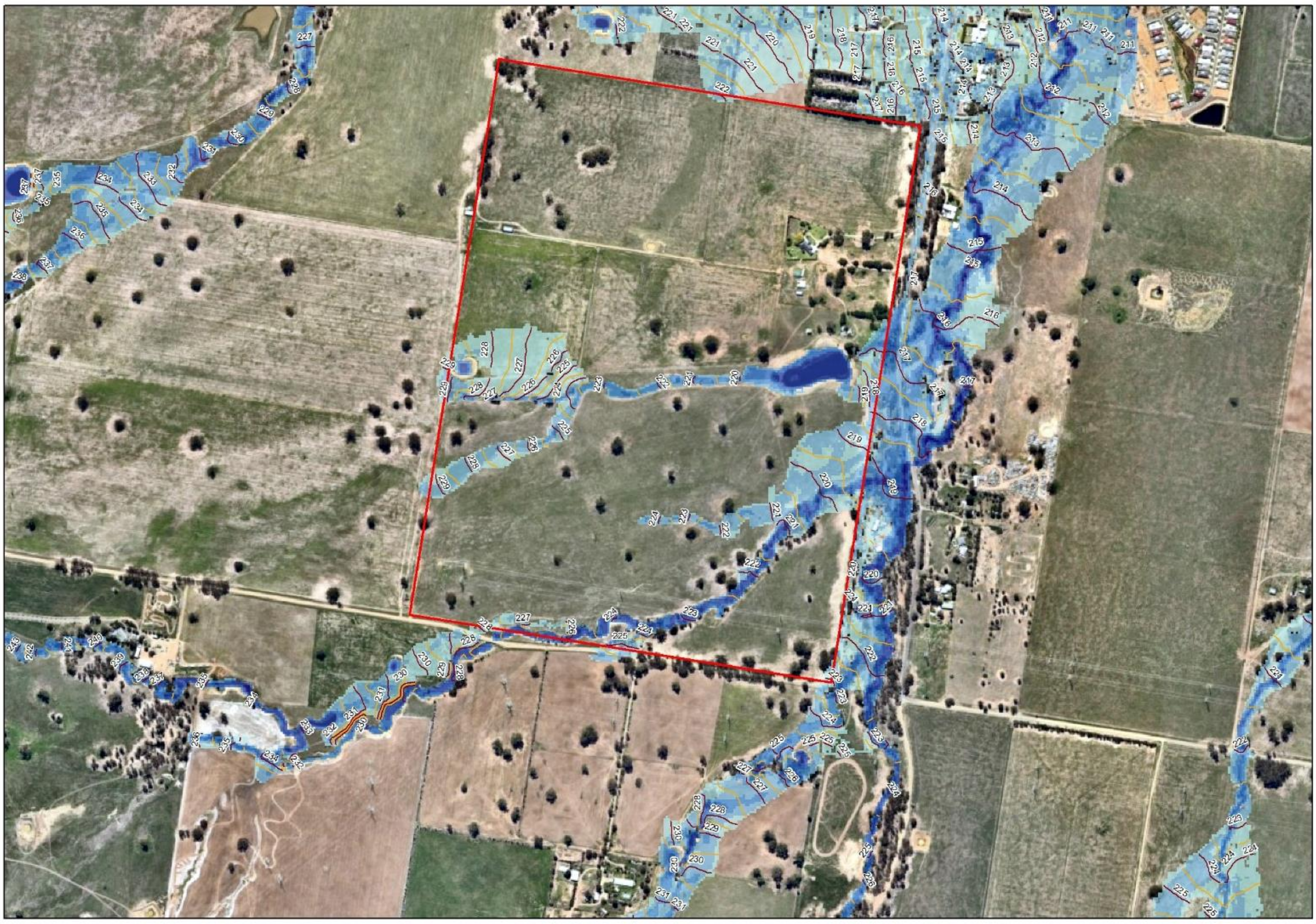
APPENDIX E STORMWATER REPORT

SUNNYSIDE VENTURES

SUNNYSIDE ESTATE WAGGA WAGGA – SITE STORMWATER MANAGEMENT PLAN

FINAL REPORT



JULY 2020

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SUNNYSIDE ESTATE WAGGA WAGGA – SITE STORMWATER MANAGEMENT PLAN

FINAL REPORT

JULY 2020

Project Sunnyside Estate Wagga Wagga – Site Stormwater Management Plan	**Project Number** **120036**
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Revision History

Revision	Description	Distribution	Authors	Reviewed by	Verified by	Date
0	Initial study report issued	WMAwater	Mark Colegate, Yuan Li	Mark Colegate		JUN 20
1	Final report	WMAwater	Mark Colegate, Yuan Li	Mark Colegate		JUL 20

SUNNYSIDE ESTATE WAGGA WAGGA – SITE STORMWATER MANAGEMENT PLAN

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LIST OF ACRONYMS

AEP	Annual Exceedance Probability
ARF	Areal Reduction Factor
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
BOM	Bureau of Meteorology
DEM	Digital Terrain Model
EY	Exceedances per Year
IFD	Intensity, Frequency and Duration (Rainfall)
m AHD	meters above Australian Height Datum
MUSIC	Model for Urban Stormwater Improvement Conceptualisation
PMP	Probable Maximum Precipitation
SSMP	Site Stormwater Management Plan
TUFLOW	one-dimensional (1D) and two-dimensional (2D) flood and tide simulation software (hydraulic model)
WBNM	Watershed Bounded Network Model (hydrologic model)
WWCC	Wagga Wagga City Council
XPRAFTS	XP Runoff Analysis and Flow Training Simulator (hydrologic model)

ADOPTED TERMINOLOGY

Australian Rainfall and Runoff (ARR, ed Ball et al, 2016) recommends terminology that is not misleading to the public and stakeholders. Therefore, the use of terms such as “recurrence interval” and “return period” are no longer recommended as they imply that a given event magnitude is only exceeded at regular intervals such as every 100 years. However, rare events may occur in clusters. For example, there are several instances of an event with a 1% chance of occurring within a short period, for example the 1949 and 1950 events at Kempsey. Historically the term Average Recurrence Interval (ARI) has been used.

ARR 2016 recommends the use of Annual Exceedance Probability (AEP). Annual Exceedance Probability (AEP) is the probability of an event being equalled or exceeded within a year. AEP may be expressed as either a percentage (%) or 1 in X. Floodplain management typically uses the percentage form of terminology. Therefore a 1% AEP event or 1 in 100 AEP has a 1% chance of being equalled or exceeded in any year.

ARI and AEP are often mistaken as being interchangeable for events equal to or more frequent than 10% AEP. The table below describes how they are subtly different.

For events more frequent than 50% AEP, expressing frequency in terms of Annual Exceedance Probability is not meaningful and misleading particularly in areas with strong seasonality. Therefore, the term Exceedances per Year (EY) is recommended. Statistically a 0.5 EY event is not the same as a 50% AEP event, and likewise an event with a 20% AEP is not the same as a

0.2 EY event. For example, an event of 0.5 EY is an event which would, on average, occur every two years. A 2 EY event is equivalent to a design event with a 6-month Average Recurrence Interval where there is no seasonality, or an event that is likely to occur twice in one year.

The Probable Maximum Flood is the largest flood that could possibly occur on a catchment. It is related to the Probable Maximum Precipitation (PMP). The PMP has an approximate probability. Due to the conservativeness applied to other factors influencing flooding a PMP does not translate to a PMF of the same AEP. Therefore, an AEP is not assigned to the PMF.

This report has adopted the approach recommended by ARR and uses % AEP for all events rarer than the 50 % AEP and EY for all events more frequent than this.

Frequency Descriptor	EY	AEP (%)	AEP (1 in x)	ARI
Very Frequent	12			
	6	99.75	1.002	0.17
	4	98.17	1.02	0.25
	3	95.02	1.05	0.33
	2	86.47	1.16	0.5
	1	63.21	1.58	1
Frequent	0.69	50	2	1.44
	0.5	39.35	2.54	2
	0.22	20	5	4.48
	0.2	18.13	5.52	5
	0.11	10	10	9.49
Rare	0.05	5	20	19.5
	0.02	2	50	49.5
	0.01	1	100	99.5
Very Rare	0.005	0.5	200	199.5
	0.002	0.2	500	499.5
	0.001	0.1	1000	999.5
	0.0005	0.05	2000	1999.5
Extreme	0.0002	0.02	5000	4999.5
			↓	
			PMP/ PMP Flood	

EXECUTIVE SUMMARY

An Existing Flood Condition Assessment and Site Stormwater Management Plan has been developed using ARR 2019 current industry best practice for the proposed Rezoning and Subdivision located at 474 and 456 Plumpton Road, Rowan NSW 2650.

The existing flood characteristics of the Site have been modelled and mapped for flood events with the probability of 20%, 10%, 5%, 2%, 1%, 0.5%, and 0.2% AEPs.

The stormwater quality and quantity management facilities were designed and assessed through a MUSIC model and a XPRAFTS model, respectively. Three combined wetland and detention basins, as denoted in the conceptual plan (Diagram A), have been designed to ensure "no-worsening" stormwater peak discharges due to proposed development.

The site stormwater quality objectives for the proposed development can be achieved using the three wetlands with inlet ponds (350 m^3, 350 m^3, 350 m^3) and macrophyte zones (6,200 m^2, 6,200 m^2, 4,300 m^2). The site stormwater quantity objectives can be achieved using three detention basins on top of the wetlands with footprints of 9,820 m^2, 9,377 m^2, and 6,978 m^2, respectively, including freeboard.

All the three combined wetland and detention basins were designed to be "offline" facilities, which treat or mitigate stormwater generated within the Site only, and the external flows are to be conveyed through existing waterways with appropriate drainage design.

Diagram A: Stormwater Management Conceptual Plan (refer to Figure 4 for high resolution map)

1. INTRODUCTION

WMAwater was engaged by John Randall Consulting Pty Ltd on behalf of Sunnyside Ventures to prepare a Site Stormwater Management Plan (SSMP) to assist in the planning permit application for the proposed rezoning and development of 474 and 456 Plumpton Road, Rowan NSW 2650 (the Site).

The following report assesses the existing flood characteristics of the Site and details an initial SSMP for the proposed development. The adopted analytical process and modelling outcomes are summarized in following sections, including the development of:

- a regional coupled hydrological (WBNM) and hydraulic (TUFLOW) model based on the model from Wagga Wagga Major Overland Flow Floodplain Risk Management Study and Plan (MOFFRMS) (WMAwater, 2020, Reference 1) and the characteristics of the Site to define existing flood characteristics and inflow required to be conveyed;
- a local hydrological (XPRAFTS) model of the Site for the design of detention facilities to manage site stormwater discharges;
- and a local water quality model (MUSIC) of the Site to design treatment facilities and predict the efficiency of the proposed treatment system in the reduction of contaminants and pollutants.

2. BACKGROUND

The land parcels known as 474 and 456 Plumpton Road (the Site) are being investigated for rezoning and development of a *circa* 500 lot residential sub-division (lot sizes approx. 1,000 / 1,200 m^2). The Site is currently zoned Rural and used for agricultural activities.

The total area of the site is 110.17 ha. Stormwater management has been identified as critical to the combined rezoning and residential development application. A stormwater management strategy needs to be developed in accordance with Wagga Wagga City Council (WWCC) requirements prior to application approval.

2.1. Study Site

The Site is located in the south of Wagga Wagga off Plumpton Road. The stormwater from the Site currently discharges into Stringybark Creek which flows through the southeast corner of the Site and towards the northeast of the Site. Figure 1 shows the location of the Site and overland flow paths through the Site.

The City of Wagga Wagga has experienced flooding on numerous occasions with the most recent major flood occurring in 2012. The subject land is located outside the flood zone defined by Wagga City Council.

2.2. Previous Studies

There have been a number of regional flood studies in this area, including the following recent studies:

- Wagga Wagga Major Overland Flow Floodplain Risk Management Study (MOFFRMS) – Public Exhibition Version, WMAwater, 2020 (Reference 1)
- Wagga Wagga Revised Murrumbidgee River Floodplain Risk Management Study and Plan, WMAwater, 2018 (Reference 2)
- Wagga Wagga Detailed Flood Model Revisions, WMAwater, 2014 (Reference 3)
- Wagga Wagga LGA Murrumbidgee River Flood Modelling, WMAwater, 2012 (Reference 4)
- Wagga Wagga Major Overland Flow Flood Study (MOFFS), 2011 (Reference 5)

The MOFFRMS conducted by WMAwater is the latest flood study covering the Site, which implemented the methodology detailed in the latest best practice guideline, ARR 2019 (Reference 6). The regional model for this study was established based on the refinement of the MOFFRMS model.

3. OBJECTIVES

Establishing the existing flood conditions allows an understanding of the availability of developable land and identification of regional stormwater constraints associated with the development of the site. The defined existing (pre-development) flood characteristics will inform the inflow to the Site that are required to be conveyed through the Site after development.

The objective of the SSMP is to demonstrate that the site can be developed using best practice stormwater management principles and techniques. This will enable the subdivision to meet the stormwater management requirements set in WWCC Development Control Plan (DCP) (Reference 7) and WWCC Engineering Guidelines for Subdivision and Development Standards (Reference 8). The objectives will inform stormwater designs and ensure that stormwater quality and quantity targets are achieved and maintained.

Specific objectives are detailed below.

Existing Flooding Objectives:

- Prepare existing flood mapping for designated range of storm events;
- Establish the existing flood characteristics for the site;
- Quantify flows into and out of the Site under existing conditions.

Site Stormwater Quality Objectives:

- 60% reduction in Suspended solids (SS);
- 40% reduction in total nitrogen (TN);
- 45% reduction in total phosphorus (TP);
- 90% reduction in gross pollutants (GP).

Site Stormwater Quantity Objectives:

- No-worsening stormwater peak discharges after development.

4. EXISTING FLOOD CONDITIONS

The Lake Albert flood model, a subset of the entire model from the MOFFRMS (Reference 1), was used as a base model for this study and minor refinements were carried out to characterise existing flood conditions for the Site.

The key features of the Lake Albert flood model are summarised below:

- Hydrological model:

- A network hydrological model was set up in WBNM;
- Probability Neutral Burst Initial Losses (PNBIL) from ARR Data Hub (Reference 9) were adopted;
- Continuous Losses from ARR Data Hub were adjusted by the multiplier 0.4 as suggested by NSW Specific Data Info in ARR Data Hub (Reference 10);
- Areal Reduction Factor (ARF) parameters from ARR Data Hub were adopted;
- A single (average of the whole MOFFRMS catchment) IFD from BOM 2016 IFD (Reference 11) was used for each AEP.

- Hydraulic model:

- A 2D hydraulic model were set up using TUFLOW modelling tool;
- Digital Elevation Model (DEM) with 1 m resolution was used;
- Modelling grid size was set to be 5 m;
- Key stormwater drainage network and hydraulic constraints were incorporated.

For a full description of the Lake Albert flood model, refer to MOFFRMS (Reference 1).

