care		Contour (1m)		
	Carvaran Park		Contour (0.5m)		



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)**

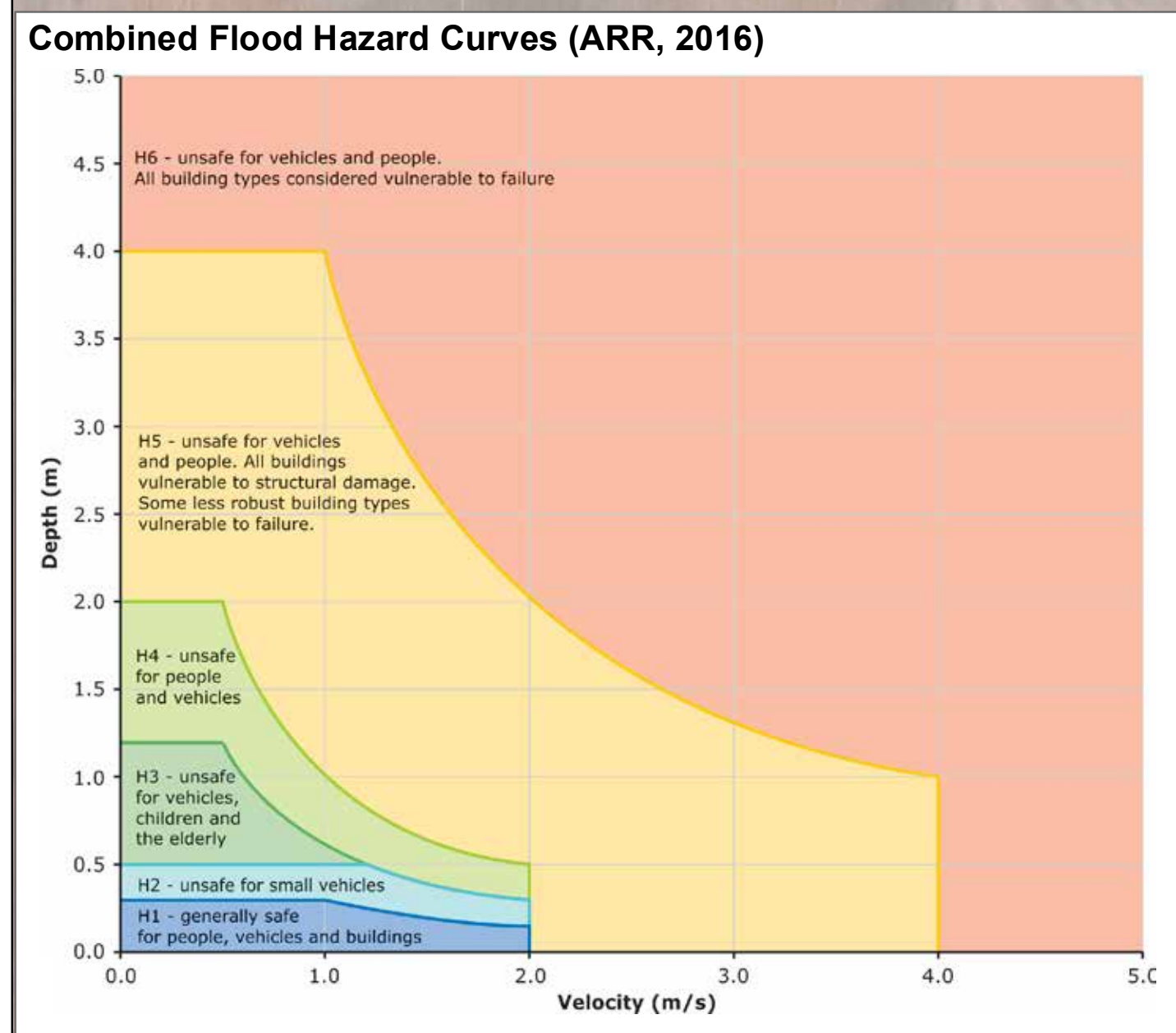
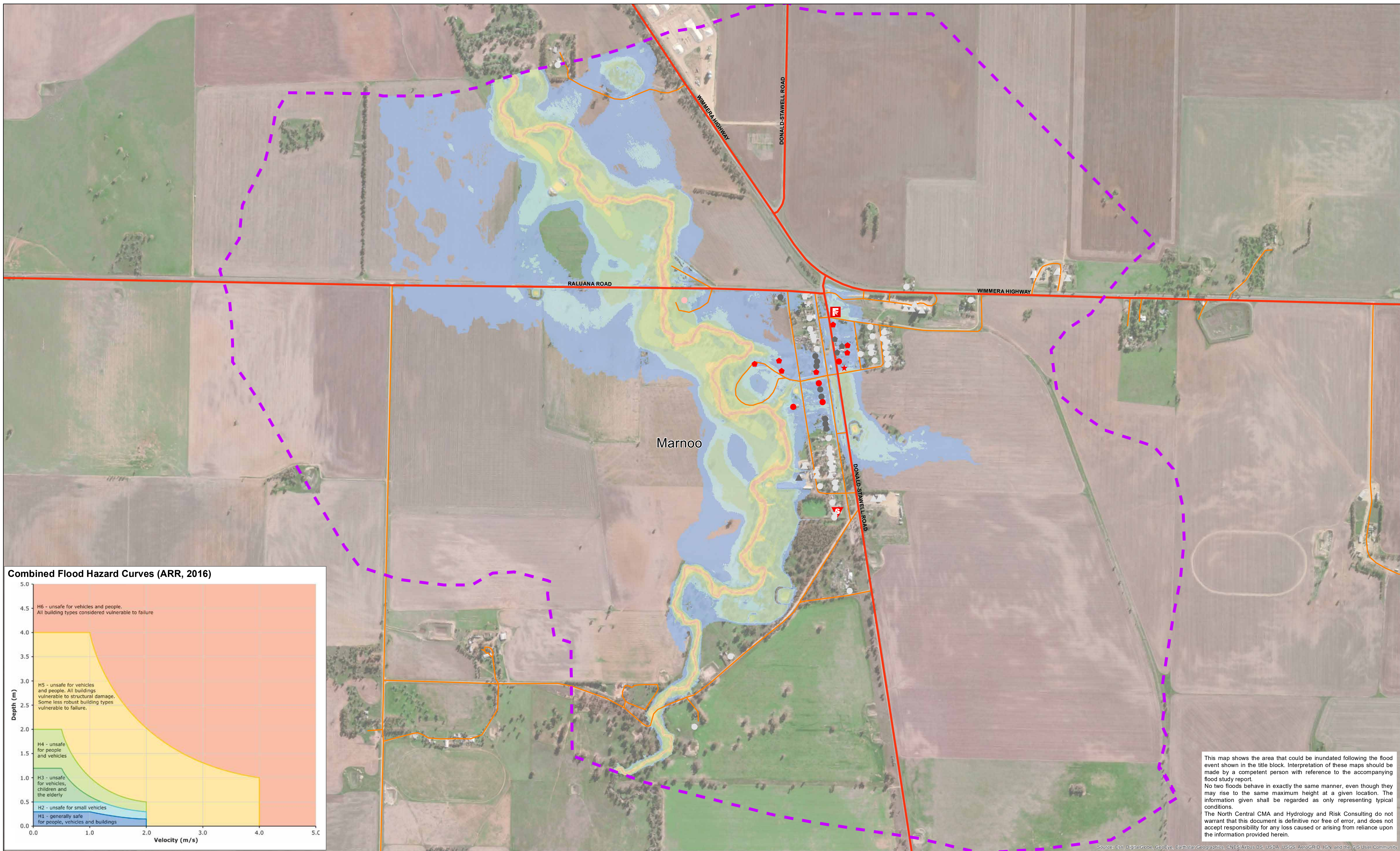
**Marnoo - 0.5% AEP Flood Event**

