Bylong Park

Flood risk assessment

Prepared for Greyhound Racing NSW
May 2022

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Flood risk assessment

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1 Introduction

1.1 Background

Greyhound Racing New South Wales (Greyhounds NSW) propose the development of an animal boarding and rehabilitation facility at ‘Bylong Park’ 1949 Martindale Road, Denman (the site). The facility will be used for boarding and rehabilitating greyhound dogs prior to their adoption and 'rehoming' via the NSW Greyhounds As Pets programme. The proposal requires the construction of facilities to accommodate and provide veterinary care for up to 400 dogs and includes:

- construction of 20 kennel blocks of 20 kennels/dogs;
- a new veterinary and supporting services building (the farmstead);
- renovation of existing stable building as an outdoor covered area; and
- sewerage, waste-treatment and plumbing works.

Once operational, the facility will be the first of its kind in NSW and will employ the equivalent of 24 full-time staff and volunteers.

EMM Consulting Pty Ltd (EMM) prepared a flood risk assessment (EMM 2020) to inform the location of the proposed kennels and other infrastructure and establish the 1% annual exceedance probability (AEP) flood extent and level for the site. The flood risk assessment was provided to Muswellbrook Shire Council (hereinafter referred to as Council) as part of the Development Application (DA) submission.

Council has since requested further information be provided on flooding aspects of the proposed development, including site access arrangements. Several comments were also received from the community regarding flooding at the site.

This report is an update to the EMM (2020) flood risk assessment and has been prepared to address Council’s request for information (RFI).

1.2 Council consultation and report scope

Council provided a RFI on flood aspects of the proposed development March 2022. EMM subsequently contacted Council 7 March 2022 to discuss Council’s RFI and concerns. Council’s RFI primarily related to providing:

- further assessment of the frequency, duration and streamflow conditions that restrict access to the site;
- evaluation and justification of a proposed access strategy; and
- consideration of risks associated with a probable maximum flood (PMF) at the site and a description of how flood risk would be managed in extreme events.

This report provides additional information to address Council’s RFI and includes an options assessment of various access strategy arrangements. Table 1.1 itemises Council’s RFI and identifies the sections of this report where each item is addressed.

Table 1.1 Response to Council's request for information

No.	Request for information	Where addressed in this report
1	The flood impact assessment submitted with the development application predominately considers the impact of the 1% AEP event on the proposed development. Further analysis is required in relation to more frequent flood events and their inundation of the Martindale Creek crossing that provides access to the site. It is recommended that:	
	a) Further modelling is undertaken to identify the type of rainfall-runoff event that would restrict 2WD and 4WD vehicle access across this crossing, including identification of velocity x depth hazard.	Section 4.2
	b) Identify the duration in hours and days and frequency that typical rainfall-runoff would restrict above mentioned vehicle access to the site within the identified catchment.	Section 4.4
	c) Identify on average how many days access to the site would be restricted by flooding of the creek crossing for relevant peak events (or provide separate averages for years influenced by El Nino, La Nina and neutral weather patterns).	Section 4.4
	d) Consider and discuss any findings related to the frequency and duration of the access inundation when affected by flooding. Give further consideration to the recommended strategy for providing access. Any further evaluation of this issue should have regard to the site's operational requirements, likelihood of greyhounds needing to be transported to or from the site during flood events and how this would be managed with any flood free access provided.	Chapter 6
	e) Where it remains proposed for a flood free access to be provided by a flying fox, or a new greyhound friendly pedestrian step bridge or similar a plan should be provided for the flood free access along with any works within the road reserve to provide suitable space and pavement construction for vehicle parking for operational staff and delivery vehicles that may be required to access the site or make deliveries during flood events.	Flood free access via flying fox or pedestrian bridge are not proposed.
	f) Modelling of flood behaviour that defines the variation over time of flood levels, extents, and velocities for each of the critical design events. This may require modelling of shorter duration 100-year average recurrence interval and PMF or equivalent extreme events to provide advice in relation to the potential differences in time available for response.	Section 5.3.3 Section 5.4.3
	g) Consideration of the impacts of the PMF event on the site and the differences in catchment time response to determine flood warning requirements and evacuation requirements as a risk management strategy considering difficulties in SES evacuating the site and/or rescue of hundreds of animals and staff.	Section 5.4.3 Section 7.4

1.3 Report structure

This report is structured as follows:

- Chapter 2 describes existing site conditions;
- Chapter 3 describes the assessment methodology including available data and relevant guidelines;
- Chapter 4 characterises streamflow conditions and site access constraints associated with the existing access road causeway;
- Chapter 5 describes the flood modelling methodology and results;
- Chapter 6 provides an assessment of several site access options;

- Chapter 7 provides a flood risk management approach for the overall development and proposed site access arrangement; and
- Chapter 8 provides a summary of this report.

The following information is provided in the report appendices:

- Appendix A – Flow hydrographs (ie hydrology model results);
- Appendix B – Flood mapping; and
- Appendix C – Provisional site access management plan.

2 Site description

The site has an area of approximately 135 hectares (ha) and is in a closed valley approximately 21 kilometres (km) from the township of Denman. Martindale Road is a single lane bitumen road and is the only means of access to the various rural holdings within the valley.

The site is located within the valley floor to the east of Martindale Creek, which has a contributing catchment area of approximately 247 km^2 to the downstream boundary of the site. The upstream catchment comprises steep, undeveloped bushland. The Martindale Creek valley is characterised by flat to undulating hills that rise steeply towards the rugged terrain to the east and west. The low-lying western portion of the site is expected to be flood prone. Existing site dwellings and infrastructure are located on a hilltop that is elevated approximately 10 metres (m) above the Martindale Creek channel bed. Martindale Creek discharges to the Hunter River approximately 15 km downstream of the site.

Catchment characteristics observed during the site visit are provided in Table 2.1.

Table 2.1 Catchment characteristics

Observation	Photograph
Martindale Creek Valley Topography of the valley floor is characterised by flat to undulating terrain bound by steep rugged terrain to the east and west. The upstream catchment is characterised by heavily vegetated bushland and steep terrain. Photograph: Typical valley section looking downstream towards the site.	
Martindale Creek – floodplain southern portion of the site The floodplain at the southern end of the site is primarily open grassland with some scattered trees. Photograph: Southern site boundary looking towards Martindale Creek.	

Table 2.1 Catchment characteristics

Observation	Photograph
Martindale Creek – at site access waterway crossing Martindale Creek has a shallow main channel with a fine sediment base. Channel banks contain medium to high density vegetation with larger trees overlying smaller shrubs. The channel width was observed to range between 4 and 6 m. Flows within the channel were observed to be approximately 300 millimetres (mm) deep during the site inspection. No waterway structures were observed within Martindale Creek in vicinity of the site. The waterway crossing providing access to the site is a concrete causeway that forms part of the channel bed. Flows over the causeway were approximately 200 mm deep during the site inspection. Photograph: Martindale Creek (looking upstream) where it crosses the access road to the site.	
Martindale Creek – northern portion of the site Vegetation within the Martindale Creek channel and along the channel banks varies within the site. The section of creek along the north-western border of the site comprises fewer trees but has greater density reeds along the banks and within the channel. Photograph: Martindale Creek (looking downstream) near the downstream end of the site.	
Martindale Creek – floodplain northern portion of the site The floodplain at the northern end of the site is primarily open grassland. Martindale Creek has a steep and densely vegetated northern overbank immediately downstream of the site. Photograph: Northern site boundary looking in the direction of Martindale Creek flow.	

3 Assessment methodology

3.1 Overview

This chapter describes the data, methodology and guidelines that have been used to inform the assessment.

3.2 Available data

The following data was used to characterise streamflow within Martindale Creek and inform the flood modelling methodology:

- Design rainfall intensity information obtained from the Bureau of Meteorology (BoM).
- Rainfall losses and temporal pattern information obtained from the Australian Rainfall and Runoff Data Hub (Babister et al. 2016).
- Detailed site survey obtained from C.M.S Surveyors Pty Limited and dated 11 December 2020.
- LiDAR digital elevation model (DEM) data of the Martindale Creek floodplain at 2 m resolution (dated April 2018) obtained from NSW Government Department of Finance, Services and Innovation (DFSI) – Spatial Services department.
- SRTM DEM data at 30 m resolution for the Martindale Creek catchment (dated 2000) obtained from NSW Government DFSI – Spatial Services department.
- Stream gauge data from WaterNSW operated Macdonald River at Howes Valley (station number 212021) stream gauge.
- *Hunter River Flood Study (Muswellbrook to Denman) Model Revisions Report* (RHDHV 2017).
- Observations during a site visit undertaken July 2020.
- Images of Martindale Creek during periods of elevated streamflow provided by Greyhounds NSW.

3.3 Streamflow analysis methodology

Streamflow analysis was completed to characterise flow conditions within Martindale Creek at the existing access road causeway. This analysis provides estimates of streamflow conditions (ie peak flow and duration) and hydraulic characteristics (ie flow depth and velocity) for various high flow conditions, ranging from extended periods of high flow that occur frequently to flood events that occur occasionally. The outcomes of this analysis are used to establish safe access restrictions for the existing causeway and other access options (refer to Chapter 6).

The following approach was applied to assess flow conditions within Martindale Creek at the existing causeway:

1. Review of available data and information for completeness and reliability.
2. Characterise flow depth, velocity, and velocity/depth product for varying flowrates at the existing causeway location.
3. Compare site specific flow conditions to flood hazard guideline values (refer to Section 3.5.3) to determine flow-based thresholds for safe access to the site.

4. Characterise the streamflow regime using data from a regional stream gauge to determine the frequency and duration of streamflow events that may restrict safe site access.

Flow conditions and flood hazard for the existing site access causeway are described in Section 4.2. The streamflow regime at the site is characterised in Section 4.3. Site access constraints are described in Section 4.4.

3.4 Flood modelling approach

The following assessment approach was applied to characterise flooding conditions at the site:

1. Review of available data and information for completeness and reliability. The available data and information were used to inform hydrologic and hydraulic model methodologies and assumptions.

2. Undertake flood frequency analysis for Martindale Creek (using data from the regional reference gauge) to provide confidence in flood model design flow estimates.

3. Development of a hydrologic model of the Martindale Creek catchment to the downstream extent of the site. The hydrologic model was established with the Watershed Bounded Network Model (WBNM) software and parameterised to the flood frequency analysis. Streamflow hydrographs from the hydrologic model were used to inform a two-dimensional (2D) hydraulic model.

4. Development of a 2D hydraulic model covering the Martindale Creek floodplain adjacent to the site and key drainage lines through the site. The hydraulic model was established using TUFLOW software. The TUFLOW model was used to simulate surface flows and establish flood conditions.

5. Processing and presentation of flood model results to characterise flood extent, level, depth and hazard for the site.

Hydrologic and hydraulic model methodologies and results are described in Section 5.3 and Section 5.4 respectively.

3.5 Relevant guidelines

3.5.1 Australian Rainfall and Runoff

Australian Rainfall and Runoff (ARR 2019) (Ball et al. 2019) is a national guideline used for the estimation of design flood characteristics in Australia. The key objective of ARR 2019 is to provide the best available information on design flood estimation in a manner suitable for use by Australian practitioners. Ultimately the outcomes aim to support provision of reliable and robust estimates of flood risk, support risk mitigation and community resilience.

Recommended methodologies and supporting data and information from ARR 2019 (and the ARR Data Hub) have been applied to develop estimates of design flood events in Chapter 5.

3.5.2 Flood Risk Management Manual

The NSW Flood Risk Management Manual (DPE 2022) supports the NSW Flood Prone Land Policy. The policy has the primary objective of reducing the impact of flooding and flood liability on individual owners and occupiers of flood prone land, and to reduce private and public losses resulting from floods. At the same time, the policy recognises the benefits from occupation and development of flood prone land.

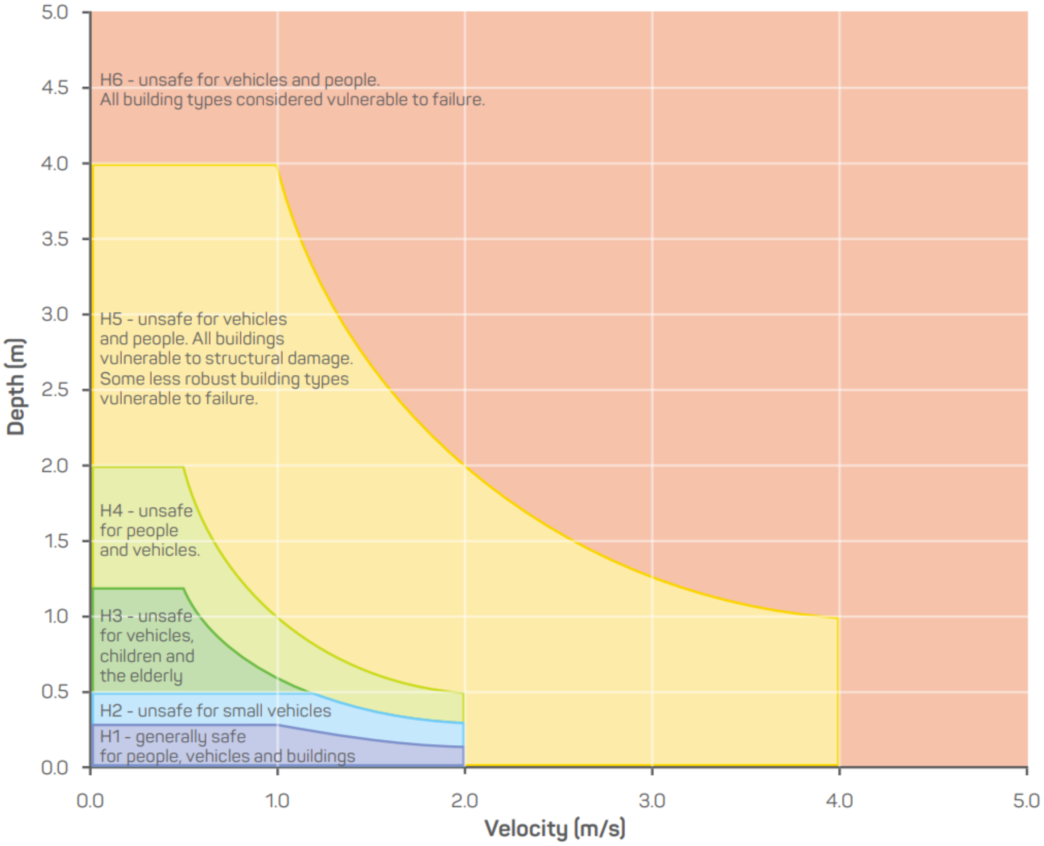
The Flood Risk Management Manual draws on information contained in the Australian Disaster Resilience Guideline flood hazard guideline (AIDR 2017) when describing flood hazard.

3.5.3 Australian Disaster Resilience Guideline: Flood hazard

The Australian Disaster Resilience Guideline flood hazard guideline (AIDR 2017) describes flood vulnerability using thresholds related to the stability of people and vehicles as they walk or drive through flood waters, or shelter in a building during a flood.

i General flood hazard curves

The general flood hazard vulnerability curves presented in the flood hazard guideline (AIDR 2017) have been used to describe flood hazard for the site and are reproduced in Figure 3.1. The corresponding flood hazard classification limits for each threshold curve are tabulated in Table 3.1.



Source: AIDR (2017)

Figure 3.1 General flood hazard vulnerability curve

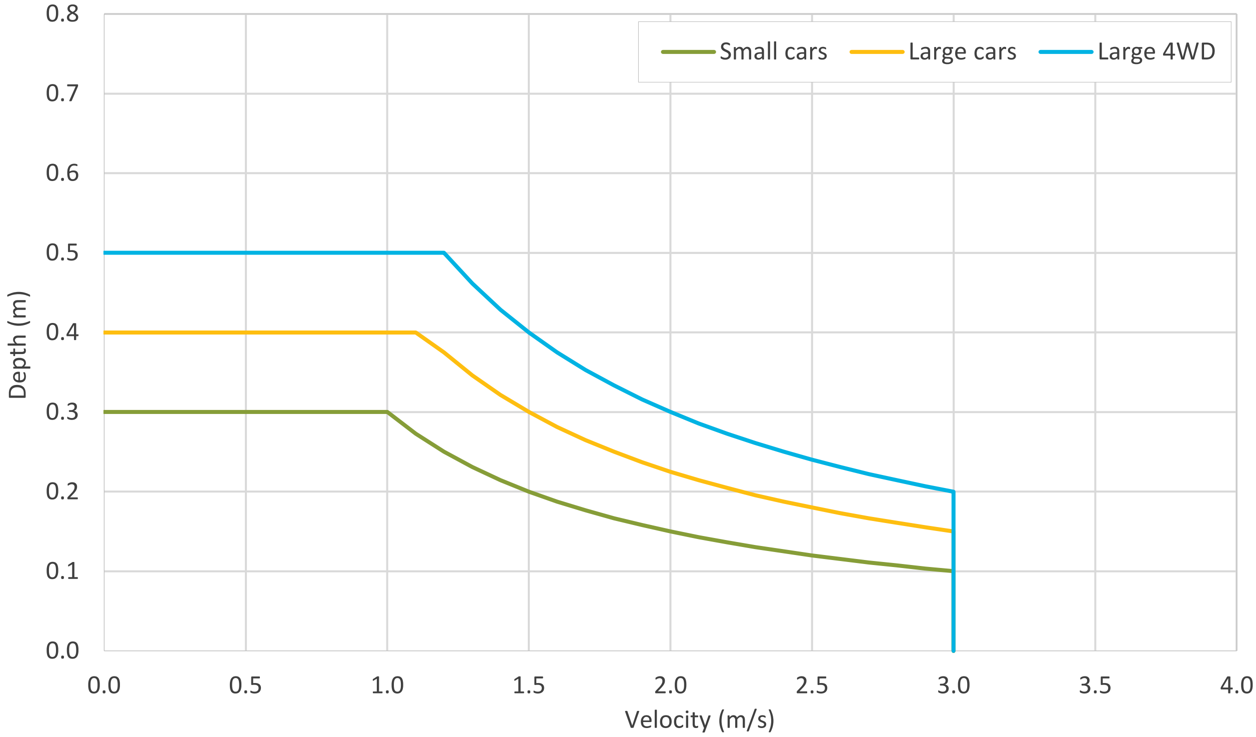
Table 3.1 Flood hazard threshold classification limits

Hazard classification	Classification limit			Description
	Still water depth (m)	Velocity (m/s)	Depth x velocity (m^2/s)	
H1	0.3	2.0	≤0.3	Generally safe for vehicles, people, and buildings.
H2	0.5	2.0	≤0.6	Unsafe for small vehicles.
H3	1.2	2.0	≤0.6	Unsafe for vehicles, children, and the elderly.
H4	2.0	2.0	≤1.0	Unsafe for vehicles and people.
H5	4.0	4.0	≤4.0	Unsafe for vehicles and people. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure.
H6	-	-	≤4.0	Unsafe for vehicles and people. All building types considered vulnerable to failure.

Source: AIDR (2017)

ii Vehicle specific flood hazard curves

The flood hazard guideline (AIDR 2017) also references specific flood hazard classifications for vehicles based on the outcomes of *Australian Rainfall and Runoff Project 10: Appropriate Safety Criteria for Vehicles* (Shand et al. 2011). The flood hazard thresholds for vehicle stability recommended by Shand et al. (2011) are reproduced in Figure 3.2.



Source: Shand et al. (2011)

Figure 3.2 Flood hazard thresholds for vehicle stability in floods

A comparison between the vehicle specific flood hazard curves in Figure 3.2 and the general flood hazard curves in Figure 3.1 indicates:

- flood hazard for small vehicles is similar to general flood hazard category H1;
- flood hazard for large 4WD vehicles is similar to general flood hazard category H2;
- an additional flood hazard curve has been developed for 'large cars' which is shown to lie between small vehicles and large 4WD vehicles; and
- the upper limiting velocity threshold is increased from 2 m/s to 3 m/s. However, these high velocities will not occur at shallow flow depths for the site.

In general, the vehicle specific curves are similar to the flood hazard curves Figure 3.1 with the exception of higher velocity thresholds. The vehicle specific flood hazard curves are considered when describing site access constraints in Section 4.4.

4 Streamflow analysis

4.1 Overview

The existing site access road crosses Martindale Creek via a concrete causeway. Safe access to the site is restricted when flow conditions within Martindale Creek exceed the safe access thresholds described in Section 3.5.3. This chapter characterises flow conditions at the existing causeway and estimates the frequency and duration at which site access would be constrained under existing access conditions. The same methodology is also used to assess the alternative access arrangements (refer to Chapter 6).

4.2 Safe access thresholds

4.2.1 Flow conditions

Flow conditions over the existing causeway were characterised using the hydraulic model described in Section 5.4. This was achieved by gradually increasing the modelled streamflow in Martindale Creek and recording the corresponding simulated flow depth and velocity over the causeway at each flowrate. The resulting flowrate to depth, velocity, and velocity/depth (VD) product relationships are shown in Figure 4.1. Relevant limits/thresholds established in Section 3.5 are also shown for context.

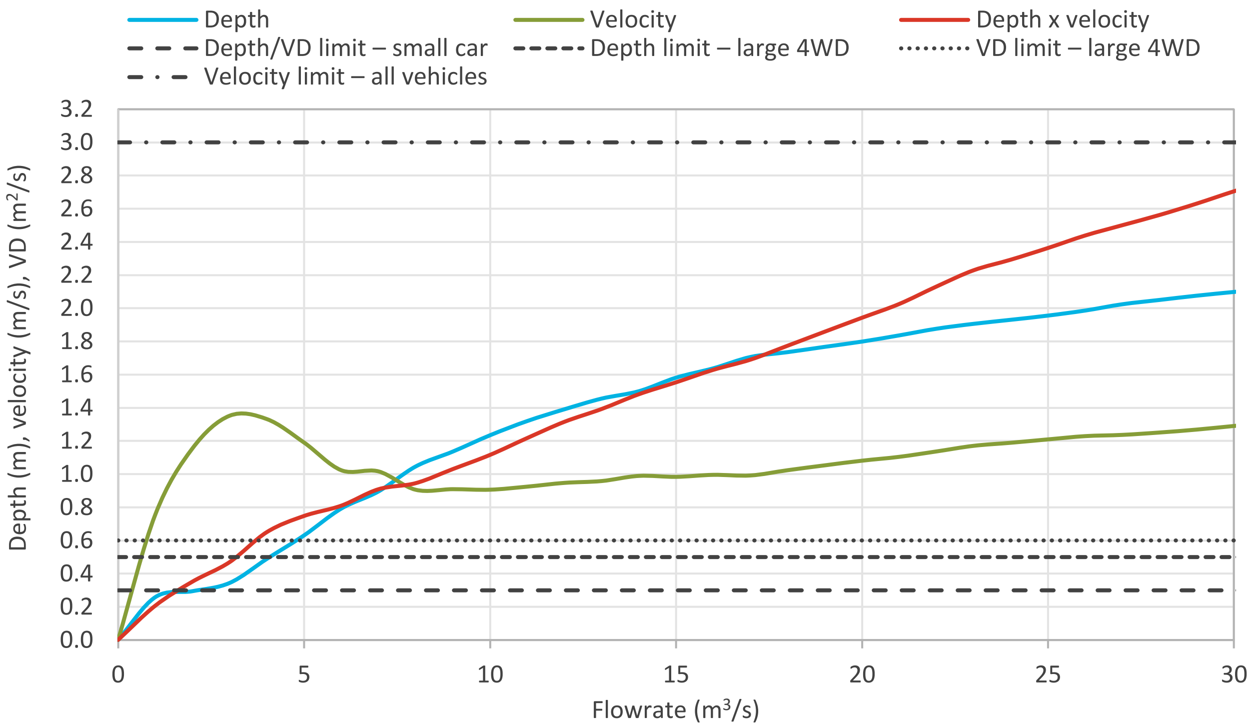


Figure 4.1 Existing causeway flow conditions

The curves presented in Figure 4.1 show:

- Velocity increases rapidly at lower flowrates when streamflow is primarily contained within the existing causeway footprint (ie at flow depths less than 0.3 m). The initial higher velocity is expected to be associated with weir flow processes caused by the concrete causeway and a lower downstream tailwater level. The maximum velocity is shown to be 1.4 m/s.

- As the flowrate increases, the causeway becomes 'drowned' and a decreasing velocity trend occurs between flowrates of 3–8 m^3/s. Velocity gradually increases again for flowrates above 8 m^3/s.
- Flow depth increases faster at lower flowrates than higher flowrates as more waterway area becomes available once overbank flows commence.
- The flow velocity/depth product is the limiting factor for both small and large 4WD vehicles accessing the site, with access restricted when streamflow exceeds 1.6 m^3/s and 3.7 m^3/s respectively.