The refinements of the Lake Albert model made for this study are summarised below:

- Hydrological model:

- Sub-catchment delineation around the Site was refined according to the Site boundary, as illustrated in Figure 2;
- Areas were recalculated for those adjusted/new sub-catchments around the Site with fraction impervious retained as 0% as per the MOFFRMS;
- The IFD for each AEP was averaged for the study catchment rather than the whole MOFFRMS catchment;
- The ARFs were updated to the catchment area draining to Stringybark Creek through the Site, which were previously based on the entire catchment area;
- The critical durations and representative temporal patterns were selected for the Site.

- Hydraulic model:

- TUFLOW model was updated with new inflow locations (2d_sa) for the new WBNM sub-catchments;
- Additional reporting locations/cross-sections (2d_po) were added to extract flow information within/around the Site.

Hydrological modelling was carried out for ten (10) temporal patterns, a range of AEPs (20%, 10%, 5%, 2%, 1%, 0.5%, and 0.2% AEPs), and a range of storm durations (30 min to 12 hr) using the updated WBNM model. The critical duration and representative temporal pattern for each AEP were selected based on peak flow through the Site.

The selected events were then modelled through updated TUFLOW to characterise existing flood conditions for the Site. Flood depth and height mapping were produced and are shown in Figure B1 to Figure B7. Flood hazard categories were determined in accordance with the Australian Disaster Resilience Handbook Collection (Reference 12). Hazard categories mapping are illustrated in Figure B8 to Figure B14. A summary of this categorisation is provided in Diagram 1.

The existing flood characteristics indicate that the Site can be naturally split into three (3) sub-sites, i.e., the northern sub-site (including LA_122c, LA_122d, LA_122i, LA_122h, and LA_122g), the middle sub-site (including LA_101e, LA_101f, and LA_101g), and the southern sub-site (including LA_093d, LA_093c, LA_093e, LA_093f, and part of LA_102a).

The stormwater from upstream sub-catchments LA_122a and LA_122b flows across the northwest corner of northern sub-site as sheet flow. The middle sub-site receives stormwater from upstream sub-catchments LA_101a, LA_101b, LA_101c, and LA_101d, and convey the stormwater through the Site within a naturally formed local waterway. The Stringybark Creek flows through the southern sub-site and then flows towards the north along the eastern boundary of the Site. Peak discharges into and out of the Site for each AEP are annotated in Figure B1 to Figure B7.

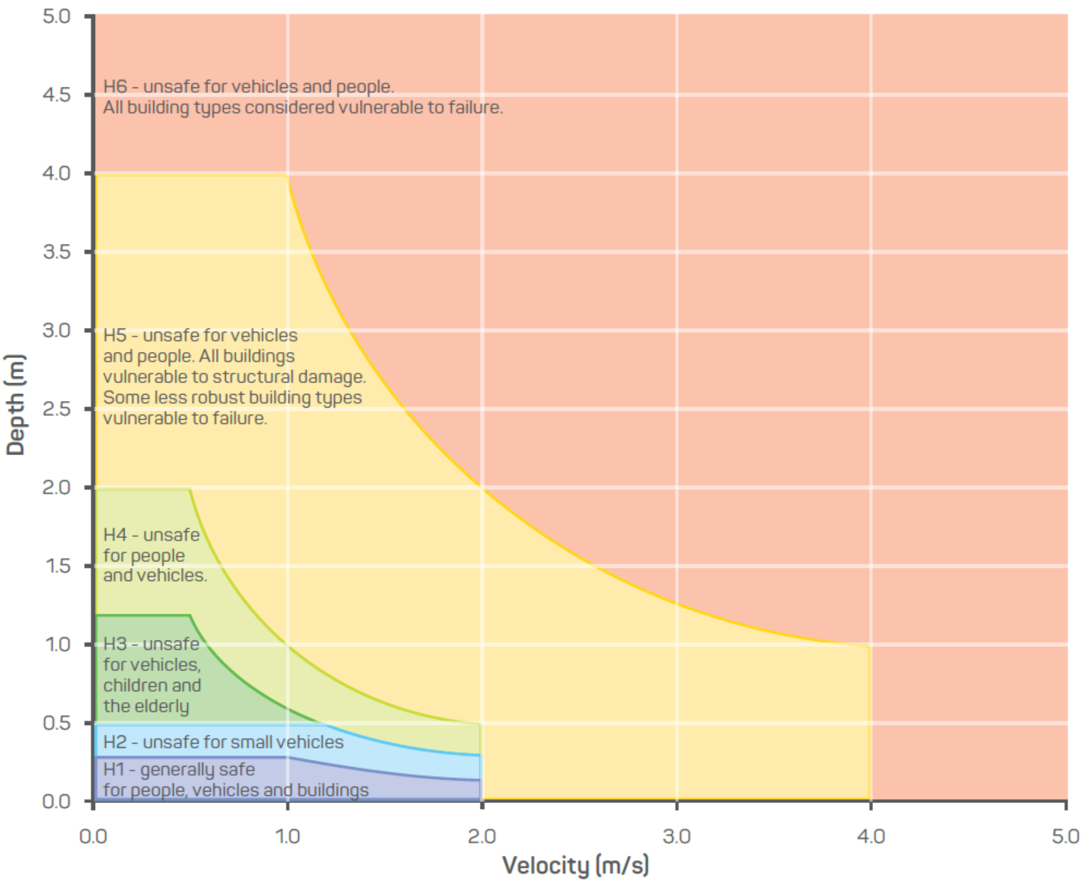

Diagram 1: General Flood Hazard Vulnerability Curves (Reference 12)

5. SITE STORMWATER MANAGEMENT

The objective of the Site Stormwater Management Plan (SSMP) is to mitigate adverse impacts on stormwater discharges resulting from the development of the Site. Site stormwater discharge will meet the conditions and requirements for stormwater management. These requirements ensure that appropriate design and stormwater mitigation is applied to ensure that stormwater quality and quantity targets are achieved and maintained. The specific site stormwater objectives for proposed developments of the Site are detailed in Section 3.

5.1. Site Delineation

The aim of this study is to develop a preliminary stormwater management plan to inform the permit application process. A plan of subdivision has not been prepared at this stage. Therefore, the existing Site topography was used as a basis for SSMP development.

As concluded in Section 4, the Site was delineated into three sub-sites, i.e., S1 (northern sub-site), S2 (middle sub-site), and S3 (southern sub-site), based on the existing topography. The delineation is shown in Figure 3.

Based on the existing flood characteristics, it is suggested to design “offline” stormwater management facilities to mitigate/treat stormwater locally generated by the Site while convey the external flow through the Site by appropriate civil conveyance design. Specifically, the sheet flow across the northwest corner of the Site can be captured by a perimeter swale along the western boundary and conveyed around the Site to the northern point of discharge. Stormwater runoff can also be conveyed within the proposed road reserves via kerb and channel, and proposed drainage system. The existing waterways delineating the middle and southern sub-sites are suggested to be retained with minor modification to allow the conveyances of the external flows.

The benefit of implementing offline management facilities is that the sizes of facilities, such as detention basins and wetlands, can be minimised to account for Site discharge only by avoiding conveyance of all external flows through the proposed mitigation/treatment train. Inflow from significant waterways, such as Stringybark Creek, can be difficult to detained through on-site detention facilities due to volume requirements.

In this case, an end-of-line combined wetland (for water quality) and detention basin (for water quantity) was conceptually designed for each of the three sub-sties, as detailed in below sections. The sub-site area and further breakdown are summarised in Table 1, based on the following assumptions:

- 1% AEP flood extent (depth > 50 mm) within the site are reserved area for flood way (non-developable) to convey external flood. The rest area of each sub-site will be conveyed to detention basin/wetland (Contributing Area);
- Powerline reserve area in S3 is considered as non-developable but needs to be conveyed to detention basin/wetland;
- Road reserve is 30% of the developable area with 65% fraction impervious after development;
- Residential area is 70% of the developable area with 50% fraction impervious after

development.

Table 1: Site Breakdown

Sub-site	Land type	Contributing Area to Basin	Pervious Area (Existing/ Developed)	Impervious Area (Existing/ Developed)
S1 (35.8 ha)	Residential (25.1 ha)	35.8 ha	35.8 ha / 16.3 ha	0 ha / 19.5 ha
	Road reserve (10.7 ha)			
S2 (39.8 ha)	Residential (24.9 ha)	35.6 ha	35.6 ha / 16.2 ha	0 ha / 19.4 ha
	Road reserve (10.7 ha)			
	Flood reserve (4.2 ha)	-	-	-
S3 (34.9 ha)	Residential (18.1 ha)	30.3 ha	30.3 ha / 16.2 ha	0 ha / 14.1 ha
	Road reserve (7.8 ha)			
	Powerline reserve (4.4 ha)			
	Flood reserve (4.6 ha)	-	-	-

5.2. Stormwater Quality

Assessment of the quality of stormwater discharge from the developed Site was undertaken using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) by eWater. It allows the analysis of stormwater quality and the assessment of the efficiency of the treatment facilities. The operation of MUSIC requires climatic forcing, i.e., rainfall and potential evapotranspiration (PET), and geological parameters.

5.2.1. Climatic Inputs

Wagga Wagga AMO is one of the closest rain gauges to the Site with high quality pluviograph records. Ten (10) years of pluviograph data from 01/01/1990 to 01/01/2000 recorded by Wagga Wagga AMO station were used together with the monthly average PET data at the same location.

5.2.2. Geology

The default soil parameters from MUSIC were adopted as shown in Table 2.

Table 2: Soil Characteristics for the Study Site

Parameter	Urban Residential
Rainfall Threshold (mm/day)	1
Soil Capacity (mm)	120
Initial Storage (%)	25
Field Capacity	80
Infiltration Capacity coefficient a	200
Infiltration Capacity coefficient b	1
Initial Depth (mm)	10
Daily Recharge Rate (%)	25
Daily Base flow Rate (%)	5
Daily Deep Seepage Rate (%)	0

5.2.3. Model Structure

A water quality model was set up in MUSIC, as shown in Diagram 2. Each sub-site was defined as a source node and connected to an end-of-line wetland. Fraction impervious under developed conditions for each source node were implemented as shown in Table 1.

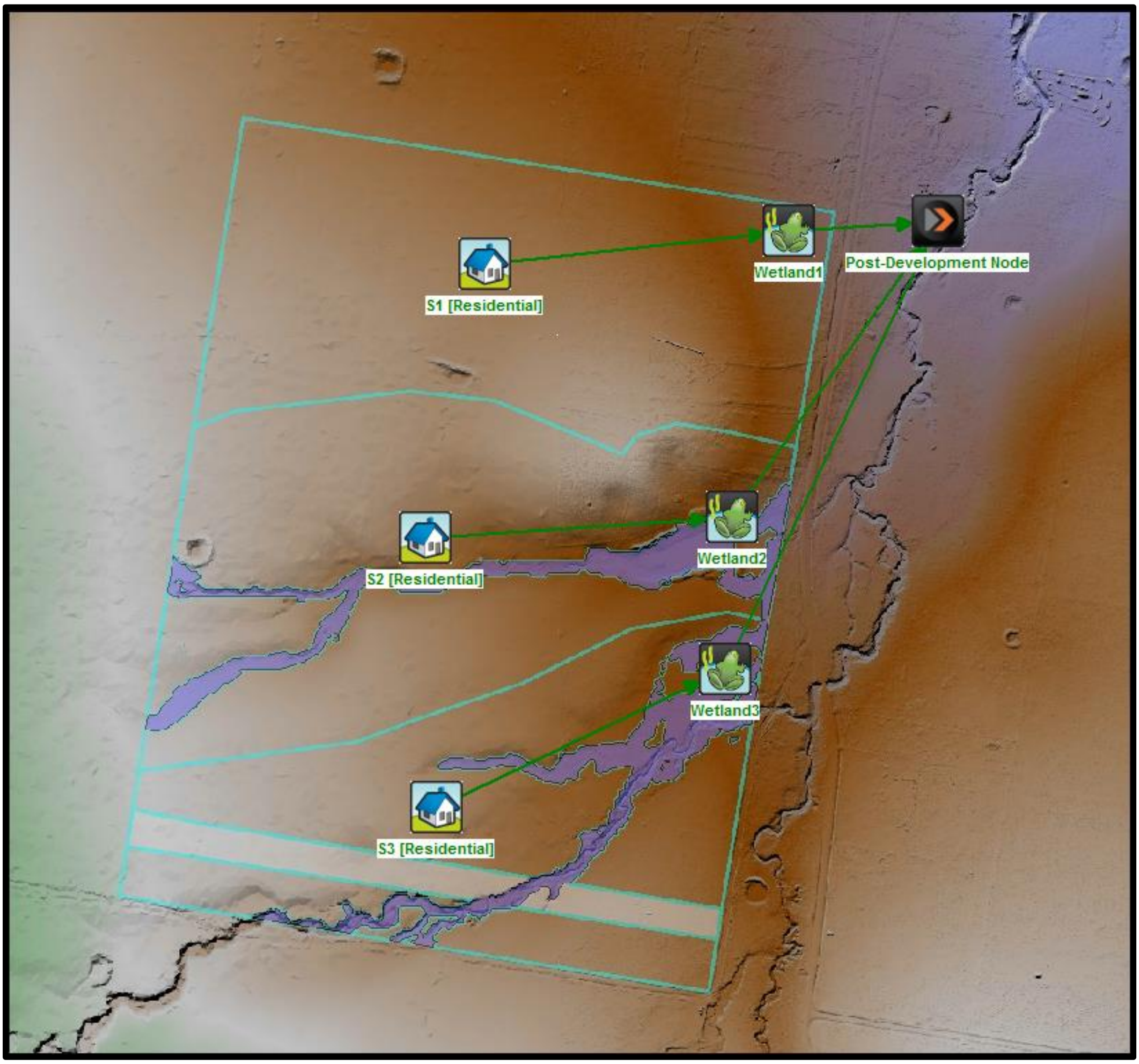

Diagram 2: MUSIC Network Schematic

5.2.4. Modelling Results

Each wetland was optimised to ensure that water quality from the developed Site meets stormwater quality objectives (Section 3). The following rules as suggested by WaterNSW (Reference 13) were applied while optimising the wetlands:

- The constructed wetland should then be modelled with an inlet pond with a volume more than 10% of the wetland's permanent pool volume.
- Extended detention should not exceed 0.5 m unless it can be shown that a higher depth is achievable without flooding impacts.

- The permanent pool volume in the constructed wetland should not exceed the surface area (at permanent pool level) multiplied by one metre unless more detailed information is provided of the wetland configuration.
- Exfiltration shall be 0 mm per hour unless 'lost' water is returned to the model via a secondary drainage link or it can be demonstrated that infiltrated runoff would not contribute to observed flows downstream either through surface runoff, seepage into drainage lines, interflow or groundwater (for example deep sandy soils).
- The evaporative loss shall be the default value of 125% of the relevant potential evapotranspiration (PET) value.
- The notional detention time of the wetland should typically be between 48 to 72 hr to ensure optimal treatment of nutrients.

The proposed wetland configurations and the stormwater quality treatment efficiencies are summarised in Table 3 and Table 4, respectively.