Meters

Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 26/02/2020	Map No.: 21 - 200 - 3





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.

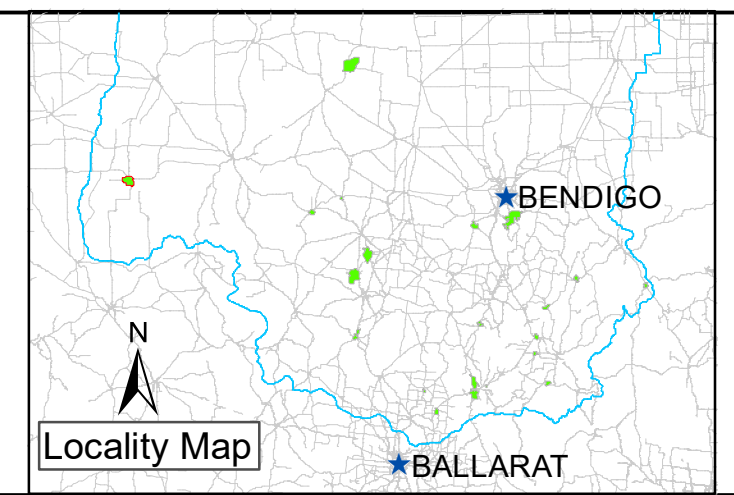
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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HazardsMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

CFAMFB Fire Station	Main Road	<b>Building Classification</b>
Police Station	Tertiary Road	Residential
Hospital	Railway Line	Commercial
School/College	Flood Model Extent	Industrial
Nursing Home/Aged Care		Public
Caravan Park		<b>Building Inundation</b>
		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	

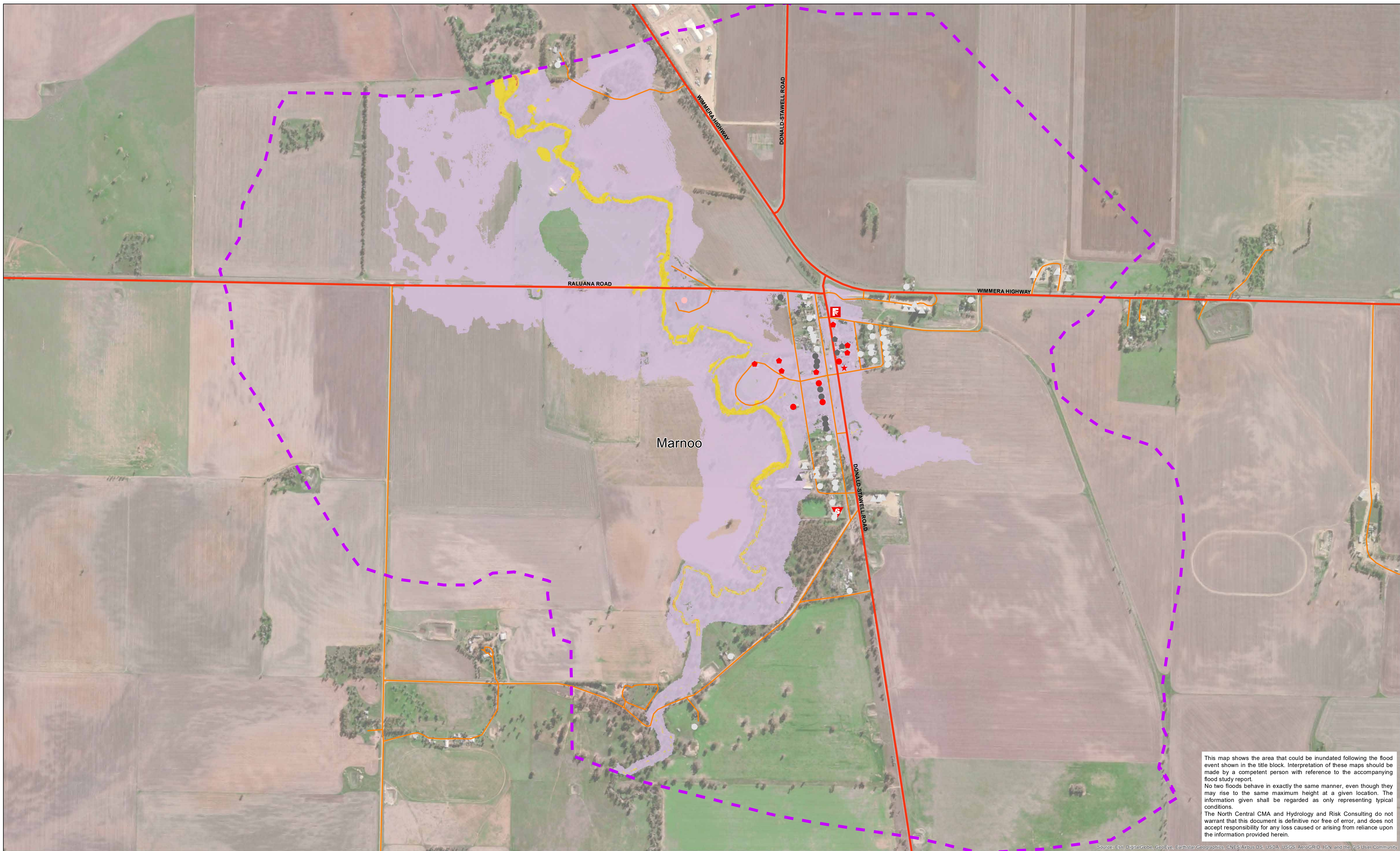
**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT**  
**MAXIMUM HAZARD**