The limiting flow conditions for vehicle access across the existing causeway are summarised in Table 4.1. The frequency and duration of restrictions are described in Section 4.4.

Table 4.1 Existing causeway access limitations

Vehicle type	Depth		Velocity		Velocity x depth		Limiting flowrate (m^3/s)
	Limit (m)	Flowrate (m^3/s)	Limit (m/s)	Flowrate (m^3/s)	Limit (m^2/s)	Flowrate (m^3/s)	
Small car	0.3	2.2	2.0	N/A	≤0.3	1.6	**1.6**
Large 4WD	0.5	4.1	2.0	N/A	≤0.6	3.7	**3.7**

4.2.2 Flood hazard

Flood hazard at the existing causeway has been characterised using the general flood hazard curve in Figure 3.1 and the causeway specific flowrate to velocity/depth curves in Figure 4.1. The flood hazard category (H1 to H6) at the causeway for a given flowrate within Martindale Creek is shown Figure 4.2.

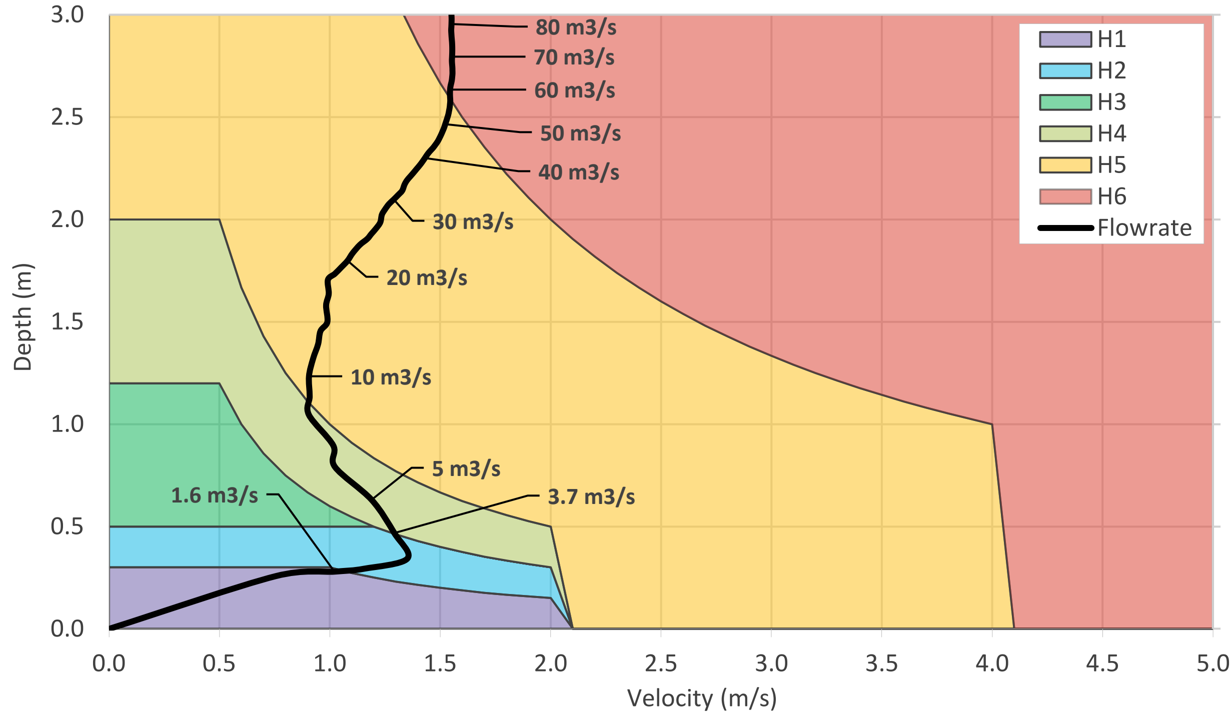


Figure 4.2 Existing causeway flood hazard classification

The flood hazard classification data shown in Figure 4.2 indicates:

- hazard classifications H1 and H2 are exceeded at a flowrate of 1.6 m^3/s and 3.7 m^3/s respectively;
- the flow regime transitions directly from H2 to H4 as the velocity/depth limiting factor of 0.6 m^2/s is exceeded in all flow rates above 3.7 m^3/s; and
- hazard classifications H4 and H5 are exceeded at a flowrate of 8.7 m^3/s and 54.7 m^3/s respectively.

As described in Section 3.5.3, hazard classification H3 is generally considered low risk for adult stability in floodwaters. As the flow regime transitions directly from hazard classification H2 to H4, H3 does not apply, and the limiting flow rate (3.7 m^3/s) for H2 and large 4WD vehicles is also applicable to pedestrian crossing of the causeway.

The vehicle specific flood hazard curves presented in Figure 3.1 show flow velocities greater than 2 m/s may be acceptable for vehicle passage if flow depth remains relatively low. The flowrate curve in Figure 4.2 shows flow depth is the controlling factor for flood hazard and that velocities in excess of 2 m/s are not experienced for flow depths less than 3 m. Hence, the vehicle specific flood hazard curves result in the same hazard classification as the general curves for the site access causeway.

4.3 Streamflow regime

4.3.1 Overview

Streamflow analysis has been undertaken to estimate frequency and duration of flow conditions that will exceed the safe access thresholds established in Section 4.2.

4.3.2 Methodology

Martindale Creek is an ungauged catchment. Stream gauge data is available for the upper Macdonald River catchment, which is immediately south-east of the Martindale Creek catchment (refer to Figure 5.3). Streamflow for the upper Macdonald River catchment is recorded at WaterNSW operated Macdonald River at Howes Valley (station number 212021) stream gauge, which has a contributing catchment of 299 km^2.

Streamflow characteristics at the Macdonald River gauge are expected to be similar to that of Martindale Creek at the site due to similar locations (adjacent catchments), catchment size (299 km^2 verse 247 km^2) and similarity of predominate land use (steep, undeveloped bushland). Hence, in the absence of catchment-specific data, streamflow data from the Macdonald River gauge was used to characterise the streamflow regime of Martindale Creek at the site.

It should be noted that higher maximum streamflow rates and volumes are expected for the Macdonald River gauged compared to Martindale Creek at the site due to the larger catchment size. For simplicity, the Macdonald River streamflow data has not been adjusted to account for the difference in catchment sizes when describing streamflow regime in this section. The impact of different catchment sizes is considered as part of the flood frequency analysis described in Section 5.2.

Historical streamflow data at the Macdonald River at Howes Valley gauge is available between 1976–1993 and 2008–2022, a 30-year period. Streamflow was not recorded at the gauge between 1993 and 2008. The reason for the data gap is unknown. However, it is noted that the June 2007 flood was not recorded at the gauge. The historical streamflow record is shown in Figure 4.3.

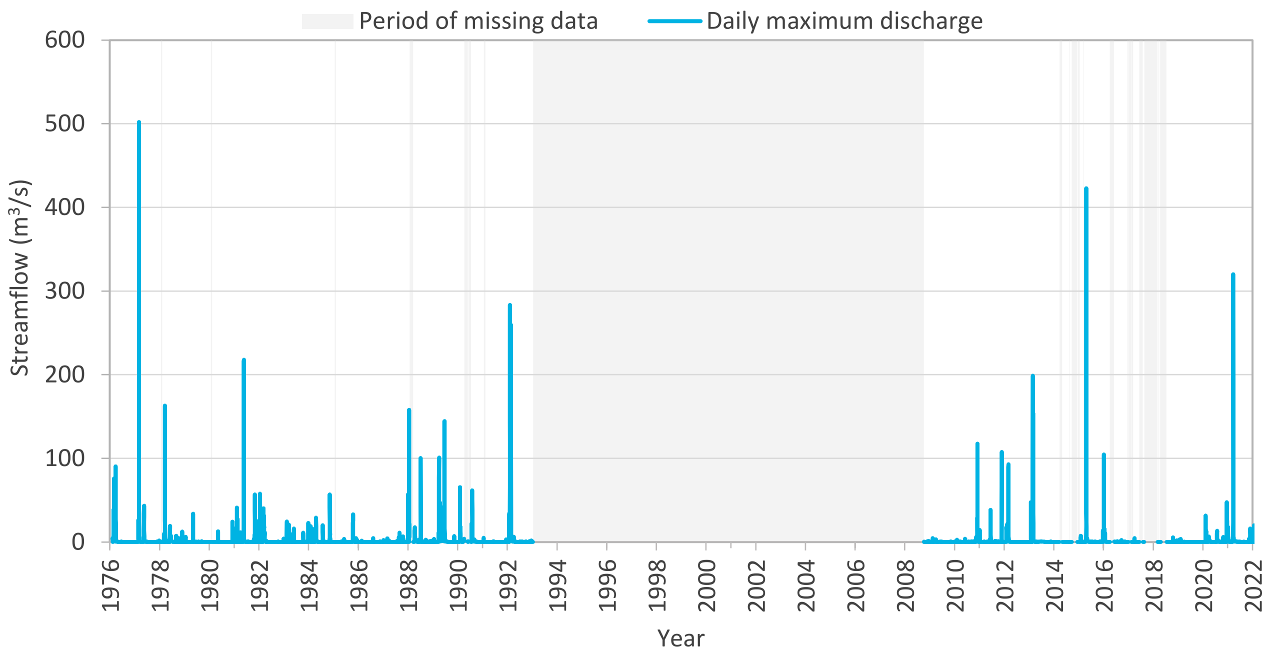


Figure 4.3 Historical maximum daily streamflow record – Macdonald River at Howes Valley

4.3.3 Streamflow hydrographs

The rainfall runoff response in the catchment was investigated by extracting hydrographs from typical streamflow events that generate high flows but would not be considered floods (refer to Figure 4.4) along with hydrographs from the largest recorded streamflow events (refer to Figure 4.5). It is noted that streamflow in Figure 4.5 is shown using a log scale. The safe access threshold flow rate for a Large 4WD (3.7 m^3/s) established in Section 4.2 is also shown for context.

The streamflow hydrographs presented in Figure 4.4 and Figure 4.5 indicate:

- The streamflow rate can rise rapidly for both typical low flow and large runoff events with site access restrictions occurring within a matter of hours.
- Typical streamflow events result in site access being restricted for several hours to several days depending on the magnitude of the event and rainfall distribution. Site access is generally re-established within three days of the rainfall event occurring.
- Large streamflow events result in site access being restricted for longer periods of time with site access generally re-established within 10 days.

While the streamflow hydrographs presented in Figure 4.4 and Figure 4.5 only represent a small portion of the possible catchment rainfall runoff responses, they are expected to provide a good indication of how rapidly streamflow can rise (hours) and remain elevated (days) within the catchment.

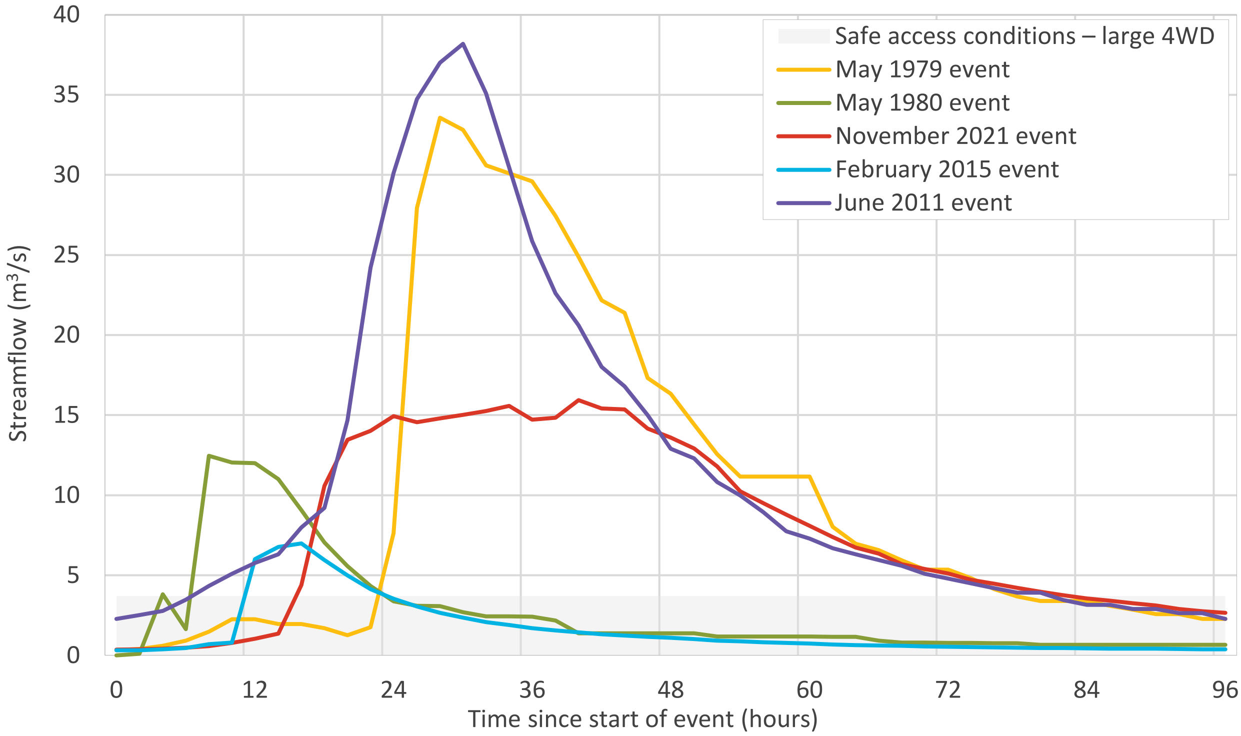


Figure 4.4 Observed streamflow hydrographs – typical streamflow events

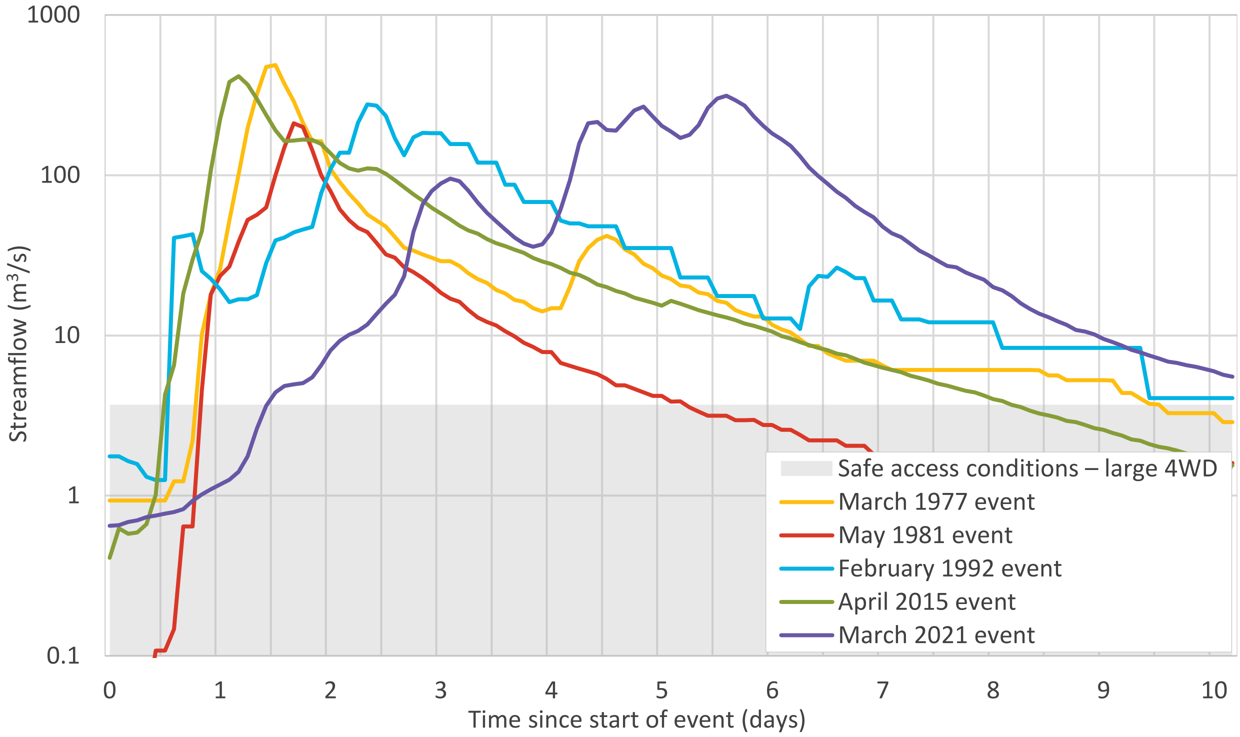


Figure 4.5 Observed streamflow hydrographs – largest streamflow events

4.3.4 Flow duration curve

Flow duration curves provide a statistical representation of the frequency of various flow rates. A flow duration curve was developed for the Macdonald River at Howes Valley gauge based on daily maximum streamflow values over 30 years of historical data (1976–1993 and 2008–2022) and is shown in Figure 4.6. Flow duration curves for each decade of the historical dataset are also shown to provide context for dry (2010-2020) and wet (2020-2022) periods.

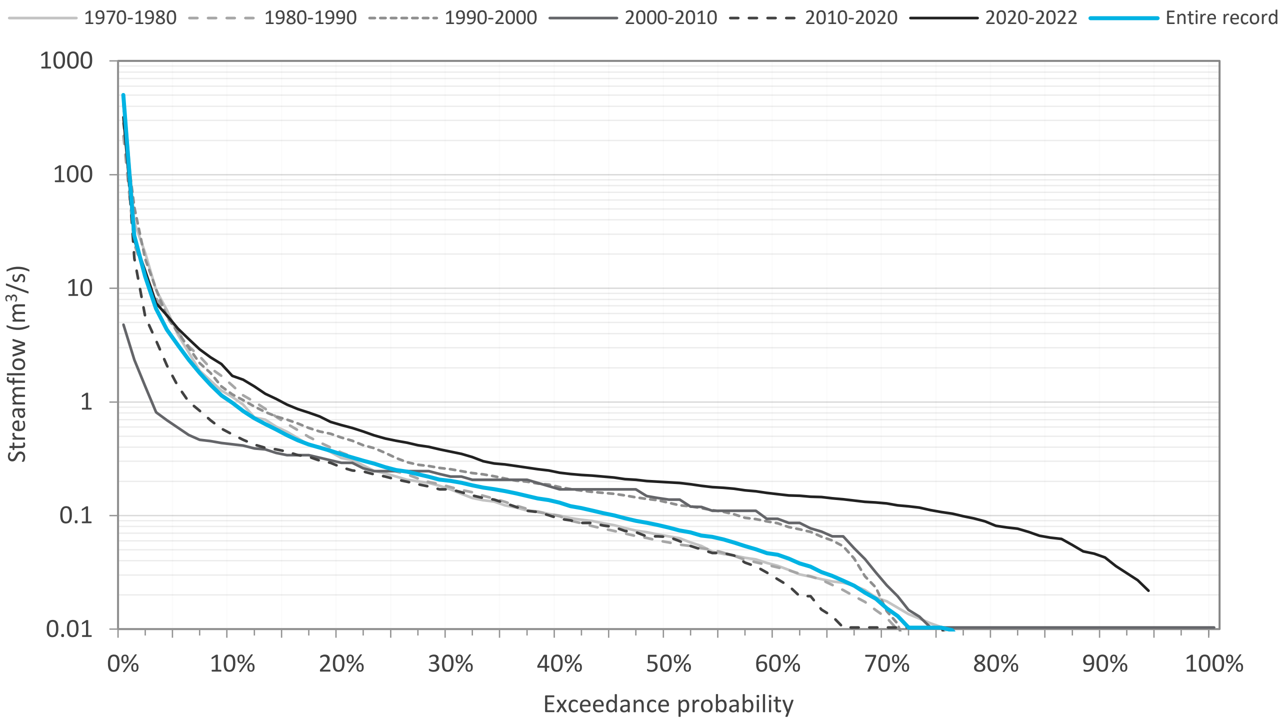


Figure 4.6 Flow duration curves – Macdonald River at Howes Valley

The flow duration curves presented in Figure 4.6 indicate:

- Streamflow of less than 1 m^3/s ranges from 84% of the time in wet periods to 93% of the time in dry periods, and 91% of the time over the entire record.
- Streamflow was observed to exceed the small vehicle safe access threshold of 1.6 m^3/s less than 8% of the time over the entire record and up to 12% of the time in wet periods.
- Streamflow was observed to exceed the large 4WD vehicle safe access threshold of 3.7 m^3/s less than 5% of the time over the entire record and up to 7% of the time in wet periods.

4.4 Site access restrictions

The information presented in Section 4.2 and Section 4.3 was used to characterise the frequency and duration of site access restrictions over the 30-year streamflow record. The estimated frequency of streamflow events that would restrict access for small car and large 4WD vehicles is shown in Figure 4.7. Streamflow events that would restrict safe site access are shown to occur more than five and six times per year in 50% of years for large 4WD and small vehicles respectively. More than 10 events per year are expected to occur in 10% of years.

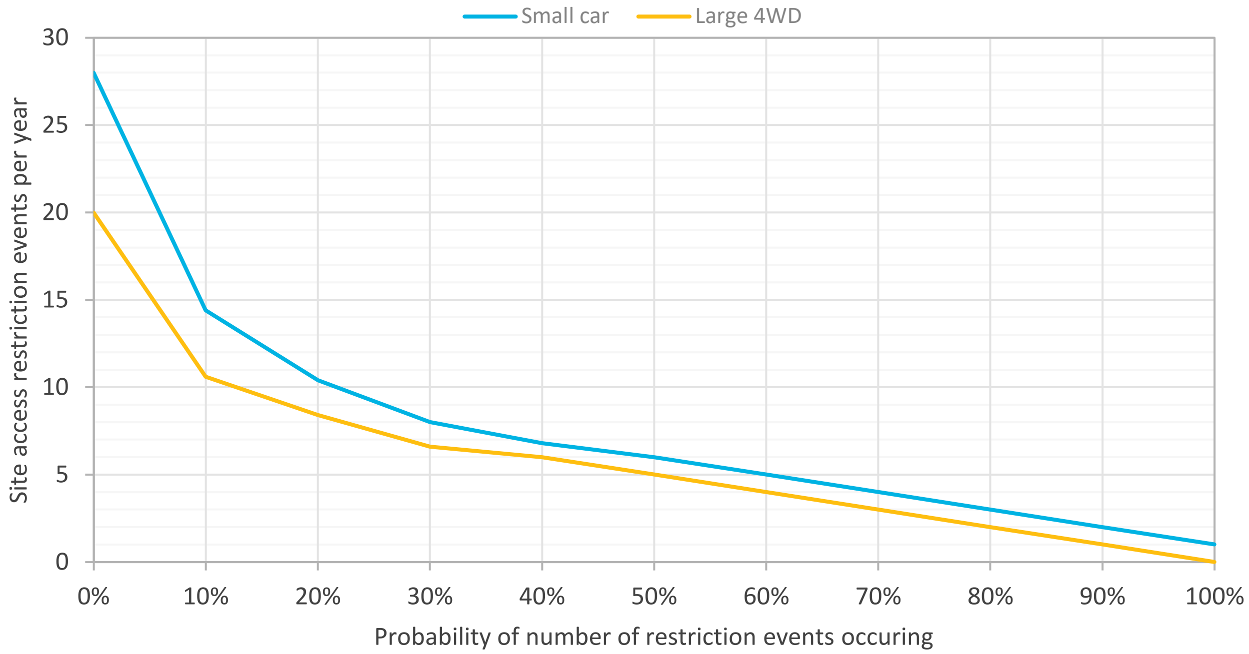


Figure 4.7 Number of site access restricting streamflow events per year

Exceedance curves representing the duration of streamflow events that would restrict access for small cars and 4WD vehicles are presented in Figure 4.8. The curves show that in 50% of events, safe access would be restricted to approximately 1 day for large 4WD vehicles and 1.5 days for small cars. Restrictions of more than 6 days occur in approximately 10% of events.