Table 3: Wetland Requirements

Parameter	Wetland 1 (Site 1)	Wetland 2 (Site 2)	Wetland 3 (Site 3)
Low Flow By-pass (m^3/s)	0	0	0
High Flow By-pass (m^3/s)	100	100	100
Inlet Pond Volume (m^3)	350	350	250
Surface Area (m^2)	6,200	6,200	4,300
Extended Detention Depth (m)	0.5	0.5	0.5
Permanent Pool Volume (m^3)	2,480	2,480	1,720
Initial Volume (m^3)	1,240	1,240	860
Exfiltration Rate (mm/hr)	0	0	0
Evaporative Loss as % of PET	125	125	125
Equivalent Diameter (mm)	90	90	80
Overflow Weir Width (m)	3	3	3
Notional Detention Time (hr)	64.5	64.5	56.6

Table 4: Stormwater Quality Treatment Efficiency

Parameter	Reduction (%)			Objective (%)
	Wetland 1	Wetland 2	Wetland 3	
Total Suspended Solids (kg/yr)	77.4	78.3	77.1	60
Total Phosphorus (kg/yr)	63.1	63.9	62.7	45
Total Nitrogen (kg/yr)	40.2	40.2	40.2	40
Gross Pollutants (kg/yr)	100.0	100.0	100.0	90

5.3. Stormwater Quantity

Assessment of the quantity of stormwater discharge from the developed Site was undertaken by establishing a local hydrological model in XPRAFTS. It allows the quantification of Permissible Site Discharges (PSD) and the optimisation of the detention basins. The following sections summarises the model establishment, PSD estimation, detention basin optimization and mitigation results.

5.3.1. XPRAFTS Parameter Identification

As the Lake Albert WBNM was calibrated and validated through MOFFRMS (Reference 1), most of the parameters adopted in the WBNM were directly implemented for the XPRAFTS. This includes the implementation of:

- Probability Neutral Burst Initial Losses (PNBIL) from ARR Data Hub by applying Storm Initial Losses from ARR Data Hub and back-calculated Pre-burst (Storm IL - PNBIL);
- Continuous Losses adjusted by the multiplier 0.4;
- The ARFs updated to the catchment area draining to Stringybark Creek;
- The catchment averaged IFDs;

The catchment (hillslope) and river routing are modelled through different methods in WBNM and XPRAFTS, therefore, the calibrated routing parameters from WBNM cannot be directly applied to XPRAFTS. To identify the routing parameters, a local calibration model was set up in XPRAFTS with exactly the same sub-catchments as in WBNM as shown in Diagram 3, and the XPRAFTS model was calibrated to the WBNM model at the same location (total outflow from sub-catchment LA_101g).

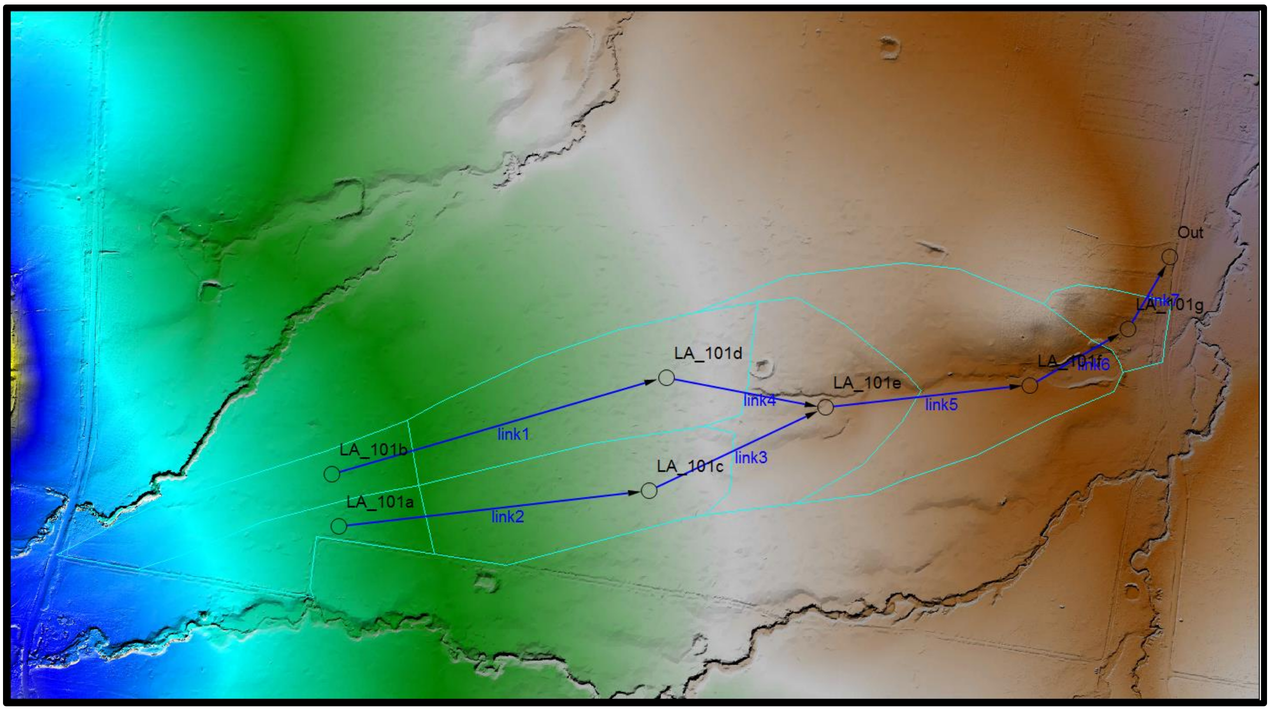

Diagram 3: The Local Calibration XPRAFTS Model Schematic

For this study, the river routing in XPRAFTS were represented through “lagging” links, where the “lags” were calculated by Kirpich Time of Concentration method, as in

$$t = \alpha \times \frac{L^{0.37}}{S^{0.385}} \quad \text{Equation 1}$$

where *L* is the river length (ft); *S* is the river slope (ft/ft); *α* is a parameter which was then calibrated together with the catchment routing parameter Manning's coefficient *n* (rural).

The model was calibrated for 1% AEP event and validated for 20% to 2% AEP events. The adopted parameters are summarised in Table 5. The total peak flows from XPRAFTS and WBNM are shown in Diagram 4.

Table 5: Adopted Routing Parameters

Parameter	Adopted Value
α (Kirpich)	0.012
n (Manning's coefficient)	0.032

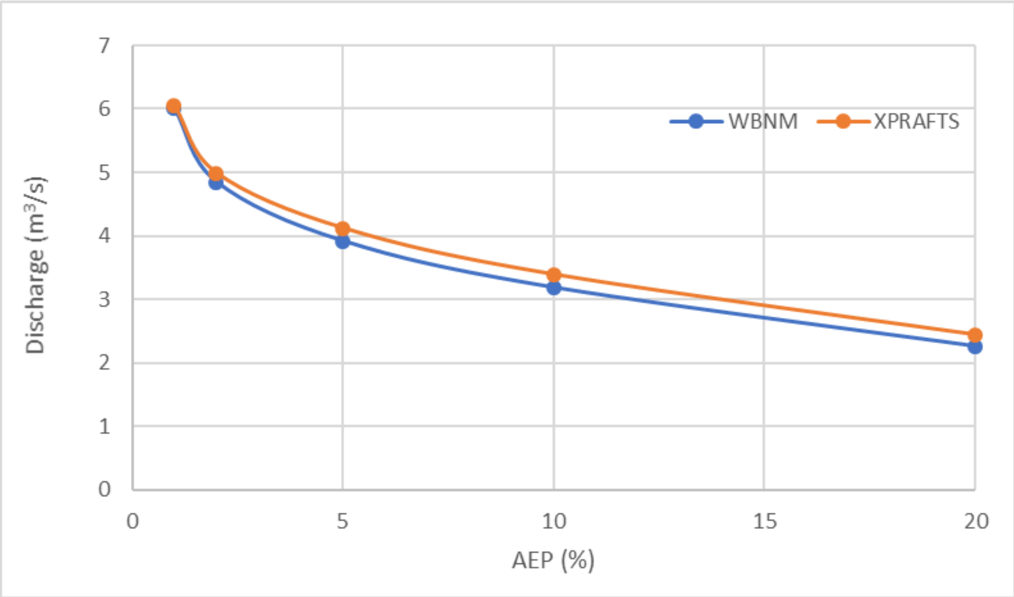

Diagram 4: Total Peak Flow Comparison

5.3.2. Existing Site Conditions

A site-based local XPRAFTS model was established, as shown in Diagram 5. The fraction impervious for each sub-site was set to 0% as shown in Table 1 to represent the existing conditions.

An ensemble of storm events was used to simulate 20% to 1% AEP events and evaluate the stormwater peak discharges generated by the contributing catchment areas.

The critical duration for each design event probability and each sub-catchment may vary depending on a number of conditions. Therefore, to ascertain the critical storm duration impacting the site, the consideration of a number of storm durations is important. For this study, the temporal patterns from 30 min to12 hr duration for each AEP were analysed. The median temporal patterns were selected and the critical peak discharge rates (i.e., the duration produce the highest peak flow) for all AEPs were simulated and used as PSDs for detention basins design.
The PSD for each AEP was determined and tabulated in Table 6.

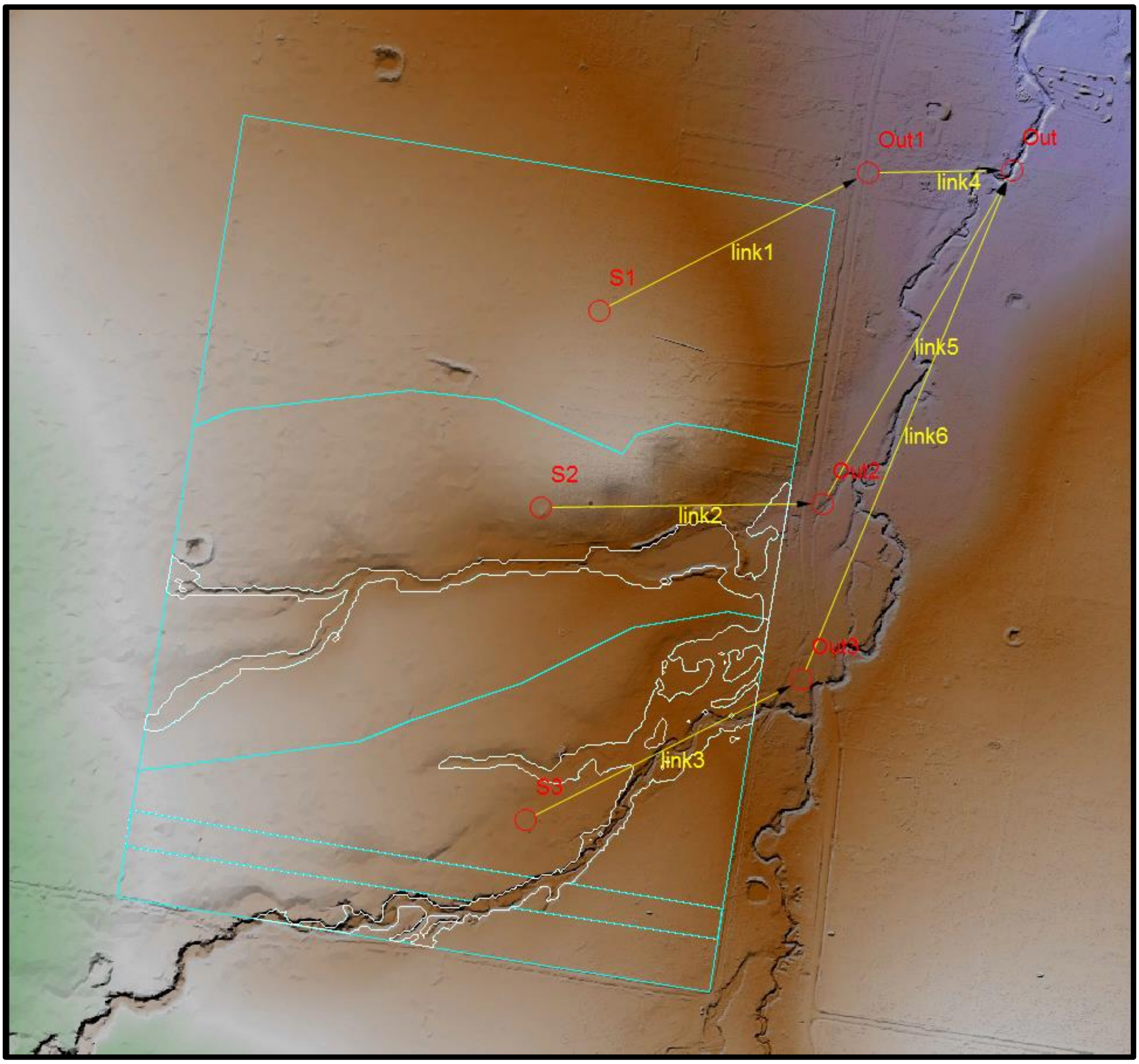

Diagram 5: The Local Site-based XPRAFTS Model Schematic for Existing Conditions

Table 6: Permissible Site Discharges

	S1		S2		S3	
AEP	Critical Peak Discharge (m^3/s)	Event Duration	Critical Peak Discharge (m^3/s)	Event Duration	Critical Peak Discharge (m^3/s)	Event Duration
1%	2.63	1.5 hr	2.60	1.5 hr	2.24	1.5 hr
2%	2.11	1.5 hr	2.08	1.5 hr	1.79	1.5 hr
5%	1.73	2 hr	1.71	2 hr	1.47	2 hr
10%	1.39	2 hr	1.37	2 hr	1.18	2 hr
20%	0.98	3 hr	0.96	3 hr	0.83	3 hr

5.3.3. Developed Site Conditions

The site-based local XPRAFTS model was revised by incorporating three (3) on-site detention basins, as shown in Diagram 6. The pervious and impervious areas for each sub-site were set according to the values in Table 1 to represent the developed conditions. The median temporal pattern was selected for each duration and each AEP under developed (unmitigated) conditions, which were then used for basin design.

A detention basin was designed on top of each wetland for each sub-site. The conceptual footprint (assumed to be the surface area plus inlet pond area) of each wetland was used as the bottom area for the detention basin. Basin stage-storage relationships were conceptually designed based on the assumed bottom footprints and 1:6 side slope. The basin outlet configurations were adjusted to minimize the requirement for the total footprint of each basin and to ensure that a 'no worsening' of discharge from the developed Site is achieved.