**Marnoo - 0.5% AEP Flood Event**

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 26/02/2020	Map No.: 21 - 200 - 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.

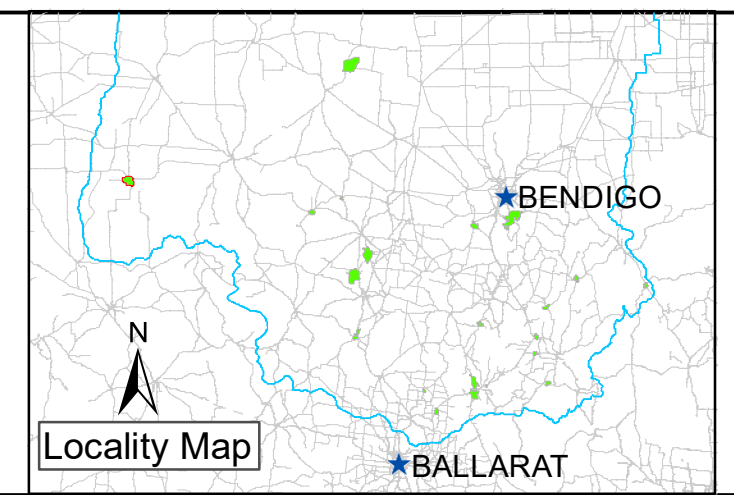
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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VmaxMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

	CFAMFB Fire Station		Main Road	<b>Building Classification</b>		< 1
	Police Station		Tertiary Road			1 - 2
	Hospital		Railway Line			2 - 3
	School/College		Flood Model Extent			> 3
	Nursing Home/Aged Care					
	Carvaran Park			<b>Building Inundation</b>		