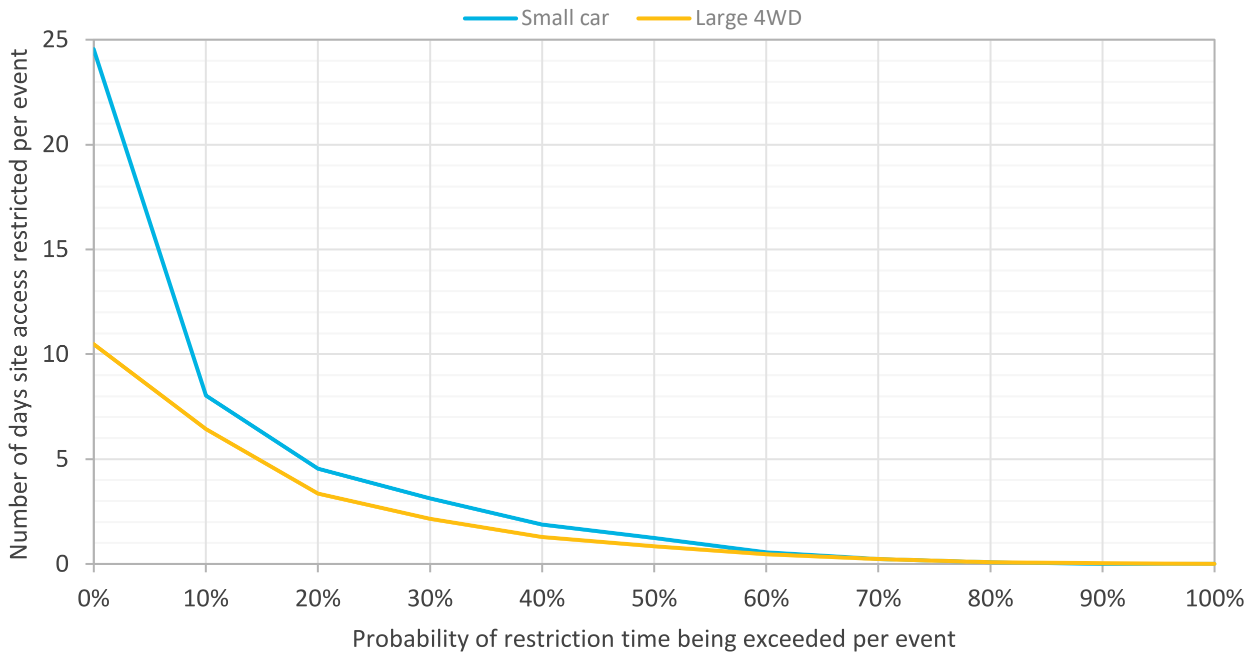


Figure 4.8 Duration of site access restrictions during a streamflow event

5 Flood modelling

5.1 Overview

This chapter describes the methodology and assumptions that were applied to develop the hydrologic and hydraulic models used to characterise existing flood conditions at the site. This section has been updated since the EMM (2020) flood risk assessment to include a flood frequency analysis, parameterisation of the hydrology model, and modelling of several additional (63.2%, 20%, and 5% AEP and PMF) design flood events.

5.2 Flood frequency analysis

5.2.1 Available data

Flood frequency analysis (FFA) was undertaken using data from the Macdonald River at Howes Valley stream gauge (refer to Section 4.3). FFA was undertaken on the maximum annual flow for 28 of the 30 years of historical data (1976–1993 and 2008–2022). Annual maximums from 1993 and 2008 were excluded due to gaps in the dataset. The maximum annual flow series is provided in Table 5.1.

Table 5.1 Maximum annual flow series – Macdonald River at Howes Valley

Year	Flowrate (m^3/s)	Year	Flowrate (m^3/s)	Year	Flowrate (m^3/s)
1976	90	1986	4	2012	93
1977	502	1987	11	2013	199
1978	163	1988	158	2015	423
1979	34	1989	145	2016	104
1980	24	1990	66	2017	5
1981	218	1991	5	2019	4
1982	58	1992	283	2020	47
1983	24	2009	5	2021	320
1984	57	2010	118		
1985	33	2011	107		

5.2.2 Flood frequency approach and results

FFA was undertaken using the software package TUFLOW FLIKE. FLIKE is an extreme value analysis package that calculates the probability of flood events based on historical records using the highest instantaneous discharge rate in each year of record. The use of FLIKE for FFA is recommended in the ARR 2019 guidelines (Ball et al. 2019).

In many Australian watercourses there are often years in which there are no floods. The annual maximum from those years is not representative of the population of floods and can unduly influence the fit of the distribution (Ball et al. 2019). The annual maximum flow series at the gauge was analysed using the Grubbs-Beck test for statistical outliers, with five events (1991, 2017, 2009, 1986, 2019) with a peak flow less than 11.3 m^3/s censored from the record during analysis. Application of the Grubbs-Beck test was undertaken in unison with visual assessment of the applied distribution.

The Log-Pearson III distribution was found to be the most suitable probability distribution for the streamflow record. The resulting flood frequency curve is shown in Figure 5.1.

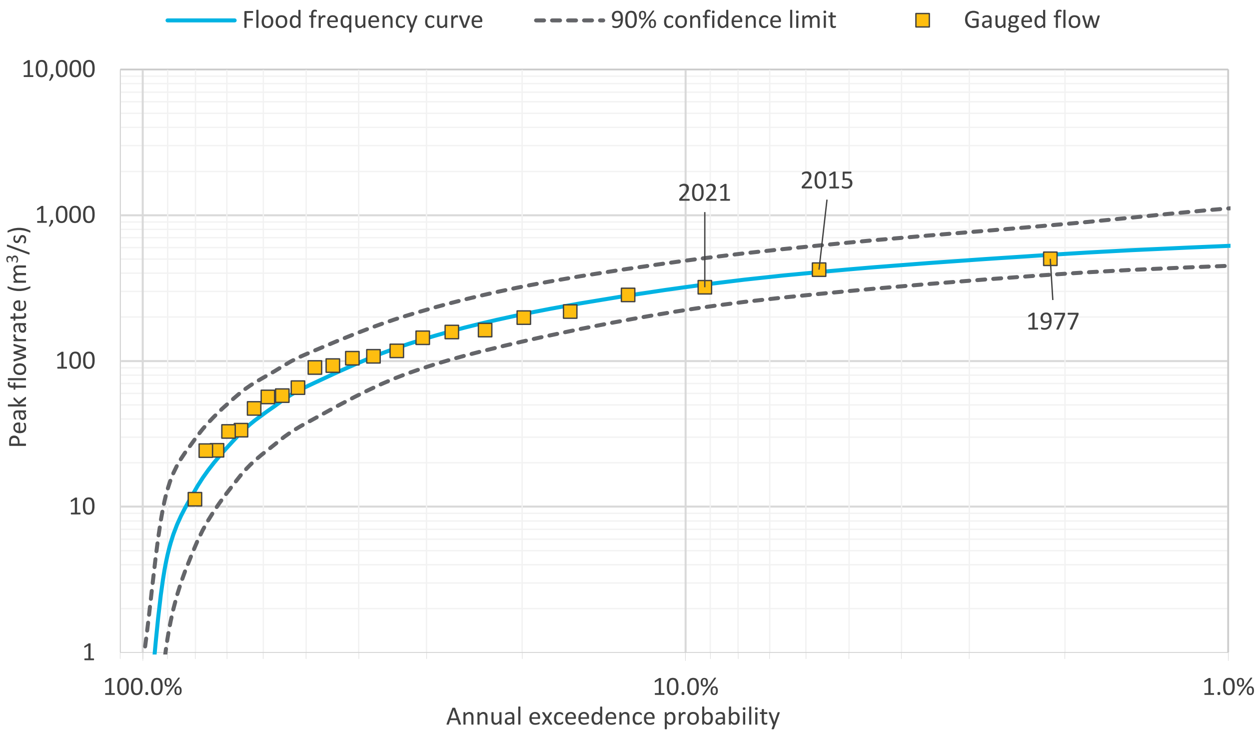


Figure 5.1 Flood frequency curve – Macdonald River at Howes Valley

5.2.3 Scaling of flood frequency analysis results to site catchment area

The FFA for Macdonald River at Howes Valley stream gauge has been used to define the flood behaviour of Martindale Creek at the site. This is considered appropriate given the proximity of the catchments, and similarity in catchment size and land-use.

The FFA determined flow rates were scaled to account for the difference in catchment size between the Macdonald River at Howes Valley stream gauge (299 km^2) and the Martindale Creek catchment size at the site (247 km^2). Streamflow scaling was completed using the methodology describe in Hydrological Recipes (Grayson et al. 1996), whereby streamflow at the site was calculated by the following:

$$Streamflow\ multiplier = (A_C/A_G)^b$$

Where, A_C is the area of the ungauged catchment;

A_G is the area of the gauged catchment; and

b is a streamflow adjustment exponent using the default value of 0.7.

The resulting streamflow multiplier for the Martindale Creek catchment at the site is 0.87. The scaled peak flowrates are compared against the Macdonald River at Howes Valley gauged flowrates for several flood event magnitudes in Table 5.2. The scaled FFA curve is shown in Figure 5.2.

Table 5.2 Flood frequency analysis – comparison of scaled peak flow rates

Annual exceedance probability	Peak flood flowrate (m^3/s)	
	FFA – Macdonald River at Howes Valley	Scaled flow – at site
63.2%	37	32
20%	209	182
10%	322	280
5%	426	371
2%	544	473
1%	617	537

5.2.4 Application to WBNM hydrologic model

The FFA has been used to parameterise the WBNM hydrologic model described in Section 5.3. The hydrologic model initial and continuing losses were adjusted until a reasonable fit to the scaled FFA curve was achieved. An initial loss of 55 mm was determined to provide a good fit for the 63.2% AEP event while an initial loss of 15 mm was determined to provide a good fit for all other less frequent flood events modelled for parameterisation purposes. A continuing loss of 1.1 mm/hour provided a good fit for all flood events.

The parameterised WBNM model flows are compared against the scaled FFA curve in Figure 5.2. The WBNM modelled flows are shown to be a close match to the scaled FFA curve with more frequent events slightly overestimating flow and less frequent events underestimating flows. All WBNM modelled flows are within the 90% confidence limits.

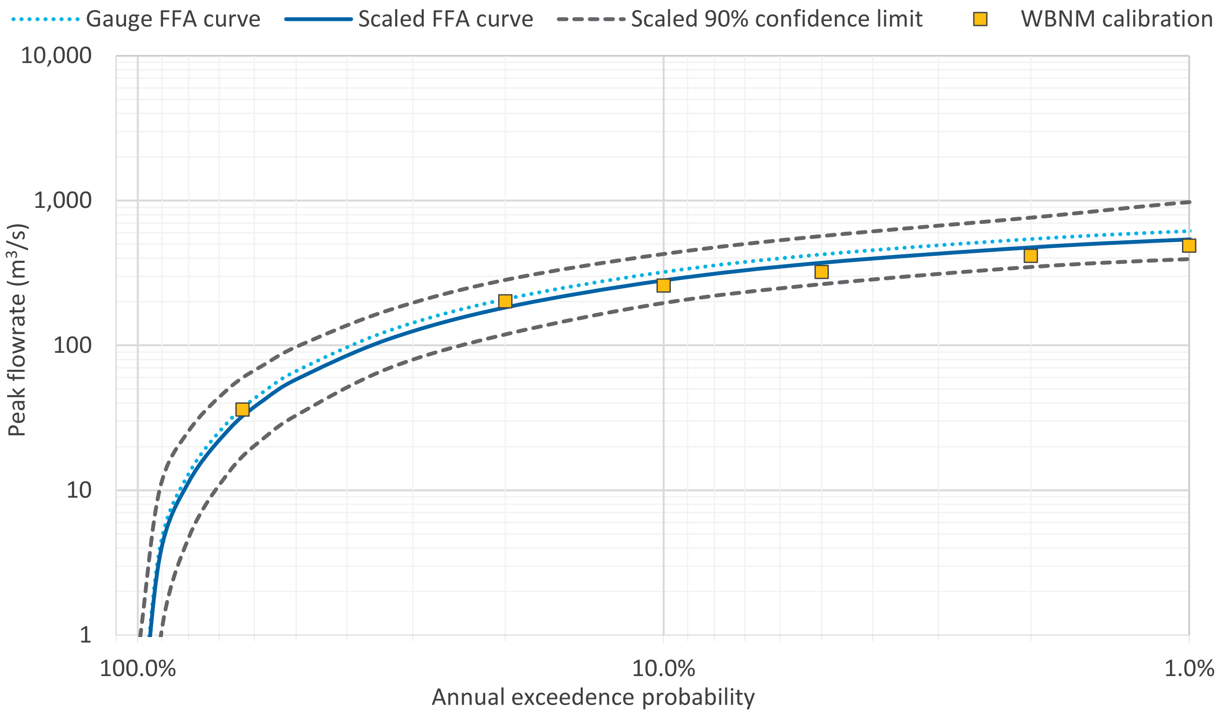


Figure 5.2 Hydrology model parameterisation to flood frequency curve

5.3 Hydrology

5.3.1 Overview

The site is in the lower portion of the Martindale Creek Catchment. Hydrologic modelling was undertaken to establish the 63.2%, 20%, 5% and 1% AEP and PMF streamflow hydrographs at the site. The streamflow hydrographs were applied to the hydraulic model (discussed in Section 5.4) to establish flood characteristics for the site. This section describes the hydrologic modelling approach and results.

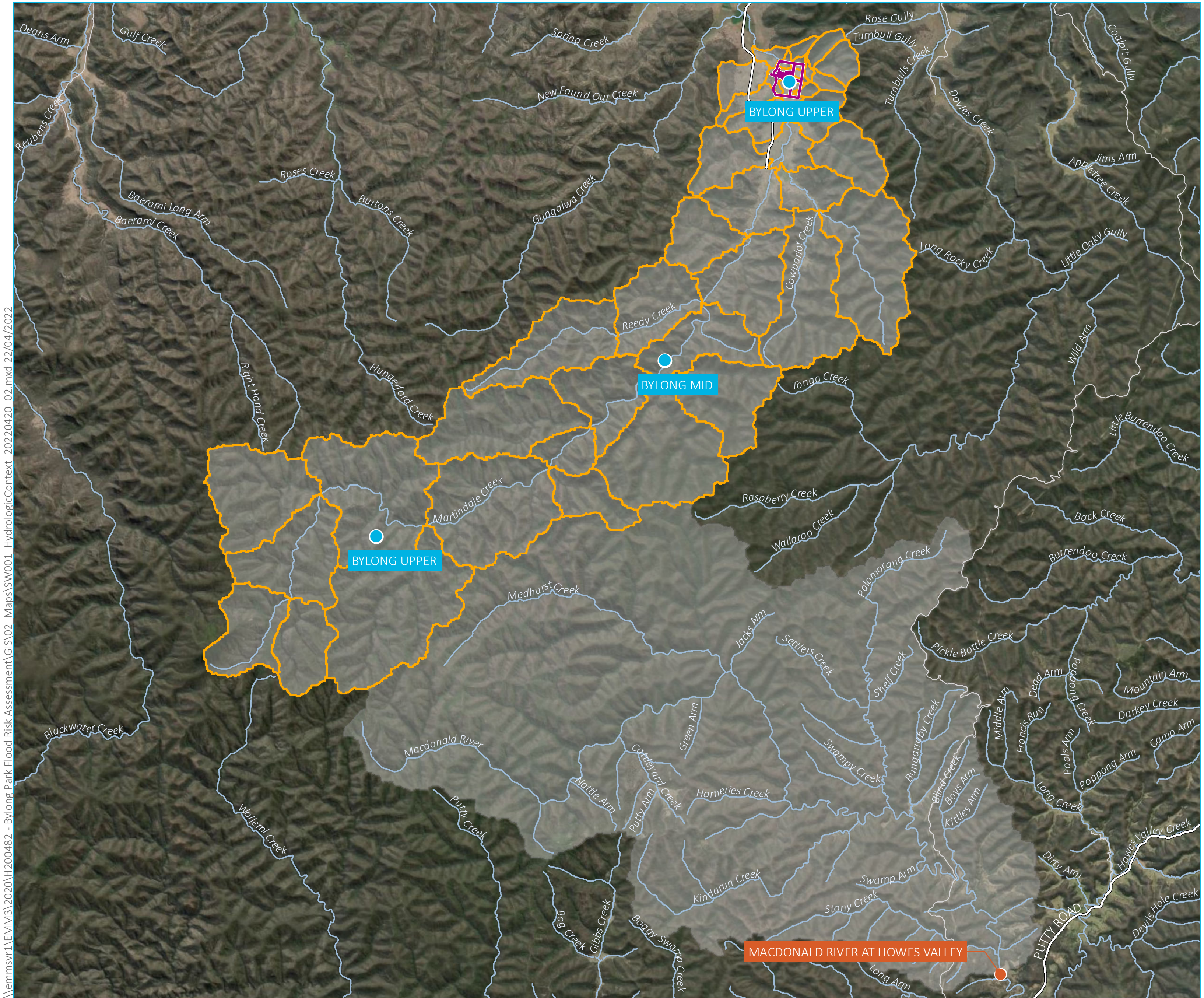
5.3.2 Hydrologic model setup

i Model schematisation and parameters

A WBNM hydrologic model was developed to determine design flows for the Martindale Creek catchment. The WBNM hydrologic model extends from the Martindale Creek headwaters to approximately 1,200 m downstream of the site, representing a total catchment area of 247 km^2. The Martindale Creek catchment was subdivided into 45 sub-catchment areas, based on SRTM DEM and available watercourse mapping. Sub-catchments in the vicinity of the site were refined using a LiDAR DEM. The sub-catchment layout adopted for the basis of the WBNM hydrologic model is shown in Figure 5.3.

WBNM parameters were determined via inspection of available data including aerial photography, the STRM and LiDAR DEMs, and observations made during the site visit. The following provides a summary of key sub-catchment data, assumptions and adopted WBNM parameters:

- all catchments were assumed to be 100% pervious;
- the WBNM theory manual (WBNM 2019) recommended catchment lag value of 1.6 has been applied across the catchment; and
- channel flow has been conveyed using the routing method and a stream lag factor of 1.0.



KEY

- Site boundary
- WBNM sub-catchment
- Macdonald River at Howes Valley gauge catchment
- Stream gauge location
- Rainfall depth location
- Major road
- Minor road
- Named watercourse

INSET KEY

- Major road
- NPWS reserve
- State forest

Source: EMM (2022); ABS (2021); DFSI (2020, 2021); ESRI (2022); GA (2011); Metromap (2022)

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Hydrologic context

Bylong Park, NSW
Flood Risk Assessment
Figure 5.3

EMM
creating opportunities

ii Design rainfall

a General storm events

Design rainfall depths were obtained from the BoM. An analysis of design rainfall depths identified a rainfall gradient across the contributing catchment. Lower rainfall depths are experienced in the lower catchment near the site. Greater rainfall depths are experienced in the upper catchment. To model the rainfall gradient, design rainfall depths were obtained at a lower, middle and upper catchment locations (refer to Figure 5.3). Design rainfall depths for the 63.2%, 20%, 5% and 1% AEP storm events are provided in Table 5.3.

Table 5.3 Design rainfall depths (lower catchment/mid catchment/upper catchment)

Duration (minutes)	63.2% AEP event (mm/storm)	20% AEP event (mm/storm)	5% AEP event (mm/storm)	1% AEP event (mm/storm)
720	43\45\48	64\67\70	88\91\94	119\123\126
1,080	49\52\57	75\79\84	104\108\113	142\147\152
1,440	55\58\64	84\88\95	117\122\129	161\167\175
1,800	59\63\69	91\96\104	128\134\143	177\185\195
2,160	62\67\74	98\103\113	138\145\155	191\200\212
2,880	68\74\82	108\115\126	154\163\176	213\225\241
4,320	76\83\93	122\131\145	176\187\204	242\257\281

Source: Bureau of Meteorology.

b Probable maximum precipitation

Probable maximum precipitation (PMP) depths represent the upper limit of possible rainfall and are used to determine flood characteristics for the PMF. The Generalised Short Duration Method (GSDM) (BoM 2003a) was used to develop PMP estimates for storm durations of 6 hours or less while the Generalised Southeast Australia Method (GSAM) (BoM 2003b) and Generalised Tropical Storm Method Revised (GTSMR) (BoM 2003c) where used to develop PMP estimates for storm durations longer than 6 hours. The calculated PMP design depths are provided in Table 5.4.

Table 5.4 Design rainfall depths – PMP event

Duration	60 mins	120 mins	180 mins	270 mins	360 mins	720 mins	1440 mins	2160 mins
PMP rainfall depth (mm)	240	350	430	510	560	765	970	1,100

iii Rainfall losses

Australian Rainfall and Runoff 2019 (Ball et al. 2019) (ARR 2019) recommends initial and continuing losses for the study area of 53 mm and 4.4 mm/hour respectively, sourced from the ARR Data Hub. The *Floodplain Risk Management Guideline* (OEH 2019) recognises that loss values for NSW from the ARR Data Hub have resulted in "a significant bias toward underestimation of flows". The guideline provides a hierarchical approach to estimating loss and pre-burst values in NSW. This approach recommends using the parameterisation losses from other studies in the study catchment or similar adjacent catchments if available and appropriate for the study.

Initial loss and continuing loss values determined as part of the flood frequency analysis (refer to Section 5.2.4) were applied to the WBNM hydrologic model. An initial loss of 55 mm was applied to the 63.2% AEP event while an initial loss of 15 mm was applied to the 20%, 5% and 1% AEP events. No initial loss was applied to the PMF event. A continuing loss of 1.1 mm/hr was applied to all modelled storm events. The adopted losses are considered conservative compared to those recommended by the ARR Data Hub.

Rainfall burst initial losses were then modified in accordance with the approach outlined in the *Floodplain Risk Management Guideline* (OEH 2019), whereby initial loss is calculated as:

$$IL_{\text{burst for design}} = IL_{\text{storm calibrated or transformed}} \times (IL_{\text{burst from ARR datahub}} / IL_{\text{storm form ARR datahub}})$$

The resulting initial losses applied to the hydrologic model are provided in Table 5.5. For storm durations where no initial loss burst depths were provided by the ARR Data Hub, the initial loss depths for the next storm duration up were used.

Table 5.5 Hydrologic model rainfall losses (initial loss burst)

	Storm event			
Event duration (minutes)	**63.2% AEP**	**20% AEP**	**5% AEP**	**1% AEP**
360	40.6	6.8	5.2	3.3
720	43.3	7.6	5.9	4.0
1080	43.0	8.3	7.6	4.2
1440	46.8	9.7	9.1	4.6
2160	51.1	11.5	10.6	6.3
2880	48.7	11.1	11.6	7.2
4320	51.8	12.4	13.4	8.3

iv Rainfall temporal patterns

Rainfall temporal patterns are used to describe how rainfall is distributed as a function of time. The recommended ARR 2019 ensemble approach to applying temporal patterns has been utilised. The ensemble approach to flood hydrology modelling applies a suite of ten temporal patterns for each duration. Areal temporal patterns have been implemented as the study area catchment size is greater than 75 km^2. The temporal patterns were obtained from ARR Data Hub for the 'East Coast South' region.

v Areal reduction factor

Areal reduction factors were derived and applied in accordance with the ARR Data Hub. Areal reduction factors were automatically applied in WBNM for the 63.2%, 20%, 5% and 1% AEP events. No areal reduction factors were applied to the PMF event.

5.3.3 Hydrologic model results

i Critical storm assessment

Hydrology model design flows have been determined using the ARR 2019 ensemble approach. The critical duration is identified as the duration with the highest mean flow and the temporal pattern which is closest to the mean flow. The temporal pattern ensemble results for each of the modelled events are shown in Figure 5.4 to Figure 5.7. The critical duration for the PMF event was 360 minutes, resulting in a peak flow rate of 5,480 m^3/s. The simulated streamflow hydrograph from the critical storm duration was used to inform the TUFLOW hydraulic model.