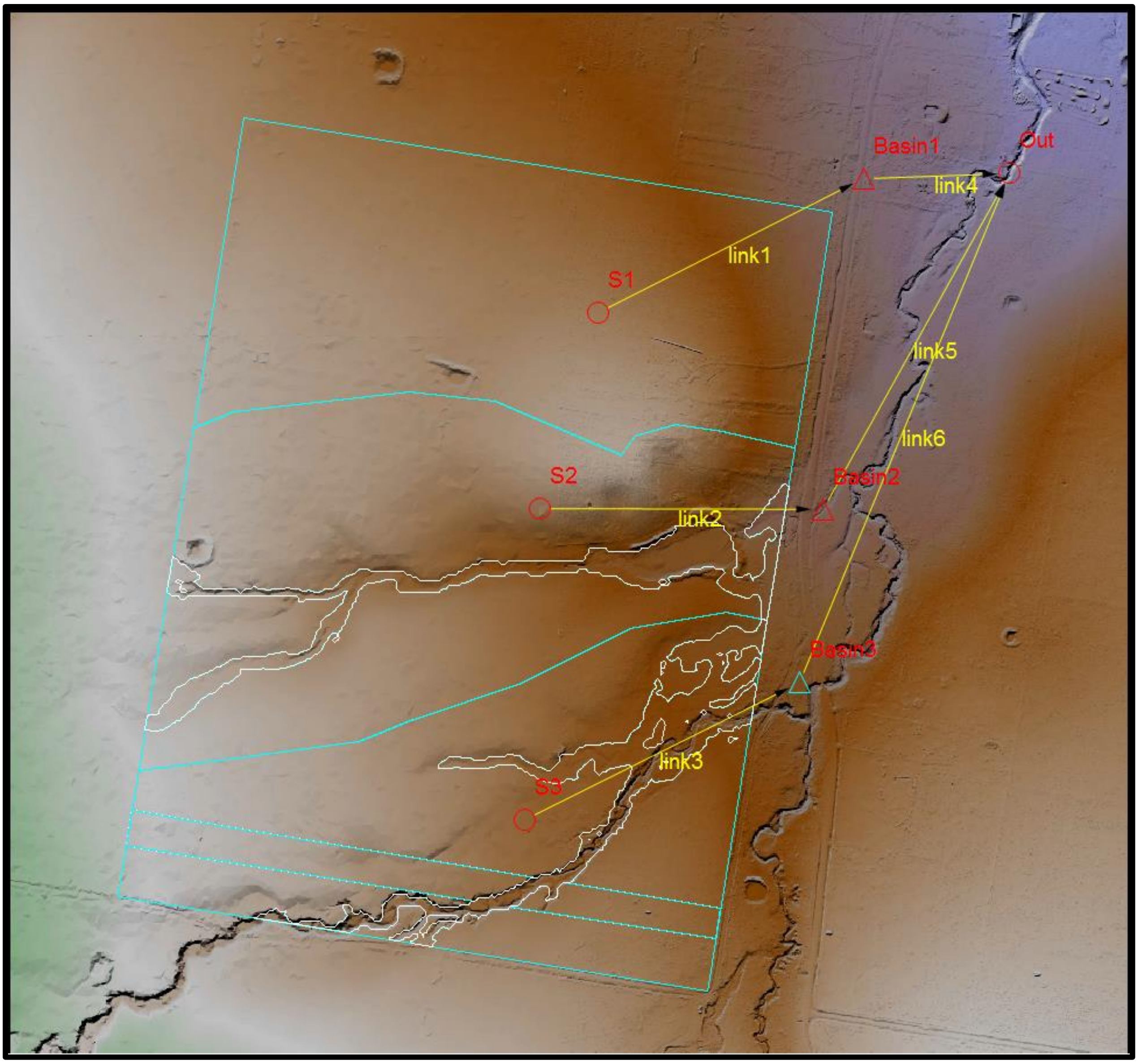

Diagram 6: The Local Site-based XPRAFTS Model Schematic for Developed Conditions

The peak discharges from sub-sites under the existing, unmitigated(developed), and mitigated(developed) conditions and the final modelled configurations of the three detention basins are summarised in Table 7 to Table 9. The modelled stage-storage-discharge relationships for the three detention basins are illustrated in Figure 5.

Table 7: Basin Requirements and Peak Discharges from Basin1 (S1)

AEP	Elevation (m AHD)	Area (m^2)	Volume (m^3)	Outlet Configuration		Mitigated Flow (m^3/s)	Unmitigated Flow (m^3/s)	PSD (m^3/s)
				IL (m AHD)	Dimension			
Bottom	215.50	6500.0						
20%	216.10		4315.6	215.50	1.4 m W × 0.5 m H (culvert)	**0.96**	3.60	0.98
10%	216.22		5286.2			**1.22**	4.55	1.39
5%	216.37		6617.5	216.22	3.5 m W (spillway)	**1.55**	5.33	1.73
2%	216.50		7693.4			**2.09**	6.29	2.11
1%	216.52		7929.2			**2.22**	7.16	2.63
Freeboard	216.82	9820.3						

Table 8: Basin Requirements and Peak Discharges from Basin2 (S2)

AEP	Elevation (m AHD)	Area (m^2)	Volume (m^3)	Outlet Configuration		Mitigated Flow (m^3/s)	Unmitigated Flow (m^3/s)	PSD (m^3/s)
				IL (m AHD)	Dimension			
Bottom	216.50	6501.9						
20%	217.11		4313.9	216.50	1.35 m W × 0.5 m H (culvert)	**0.95**	3.58	0.96
10%	217.23		5307.1			**1.21**	4.52	1.37
5%	217.39		6621.8	217.35	3.5 m W (spillway)	**1.52**	5.29	1.71
2%	217.52		7716.3			**2.07**	6.25	2.08
1%	217.55		7942.5			**2.21**	7.12	2.60
Freeboard	217.85	9377.0						

Table 9: Basin Requirements and Peak Discharges from Basin3 (S3)

AEP	Elevation (m AHD)	Area (m^2)	Volume (m^3)	Outlet Configuration		Mitigated Flow (m^3/s)	Unmitigated Flow (m^3/s)	PSD (m^3/s)
				IL (m AHD)	Dimension			
Bottom	217.50	4502.2						
20%	218.10		3032.3	217.50	1.2 m W × 0.5 m H (culvert)	**0.83**	2.63	0.83
10%	218.23		3743.0			**1.06**	3.31	1.18
5%	218.40		4744.7	218.38	3.0 m W (spillway)	**1.32**	4.05	1.47
2%	218.54		5601.6			**1.79**	4.65	1.79
1%	218.56		5744.9			**1.88**	5.20	2.24
Freeboard	218.86	6978.5						

5.4. Conceptual Plan for Stormwater Management

The conceptual plan for stormwater management for proposed development is shown in Figure 4. The indicative locations and footprints of the three combined wetland and detention basins are illustrated.

The existing external sheet flow across the northwest corner of the Site (S1) is proposed to be captured by swale / kerb and channel and conveyed directly towards north. The existing waterways are proposed to be retained to convey external flows through S2 and S3. The last section of each waterway is to be piped and discharged directly to the legal point of discharge (LPOD).

The stormwater generated within the Site will be conveyed to the three combined wetlands and detention basins through internal stormwater drainage systems, and treated / mitigated flows, which meet the SSMP objectives, will be discharged to LPODs.

6. CONCLUSIONS

An Existing Flood Condition Assessment and Site Stormwater Management Plan has been developed using ARR 2019 current industry best practice for the proposed Rezoning and Subdivision located at 474 and 456 Plumpton Road, Rowan NSW 2650.

A regional distributed hydrological (WBNM) and hydraulic (TUFLOW) model has been set up based on the MOFFRMS model using rainfall and flood estimation techniques consistent with ARR 2019, to define the existing flood characteristics of the Site for flood events with the probability of 20%, 10%, 5%, 2%, 1%, 0.5%, and 0.2% AEPs with a range of critical storm durations.

A local water quality model for the developed site has been set up with MUSIC. Three wetlands have been designed using the MUSIC model to ensure the site discharge meeting the stormwater quality objectives. A local hydrological model for the developable site has been set up with XPRAFTS. Three detention basins have been designed on top of the wetlands to ensure "no-worsening" stormwater peak discharges due to proposed development.

The site stormwater quality objectives for the proposed development can be achieved using the three wetlands as denoted in the conceptual plan (Figure 4) with inlet ponds (350 m^3, 350 m^3, 350 m^3) and macrophyte zones (6,200 m^2, 6,200 m^2, 4,300 m^2) as suggested by MUSIC modelling results.

The site stormwater quantity objectives can be achieved using three detention basins on top of the wetlands with footprints of 9,820 m^2, 9,377 m^2, and 6,978 m^2, respectively, including freeboard, based on the XPRAFTS modelling results.

All the three combined wetland and detention basins were designed to be "offline" facilities, which treat or mitigate stormwater generated within the Site only, and the external flows are to be conveyed through existing waterways with appropriate drainage design.

In conclusion, the analysis undertaken in this study has demonstrated that the site stormwater requirements and objectives can be achieved through proposed stormwater management measures. The modelling exercise and management plan are conceptual only and the functionality need to be further tested during functional design stage.

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Figures

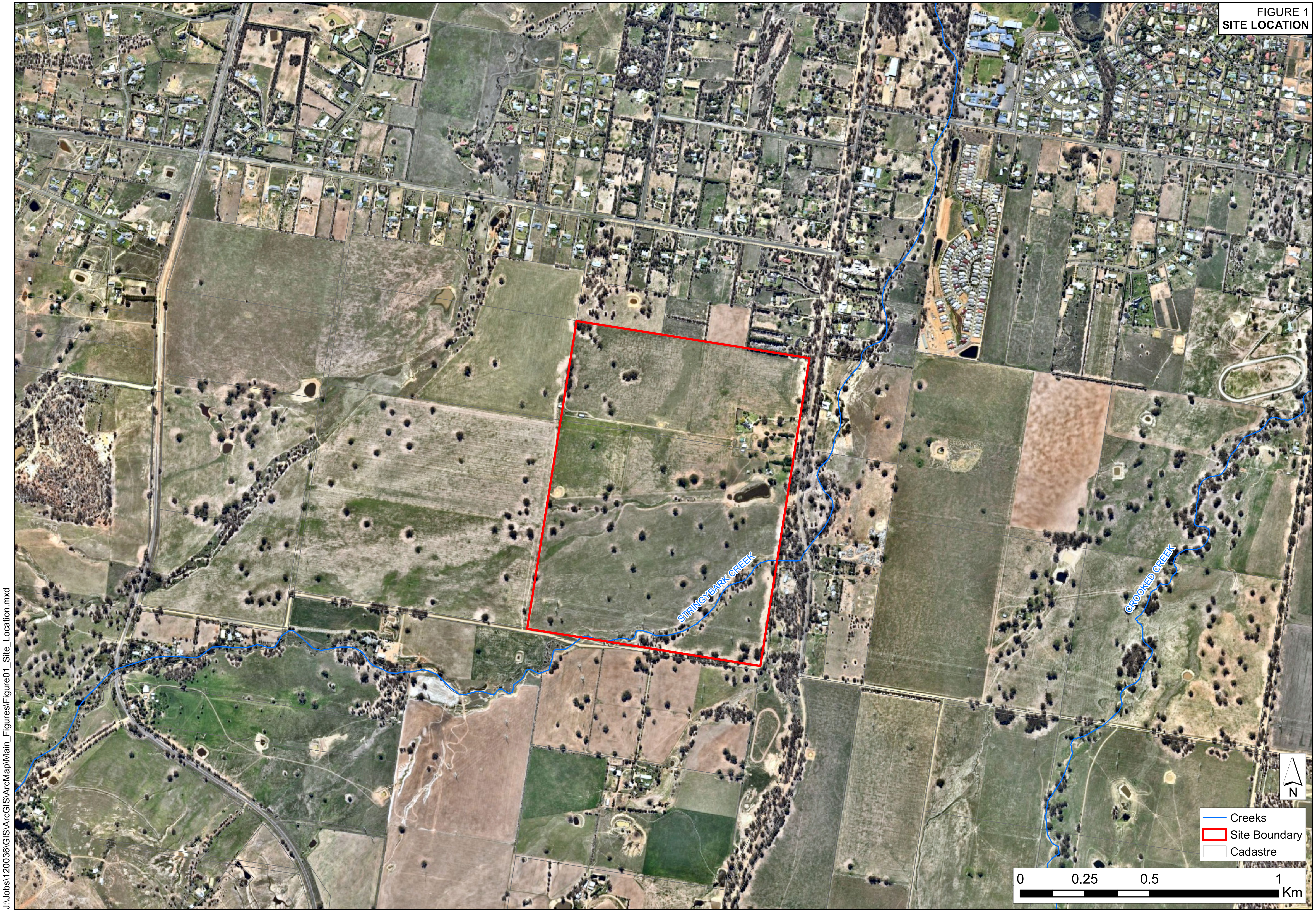
FIGURE 1
SITE LOCATION
STRINGYBARK CREEK
CROOKED CREEK
N
Creeks
Site Boundary
Cadastre
0
0.25
0.5
1
Km
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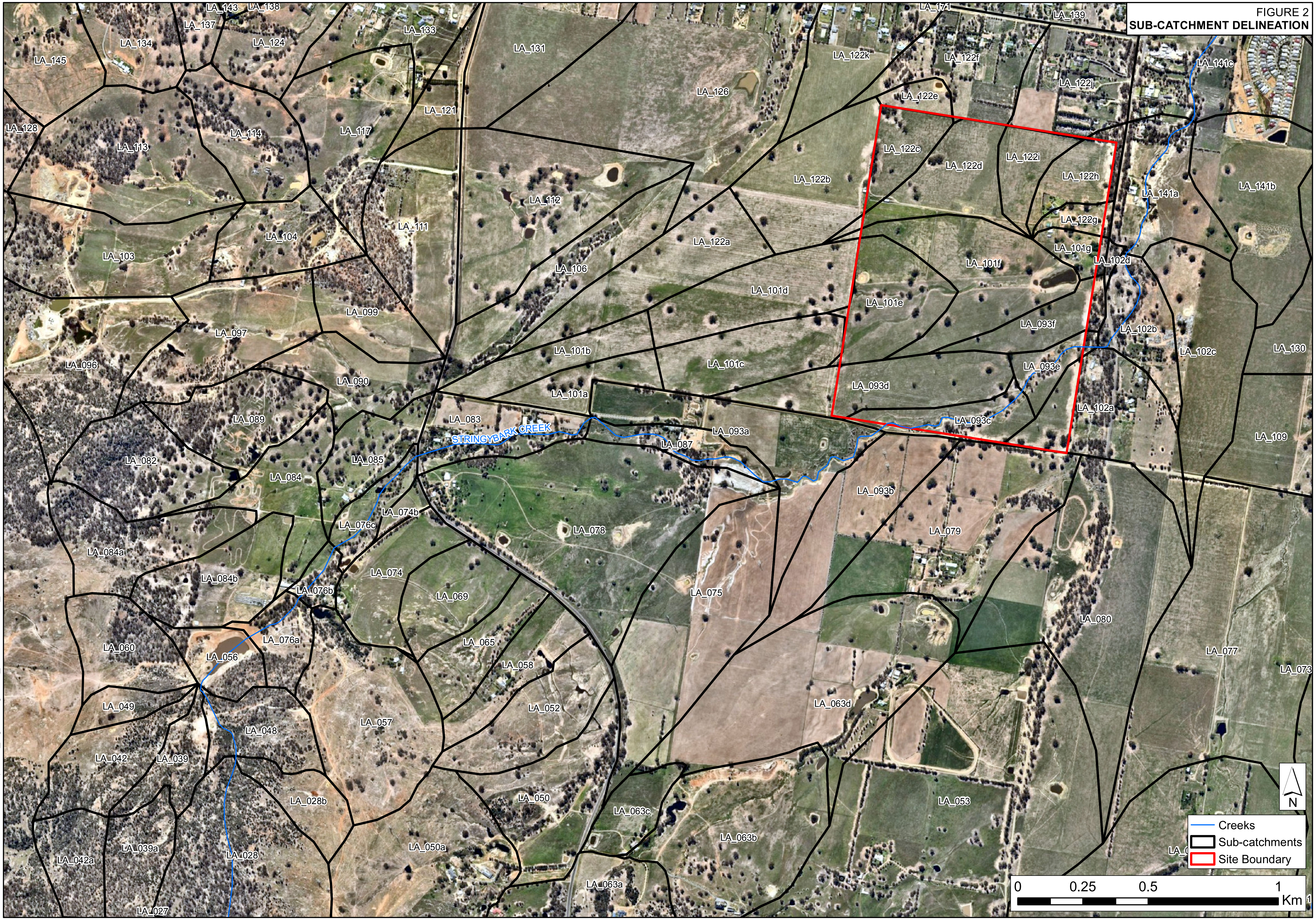