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)**

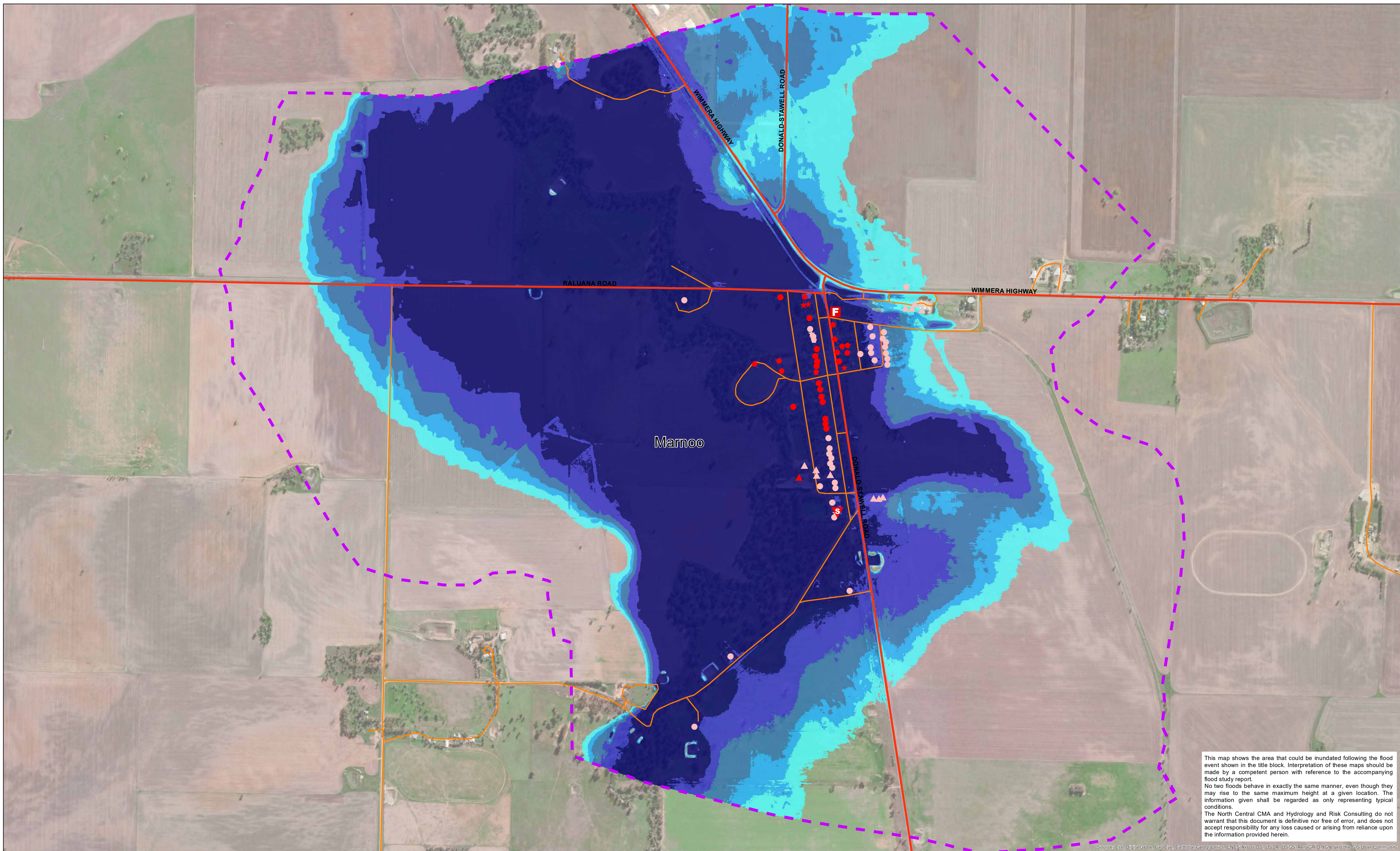
**Marnoo - 0.5% AEP Flood Event**

Meters

Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 25/02/2020	Map No.: 21 - 200 - 5





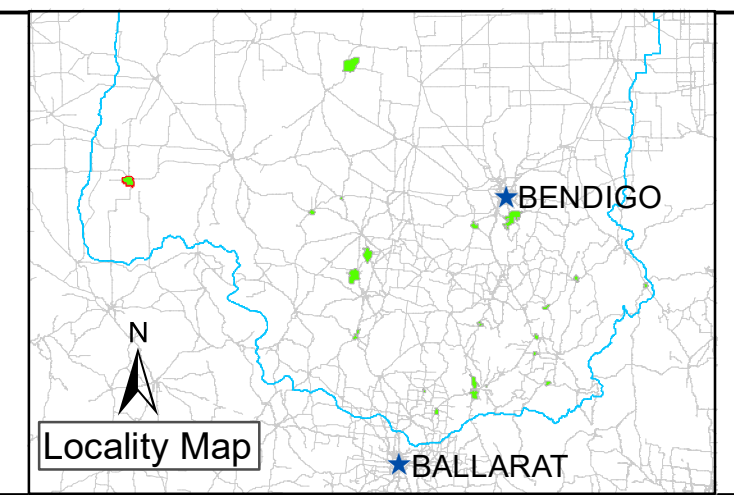
This map shows the area that could be inundated following the flood event shown in the title block. Interpretation of these maps should be made by a competent person with reference to the accompanying flood study report.

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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_DmaxMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

<b>Legend</b>		<b>Building Classification</b>		<b>Max Depth (m)</b>	
	CFA/MFB Fire Station		Residential		< 0.3
	Police Station		Commercial		0.3 - 0.5
	Hospital		Industrial		0.5 - 0.8
	School/College		Public		0.8 - 1.2
	Nursing Home/Aged Care		not inundated		> 1.2
	Caravan Park		inundated (without floor level survey)		
	Main Road		below floor level (with floor level survey)		
	Tertiary Road		above floor level (with floor level survey)		
	Railway Line				
	Flood Model Extent				



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

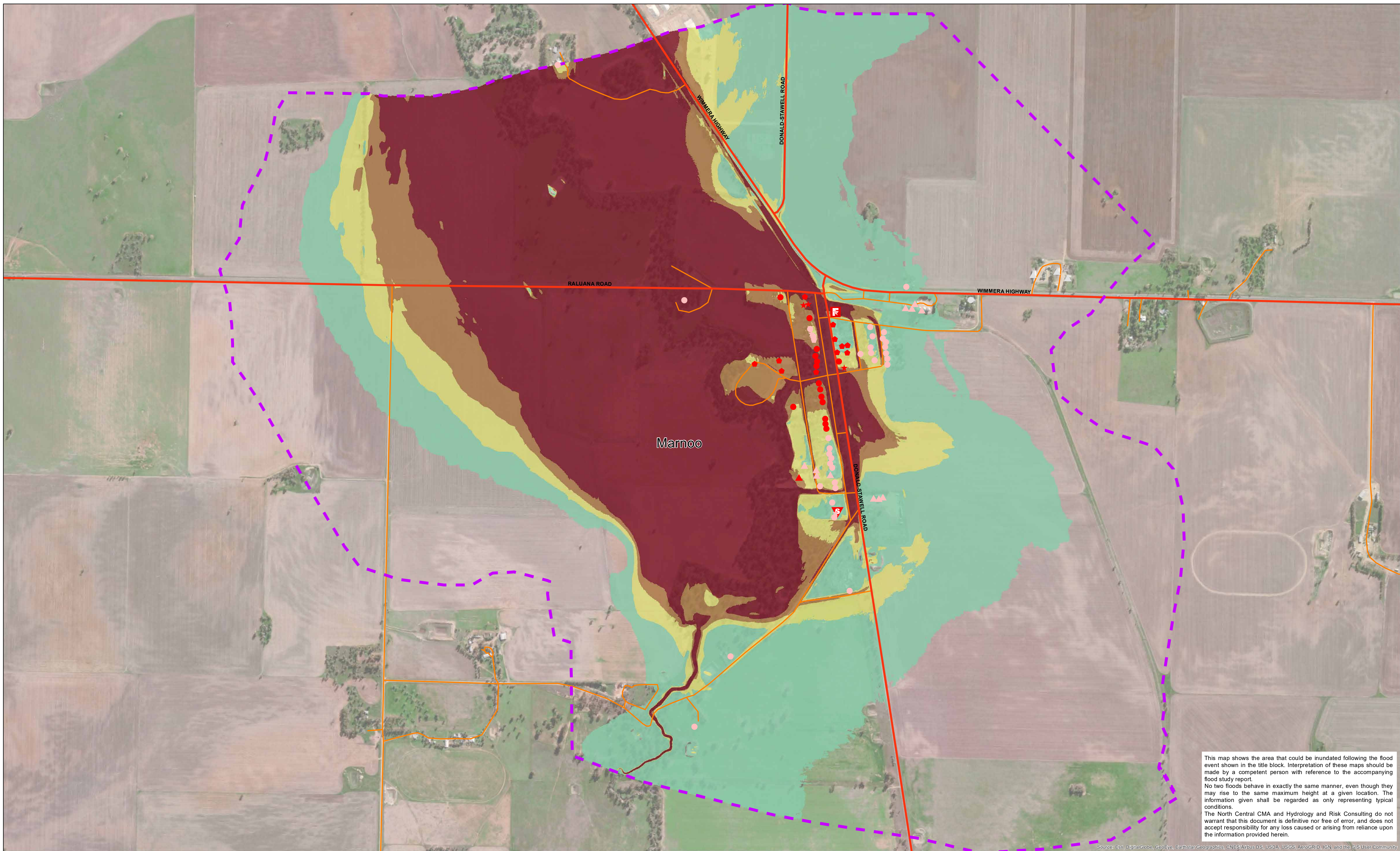
**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT**  
**MAXIMUM DEPTH (m)**