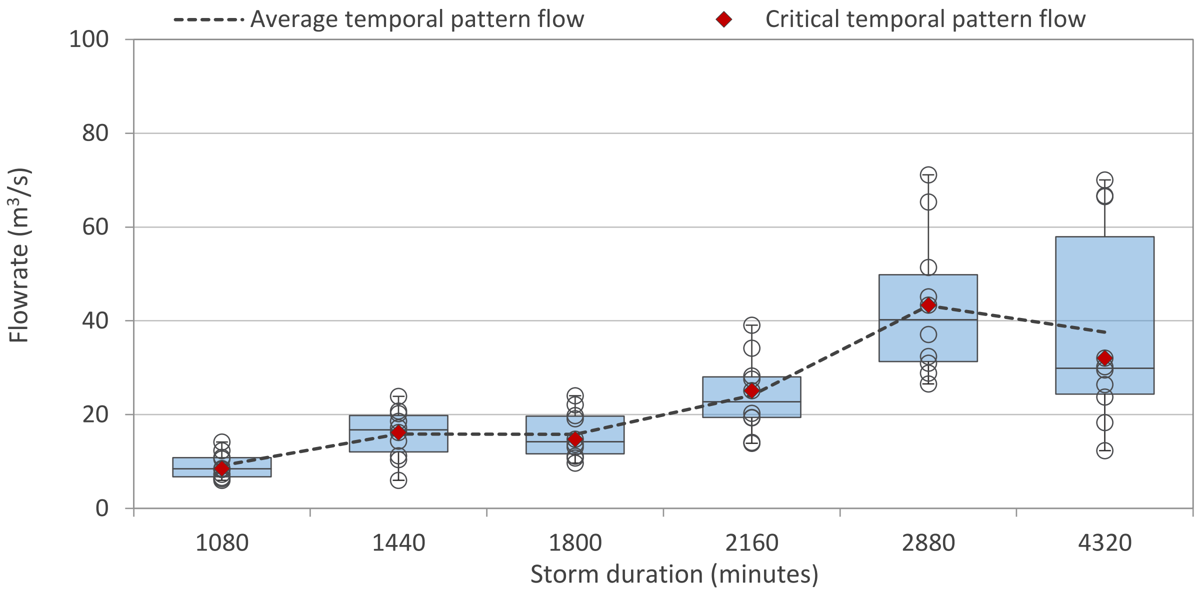


Figure 5.4 63.2% AEP critical storm duration

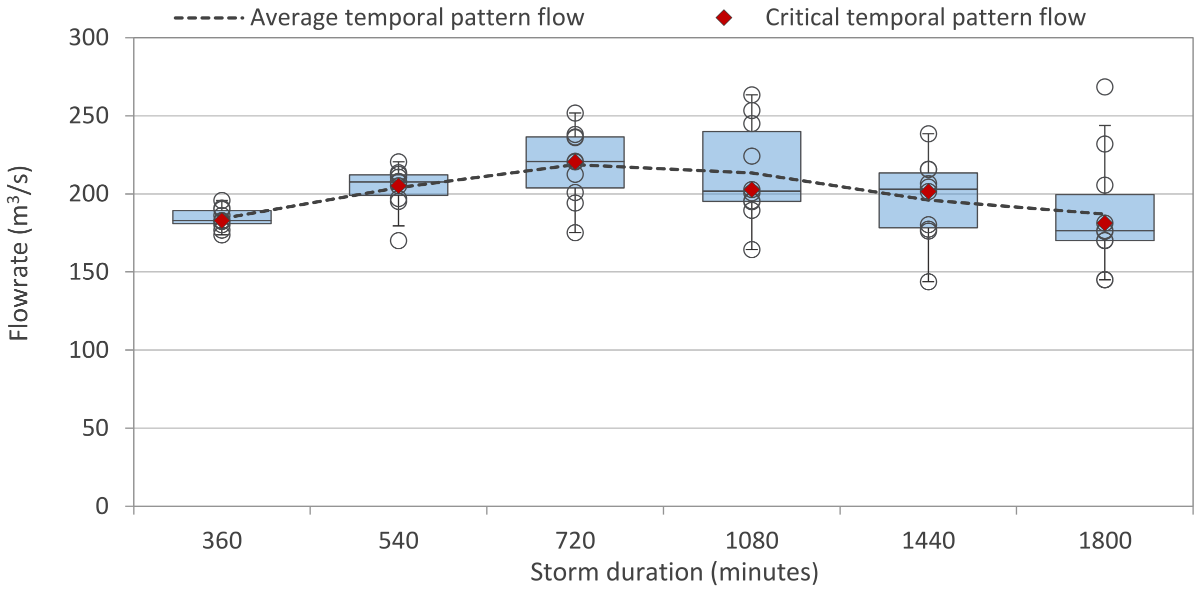


Figure 5.5 20% AEP critical storm duration

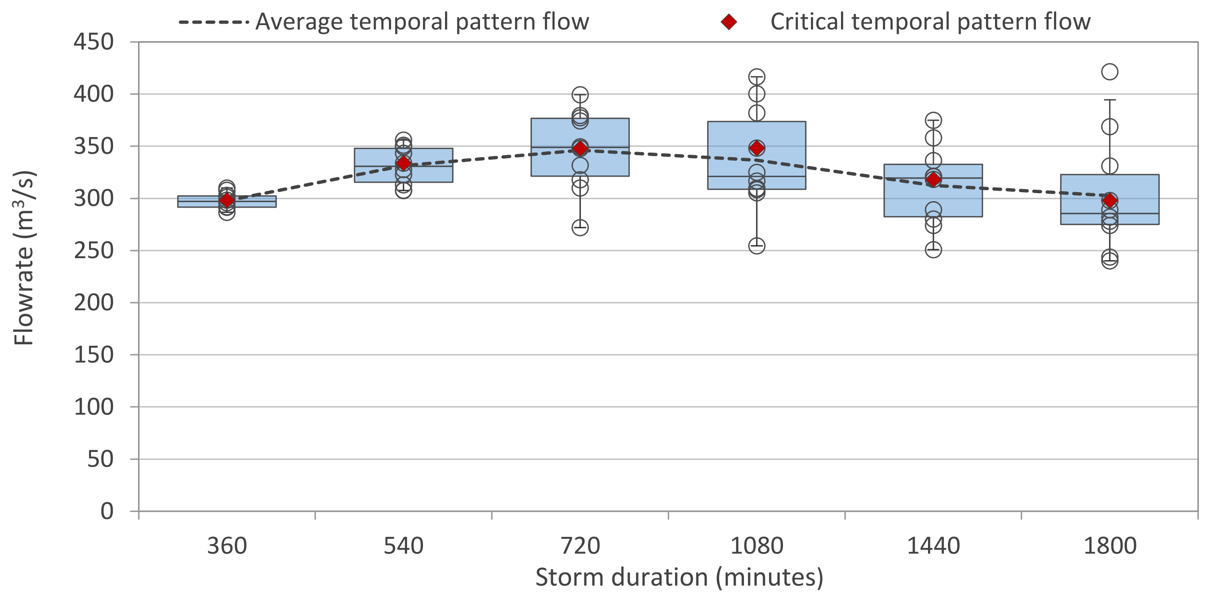


Figure 5.6 5% AEP critical storm duration

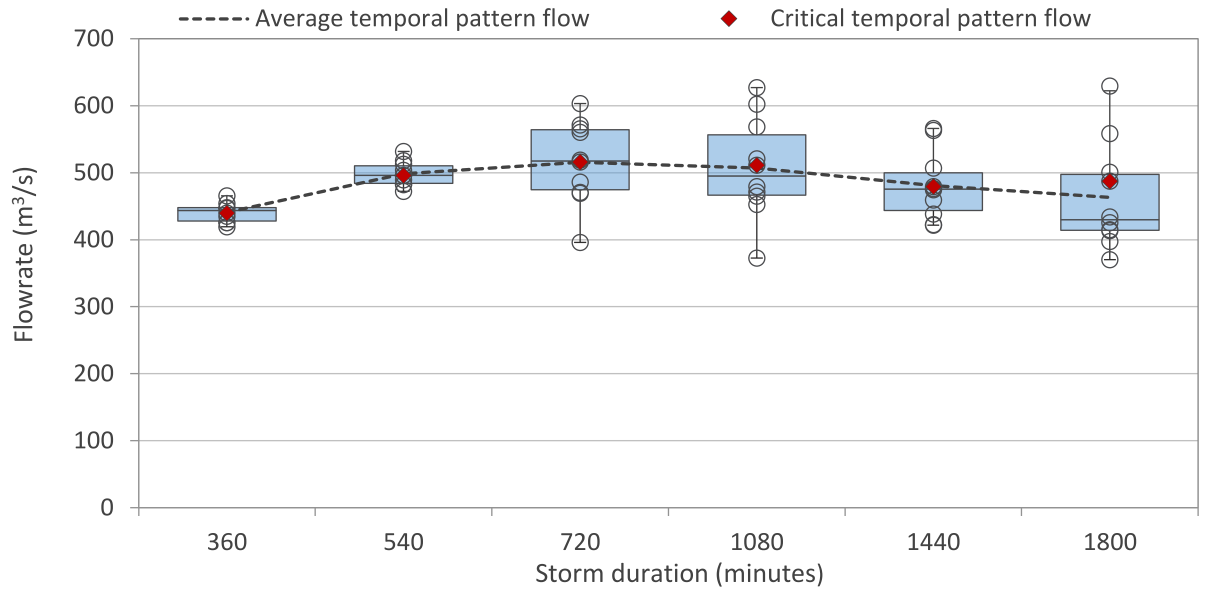


Figure 5.7 1% AEP critical storm duration

ii Flow hydrographs

Flow hydrographs for the 1% AEP critical duration temporal patterns identified as part of the critical storm assessment are shown in Figure 5.8. The ten temporal patterns for the 1% AEP critical duration (720 minutes) are shown in Figure 5.9. Flow hydrographs for the 63.2%, 20% and 5% AEP the PMF events are provided in Appendix A.

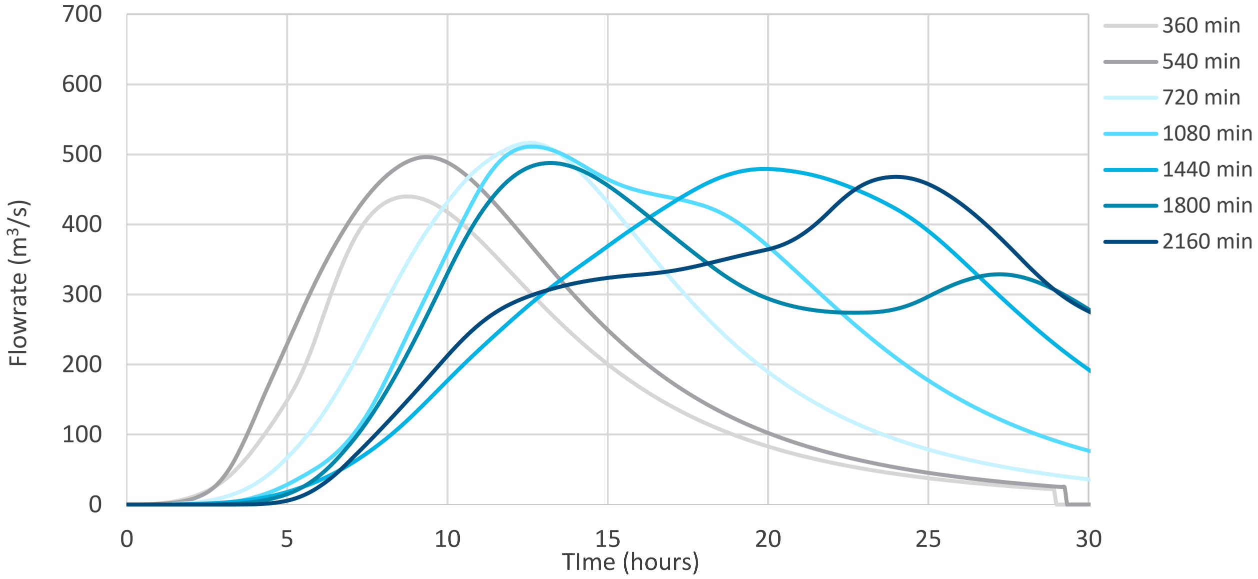


Figure 5.8 1% AEP critical duration flow hydrographs

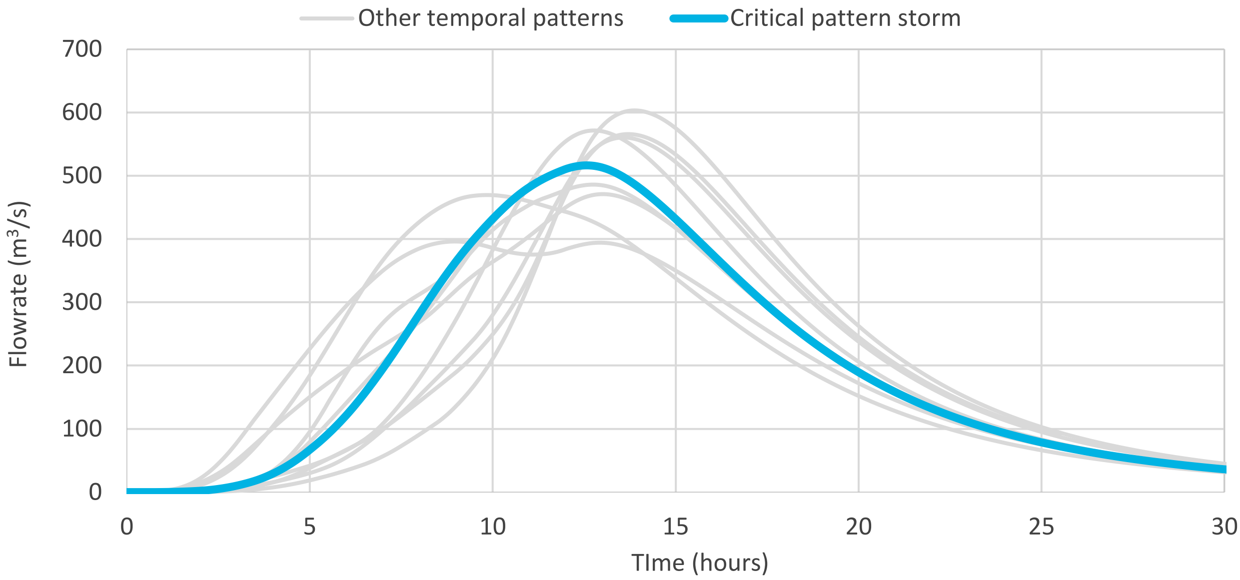


Figure 5.9 1% AEP ensemble storm flow hydrographs

5.3.4 Design flow validation

The WBNM design flow estimates have been validated against the Regional Flood Frequency Estimation (RFFE) Model. Peak flow estimates for the catchment outlet are compared in Table 5.6.

Table 5.6 Hydrologic model validation against RFFE Model

Design event	WBNM hydrology model (m^3/s)	RFFE Model design estimates (m^3/s)		
		Discharge	Upper confidence limit	Lower confidence limit
63.2% AEP	43	N/A	N/A	N/A
20% AEP	221	106	241	46
5% AEP	348	242	553	106
1% AEP	516	497	1,170	212
PMF	5,480	N/A	N/A	N/A

The results presented in Table 5.6 show peak flows for the 20% and 5% AEP events are higher than the RFFE Model estimate but still well within the lower confidence limit values. The 1% AEP peak flow estimates are similar to the RFFE Model estimates. The similarity between the two model results indicates the WBNM estimates are reliable.

5.4 Hydraulics

5.4.1 Overview

A TUFLOW hydraulic model (version 2020-01-AB) was developed to determine flood extents and levels at the site. TUFLOW is commonly used in Australia to simulate flood conditions for waterways and floodplains in urban and rural environments. This section describes the methodologies and assumptions that were applied in developing the TUFLOW model. Hydraulic model results are also described.

5.4.2 Hydraulic model setup

i Model domain and grid size

The hydraulic model domain covers an area of 312 ha and includes the primary drainage lines through the site as well as the overbank areas of Martindale Creek. The model domain extends approximately 500 m upstream and 1,200 m downstream of the site. Site observations identified that most of the minor drainage lines through the site do not have defined channels. Martindale Creek was observed to have a main channel width of approximately 4 to 6 m. A model grid size of 2 m x 2 m has been implemented to adequately model the Martindale Creek channel. The TUFLOW model domain and key features are shown in Figure 5.10.

ii Model terrain

The April 2018 LiDAR DEM has been used to inform the 2D hydraulic model terrain. The DEM was cross-referenced against available aerial imagery, topography data, and field observations. Where required, the TUFLOW model terrain was modified to represent key watercourse and floodplain features. The Martindale Creek channel alignment was modified to provide a continuous flow path of 6 m wide as per site observations. The channel thalweg was defined using detailed survey data where available. Detailed survey was also used to define the geometry of the existing causeway and access road within the TUFLOW model.

No instream structures (ie bridges or culverts) were observed during the site visit and therefore the entire TUFLOW model terrain is represented in 2D.

iii Manning's roughness

Manning's roughness values were selected using aerial imagery and site observations. Land use within The TUFLOW model domain primarily consists of cleared paddocks with medium to long grass and scattered trees. Vegetation was observed to be denser along the banks of Martindale Creek. The Manning's roughness values adopted for various land use types within the TUFLOW model are provided in Table 5.7.

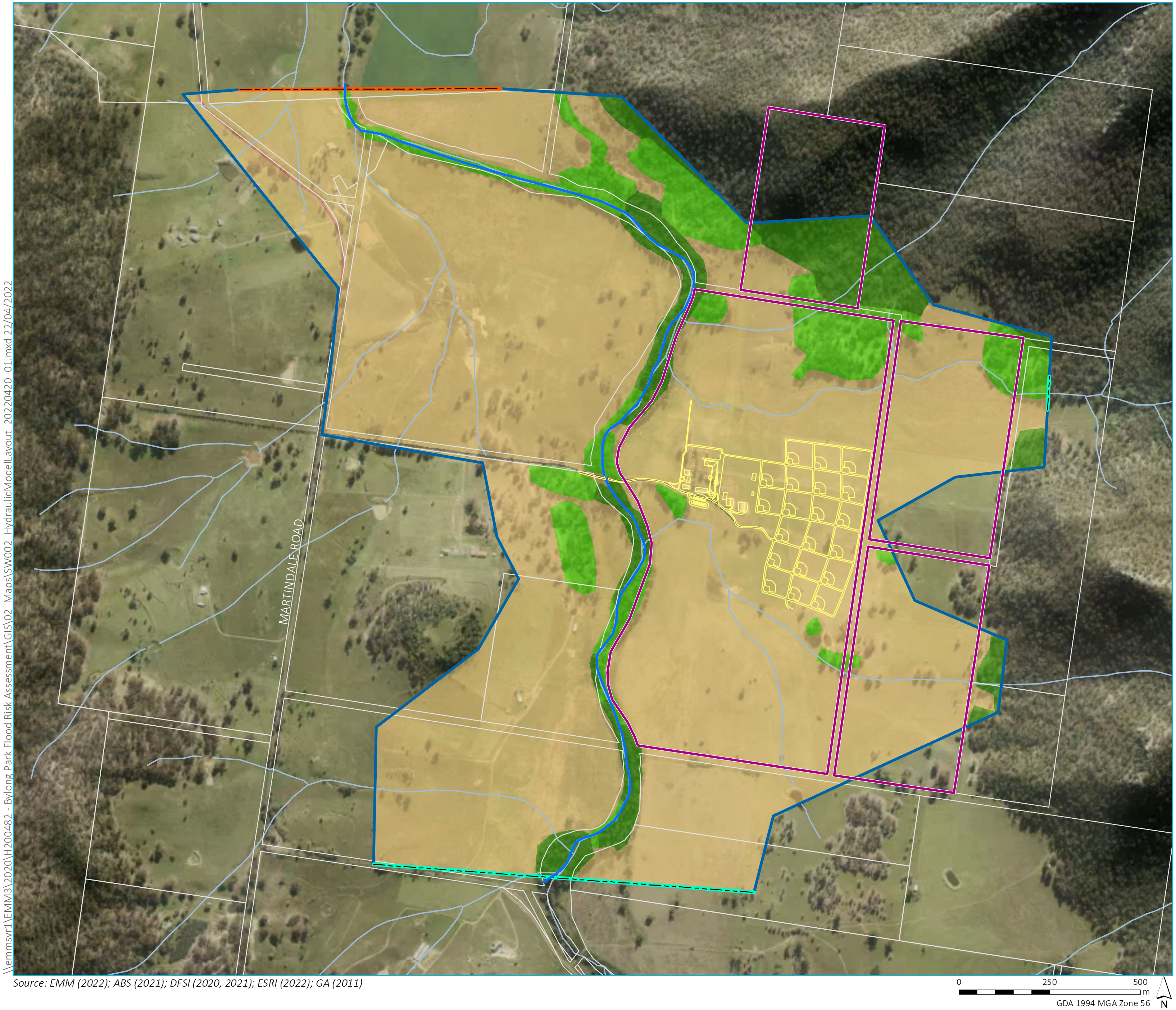
Table 5.7 Manning's roughness parameters

Land use category	Manning's roughness value
Grassland and open paddocks	0.04
Water (ie Martindale Creek main channel)	0.02
Moderate vegetation (shrubs)	0.06
Thick vegetation (trees)	0.10
Dirt roads	0.03
Paved roads	0.02

iv Boundary conditions

Two inflow boundaries were defined at the upstream limit of the model domain, representing flow along Martindale Creek and the flow from an unnamed tributary that flows east to west through the site. Inflow hydrographs for sub-catchments within the TUFLOW model domain where applied directly to the 2D grid at the relevant site boundary. All streamflow hydrographs were derived from the WBNM hydrologic model.

A single downstream boundary condition was defined at the southern limit of the model domain, representing flow out of the model along Martindale Creek. A rating curve in the form of a stage-discharge relationship was generated within TUFLOW for this boundary condition, based on an estimated floodplain slope of 0.5%.



Source: EMM (2022); ABS (2021); DFSI (2020, 2021); ESRI (2022); GA (2011)

KEY

- Site boundary
- Proposed site plan
- Watercourse/drainage line
- Cadastral boundary

TUFLOW model components

- TUFLOW site boundary
- Outflow boundary
- Inflow boundary
- Martaindale Creek channel alignment

Manning roughness

- Grassland/open paddock
- Watercourse
- Moderate vegetation
- Dense vegetation
- Dirt road
- Paved road

Hydraulic model layout

Bylong Park, NSW
Flood Risk Assessment
Figure 5.10

EMM creating opportunities

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5.4.3 Hydraulic model results

i Flood maps

Hydraulic model results are presented in a series of flood maps in Appendix B. The flood maps show the following information:

- peak flood depth, level and extent for the site; and
- peak velocity depth product (flood hazard) for the site.

Table 5.8 provides a figure schedule of the flood maps in Appendix B. Hydraulic modelling results are discussed in Section 5.4.3ii.

Table 5.8 Flood map figure schedule

Event	Peak flood depth and level	Peak velocity depth product
63.2% AEP	Figure B.1	Figure B.6
20% AEP	Figure B.2	Figure B.7
5% AEP	Figure B.3	Figure B.8
1% AEP	Figure B.4	Figure B.9
PMF	Figure B.5	Figure B.10

ii Results discussion

The hydraulic model results are summarised as follows

- Overbank flooding from Martindale Creek inundates the low-lying areas along the western boundary of the site. The remainder of the site is unaffected by mainstream flooding from Martindale Creek in events up to but not including the PMF.
- Flood waters that traverse the site from catchments to the east are generally characterised as shallow (less than 100 mm deep) overland flows.
- Existing site dwellings and infrastructure are situated approximately 6 m (at 141 m AHD) above the Martindale Creek 1% AEP flood level.
- The PMF flood extent inundates the location of the proposed farmstead building by up to 0.3 m. The corresponding velocity depth product is less than 0.3 m^2/s indicating a low flood hazard (hazard category H1) near the proposed building.
- The PMF flood extent is shown to inundate four of the proposed animal kennel areas. Flooding in the PMF primarily impacts the outdoor areas of the kennels and not the buildings. Only one kennel building experiences flooding in the PMF with depths up to 0.1 m. However, it is expected the finished floor level of the kennel buildings will be above the PMF flood level.
- The peak velocity depth product at the existing site access road causeway exceeds the safe access thresholds established in Section 4.2 in all events modelled, ranging from 3.4 m^2/s in the 63.2% AEP event to 7.2 m^2/s in the 1% AEP event.

The site is elevated approximately 25 m above the Hunter River PMF level at the confluence with Martindale Creek (RHDHV 2019). Hence, the site would not be inundated by backwater flooding from the Hunter River in any event.

6 Site access options assessment

6.1 Overview

It is predicted that site access via the existing causeway will be restricted several times per year, and for several days at a time, when flows within Martindale Creek exceed the safe access thresholds established in Section 4.2. During major flood events, access to the site may also be restricted due to the inundation of the bridges/culverts along Martindale Road. This chapter provides an assessment of options considered to improve site access when flows in Martindale Creek are elevated but below major flood levels. Options that would provide flood free access in major floods were not considered to be feasible for the development due to the significant floodplain width and need to build a structure that is several meters above floodplain levels.

The options assessment indicates the construction of a bridge or culverts over Martindale Creek provide some benefit in reducing the frequency and duration of site access restrictions compared to the existing causeway. However, site access restrictions are still expected to occur regularly and would need to be managed by operational procedures. None of the options assessed provide complete flood free access to the site under all conditions.

The options assessment is informed by the information in Chapter 4 and Chapter 5.

6.2 Options considered

6.2.1 Option 1 – maintain existing causeway access

Option 1 involves maintaining the existing access road and causeway as it currently exists. Flood risk associated with the crossing would be managed through operational procedures.