FIGURE 2
SUB-CATCHMENT DELINEATION

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FIGURE 3
SITE DELINEATION

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FIGURE 4
CONCEPTUAL PLAN FOR STORMWATER MANAGEMENT

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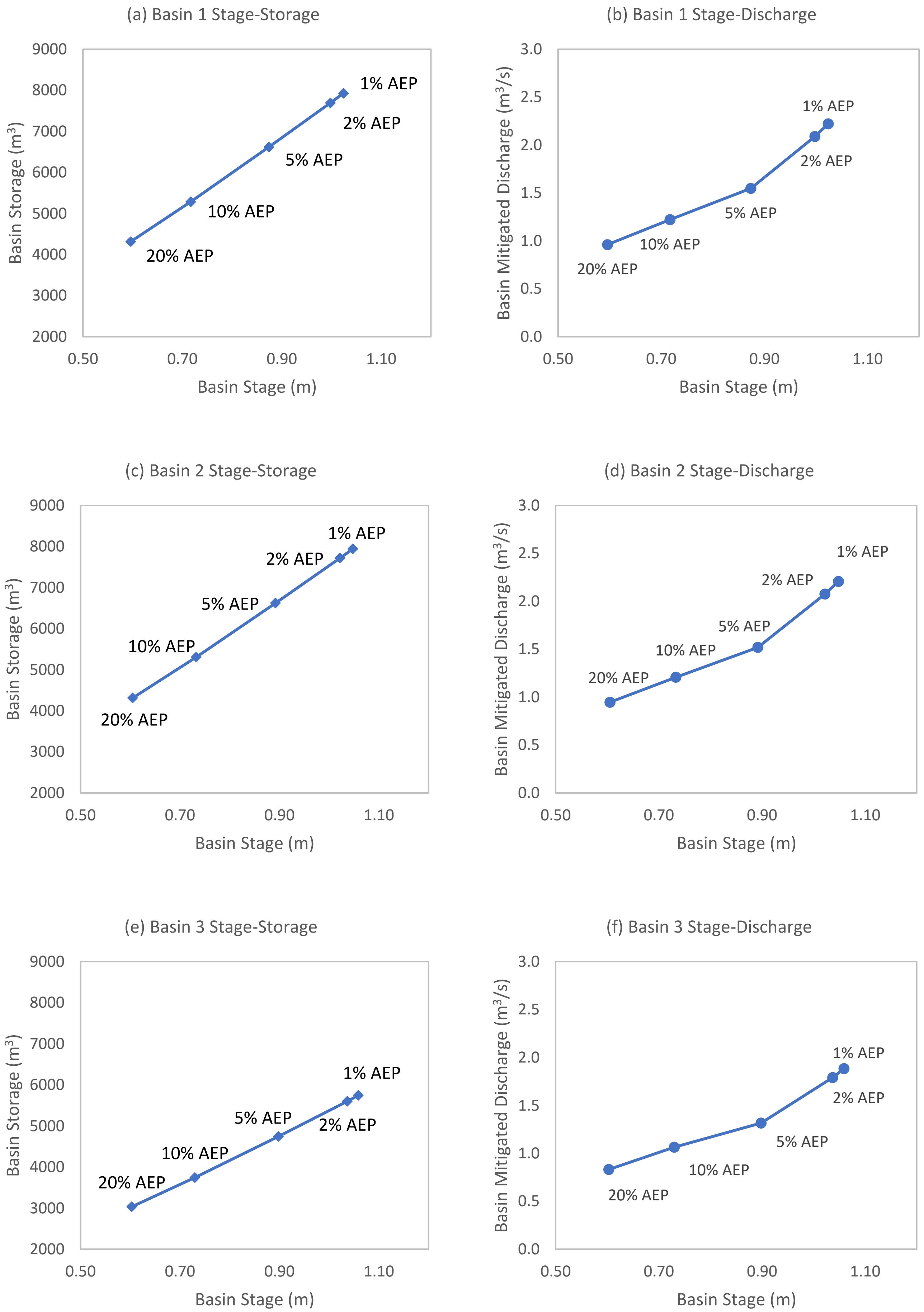
FIGURE 05
MODELLED STAGE-STORAGE-DISCHARGE RELATIONSHIPS FOR DETENTION BASINS



Appendix A

APPENDIX A. GLOSSARY

Taken from the Floodplain Development Manual (April 2005 edition)

acid sulfate soils	Are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by Acid Sulfate Soil Management Advisory Committee.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
consent authority	The Council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. **new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power.

redevelopment: refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.

disaster plan (DISPLAN) A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.

discharge The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).

ecologically sustainable development (ESD) Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.

effective warning time The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.

emergency management A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.

flash flooding Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.

flood Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.

flood awareness Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.

flood education Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves an their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.

flood fringe areas The remaining area of flood prone land after floodway and flood storage areas have been defined.

flood liable land Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).

flood mitigation standard

The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.

floodplain Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.

floodplain risk management options The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.

floodplain risk management plan A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammetic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.

flood plan (local) A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.

flood planning area The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the Aflood liable land@ concept in the 1986 Manual.

Flood Planning Levels (FPLs) FPL=s are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the Astandard flood event@ in the 1986 manual.

flood proofing A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.

flood prone land Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.

flood readiness Flood readiness is an ability to react within the effective warning time.

flood risk Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below.

existing flood risk: the risk a community is exposed to as a result of its location on the floodplain.

future flood risk: the risk a community may be exposed to as a result of new development on the floodplain.

continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.

flood storage areas Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood

	storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.
freeboard	Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
habitable room	**in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. **in an industrial or commercial situation:** an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves: - the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or - water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or

- major overland flow paths through developed areas outside of defined drainage reserves; and/or

- the potential to affect a number of buildings along the major flow path.

mathematical/computer models The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.

merit approach The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State=s rivers and floodplains.

The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the floodplain risk management plan, local floodplain risk management policy and EPIs.

minor, moderate and major flooding Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood:

minor flooding: causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded.

moderate flooding: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered.

major flooding: appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.

modification measures Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.

peak discharge The maximum discharge occurring during a flood event.

Probable Maximum Flood (PMF) The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.

Probable Maximum Precipitation (PMP) The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.

probability A statistical measure of the expected chance of flooding (see AEP).

risk Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.

runoff The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.

stage Equivalent to Awater level@. Both are measured with reference to a specified datum.

stage hydrograph A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.

survey plan A plan prepared by a registered surveyor.

water surface profile A graph showing the flood stage at any given location along a watercourse at a particular time.

wind fetch The horizontal distance in the direction of wind over which wind waves are generated.

Appendix B

APPENDIX B. FLOOD MAPPING FOR EXISTING CONDITIONS

FIGURE B1
PEAK FLOOD DEPTHS
20% AEP EVENT

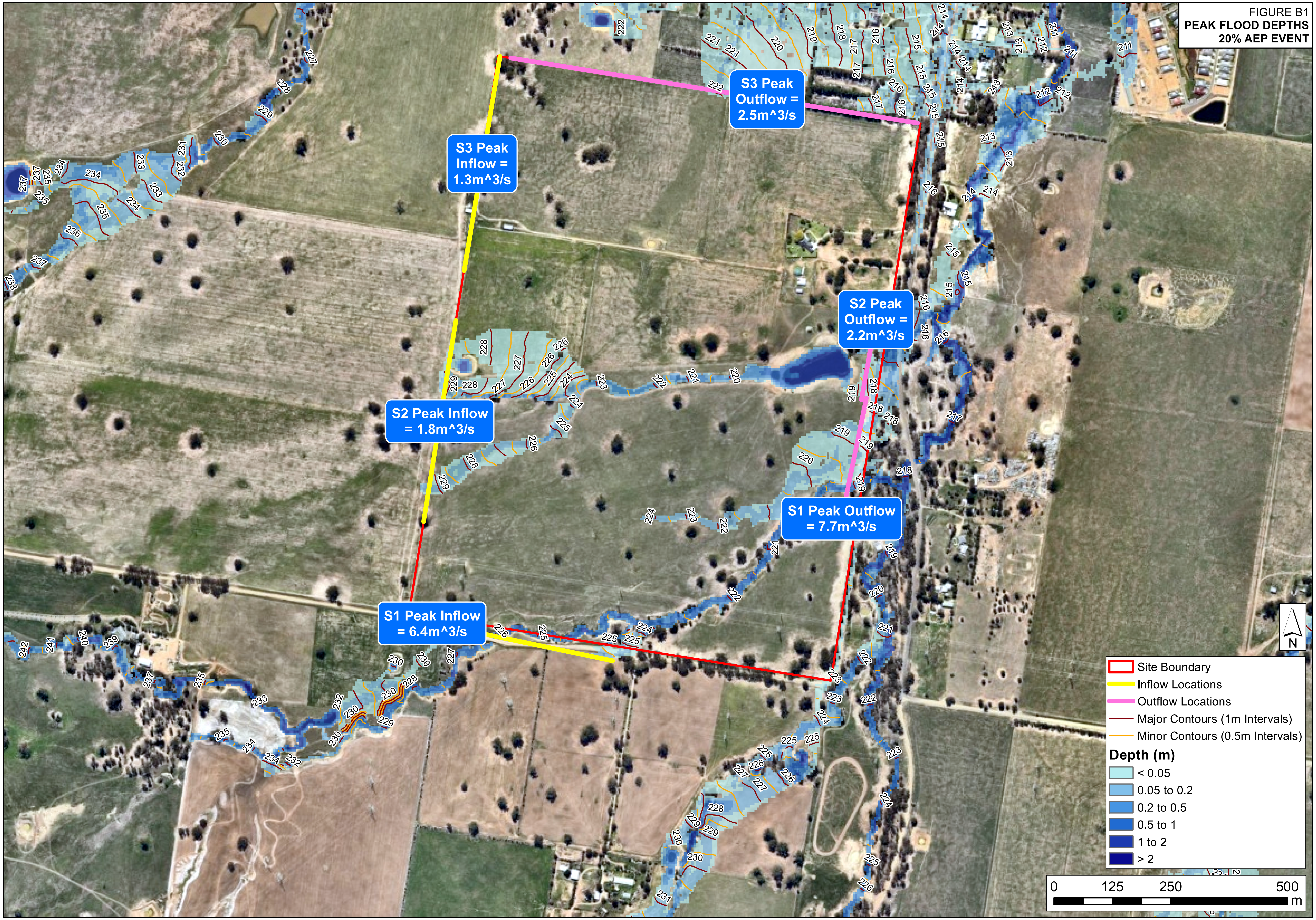


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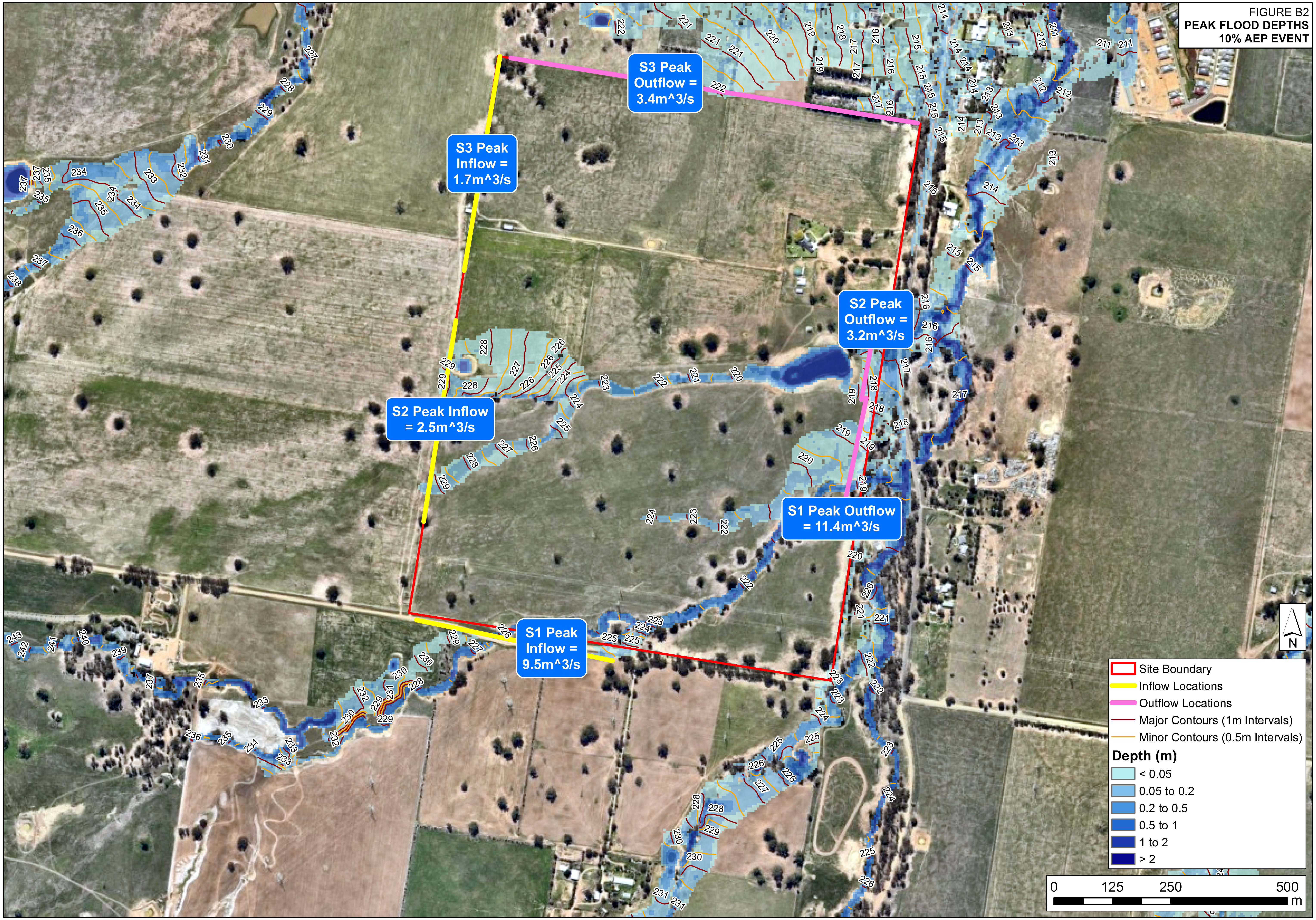
FIGURE B2
PEAK FLOOD DEPTHS
10% AEP EVENT