**Marnoo - PMF Event**

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 25/02/2020	Map No.: 21 - PMF - 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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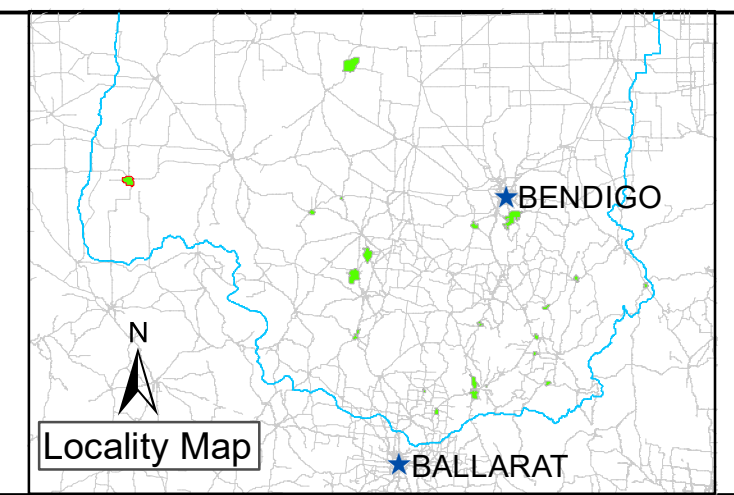
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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_VxDmaxMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

	CFAMFB Fire Station		Main Road	<b>Building Classification</b> ● Residential ● Commercial ▲ Industrial ★ Public <b>Building Inundation</b> ■ not inundated ■ inundated (without floor level survey) ■ below floor level (with floor level survey) ■ above floor level (with floor level survey)
	Police Station		Tertiary Road	
	Hospital		Railway Line	
	School/College		Flood Model Extent	
	Nursing Home/Aged Care			
	Carvaran Park			

<b>Max V x D (m<sup>2</sup>/s)</b>		< 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 (m<sup>2</sup>/s)

**Marnoo - PMF Event**

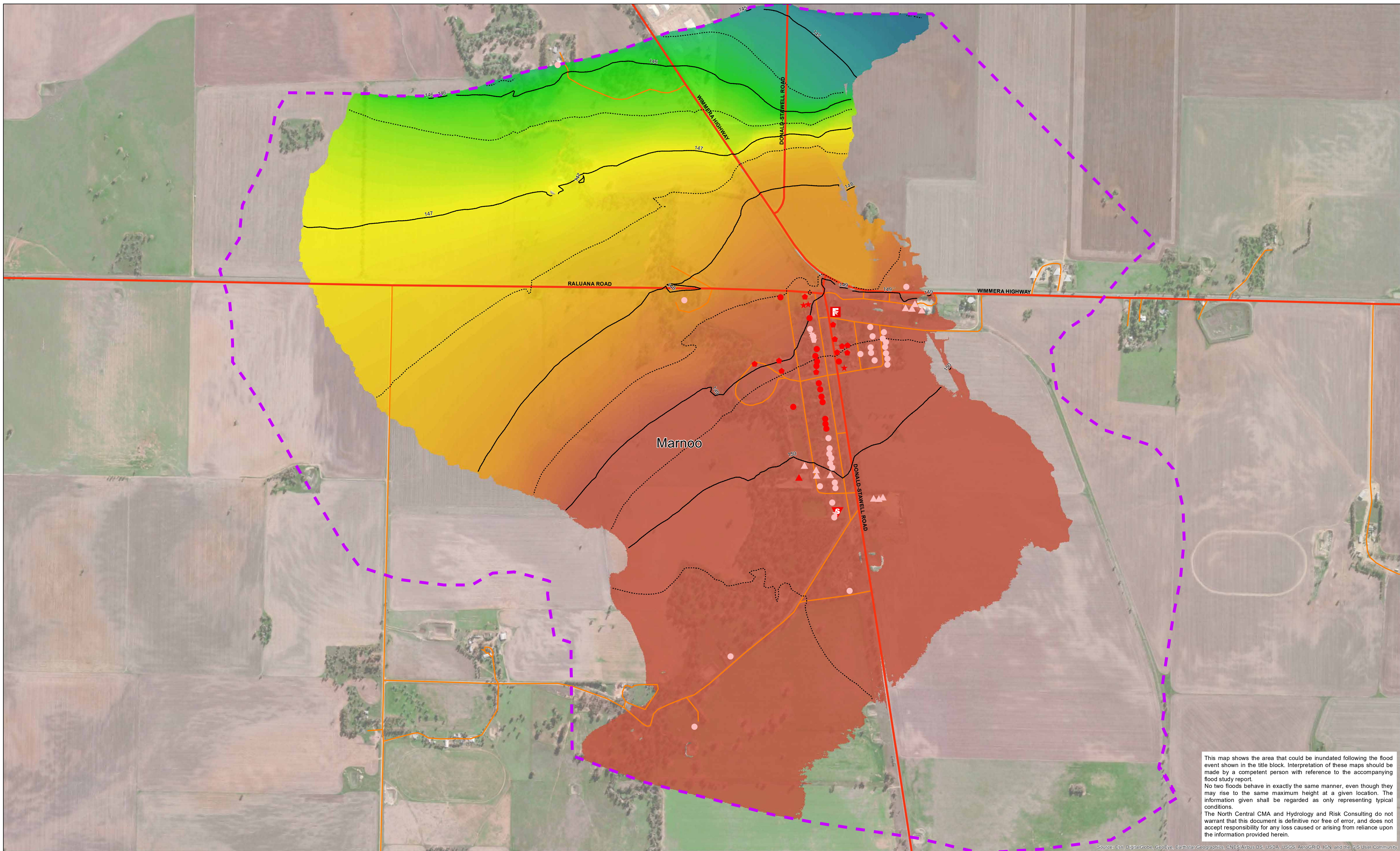
Scale: 1:7,000 when printed @ A1

Date: 25/02/2020

Map No.: 21 - PMF - 2

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54





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.