6.2.2 Option 2 – existing causeway with flood access via third party property

Option 2 includes maintaining the existing access road and causeway as the primary site access. An alternative site access route would be established to allow the site to be accessed when flows in Martindale Creek exceed the safe access thresholds established in Section 4.2. The alternative access route would traverse two third party properties (Lot 54, DP12672 and Lot 1, DP1088704) immediately north of the site. An indicative alternative access route alignment is shown in Plate 6.1. The alternative access route is approximately 3.5 km and primarily follows existing farm access tracks. The condition of the farm access tracks during wet weather is unknown and may require upgrading to allow non-4WD access.

A third party agreement would be required to secure access to the two properties.

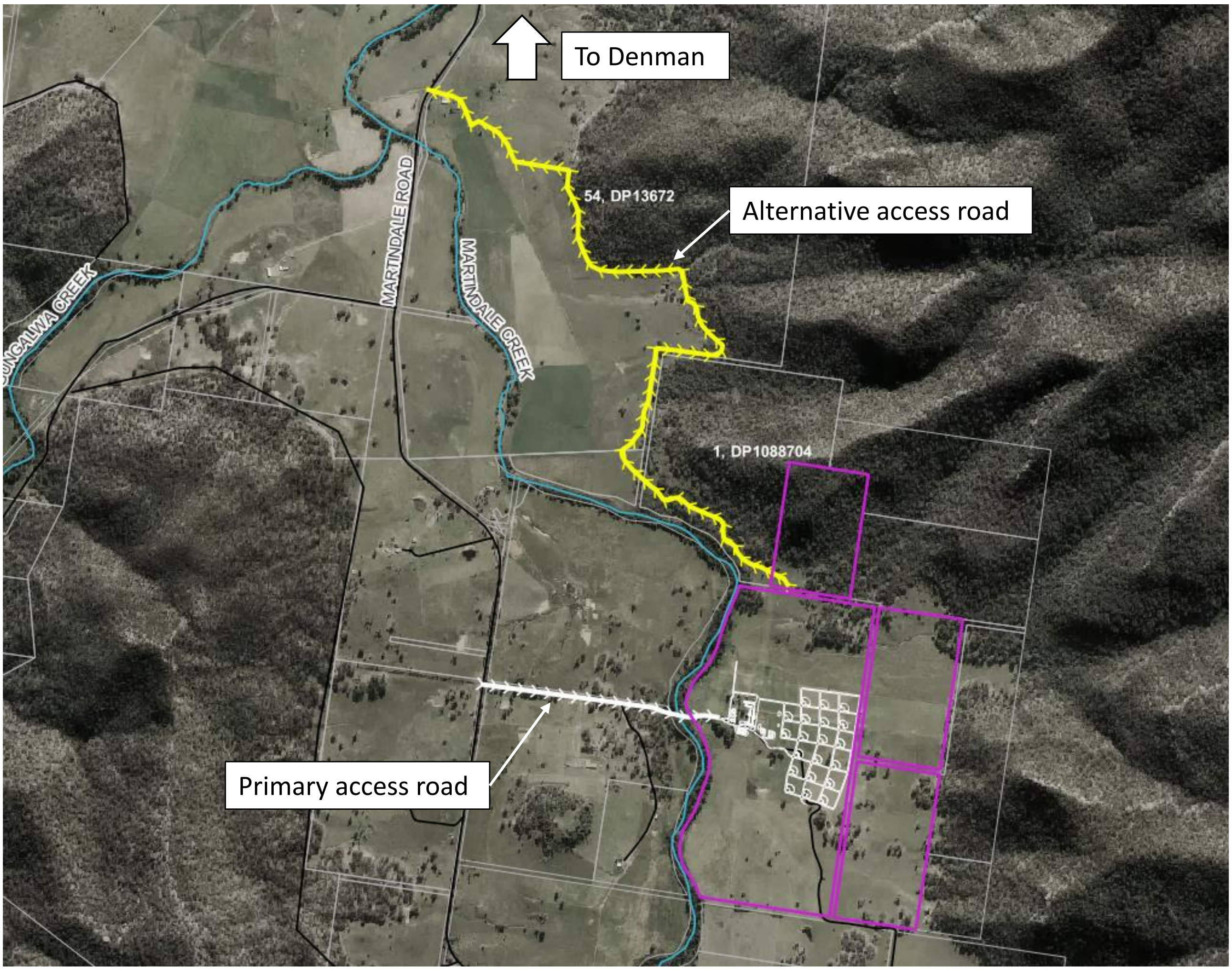

Plate 6.1 Indicative alternative access road alignment

6.2.3 Option 3 – existing causeway with pedestrian access bridge

Option 3 involves maintaining the existing access road and causeway as the primary site access. A pedestrian bridge would be constructed over Martindale Creek near the causeway to allow personnel to access the site when vehicle access is restricted. The pedestrian bridge would be designed to allow access for light vehicles such as an all-terrain vehicle (ATV) to facilitate the transfer of supplies if needed when flows in Martindale Creek exceed the site access thresholds. A higher level of flood immunity is proposed (relative to Option 4 and 5) for the pedestrian bridge due to its lower construction costs and disturbance footprint. A bridge height of 1.8 m above the creek bed level has been assumed for this assessment, resulting in a bridge span of approximately 30 m. A conceptual schematic of the pedestrian bridge is shown in Plate 6.2. The schematic shows the profile of the existing causeway, a typical creek bank section and the 63.2 % AEP (the 1-year flood) flood level. Site access restrictions would occur when the bridge deck is inundated by floodwaters. It is noted that the bridge deck is 0.6 m below the 63.2 % AEP level.

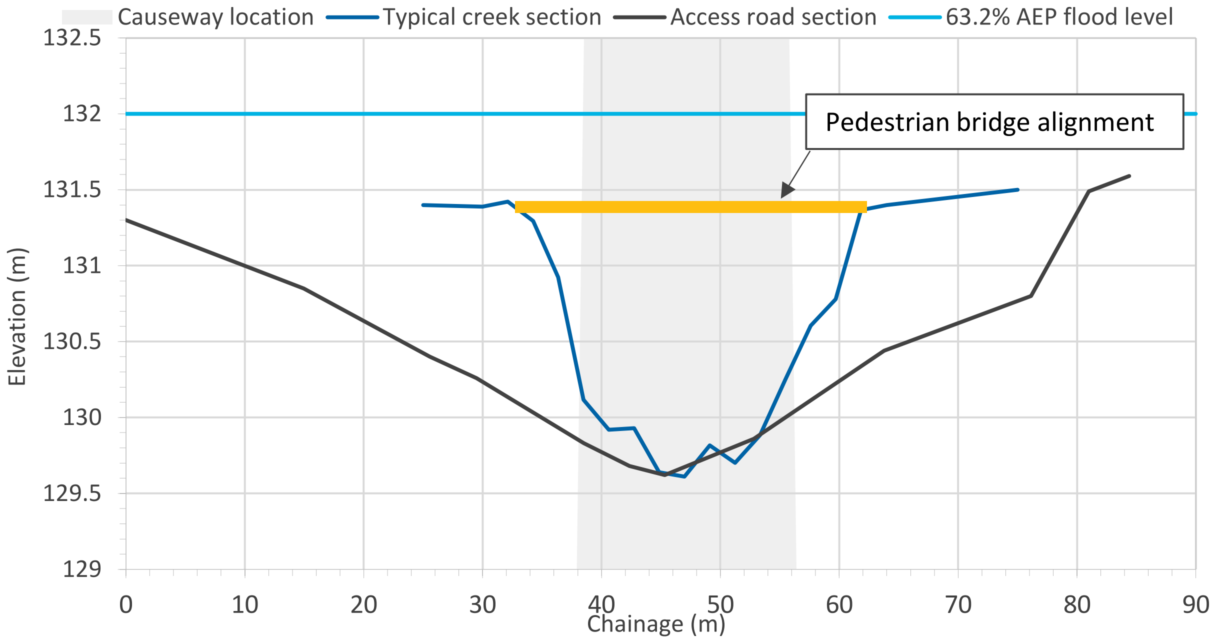

Plate 6.2 Concept pedestrian access bridge schematic

6.2.4 Option 4 – trafficable bridge

Option 4 involves upgrading the causeway to a trafficable bridge. The bridge would span the existing causeway and channel bank. A bridge height of 1.2 m above the existing causeway level has been assumed for this assessment, resulting in a bridge span of 15–20 m. As the existing access road is cut into the creek bank to cross the existing causeway, it is proposed to regrade a portion of the access road to tie into the bridge level. A similar concept is proposed for Option 5 (culvert structure). A conceptual schematic of the bridge arrangement is shown in Plate 6.3. The schematic shows the profile of the existing causeway, a typical creek bank section and the 63.2 % AEP (the 1-year flood) flood level. Site access restrictions would occur when the bridge deck is inundated by floodwaters. It is noted that the bridge deck is 1.2 m below the 63.2 % AEP level.

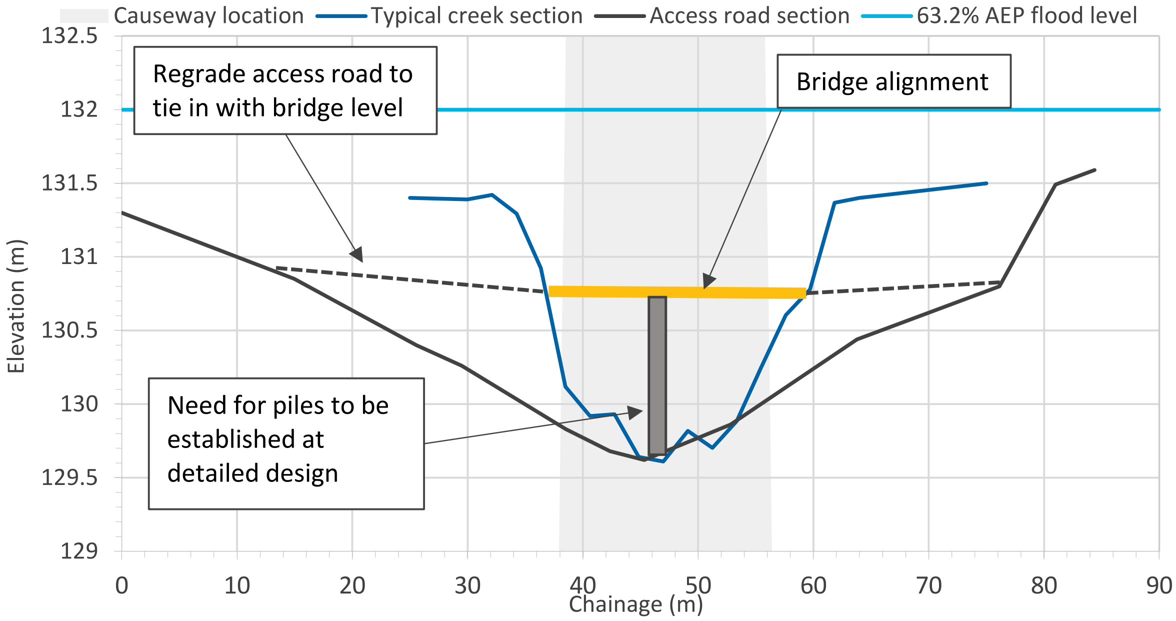

Plate 6.3 Concept trafficable bridge schematic

6.2.5 Option 5 – trafficable culvert

Option 5 involves upgrading the causeway to a trafficable culvert arrangement. Conceptually, the culvert arrangement is similar to Option 4 (trafficable bridge). Four 2.4 m wide x 1.2 m high culverts would provide a similar waterway area to Option 4. A conceptual schematic of a culvert arrangement is shown in Plate 6.4. The schematic shows the profile of the existing causeway, a typical creek bank section and the 63.2 % AEP (the 1-year flood) flood level. Site access restrictions would occur when the road over the culvert is inundated by floodwaters. It is noted that the bridge deck is 1.2 m below the 63.2 % AEP level.

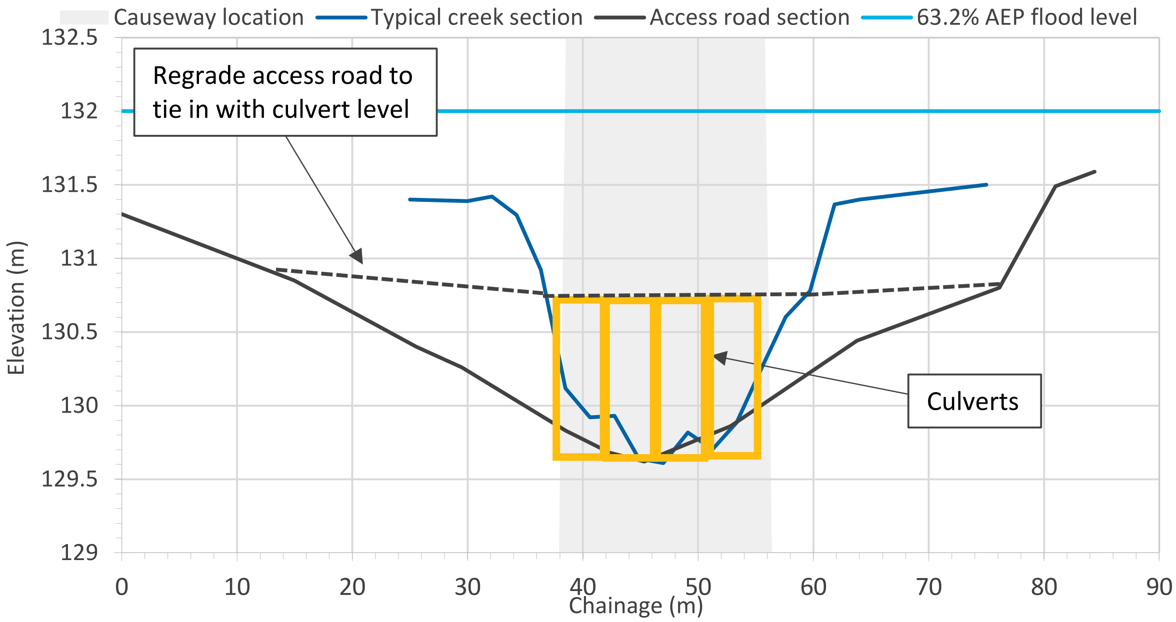

Plate 6.4 Concept trafficable culvert schematic

6.3 Assessment of site access restrictions

The frequency of site access restrictions (once water overtops the structure) for Option 3, 4 and 5 have been assessed and compared to the existing causeway (Option 1) access restrictions described in Section 4.4. For simplicity, it has been assumed that no changes in flow conditions would occur due to the structures. While the access restrictions for Option 3 represent the frequency and duration personnel would not be able to access the site via foot, this information can also be used to understand the benefits of a larger bridge or culvert arrangement (ie a culvert or bridge arrangement that provides access at 131.4 m AHD, rather than 130.7 m AHD, as per Options 4 and 5).

Option 2 has not been assessed as it may provide unimpeded access to Martindale Road when the safe access thresholds in Martindale Creek are exceeded. Further review of the road conditions in wet weather would be required to establish accessibility. It should be noted that several bridges exist on Martindale Road between the site and Denman, including one over Martindale Creek and one over the Goulburn River. Should flooding inundate one of these bridges or road sections, access to Denman would be restricted regardless of whether site access is possible. Waterway crossings along Martindale Road are expected to be flood affected less frequently and for shorter durations of time than the site access road due to flooding in Martindale Creek. Access to Denman during a major flood event is discussed in Section 7.2.

The estimated frequency of site access restrictions from Options 3, 4 and 5 is presented in Figure 6.1 while the estimated duration of site access restrictions is presented in Figure 6.2. Site access is considered restricted for Options 3, 4 and 5 once overtopping of the structure occurs (ie structures are flood free when unrestricted). Further benefits may be gained when considering the possibility to safely traverse shallow flood waters (say 100 mm) that may overtop the bridge and culvert arrangements. The analysis of site access restrictions indicates:

- Access restricting streamflow events occur five times in 50% of years for Option 1 (large 4WD), three times in 50% of years for Option 4 and 5, and two times in 50% of years for Option 3.
- Restrictions of more than one day occur on average three times per year for Option 1 (large 4WD), two times per year for Option 4 and 5, and one time per year for Option 3.
- Restrictions of more than four days occur on average once per year for Option 1 (large 4WD), once every three years for Option 4 and 5, and once every 15 years for Option 3.
- The maximum duration of access restrictions for a single streamflow event is shown to be ten days for Option 1 (large 4WD), eight days for Option 4 and 5, and five days for Option 3.

In summary, the analysis shows that Option 3, 4 and 5 decrease the frequency and duration of safe access restrictions. However, restrictions would still occur during most years and would need to be managed operationally.

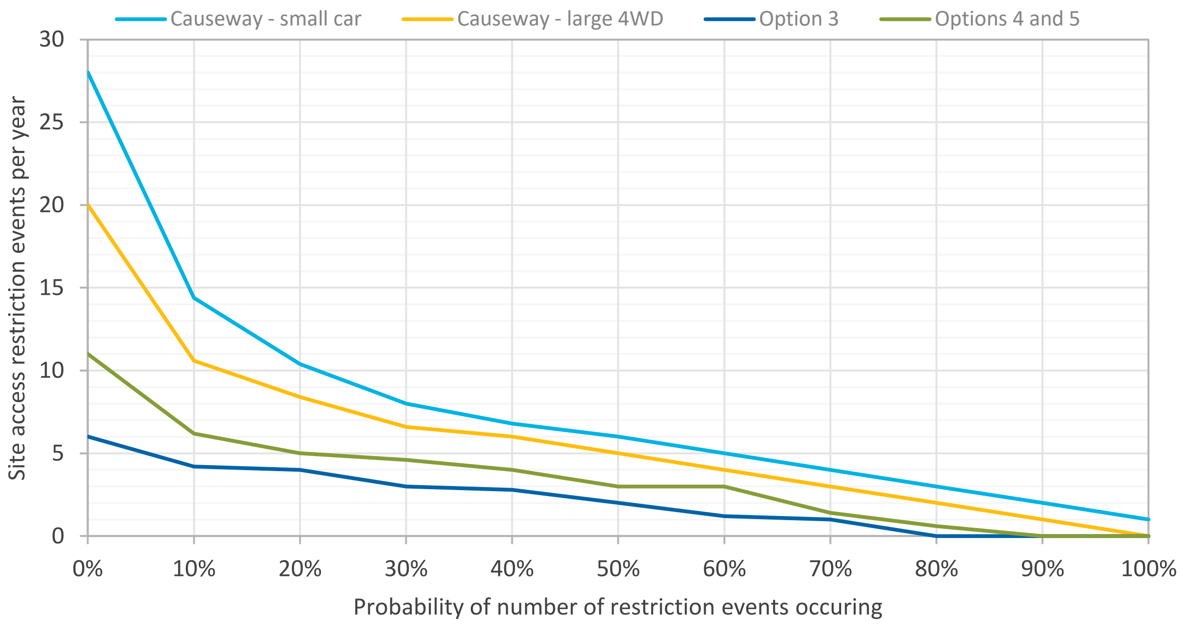

Figure 6.1 **Number of site access restricting streamflow events per year**

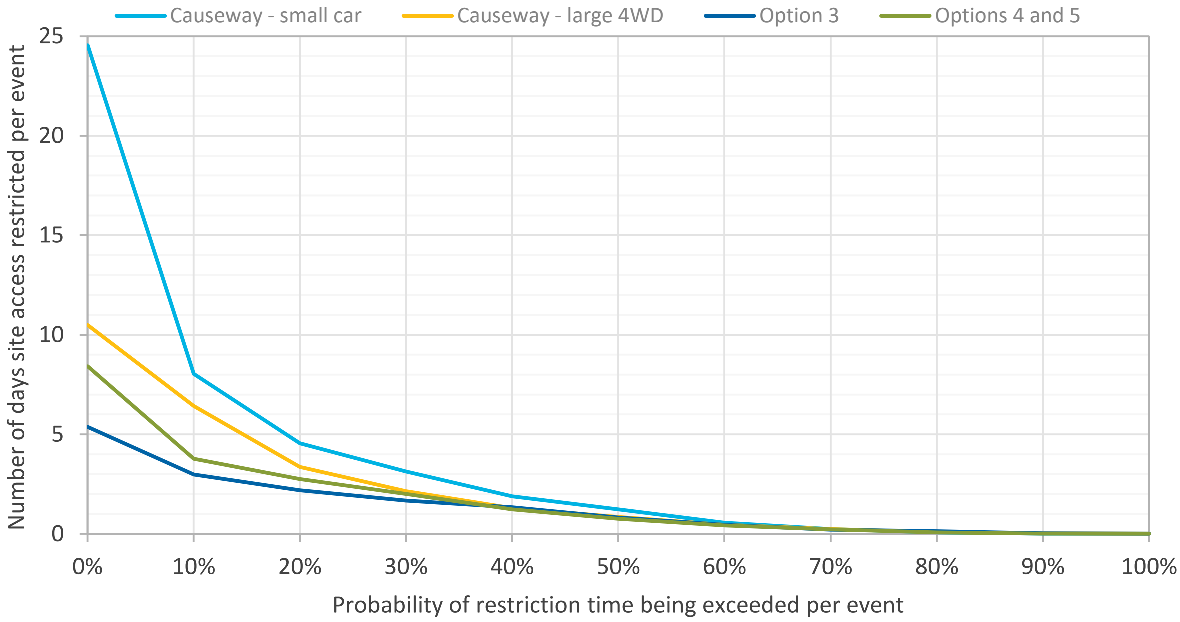

Figure 6.2 **Duration of site access restrictions during a streamflow event**

6.4 Benefits and constraints analysis

A high-level benefit and constraints analysis of the five options is provided in Table 6.1.

Table 6.1 Site access options benefits and constrains

Option	Description	Site access limitations	Benefits	Constraints
1	Maintain existing causeway	• Access restricting streamflow events occur 5 times per year in 50% of years. • Access restrictions of more than 4 continuous days occur in 20% of events.	• No upgrades to the existing access road causeway are required. • No disturbance to existing riparian vegetation and watercourse during construction.	• No improvement to site access when streamflow in Martindale Creek exceeds safe access thresholds. • Site access and associated flood risk solely managed through operational procedures. • Requirement to maintain supplies onsite to account for periods of restricted access.
2	Existing causeway with flood access via third party property	• Provides a secondary access from the site that does not cross Martindale Creek (or any other major watercourse).	• No upgrades to the existing access road causeway are required. • No disturbance to existing riparian vegetation and watercourse during construction. • Greatest level of flood access provided of the options considered (subject to road conditions and access arrangements).	• Road condition during wet weather is unknown and may require upgrading to allow non-4WD access. • Requires access to two third party properties which cannot be guaranteed for perpetuity without a binding agreement with the landholders.
3	Existing causeway with pedestrian access bridge	• Reduces access restricting streamflow events from 5 to 2 events per year in 50% of years. • Reduces access restrictions of more than 4 continuous days from occurring in 20% of events to 5% of events.	• Potential to incorporate light vehicle access (ie an ATV) to increase operational flexibility. • Potential to provide a higher level of flood access due to lower cost and footprint. • Lower impacts to Martindale Creek as channel profile under bridge likely maintained.	• Residual flood risk associated with site access would be largely unchanged compared to Option 1 and would still need to be managed by operational procedures. • Potential need for additional offsite parking which may require permission from Crown Lands and/or an agreement with neighbouring landholders. • Works within Martindale Creek riparian corridor required resulting in potential disturbance of existing vegetation and watercourse during construction. • Requirement to maintain supplies onsite to account for periods of restricted access.

Table 6.1 Site access options benefits and constrains

Option	Description	Site access limitations	Benefits	Constraints
4	Trafficable bridge	• Reduces access restricting streamflow events from 5 to 3 events per year in 50% of years. • Reduces access restrictions of more than 4 continuous days from occurring in 20% of events to 10% of events.	• Provides better vehicle access to the site compared to Option 3. • Lower impacts to Martindale Creek as channel profile under bridge likely maintained.	• Residual flood risk associated with site access would be largely unchanged compared to Option 1 and would still need to be managed by operational procedures. • Potential need for additional offsite parking which may require permission from Crown Lands and/or an agreement with neighbouring landholders. • Works within Martindale Creek riparian corridor required resulting in potential disturbance of existing vegetation and watercourse during construction. • Requirement to maintain supplies onsite to account for periods of restricted access.
5	Trafficable culvert	• Reduces access restricting streamflow events from 5 to 3 events per year in 50% of years. • Reduces access restrictions of more than 4 continuous days from occurring in 20% of events to 10% of events.	• Provides better vehicle access to the site compared to Option 3.	• Residual flood risk associated with site access would be largely unchanged compared to Option 1 and would still need to be managed by operational procedures. • Potential need for additional offsite parking which may require permission from Crown Lands and/or an agreement with neighbouring landholders. • Works within Martindale Creek riparian corridor required resulting in potential disturbance of existing vegetation and watercourse during construction. • Excavation of the Martindale Creek channel is required to bed the culverts resulting in higher impacts to the watercourse than other options. • Higher risk of blockage and ongoing maintenance burden than a bridge (key concern raised by Council). • Requirement to maintain supplies onsite to account for periods of restricted access.