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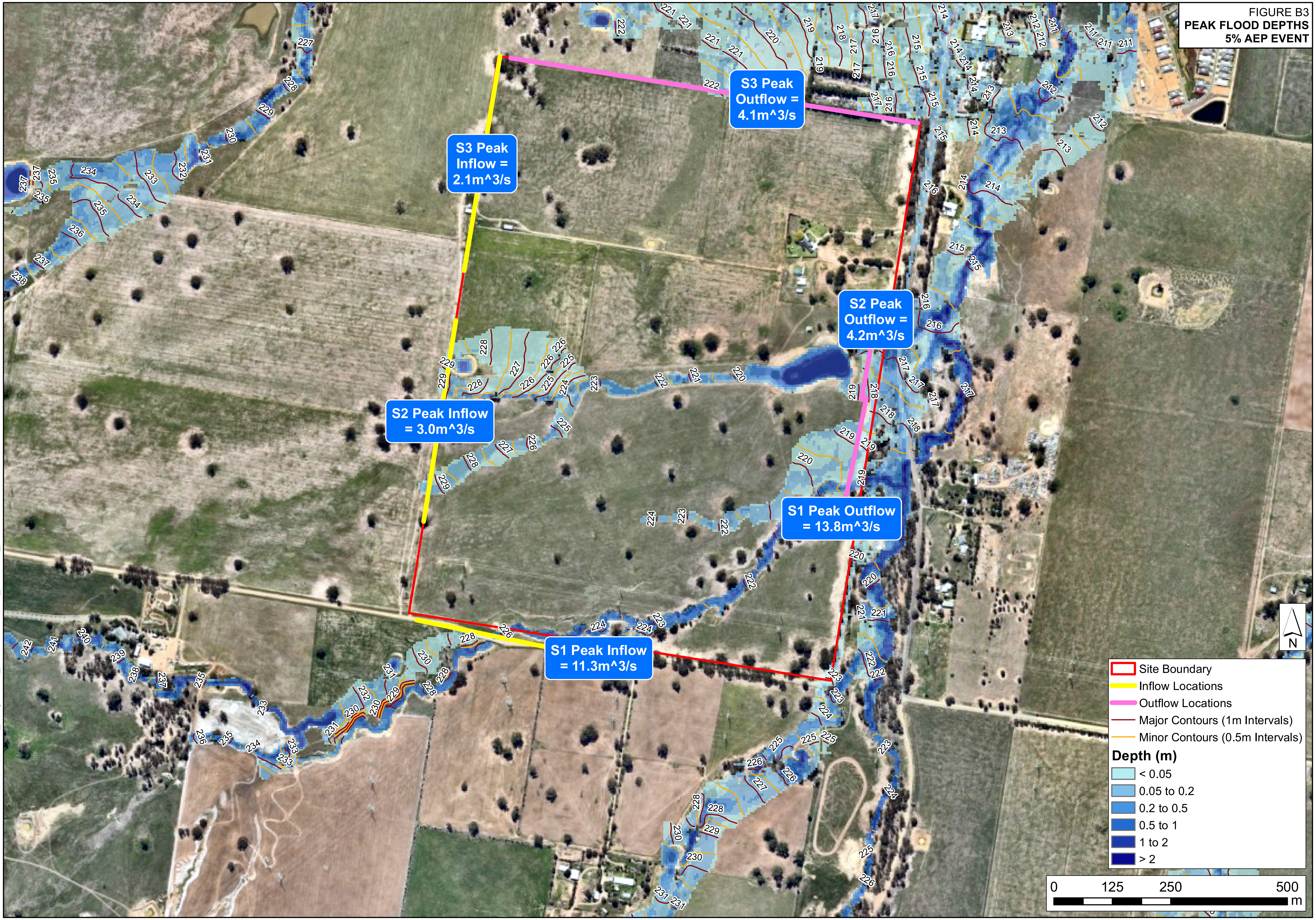

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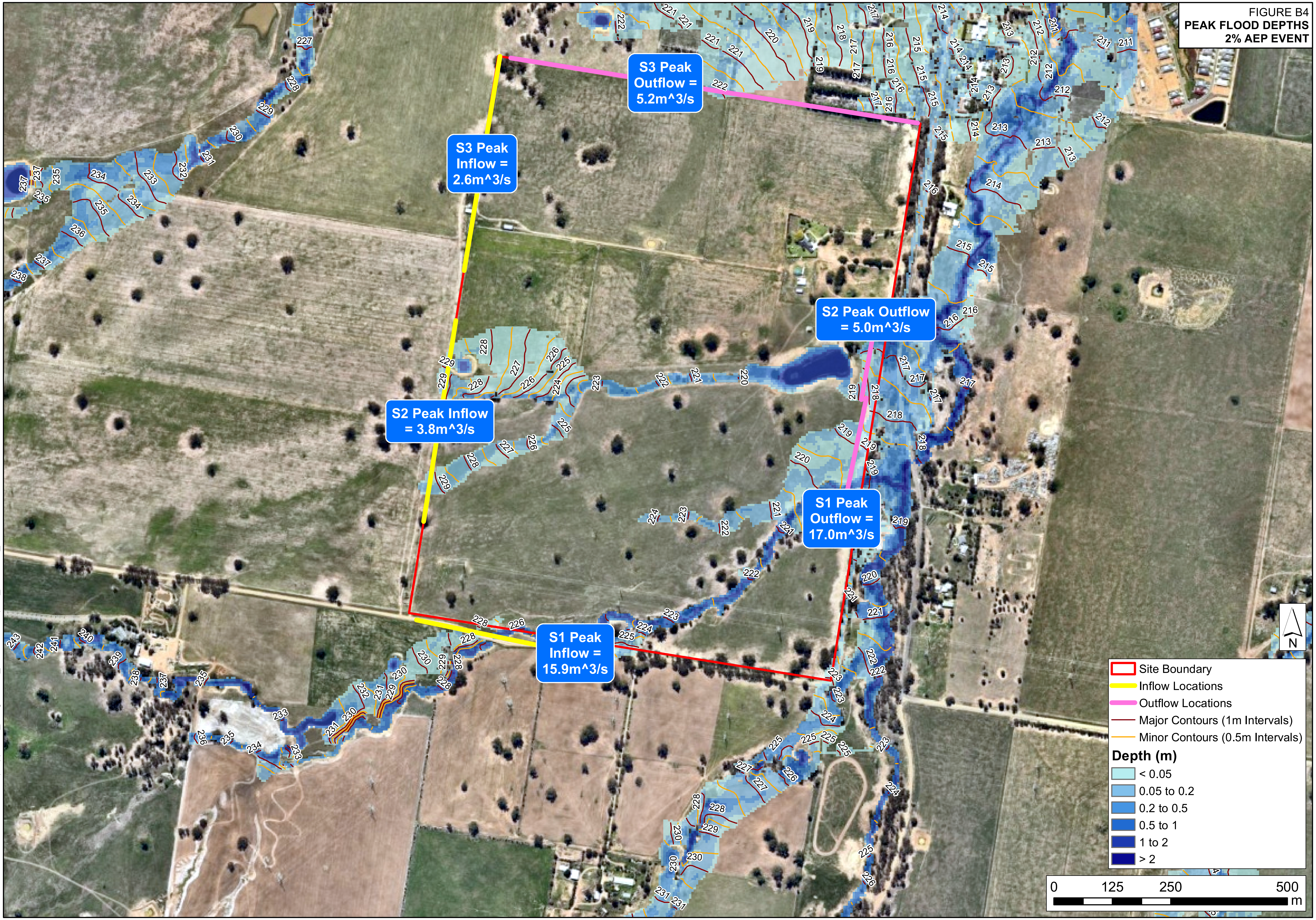

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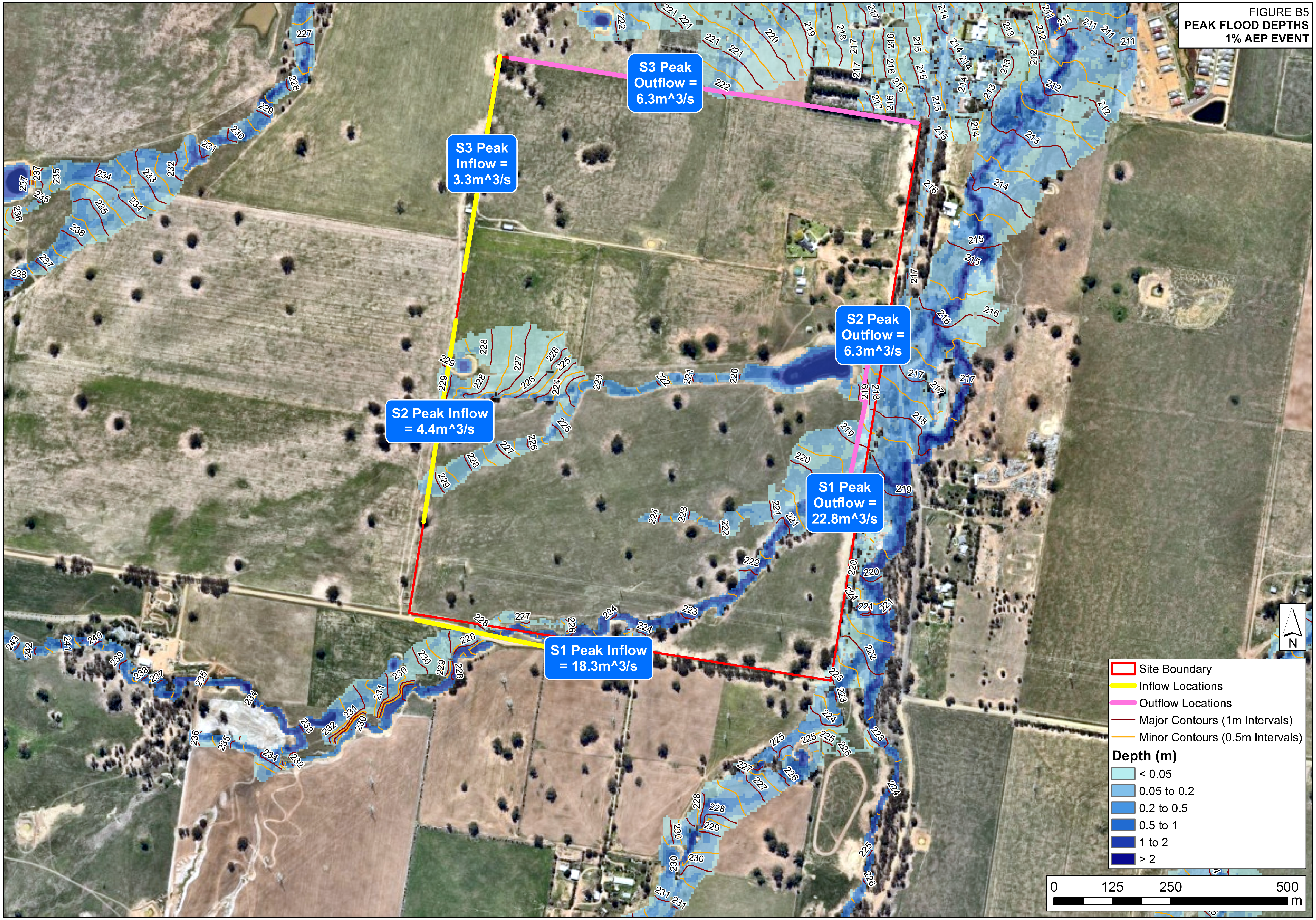

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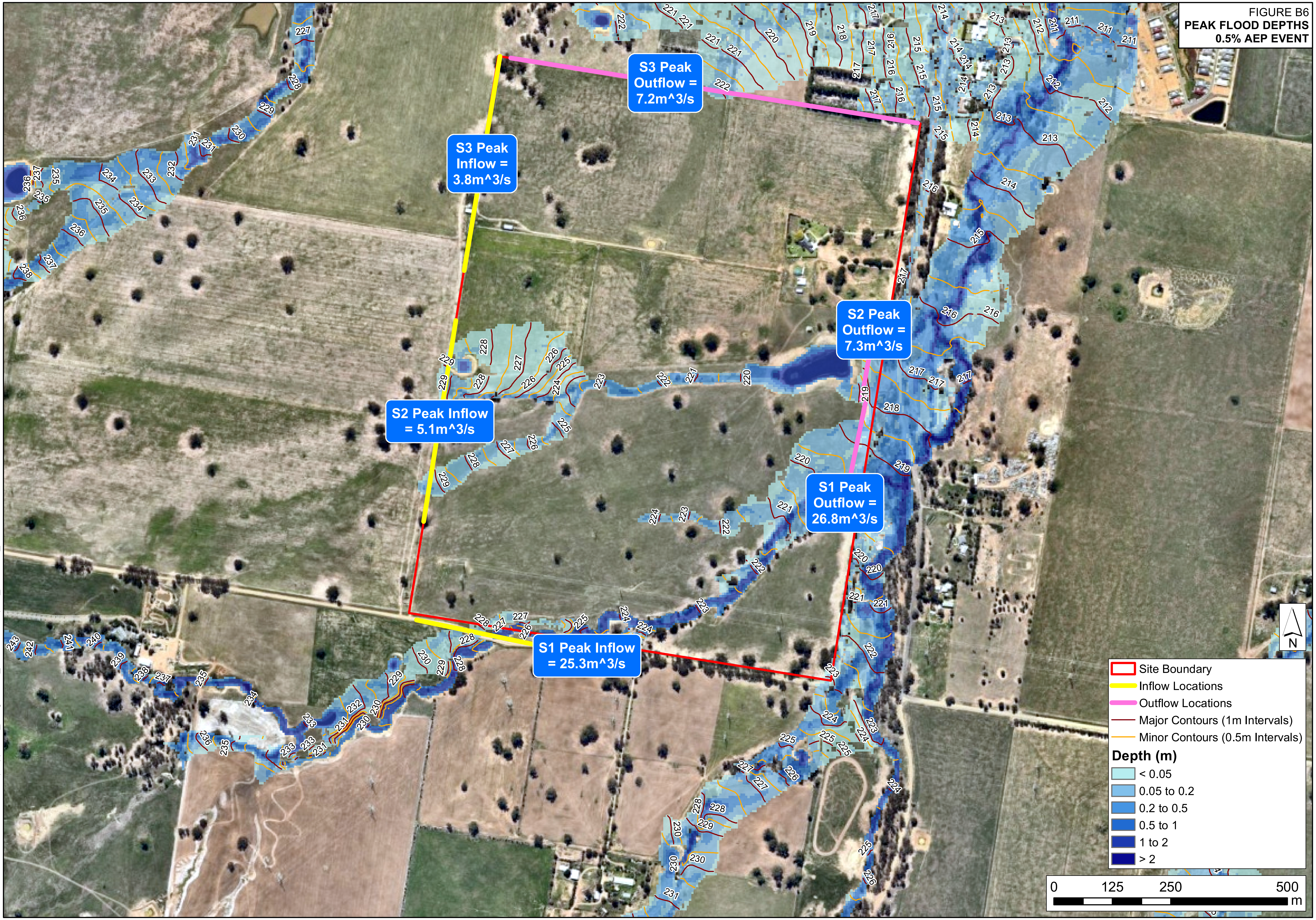
FIGURE B6
PEAK FLOOD DEPTHS
0.5% AEP EVENT