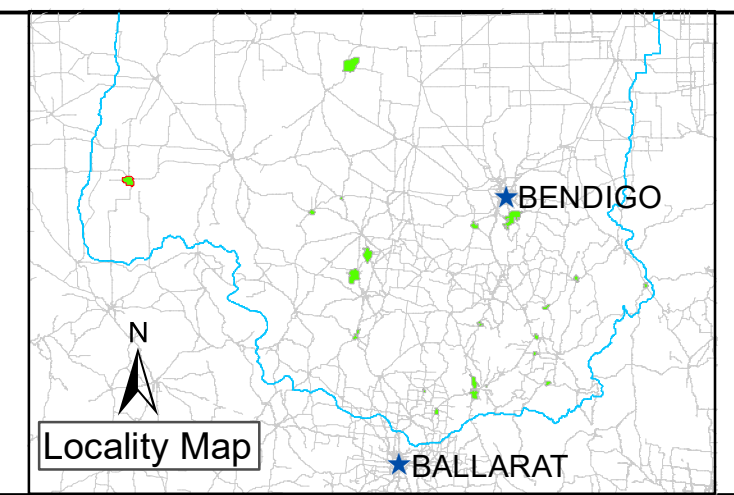
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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HmaxMGA54.mxd  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

CFAMFB Fire Station	Main Road	<b>Building Classification</b>	<b>Max WSE (mAHd) Marnoo</b>
Police Station	Tertiary Road	Residential	Value
Hospital	Railway Line	Commercial	High : 149
School/College	Flood Model Extent	Industrial	Low : 144
Nursing Home/Aged Care	Contour (1m)	Public	
Carvaran Park	Contour (0.5m)	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 WATER LEVEL (mAHd)**