6.5 Proposed site access option

6.5.1 Justification of proposed option

Option 1, maintaining the existing causeway arrangement is proposed. Option 1 is proposed over Options 2–5 as:

- Option 2 requires access to two third party properties. This cannot be guaranteed for perpetuity without a binding agreement with the landholders. The residual flood risk associated with regional flooding (refer to Section 7.2.2) would still need to be managed by operational procedures.
- The construction of a pedestrian access bridge (Option 3), trafficable bridge (Option 4) or trafficable culverts (Option 5) provides some benefit in reducing the frequency and duration of site access restrictions compared to the existing causeway arrangement. However, site access restrictions are still predicted to occur in most years with some events still restricting access for days at a time. Hence, the residual flood risk associated with site access is mostly unchanged and would still need to be managed by operational procedures.
- Works within Martindale Creek riparian corridor are required for Option 3, 4 and 5 which have the potential to disturb existing vegetation and watercourse condition during construction.

The following sections describe measures that will be implemented to manage flood risks.

6.5.2 Management measures to reduce risk associated with the causeway crossing

The following measures will be implemented to reduce risk associated with maintaining the existing causeway as the site access arrangement:

- A flood depth marker will be installed to provide a real-time measurement of streamflow depth over the existing causeway. The marker will be clearly visible from both sides of the causeway.
- Signage will be installed either side of the causeway to define unsafe access conditions. Unsafe access conditions will be defined using the flood depth marker and safe access thresholds described in Section 4.2.
- An adequately equipped large 4WD vehicle will be kept onsite to allow access to and from the site when flows in Martindale Creek exceed the small vehicle safe access thresholds but are below the large 4WD safe access thresholds.
- Equipment such as a tractor will be maintained onsite to assist in restoring the access road (if needed) once the creek crossing is safe to cross. The equipment may also allow for safe access under higher flow conditions compared to small car and large 4WD vehicles due to increased weight and clearance.
- Flood risk awareness training will be included as part of site inductions and will provide information on how to recognise when the causeway is unsafe to cross and the actions to be followed when site access is restricted.

6.5.3 Operational measures to address site access restrictions

The following measures are proposed to plan for and maintain operations when site access is restricted due to elevated streamflow in Martindale Creek:

- Monitor weather forecasts, flood forecasts and other emergency warnings within the catchment to provide an early trigger for flood preparedness actions such as ensuring there are sufficient supplies onsite and arranging staffing requirements.

- Ensure sufficient accommodation is available to allow staff to stay onsite to care for the animals during periods of limited access. Staff accommodation would be stocked with sufficient supplies for 4–6 people for 14 days. Spare uniforms would also be available onsite.
- Provide sufficient onsite storage of dog food, veterinary medicine, and other dog related supplies for 14 days.
- Non-essential staff would be required to leave the site prior to flooding occurring, if safe to do so.
- No additional animals will be transported to the site when access is restricted.
- If there is an animal emergency onsite when access is restricted, remote telephone/video support can be provided by a veterinarian who can prescribe the medication from the onsite pharmacy and the treatments can be administered under veterinary direction by trained staff members.
- An area of the site will be maintained to allow helicopter access during emergencies when site access via road is restricted. It is noted that helicopter access would be weather dependent.
- Maintain backup generators for essential services such as water purification and wastewater systems in case there is a power failure.

A Flood Risk Management Plan (FRMP) will be prepared by Greyhounds NSW when the facility's management plans are prepared following the DA approval. The FRMP will include practical measures that will be implemented by Greyhounds NSW prior to, during and after flood events to manage flood risks to staff, animals and the overall operation. A key component of the FRMP will be site access management measures. A provisional site access management plan is provided in Appendix C. This plan provides examples of practical measures that could be included in the FRMP to manage the site access restrictions.

7 Flood risk management approach

7.1 Overview

This chapter provides a flood risk assessment of the proposed development and describes the flood risk management approach. The approach will be documented in a FRMP that will be prepared post DA approval along with other site management plans.

The flood risk assessment is based on the streamflow analysis provided in Chapter 4, hydrologic and hydraulic model results provided in Chapter 5, and the proposed site access option identified in Chapter 6.

7.2 Site access

7.2.1 General operational access

The site access road crosses Martindale Creek to the west of the site. The waterway crossing comprises a concrete apron that forms the channel bed at the location of the crossing. Site access restrictions established in Section 4.4 indicate safe site access would be restricted more than five and six times per year in 50% of years for large 4WD and small vehicles respectively. Access is predicted to be restricted for more than one day on three occasions per year on average. Restrictions of more than four days occur approximately once per year on average.

The hydraulic model results presented in Section 5.4.3 show peak streamflow conditions at the causeway exceed the safe access thresholds (refer to Section 4.2) in all design events modelled.

The following measures are proposed to manage the identified risks:

- The FRMP will include practical site access management measures that can be implemented prior to, during, and after flood events to manage risks to staff, animals and the overall operation. An example site access management plan is provided in Appendix C.
- Flood depth markers and signage that clearly identify safe and unsafe streamflow conditions will be installed on both sides of the crossing.
- The operational measures described in 6.5.3 will be implemented to allow the site to operate during periods of restricted access.

7.2.2 Regional access

Martindale Road crosses Martindale Creek at several locations and the Goulburn River at one location between Denman and the site. Access to the site (from Denman) may be restricted during larger flood events when the crossings become inundated by flood waters from either Martindale Creek or the Goulburn River. Access to the broader Hunter Region may also be restricted due to flooding of the Hunter River which flows south-east of Denman.

All Martindale Road crossings were observed (during the site visit) to comprise a culvert or bridge structure which would allow flood waters to pass beneath the road up until the design capacity (which is unknown). Waterway crossings along Martindale Road are expected to be flood affected less frequently and for shorter durations of time than the site access road due to flooding in Martindale Creek.

The Goulburn River and Hunter River catchments cover a different spatial extent and are significantly larger than the Martindale Creek catchment. As a result, flooding in these rivers may not always coincide with flooding or elevated streamflow in Martindale Creek. Hence, site access may become restricted (via Denman) even though low flow conditions are experienced in Martindale Creek.

The *Muswellbrook Shire Local Flood Plan* (NSW SES 2013) notes Denman and surrounding rural properties may become isolated via road access for several days during severe flooding of the Goulburn and Hunter rivers. The proposed measure to maintain 14 days of supplies is expected to be sufficient to allow the site to operate while road access is re-established following flooding of the Goulburn and Hunter rivers.

Flood watch and warning systems are in place for the Goulburn and Hunter River catchments, hence greater warning times are expected to be available to allow the facility to prepare in the event of regional access being restricted.

Overall, regional access restrictions are likely to occur less frequently and for shorter durations than the site access restrictions. Hence, the measures described in Section 7.2.1 will be effective in managing the overall flood risks.

7.2.3 Emergency access

General operational access to the site is limited by the need to cross Martindale Creek via the existing causeway. However, the site is not considered to be completely cut off from Martindale Road and Denman when flows in Martindale Creek exceed the safe access thresholds (refer to Section 4.2), with an alternative overland access route available through third party property as per Option 2 in Section 6.2.2. Emergency services could access the site via the alternative access route should an emergency (eg medical, bush fire, etc.) occur while access to the site via the causeway is restricted. However, it is noted the condition of the access tracks during wet weather is currently unknown.

It is not proposed to use the third party property access route for general operational access. A shelter in place approach is proposed to manage flood risk once site access is restricted under general operational conditions (refer to Section 7.4).

An area of the site will be maintained to allow helicopter access to further manage potential emergency situations when site access via road is restricted. It is noted that helicopter access would be weather dependent.

7.3 Flood risk to property

Model results indicate that overbank flooding from Martindale Creek is primarily constrained to the low-lying floodplain areas at the south-west and north-west site extents. Flooding associated with drainage lines that traverse the site is generally shallow overland flow. The 1% AEP flood extent does not inundate existing or proposed infrastructure on the property (refer to Figure B.4). Much of the central and eastern portion of the site remains flood free for the 1% AEP flood event. To minimise flood risk to property the following mitigation measures are proposed:

- buildings and infrastructure will be located outside of the 1% AEP flood extent; and
- a minimum 0.5 m freeboard above the 1% AEP flood level will be provided for all habitable areas as recommended in Muswellbrook Shire Council's Development Control Plan (MSC 2009).

The PMF flood extent is shown to inundate the proposed location of the farmstead building by up to 0.3 m (refer to Figure B.5). The corresponding velocity depth product is less than 0.3 m^2/s (refer to Figure B.10). The modelled PMF velocity depth product at proposed farmstead location is substantially less than the flood hazard threshold of less than 4.0 m^2/s for building safety (H5) established in Section 4.2.2. This indicates the proposed building is at low risk of damage during the PMF event and is a suitable flood refuge location.

All but one of the proposed animal kennel buildings are shown to remain flood free in the PMF event. One kennel location is shown to be inundated by up to 0.1 m in the PMF event. However, it is expected the finished floor level of the kennel will be above the PMF flood level.

7.4 Flood risk management approach summary

A FRMP will be prepared post DA approval along with other site management plans. Table 7.1 provides a summary of the identified risks and management approach.

Table 7.1 Flood risk management approach summary

Identified risk	Key risks	Risk management approach
1 – Restricted site access		
a) Martindale Creek crossing	• Risks to life associated with using the crossing when unsafe. • Risks to the staff, animals and the operation due to extended periods of restricted access.	• The FRMP will include practical measures that can be implemented prior to, during, and after flood events to manage risks. An example site access management plan is provided in Appendix C. • Flood depth markers and signage will be installed at the crossing that clearly identify safe and unsafe streamflow conditions. • The development will provide safe flood refuge for both staff and animals for all flood events up to and including the PMF. • The operation will be provisioned to allow for 14 days of operation without resupply – see Section 6.5.3 for details.
b) Regional flooding	• As per 1a)	• As per 1a)
c) Emergency access during flood events	• Access restrictions may prevent safe emergency access and/or require the need for speciality emergency services (ie flood rescue).	• Flood free emergency access is possible via third party properties (subject to road conditions and access). • The facility will be able to provide health support to animals using trained staff, stockpiled medicine, and remote veterinary assistance. • Providing adequate area for helicopter access to the site should weather permit.
2 – Martindale Creek flooding	• Restricted access (addressed in Item 1). • Damage to infrastructure and property.	• The proposed development is located several meters above the 1% AEP flood level. • The development will provide safe flood refuge for both staff and animals for all flood events up to and including the PMF.

8 Summary

8.1 Overview

Greyhounds NSW propose the development of an animal boarding and rehabilitation facility at 'Bylong Park' 1949 Martindale Road, Denman. The facility will be used for boarding and rehabilitating greyhound dogs prior to their adoption and 'rehoming' via the NSW Greyhounds As Pets programme. The proposal requires the construction of facilities to accommodate and provide veterinary care for up to 400 dogs.

This flood risk assessment has been prepared to inform an understanding of streamflow conditions and flood characteristics at the site and provide an assessment of site access options.

This report is an update to the EMM (2020) flood risk assessment and has been prepared to address Council's request for information.

8.2 Streamflow analysis

Site access is via a causeway through Martindale Creek which forms the western site boundary. A streamflow analysis was completed to characterise flow conditions within Martindale Creek at the existing access road causeway and determine safe access thresholds for when site access via the causeway would be restricted. The streamflow analysis indicated:

- Site access would be restricted for small cars and large 4WD vehicles when streamflow in Martindale Creek exceeds 1.6 m^3/s (depth of 0.3 m) and 3.7 m^3/s (depth of 0.5 m) respectively.
- Streamflow within Martindale Creek generally rises rapidly with typical streamflow events expected to restrict access to the site for several hours to days depending on the magnitude of the event and rainfall distribution.
- Streamflow events that would restrict safe site access occur more than five and six times per year in 50% of years for large 4WD and small car vehicles respectively.
- Safe site access restrictions of more than one day are predicted to occur three times per year on average while restrictions of more than four days are predicted to occur one time per year on average.

8.3 Flood conditions

Flood conditions at the site are primarily associated with main channel flooding in Martindale Creek. Several minor tributaries to Martindale Creek drain through the site. Flood characteristics at the site are summarised as follows:

- Overbank flooding from Martindale Creek inundates the low-lying areas along the western boundary of the site. The remainder of the site is unaffected by mainstream flooding from Martindale Creek in events up to but not including the PMF.
- Flood waters that traverse the site from catchments to the east are generally characterised as shallow (less than 100 mm deep) overland flows.
- Existing site dwellings and infrastructure are situated approximately 6 m (at 141 m AHD) above the Martindale Creek 1% AEP flood level.
- Site access will be restricted for all flood events (63.2%, 20%, 5%, and 1% AEP and PMF) modelled.

- The PMF flood results in low flood hazard (hazard category H1) near the proposed farmstead building. The animal kennel buildings are predicted to remain flood free in the PMF event.

8.4 Proposed site access option

An options assessment was undertaken that considered five site access arrangements including maintaining the existing causeway (Option 1), alternative access via two third party properties (Option 2), and constructing a pedestrian bridge (Option 3), trafficable bridge (Option 4) or trafficable culverts (Option 5) over Martindale Creek.

Option 1, maintaining the existing causeway arrangement is proposed. Option 1 is proposed over Options 2–5 as:

- Option 2 requires access to two third party properties. This cannot be guaranteed for perpetuity without a binding agreement with the landholders. The residual flood risk associated with regional flooding would still need to be managed by operational procedures as per Option 1.

- Options 3–5 are still expected to result in regular site access restrictions which would require residual flood risk to be managed by operational procedures as per Option 1.

Several additional management measures are proposed to reduce the risk associated with maintaining the existing causeway site access, including:

- Monitoring weather and flood forecasts to provide early indication of when site access may become restricted and likely duration of restricted access.

- Installing a flood depth marker and signage at the causeway crossing to define when it is unsafe to cross.

- Providing flood risk awareness training as part of site inductions

- Providing sufficient onsite storage of dog food, veterinary medicine, and other dog related supplies for 14 days of operation.

- Providing safe refuge for operational staff when site access is restricted including 14 days of supplies for 4–6 people.

- Maintaining backup generators for essential services such as water purification and wastewater systems in case there is a power failure.

8.5 Flood risk management approach

A flood risk management approach is proposed to manage risk associated with restricted site access and flooding within Martindale Creek. The flood risk management approach will be documented in a Flood Risk Management Plan (FRMP) to be prepared by Greyhounds NSW when the facility's management plans are prepared following the DA approval. The FRMP will include practical measures that will be implemented by Greyhounds NSW prior to, during and after flood events to manage flood risks to staff, animals and the overall operation. A key component of the FRMP will be site access management measures. A provisional site access management plan is provided in Appendix C.

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Appendix A

Flow hydrographs

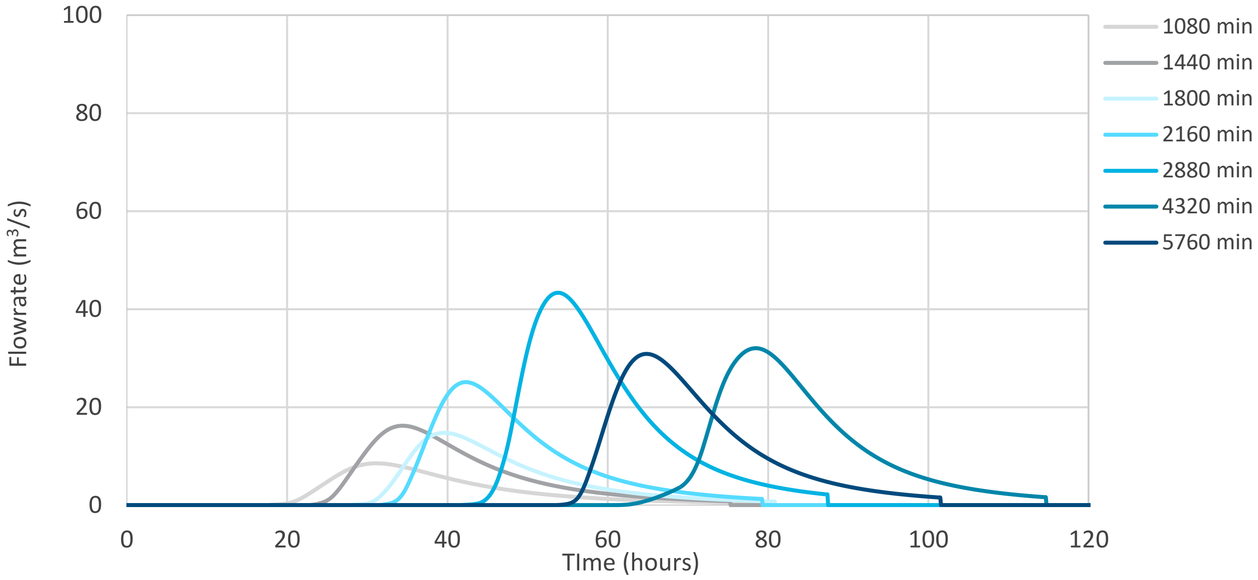


Figure A.1 63.2% AEP critical duration flow hydrographs

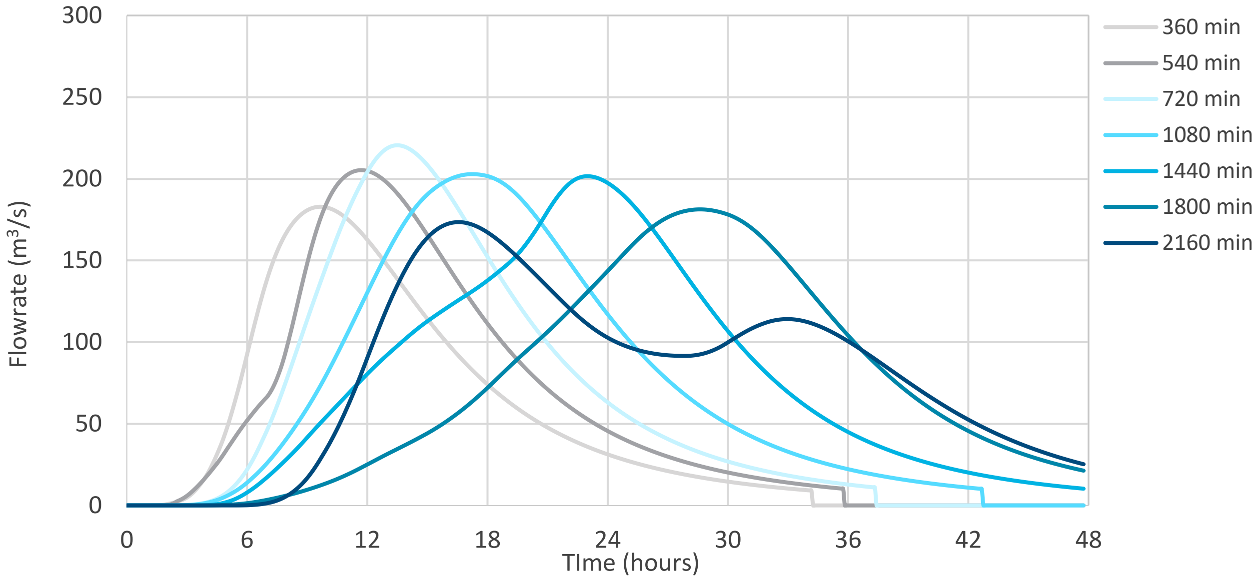


Figure A.2 20% AEP critical duration flow hydrographs

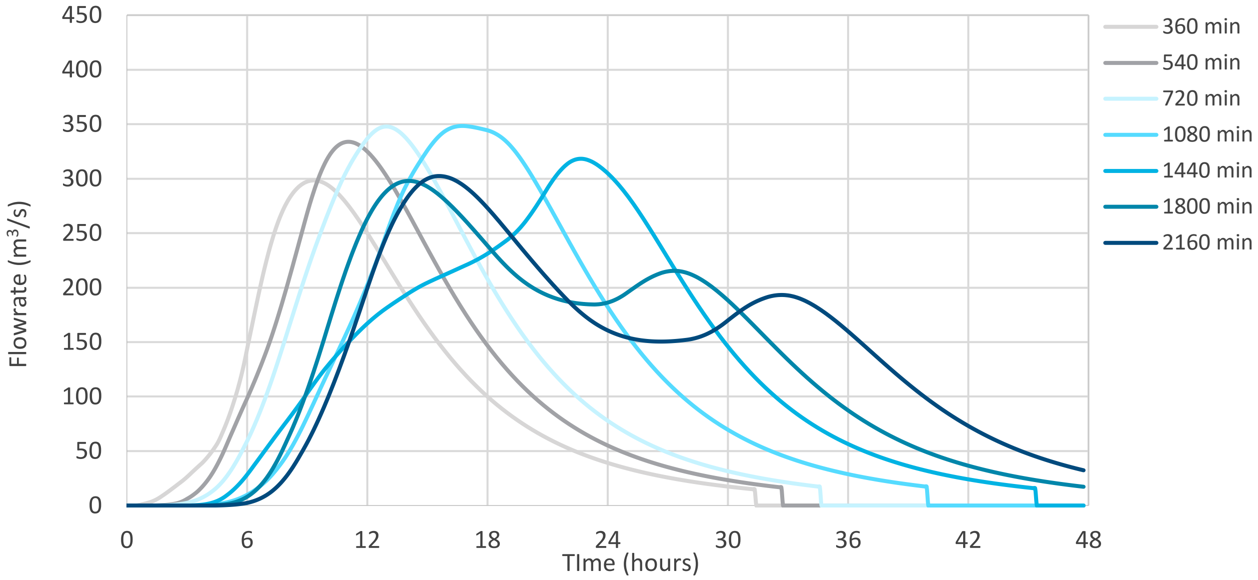


Figure A.3 **5% AEP critical duration flow hydrographs**

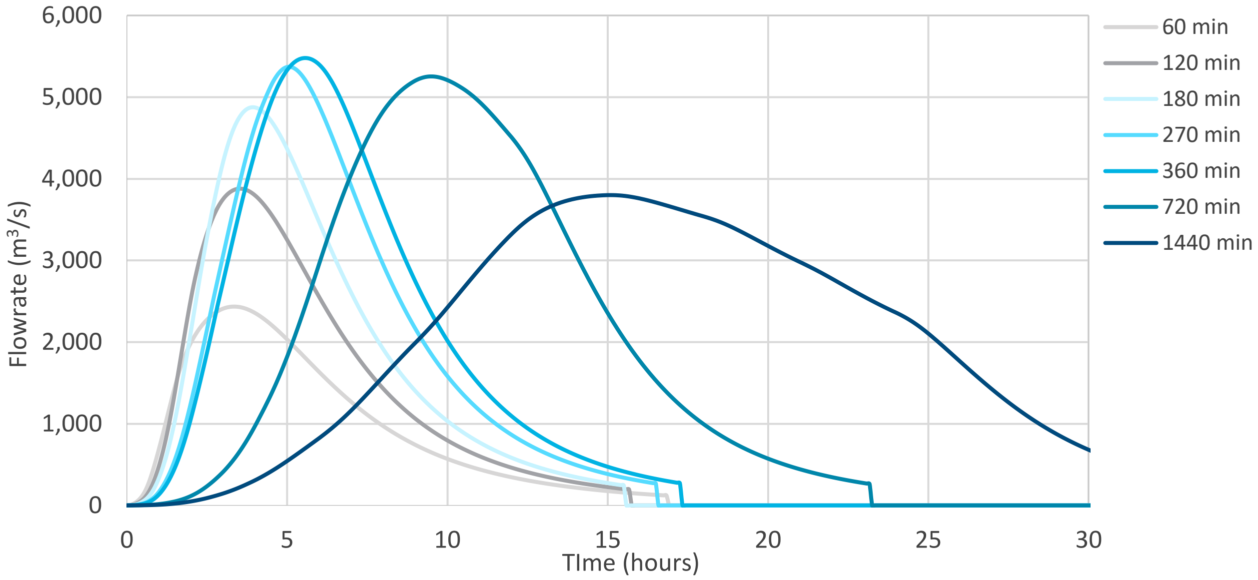


Figure A.4 **PMF critical duration flow hydrographs**

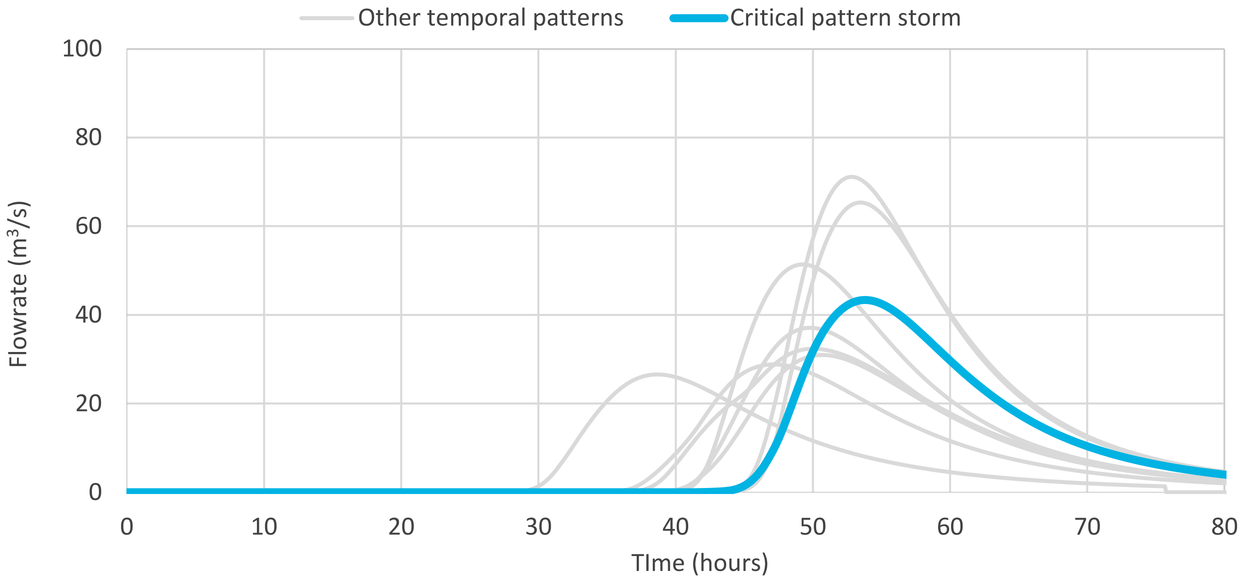


Figure A.5 63.2% AEP ensemble storm flow hydrographs – 2880-minute storm duration