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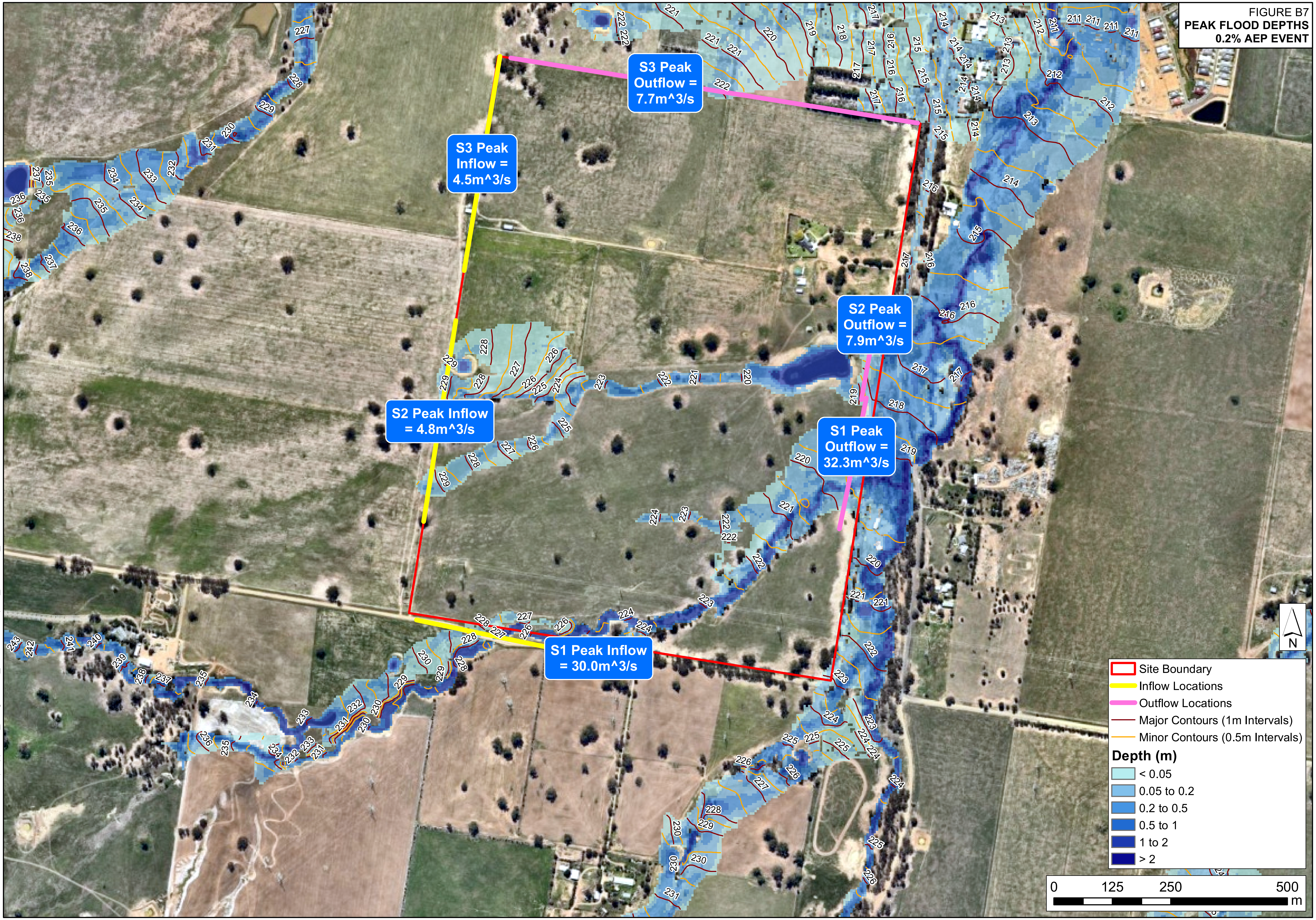

FIGURE B7
PEAK FLOOD DEPTHS
0.2% AEP EVENT

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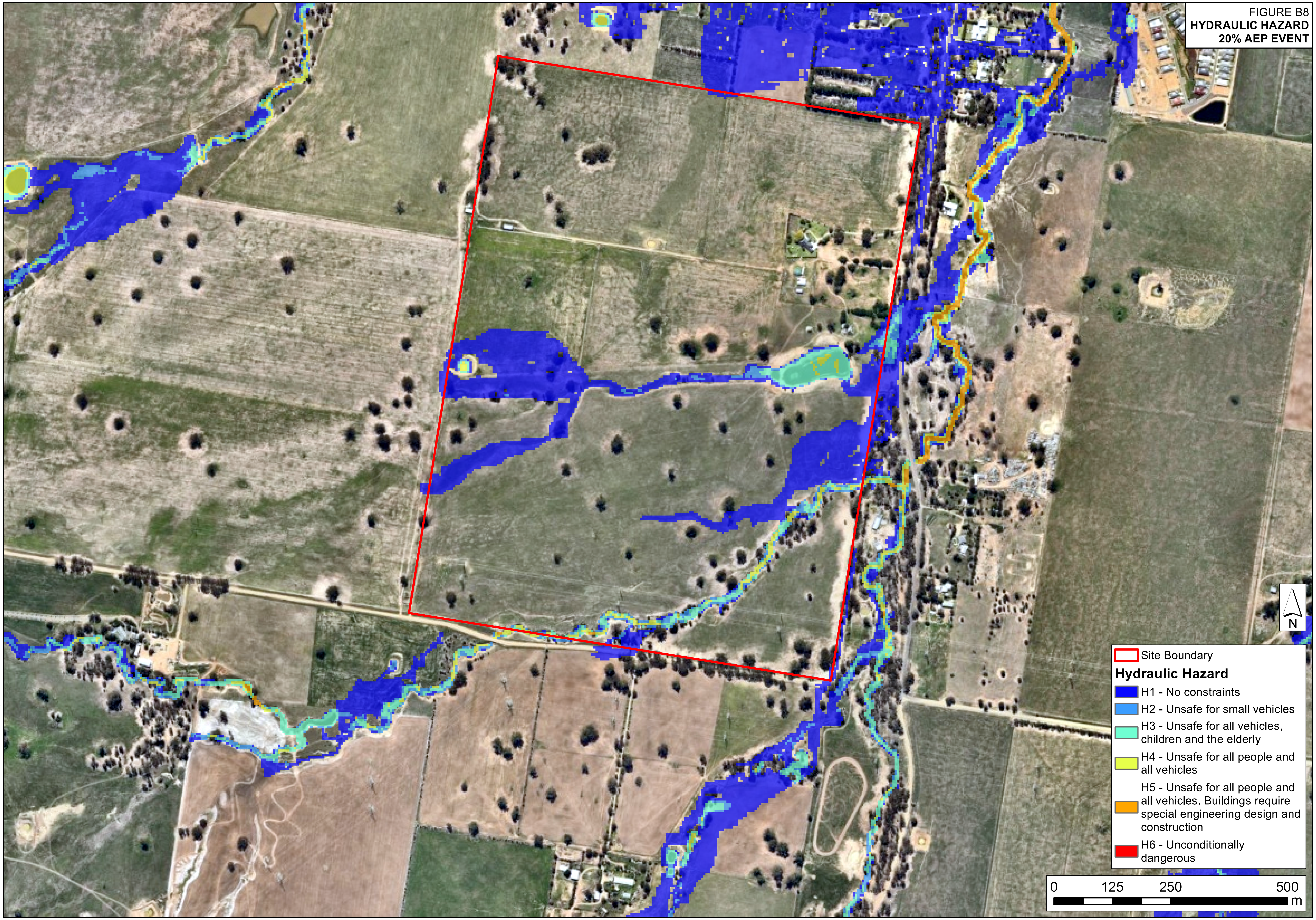

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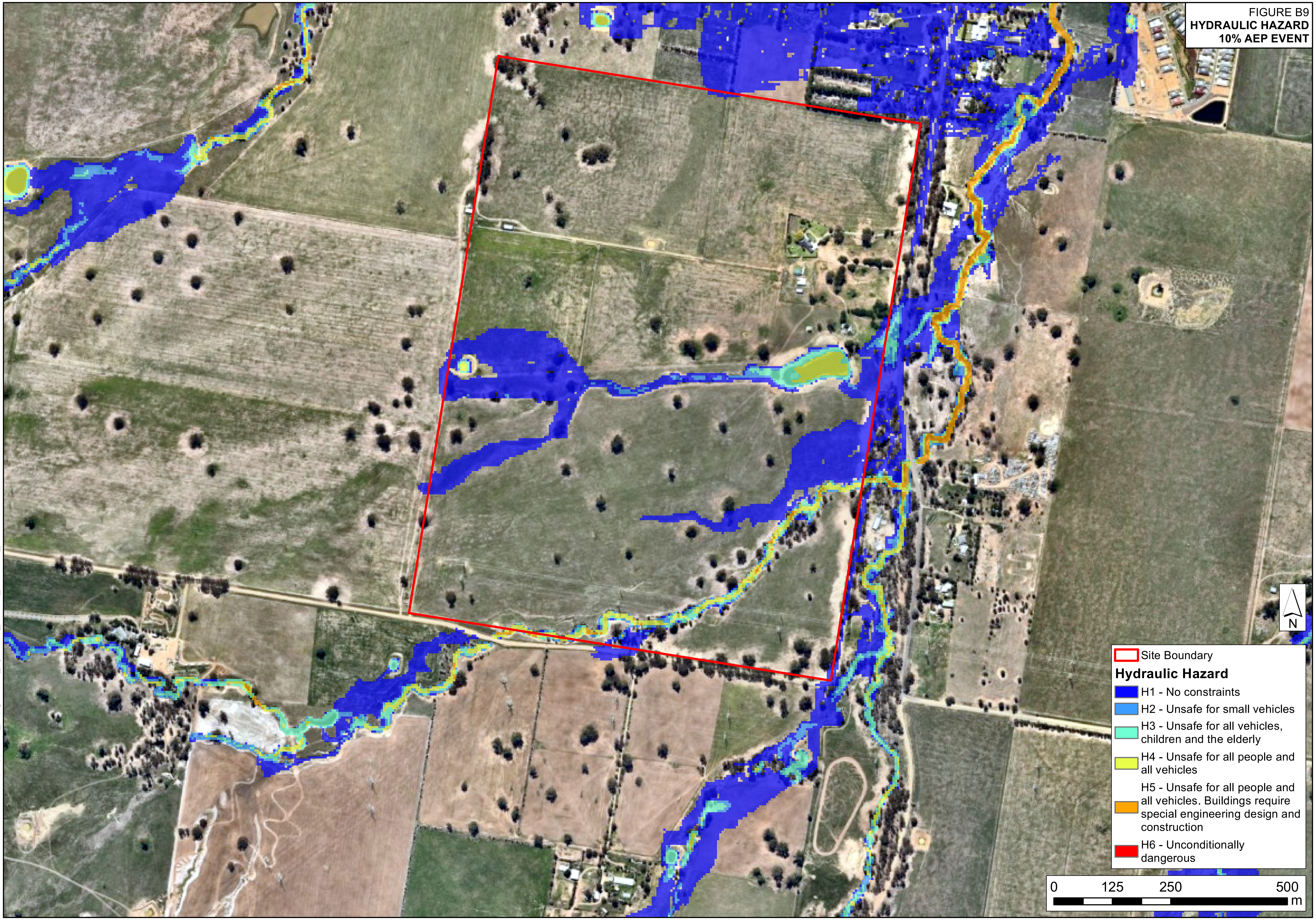

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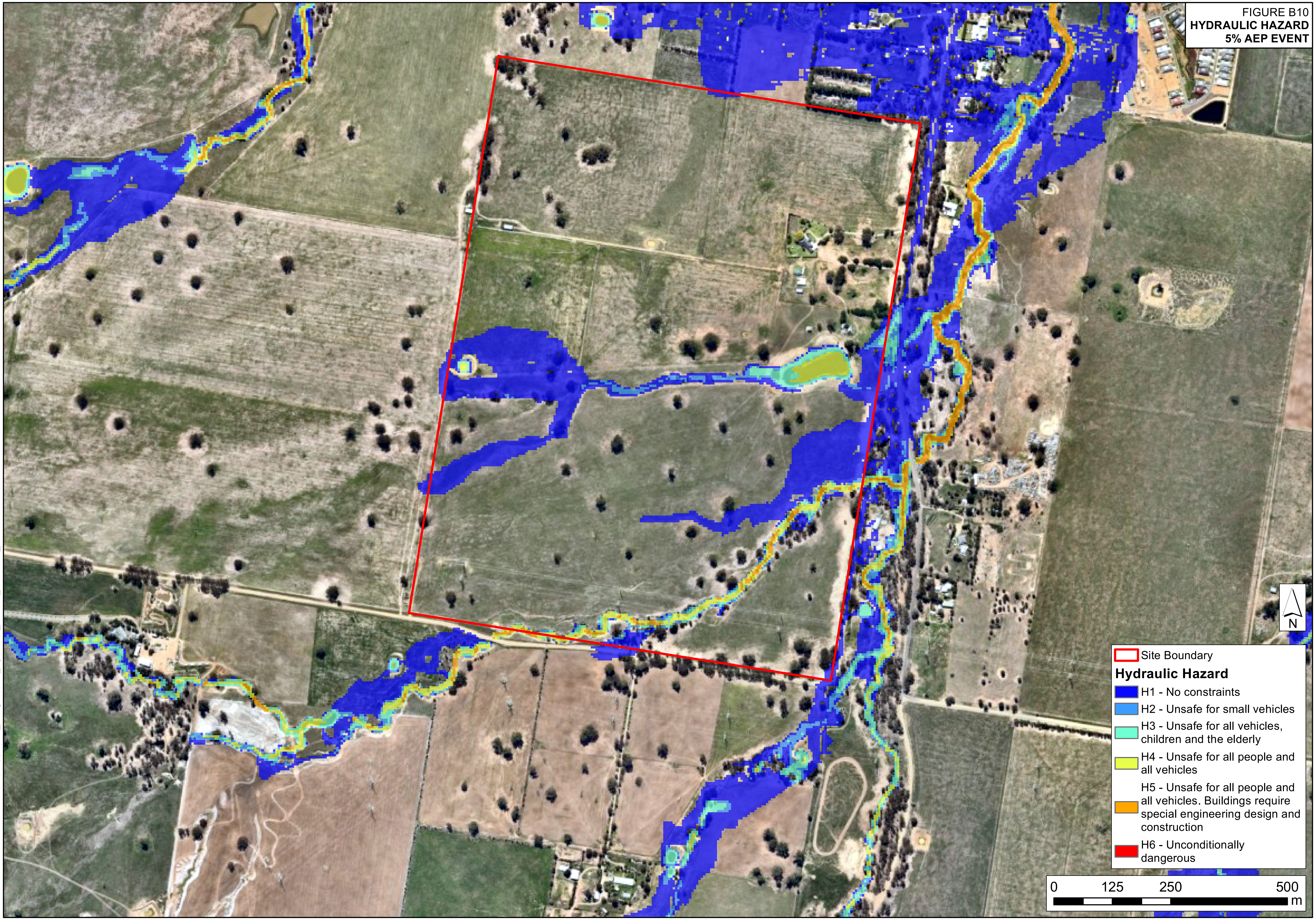
FIGURE B10
HYDRAULIC HAZARD
5% AEP EVENT