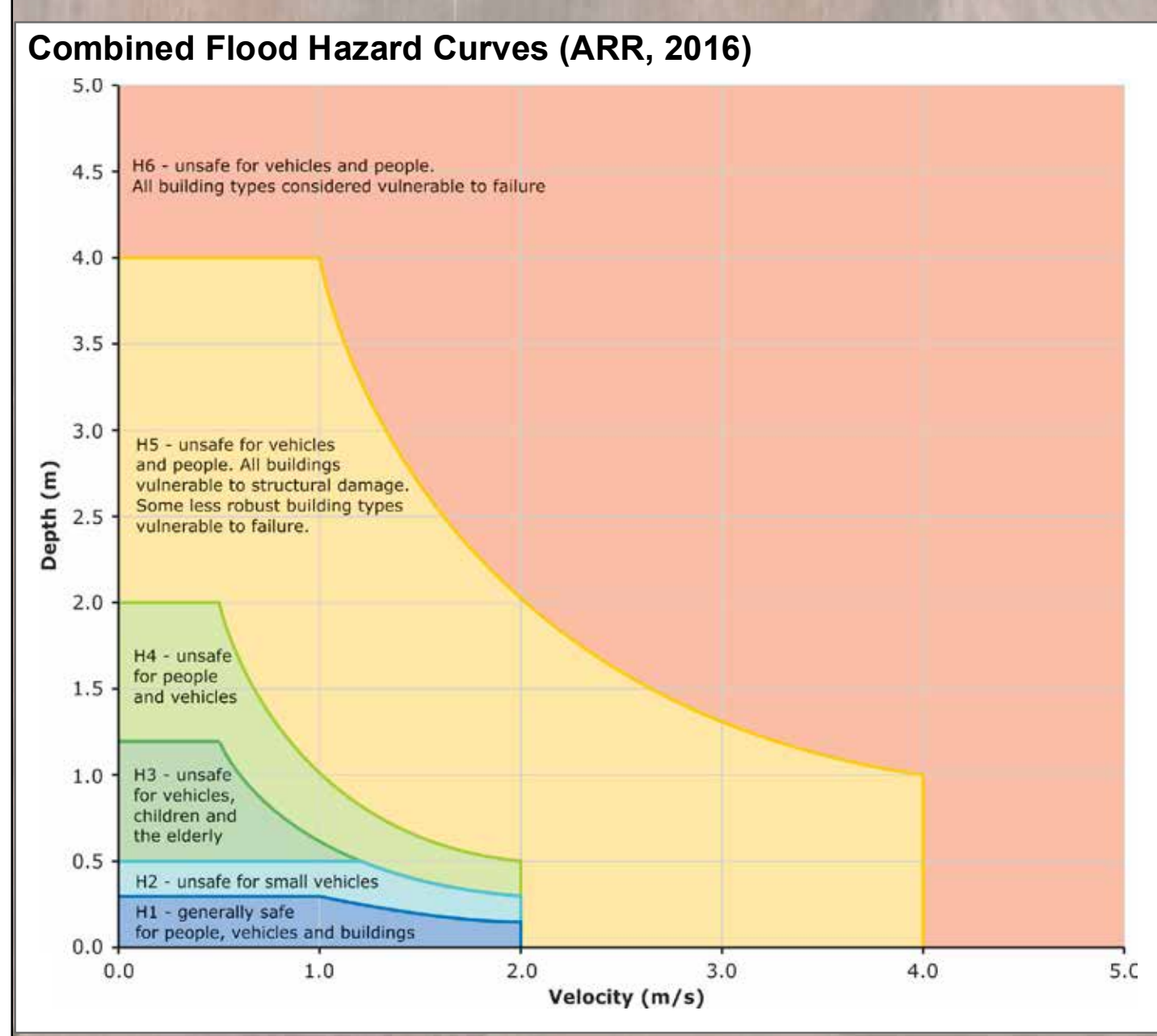
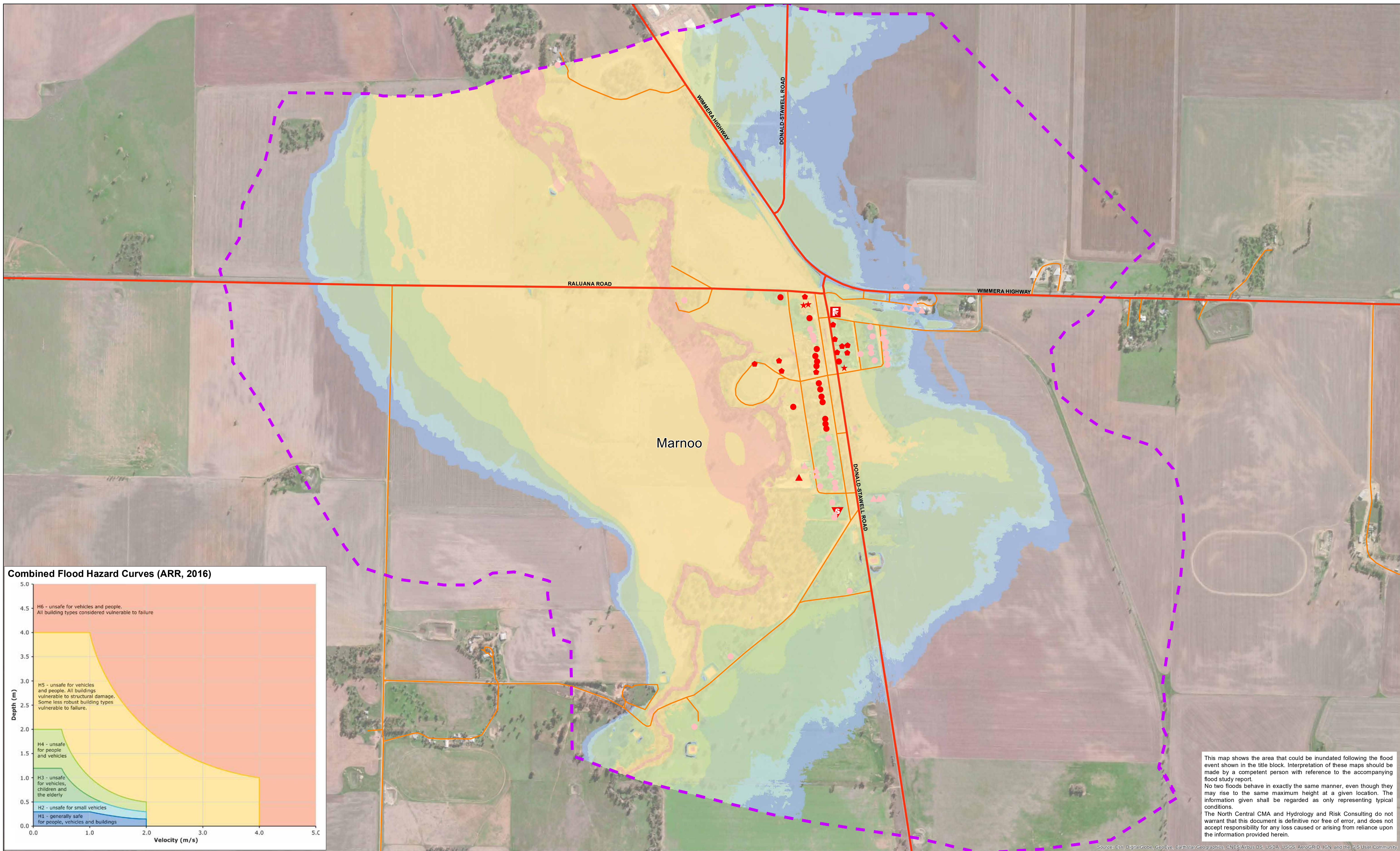
**Marnoo - PMF Event**

0 200 400 600 800  
Meters

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 26/02/2020	Map No.: 21 - PMF - 3





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.

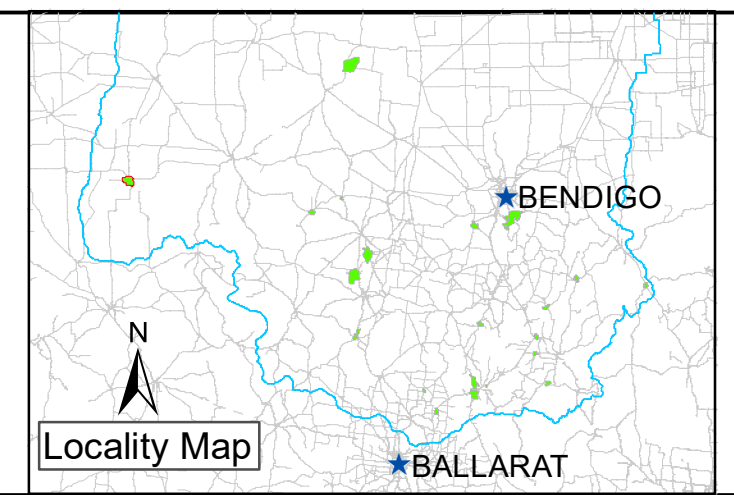
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Data Location: S:\3\_Projects\NCC0000215\_Technical\3\_Mapping\NCC00002\_InundationMapping\_Datadrivenpages\_HazardsMGA54.m  
 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

CFAMFB Fire Station	Main Road	Residential
Police Station	Tertiary Road	Commercial
Hospital	Railway Line	Industrial
School/College	Flood Model Extent	Public
Nursing Home/Aged Care		<b>Building Inundation</b>
Caravan Park		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	