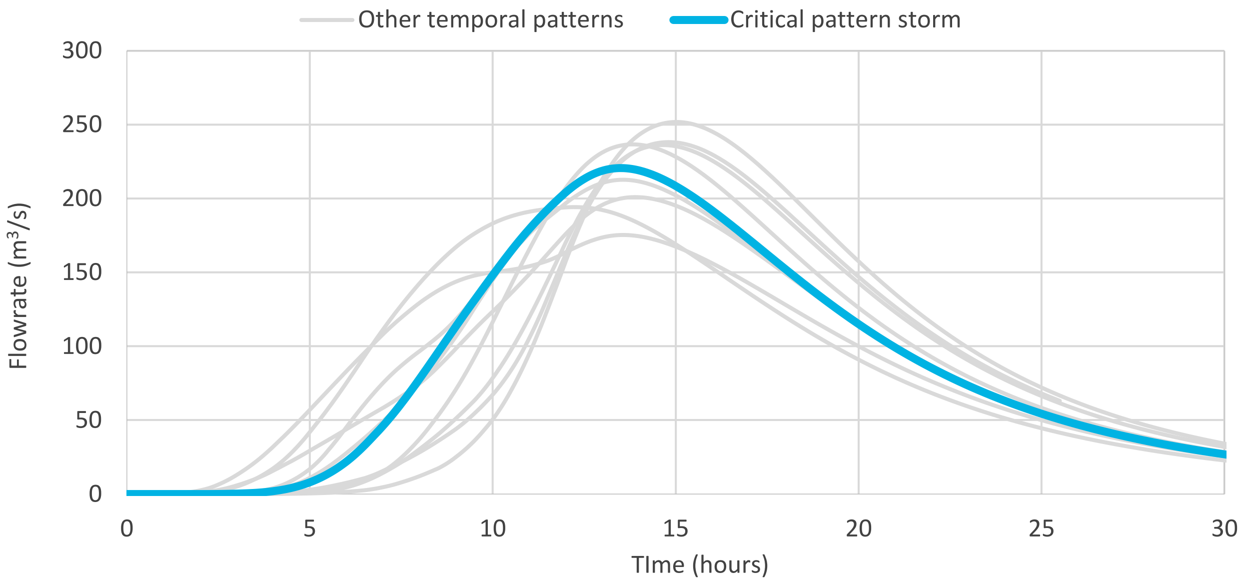


Figure A.6 20% AEP ensemble storm flow hydrographs – 720-minute storm duration

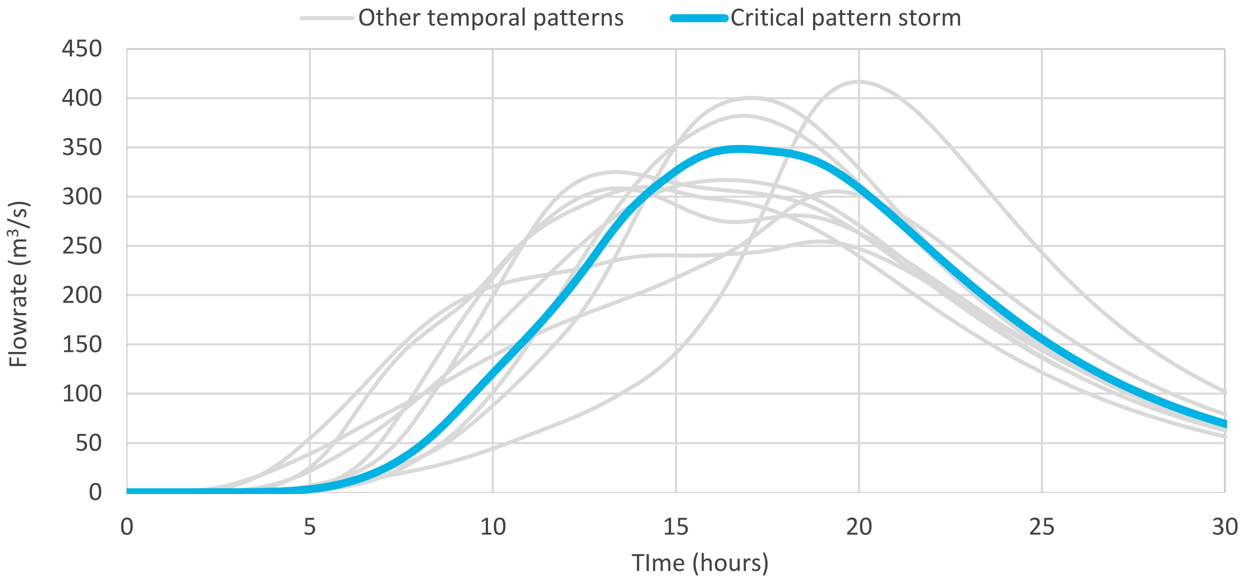
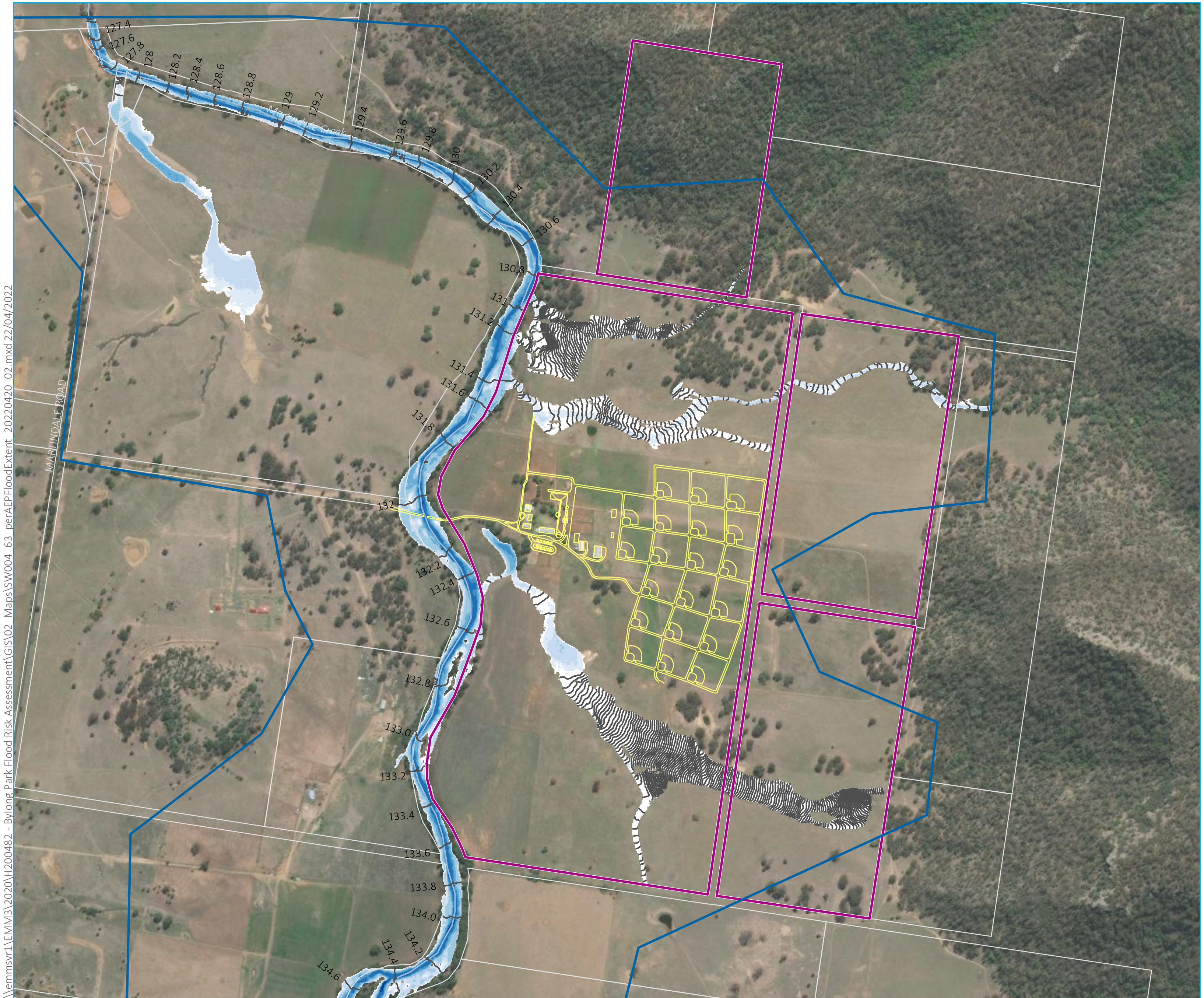


Figure A.7 5% AEP ensemble storm flow hydrographs – 1080-minute storm duration

Appendix B

Flood mapping



KEY

- Site boundary
- TUFLOW site boundary
- Proposed site plan
- 63.2% AEP flood level contour (0.2m)
- Named watercourse
- Cadastral boundary

63.2% AEP flood depth (m)

- < 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- > 3

0 250 500 m

GDA 1994 MGA Zone 56

N

Source: EMM (2022); ABS (2021); DFSI (2020,2021); ESRI (2022); GA (2011)

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63.2% AEP flood extent and depth

Bylong Park, NSW
Flood Risk Assessment
Figure B.1

EMM
creating opportunities

KEY

- Site boundary
- TUFLOW site boundary
- Proposed site plan
- 20% AEP flood level contour (0.2m)
- Named watercourse
- Cadastral boundary

20% AEP flood depth (m)

- < 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- > 3

20% AEP flood extent and depth

Bylong Park, NSW
Flood Risk Assessment
Figure B.2

EMM
creating opportunities

Source: EMM (2022); ABS (2021); DFSI (2020,2021); ESRI (2022); GA (2011)

0 250 500 m
GDA 1994 MGA Zone 56
N

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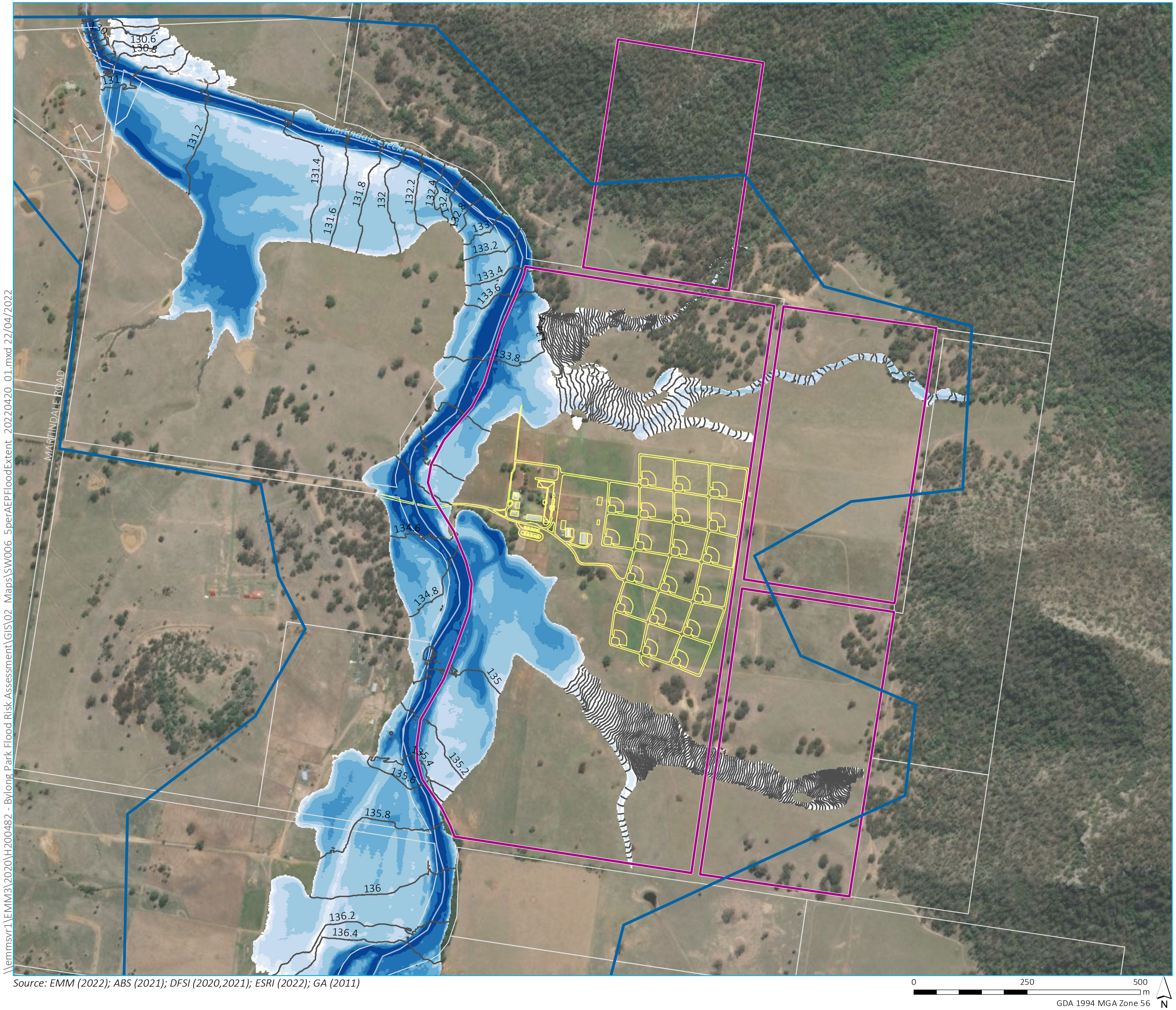

KEY

- Site boundary
- TUFLOW site boundary
- Proposed site plan
- 5% AEP flood level contour (0.2m)
- Named watercourse
- Cadastral boundary

5% AEP flood depth (m)

- < 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- > 3

Source: EMM (2022); ABS (2021); DFSI (2020,2021); ESRI (2022); GA (2011)

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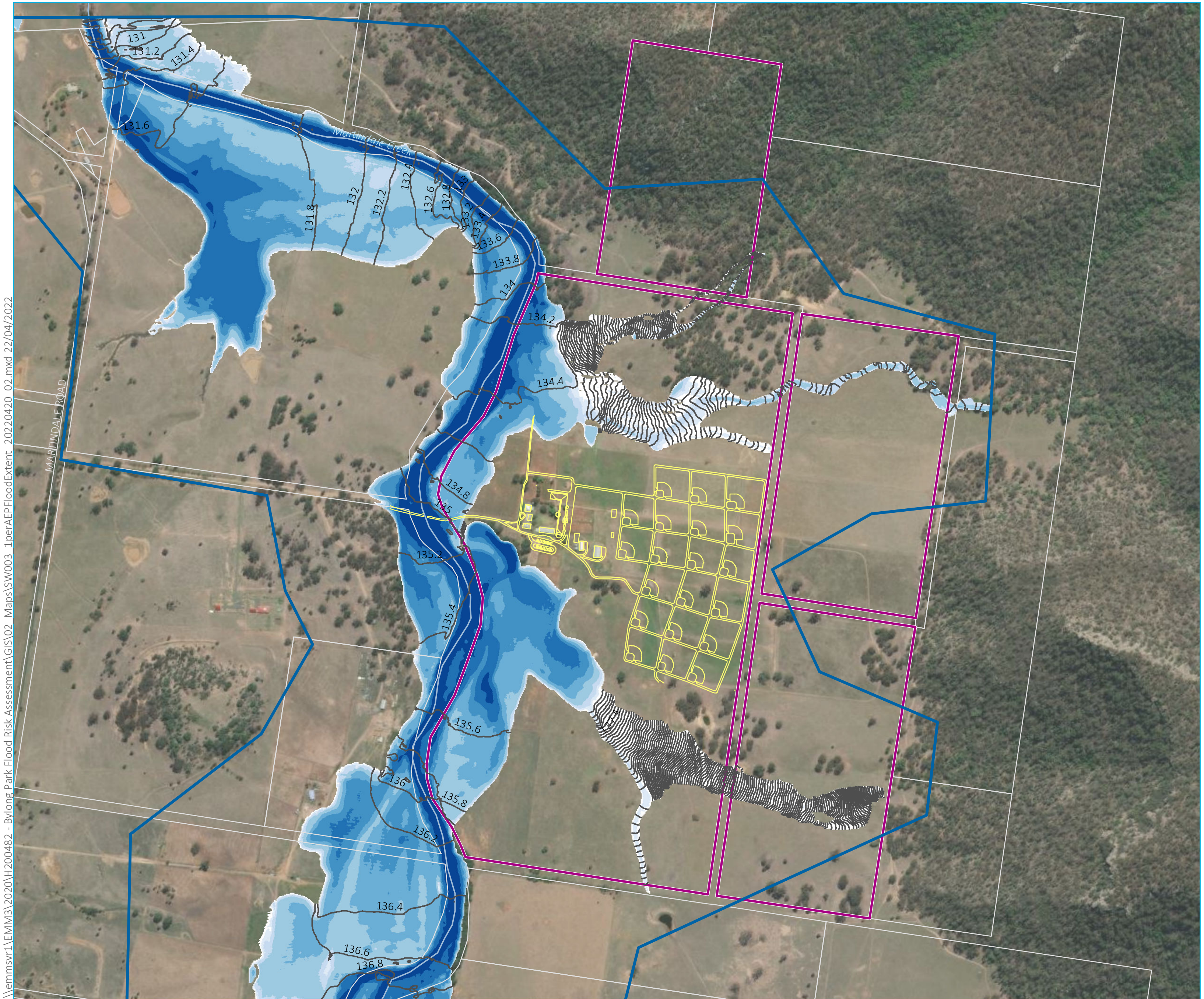
5% AEP flood extent and depth

Bylong Park, NSW
Flood Risk Assessment
Figure B.3

EMM
creating opportunities



KEY

- Site boundary
- TUFLOW site boundary
- Proposed site plan
- 1% AEP flood level contour (0.2m)
- Named watercourse
- Cadastral boundary

1% AEP flood depth (m)

- < 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- > 3

Source: EMM (2022); ABS (2021); DFSI (2020,2021); ESRI (2022); GA (2011); Metromap (2022)

0 200 400 m

GDA 1994 MGA Zone 56

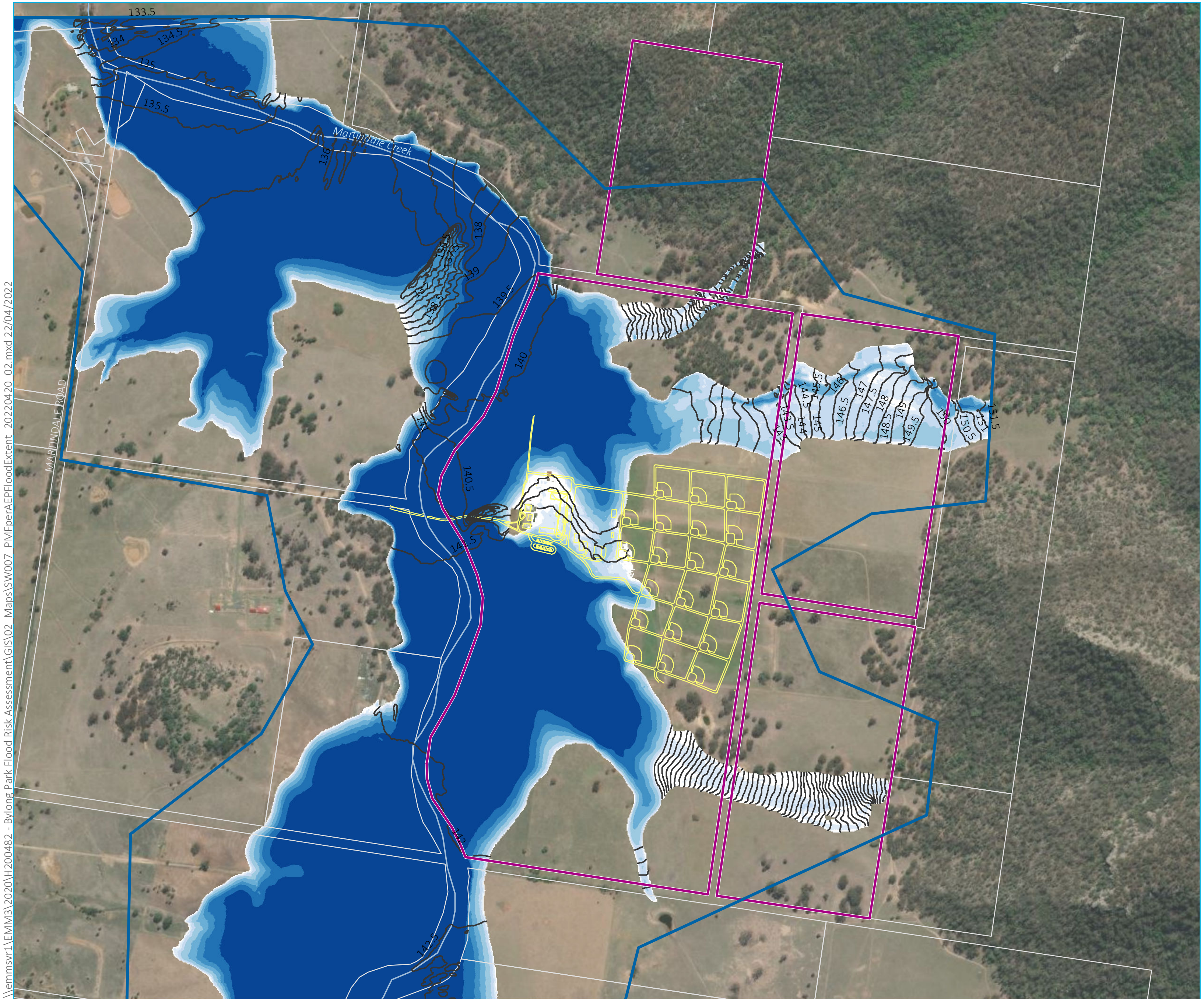
N

1% AEP flood extent and depth

Bylong Park, NSW
Flood Risk Assessment
Figure B.4

EMM
creating opportunities

\\emmsvr1\EMM3\2020\H200482 - Bylong Park Flood Risk Assessment\GIS\02_Maps\SW003_1perAEPFloodExtent_20220420_02.mxd 22/04/2022



\\emmsvr1\EMM3\2020\H200482 - Bylong Park Flood Risk Assessment\GIS\02_Maps\SW007_PMFperAEPFloodExtent_20220420_02.mxd 22/04/2022

KEY
- Site boundary
- TUFLOW site boundary
- Proposed site plan
- PMF flood level contour (0.2m)
- Named watercourse
- Cadastral boundary