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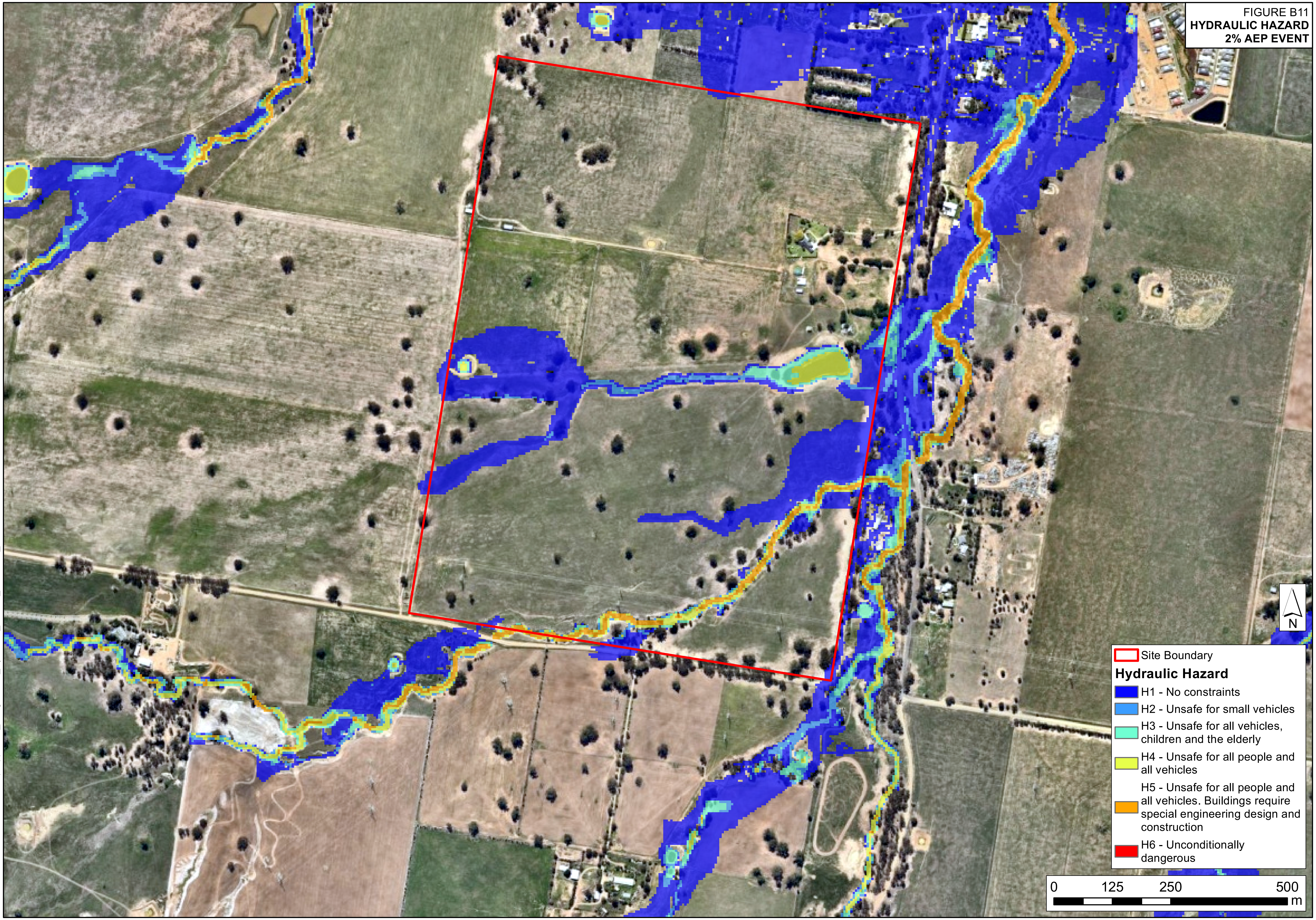

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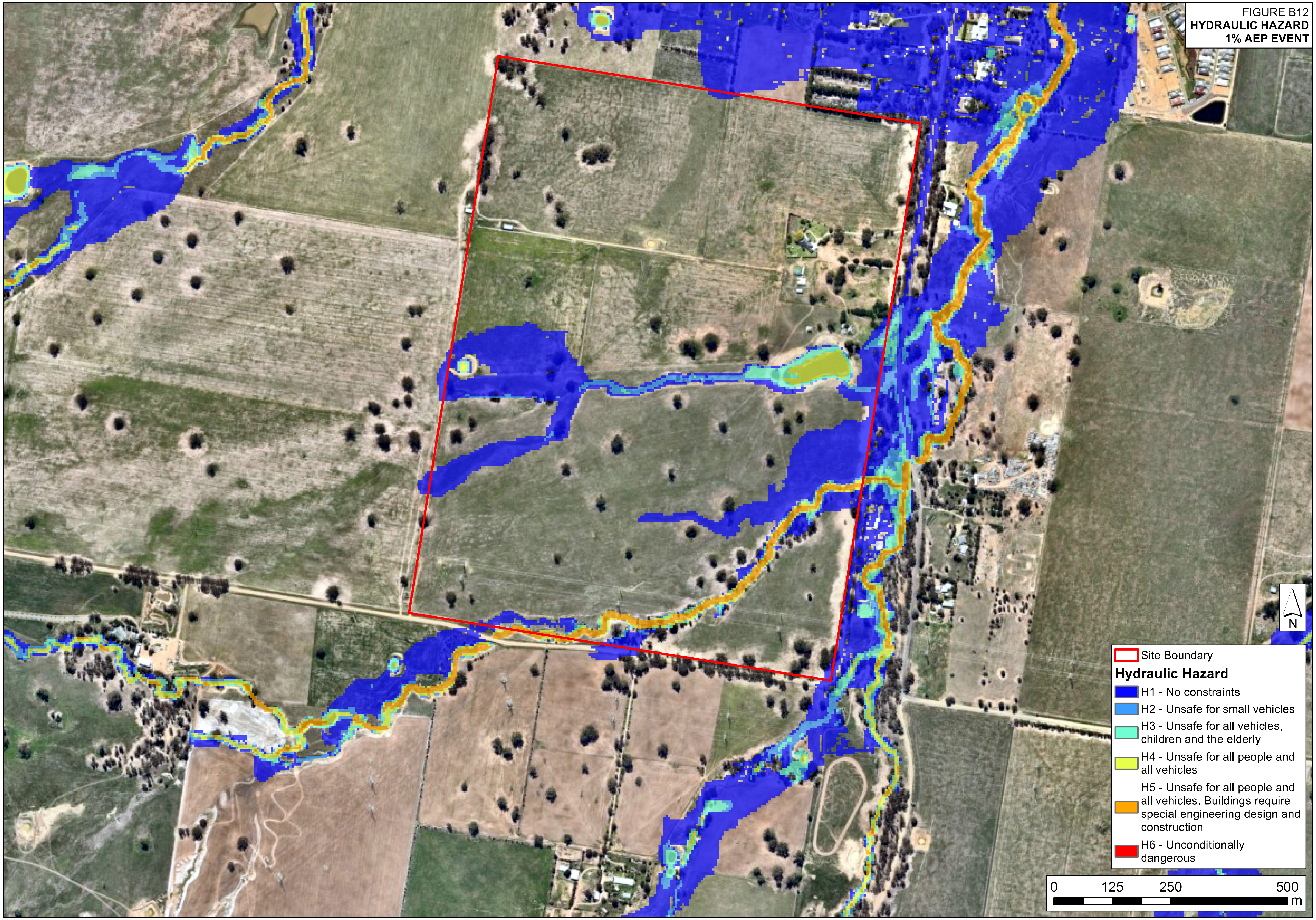

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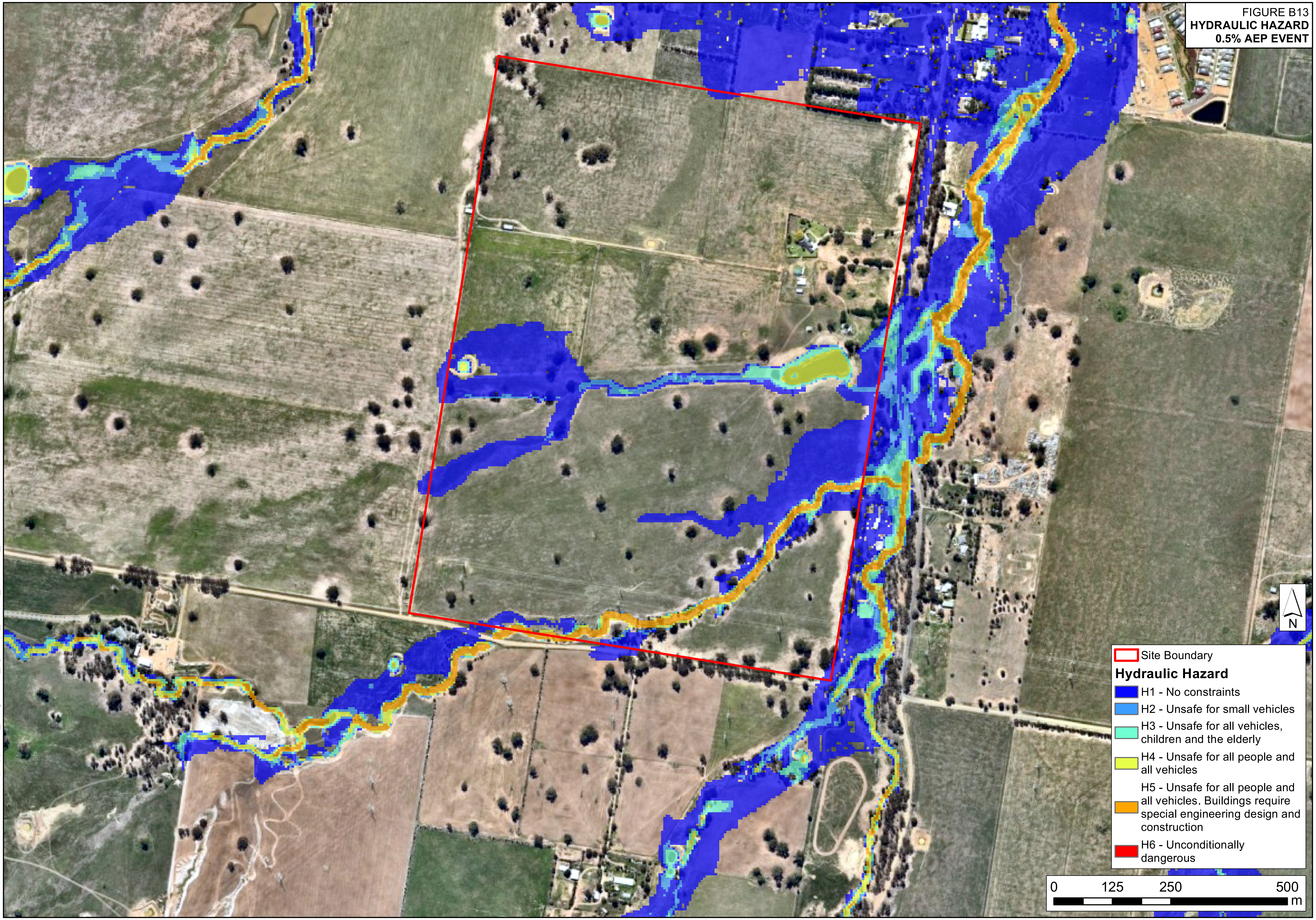

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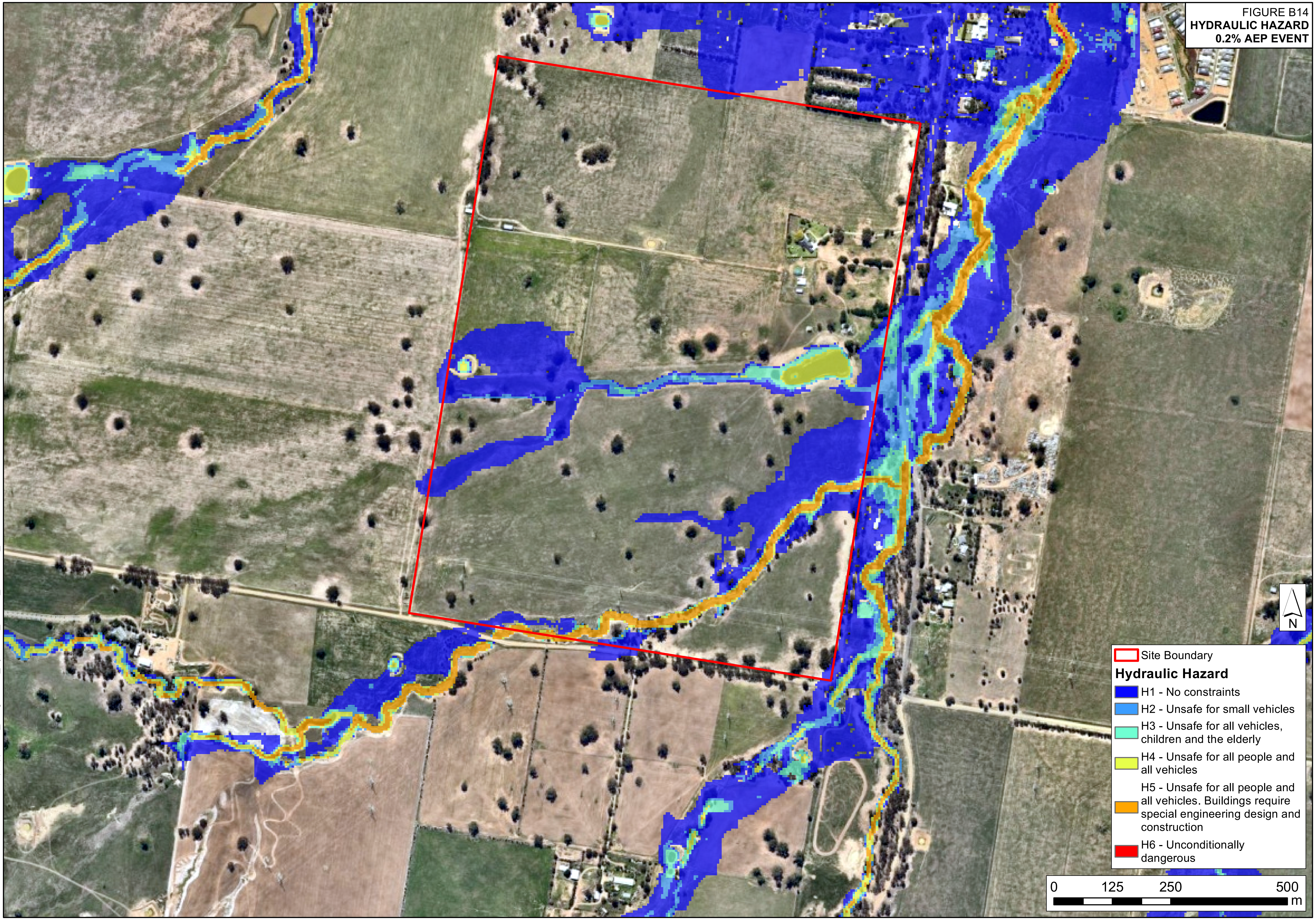

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