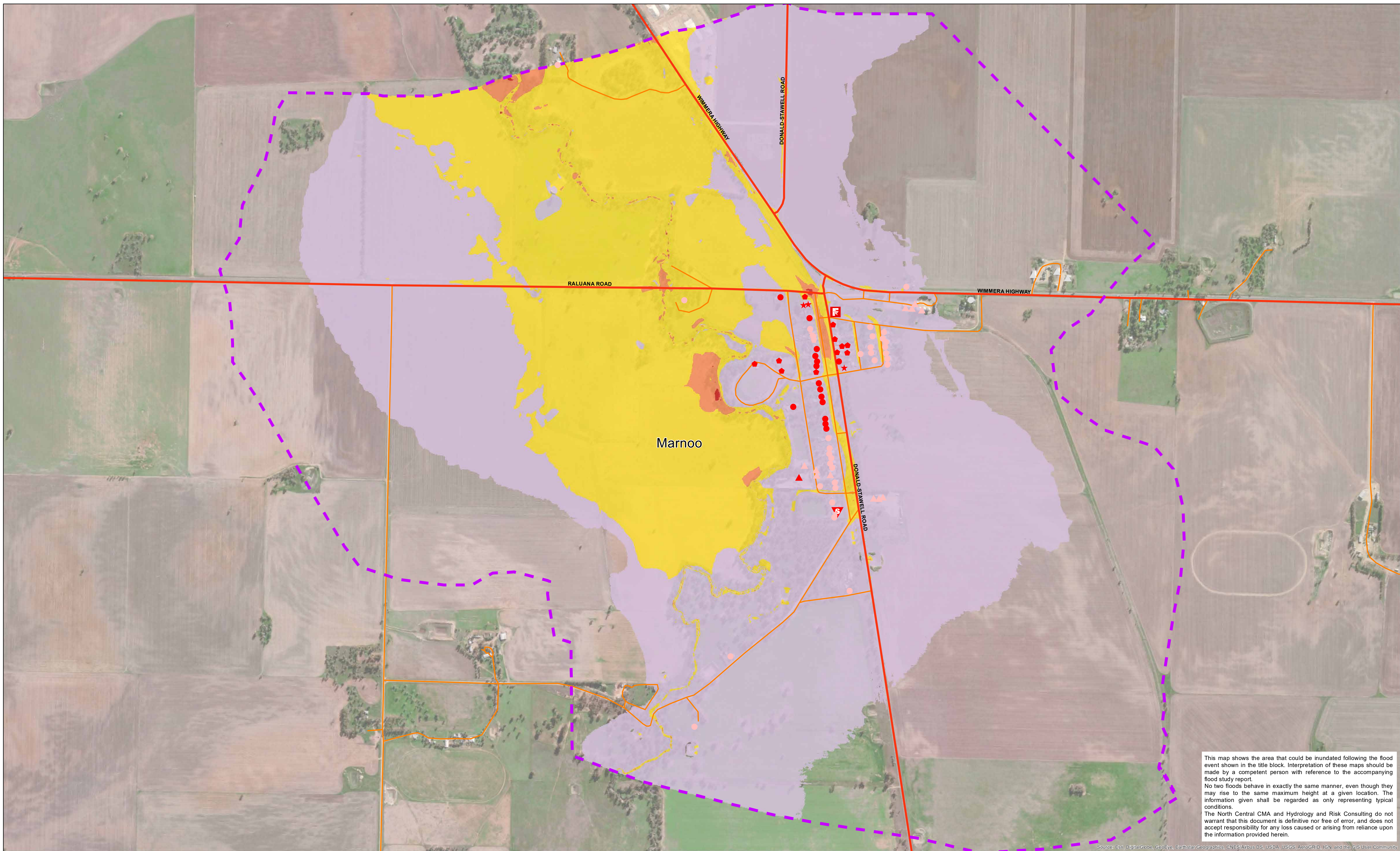
**NORTH CENTRAL CMA RAPID FLOOD RISK ASSESSMENT**  
**MAXIMUM HAZARD**

**Marnoo - PMF Event**

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 26/02/2020	Map No.: 21 - PMF - 4





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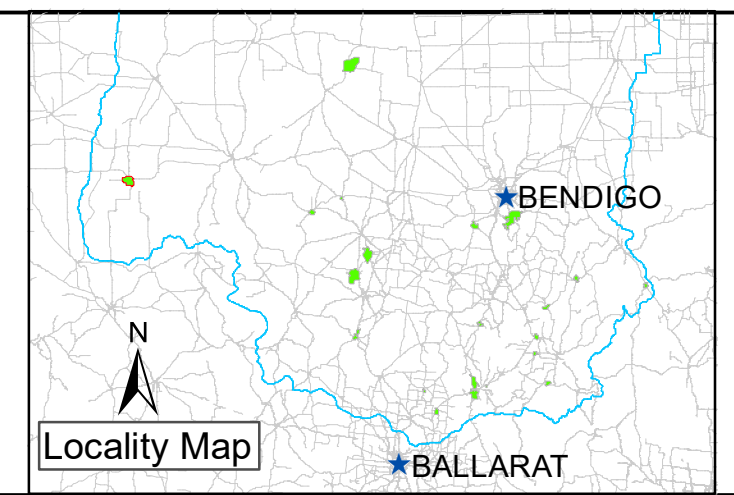
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 Roads Layer: Vicmap; Imagery: ESRI; Geoscape Polygons: Navigate, PSMA Australia,

**Legend**

CFAMFB Fire Station	Main Road	<b>Building Classification</b>	<b>Max Velocity (m/s)</b>
Police Station	Tertiary Road	Residential	< 1
Hospital	Railway Line	Commercial	1 - 2
School/College	Flood Model Extent	Industrial	2 - 3
Nursing Home/Aged Care		Public	> 3
Carvaran Park		<b>Building Inundation</b>	
		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 VELOCITY (m/s)**

**Marnoo - PMF Event**

Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 54

Scale: 1:7,000 when printed @ A1	Date: 25/02/2020	Map No.: 21 - PMF - 5