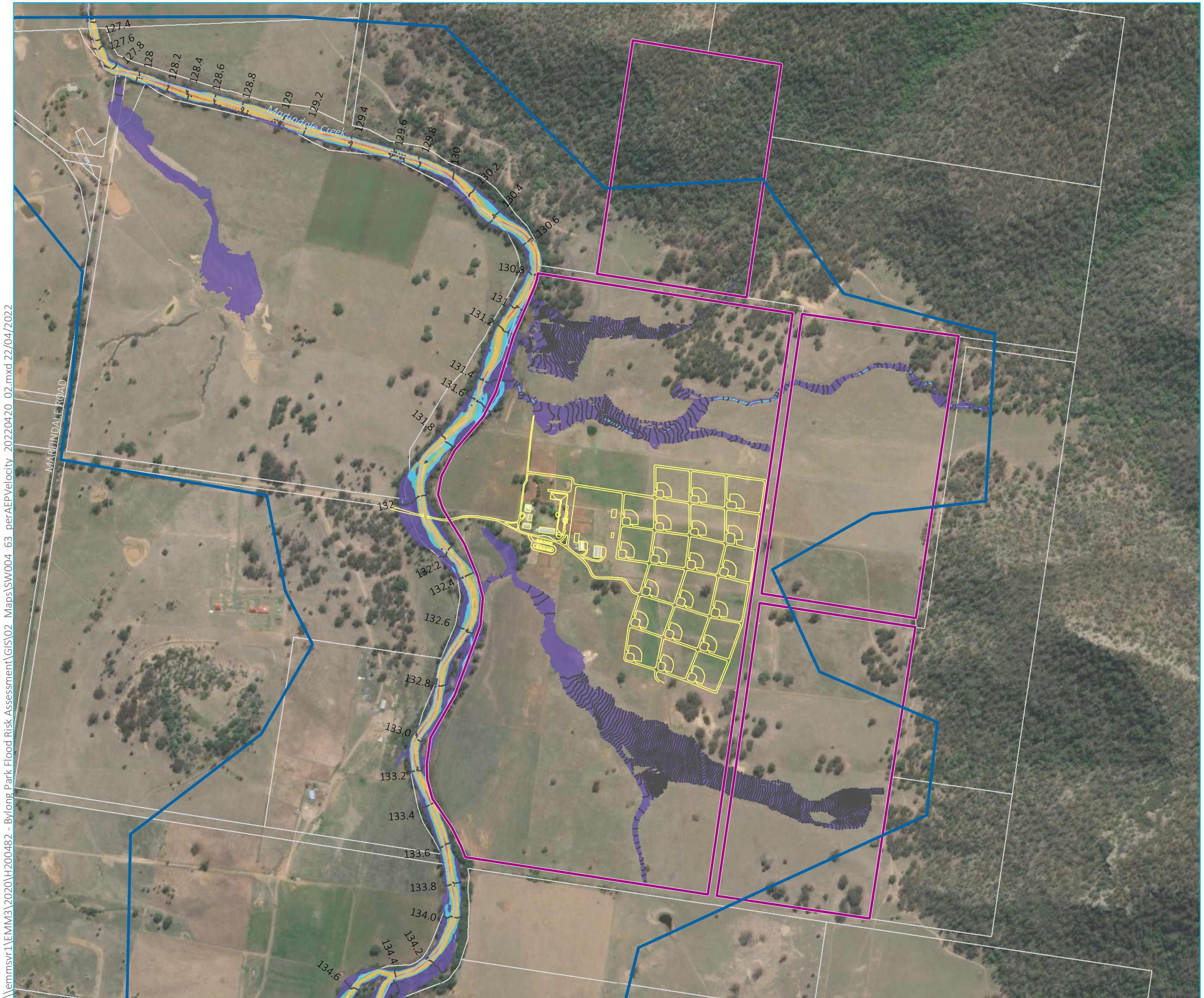
PMF flood depth (m)
- < 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 3
- > 3

Source: EMM (2022); ABS (2021); DFSI (2020,2021); ESRI (2022); GA (2011)

PMF flood extent and depth

Bylong Park, NSW
Flood Risk Assessment
Figure B.5

EMM
creating opportunities



\\emmsvr1\EMM3\2020\H200482 - Bylong Park Flood Risk Assessment\GIS\02_Maps\SW004_63_perAEPVelocity_20220420_02.mxd 22/04/2022

Source: EMM (2022); ABS (2021); DFSI (2020,2021); ESRI (2022); GA (2011)

KEY

- Site boundary
- TUFLOW site boundary
- Proposed site plan
- 63.2% AEP flood level contour (0.2m)
- Named watercourse
- Cadastral boundary

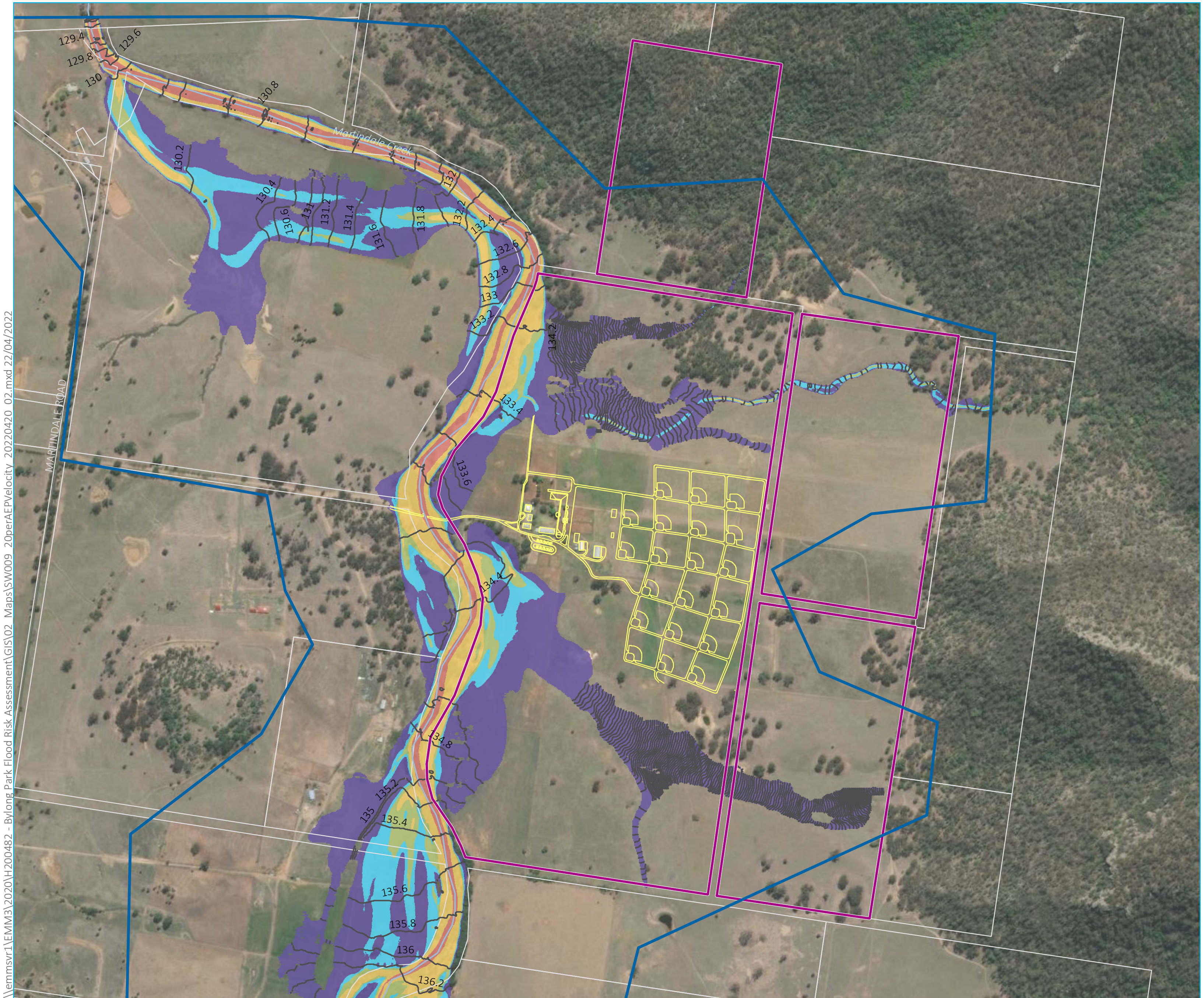
63.2% AEP velocity depth product (m2/s)

- 0.0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.0
- 1.0 - 4.0
- >4

63.2% AEP velocity depth product

Bylong Park, NSW
Flood Risk Assessment
Figure B.6

EMM
creating opportunities



KEY

- Site boundary
- TUFLOW site boundary
- Proposed site plan
- 20% AEP flood level contour (0.2m)
- Named watercourse
- Cadastral boundary

20% AEP velocity depth product (m2/s)

- 0.0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.0
- 1.0 - 4.0
- >4

20% AEP velocity depth product

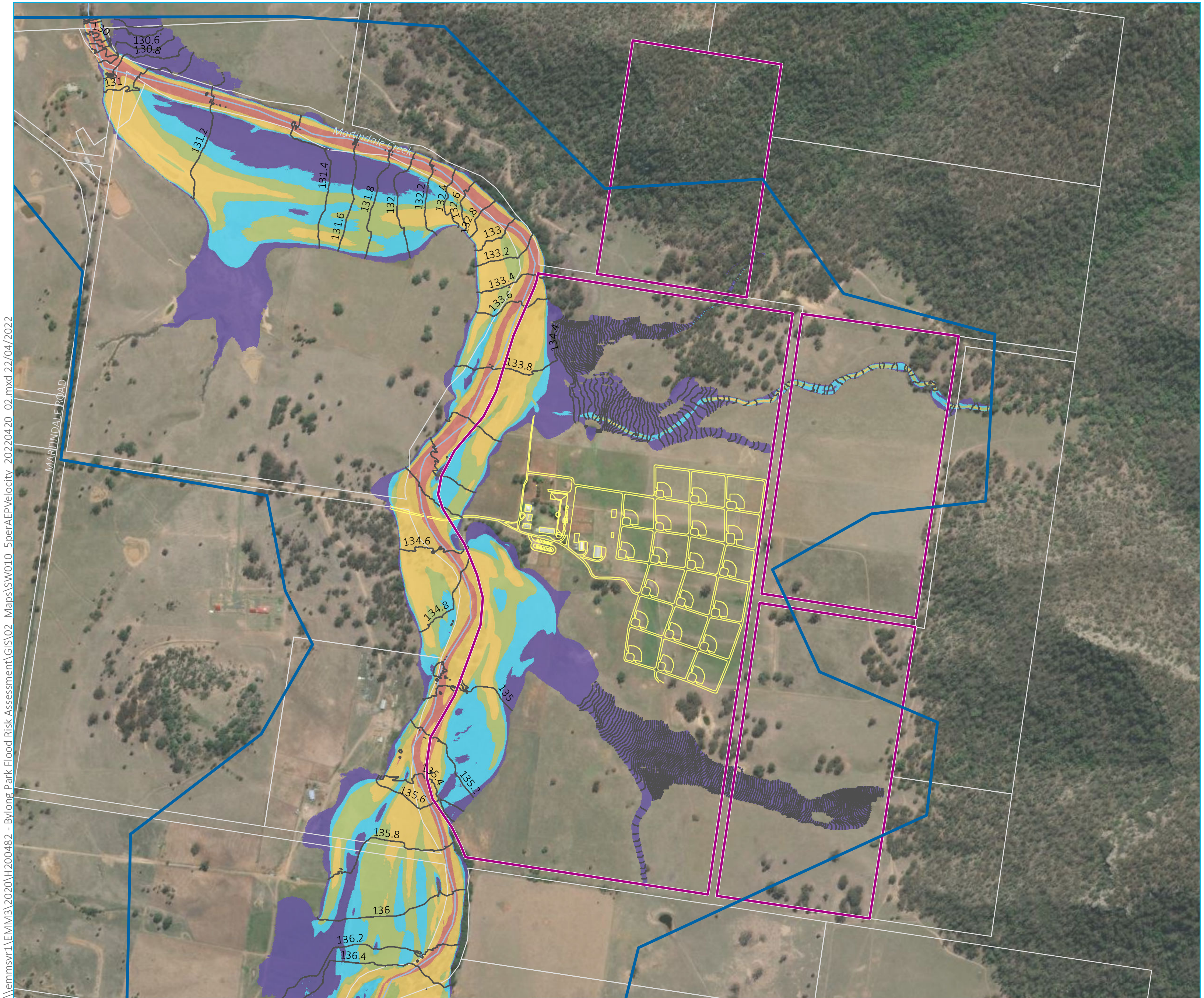
Bylong Park, NSW
Flood Risk Assessment
Figure B.7

EMM creating opportunities

Source: EMM (2022); ABS (2021); DFSI (2020,2021); ESRI (2022); GA (2011)

0 250 500 m
GDA 1994 MGA Zone 56
N

\\emmsvr1\EMM3\2020\H200482 - Bylong Park Flood Risk Assessment\GIS\02_Maps\SW009_20perAEPVelocity_20220420_02.mxd 22/04/2022



KEY

- Site boundary
- TUFLOW site boundary
- Proposed site plan
- 5% AEP flood level contour (0.2m)
- Named watercourse
- Cadastral boundary

5% AEP velocity depth product (m2/s)

- 0.0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.0
- 1.0 - 4.0
- >4

Source: EMM (2022); ABS (2021); DFSI (2020,2021); ESRI (2022); GA (2011)

0 250 500 m
GDA 1994 MGA Zone 56
N

5% AEP velocity depth product

Bylong Park, NSW
Flood Risk Assessment
Figure B.8

EMM
creating opportunities

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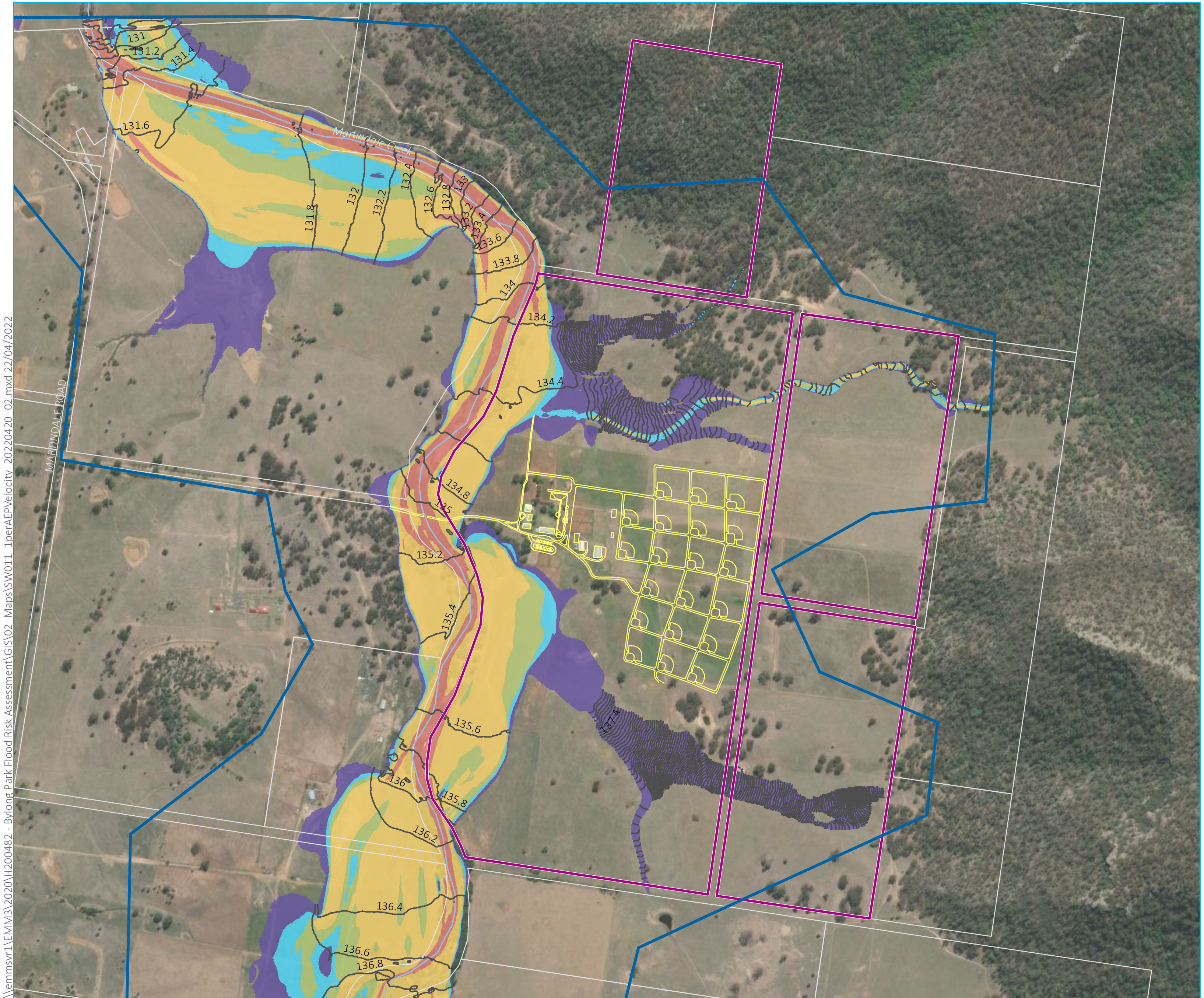


KEY

- Site boundary
- TUFLOW site boundary
- Proposed site plan
- 1% AEP flood level contour (0.2m)
- Named watercourse
- Cadastral boundary

1% AEP velocity depth product (m2/s)

- 0.0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.0
- 1.0 - 4.0
- >4

Source: EMM (2022); ABS (2021); DFSI (2020,2021); ESRI (2022); GA (2011)

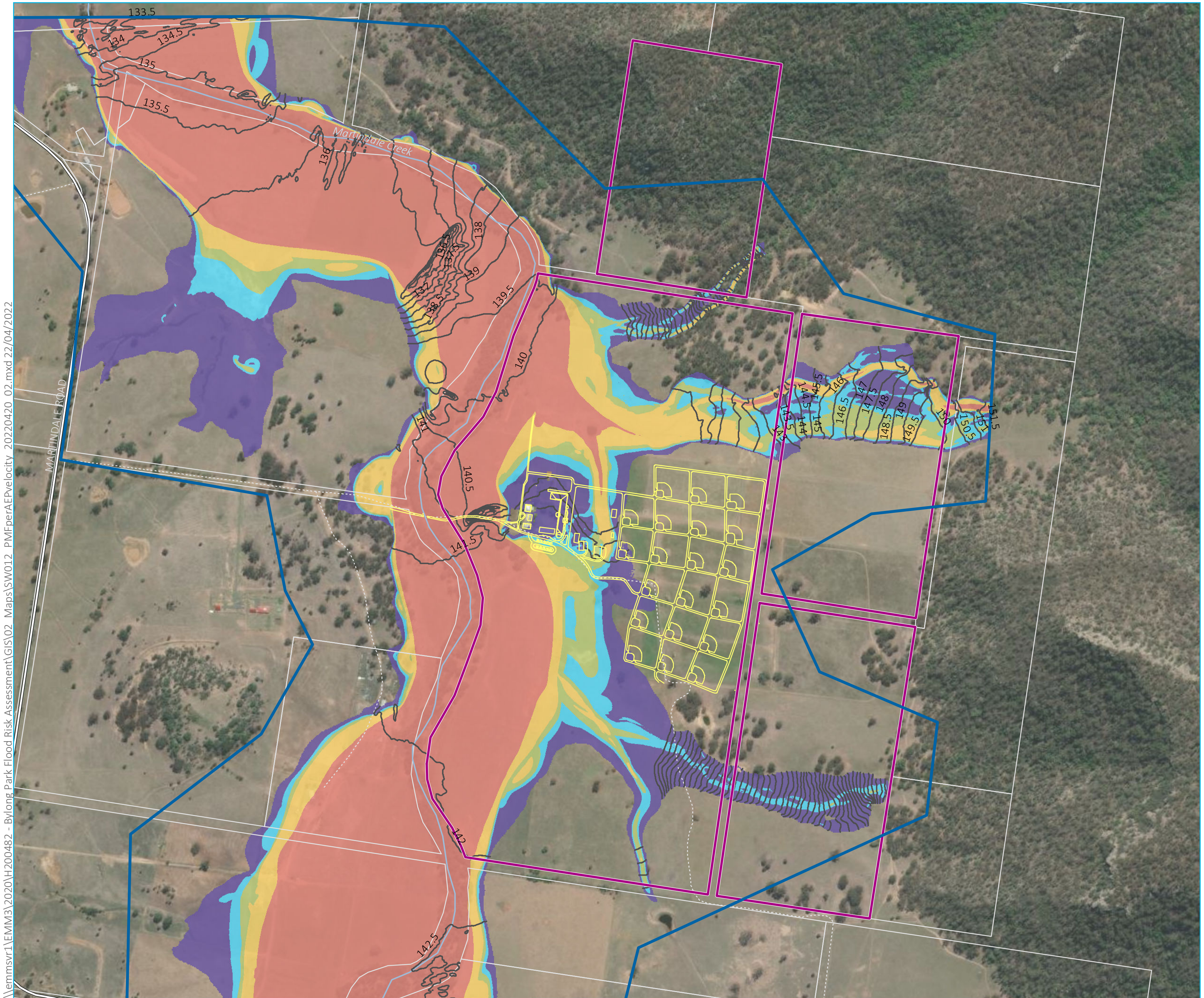
0 250 500 m
GDA 1994 MGA Zone 56
N

\\emmsvr1\EMM3\2020\H200482 - Bylong Park Flood Risk Assessment\GIS\02_Maps\SW011_1perAEPVelocity_20220420_02.mxd 22/04/2022

1% AEP velocity depth product

Bylong Park, NSW
Flood Risk Assessment
Figure B.9

EMM
creating opportunities



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Source: EMM (2022); ABS (2021); DFSI (2020,2021); ESRI (2022); GA (2011)

0 250 500 m
GDA 1994 MGA Zone 56
N

KEY
- Site boundary
- TUFLOW site boundary
- Proposed site plan
- PMF flood level contour (0.2m)
- Named watercourse
- Cadastral boundary

PMF velocity depth product (m2/s)
- 0.0 - 0.3
- 0.3 - 0.6
- 0.6 - 1.0
- 1.0 - 4.0
- >4

PMF velocity depth product

Bylong Park, NSW
Flood Risk Assessment
Figure B.10

EMM
creating opportunities

Appendix C

Provisional site access management plan

A Flood Risk Management Plan (FRMP) will be prepared by Greyhounds NSW when the facility's management plans are prepared following the DA approval. This provisional site access management plan provides examples of practical measures that could be included in the FRMP to manage the site access restrictions.

The practical measures are described in Table C.1.

Table C.1 Provisional site access management plan

ID	Trigger	Action required	Timing	Follow up actions
1	Streamflow conditions and rainfall forecasts are to be monitored on a regular basis to identify the likelihood and extent and magnitude of access restrictions occurring in the next five days.	If minor short-term restrictions are considered likely to occur: • Inform relevant staff that site access may be restricted for short periods of time in the coming days. • Prepare operations for short term access restrictions. • Continue to monitor rainfall forecasts and streamflow conditions.	• Immediately once rainfall in the catchment is predicted.	• Nil
2	ID 1 applies if minor short-term restrictions are considered likely to occur. ID 2 applies of if more extensive restrictions are considered likely to occur.	If more extensive restrictions are considered likely to occur: • Inform staff that site access may be restricted for more than a day at a time. • Evacuate any non-essential staff prior to predicted start of rainfall. • Prepare operations for longer term restrictions. • Continue to monitor rainfall forecasts and streamflow conditions.	• Immediately once rainfall in the catchment is predicted.	• Provide regular updates to relevant staff.
3	Flow depth over access causeway exceeds **0.3 m**.	• Inform staff site access is only via 4WD vehicle. • Continue to monitor rainfall forecasts.	• Immediately once the safe access threshold has been exceeded.	• Proceed with actions outlined for ID 4 if streamflow continues to rise. • Provide regular updates to relevant staff.
4	Flow depth over access causeway exceeds **0.5 m**.	• Inform staff site access is closed for all vehicles. • Shelter in place until site access is re-established. • Operations to follow site access restricted procedures.	• Immediately once the safe access threshold has been exceeded.	• Continue to monitor rainfall forecasts to identify when site access may be re-established. • Provide regular updates to relevant staff.
5	Flow depth recedes below 0.5 m (and not expected to immediately rise again)	• Inform staff site access has been re-established for large 4WD vehicles.	• As required to allow staff to enter or leave site.	• Monitor rainfall forecast to confirm streamflow will continue to fall.
6	Flow depth recedes below 0.3 m (and not expected to immediately rise again)	• Inform staff site access has been re-established for all vehicles.	• As required to allow staff to enter or leave site.	• Provide regular updates to relevant staff.