Warren Smith and Partners
Level 1, 123 Clarence Street
SYDNEY, NSW 2000

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4 August 2017

Attention: **Ms Nicole Meo**

Dear Nicole,

Re: Flood Assessment at 166 – 176 Saint Andrews Rd, Varroville

INTRODUCTION

WMAwater Pty Ltd. was engaged to provide a site flood assessment for the proposed development at the above subject site (Figure 1A). The proposal is to convert the site into a cemetery, with the last stage ending in 2171 (Reference 1). The cemetery will include seven buildings, access roads and burial area. Figure 1B shows the proposed configuration. The site is within the Campbelltown Council LGA.

The site is currently zoned as *RE1 Public Recreation* for the upper part and *E3 Environmental Management* for the rest of the site as per the planning control map. The site is the main contributory catchment and several flow paths and creeks flow through it before reaching the motorway (Reference 2).

WMAwater has undertaken a site specific flood study for the site to establish flood levels and flows and show the position of the flow paths for the 1% AEP event.

The study was conducted in accordance with methodology recommended in Australian Rainfall and Runoff (ARR, 2016).

FLOOD-RELATED DEVELOPMENT CONTROLS

The Campbelltown DCP (Reference 3) is applicable to this development proposal. From Part 2, *Requirement applying to all types of development* - Section 2.8, the floor level depends on the depth of 100 Year ARI (1% AEP) flood and the proximity to major stormwater lines (basins). If the building is not close to a flow path the floor level can be set to 0.15m above ground. Based on the flood conditions at the site, the relevant freeboard controls have been identified below.

Building location	Close to creek or major storm water line (basins)	Any other room		Garage or shed	
Storm Event	1% AEP				
Depth Value	Any depth	>0.3 m	< 0.3 m	>0.3 m	<0.3 m
Freeboard	0.5 m	0.5 m	0.3 m	0.3 m	0.1 m

WMAwater Pty Ltd (Formerly Webb McKeown and Associates)

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A specific Guideline applies to underground carpark.

"*These facilities must demonstrate that access and entry points are not affected by the 100 yr ARI flood. This includes ventilation openings, windows and access points. The following considerations will be evaluated for any proposal for underground car parking:*

- *Provision for safe and clearly sign posted flood free pedestrian escape routes for events in excess of the 100 yr ARI must be demonstrated separate to the vehicular access ramps;*
- *Consideration must also be given to evacuation of disabled persons;*
- *Pump out systems must have at least 2 independent pumps each sized to satisfy the pumpout volumes individually;*
- *The two (2) pumps are to be designed to work in tandem to ensure that both pumps receive equal usage and neither pump remains continuously idle;*
- *The lip of the driveway must be located at or above the 100 Yr ARI flood level;*
- *Any ramp down to an underground carpark must be covered to minimize rainwater intrusion;*
- *The basement parking area must be graded to fall to the sump;*
- *The pump-out system must be independent of any gravity stormwater lines except at the site boundary where a grated surface inlet pit is to be constructed providing connection to Council's road drainage system; and*
- *Engineering details and manufacturers specifications for the pumps, switching system* and sump are to be submitted for approval prior to issue Of the Construction Certificate.

METHODOLOGY

The catchment draining to the subject site was identified through the use of topographic data (Airborne Laser Scanning (ALS) in this case), with a total catchment area of 2.4 km^2. A site inspection, survey and the ALS were used to identify major topographic features. Storm water locations and sizes were also identified during the site inspection.

The modelling approach to determine design flood levels in this small rural catchment could either be undertaken using a traditional runoff routing hydrologic model with inputs at several locations to a hydraulic model of the floodplain, or what is known as a Rainfall on Grid approach. The latter approach was preferred on this catchment due to the need to model numerous small tributary creeks. However, in order to comply with the ARR 2016 design rainfall temporal pattern approach, 10 temporal patterns need to be run for each storm duration to determine the critical storm duration.

To simplify the ARR 2016 design approach a WBNM model was developed and used in conjunction with the TUFLOW hydraulic model to determine the critical storm duration temporal pattern. This critical storm duration temporal pattern was then input to the Rainfall on Grid hydraulic model (after some adjustments to match the peak flows at various locations from the WBNM hydrologic model) and used to determine design flood levels and flows. This approach provides greater confidence in the design flows than just using a Rainfall on Grid approach as there are no default parameters for use in a Rainfall on Grid approach whilst there are for WBNM.

A brief summary of the work undertaken is described below.

HYDROLOGY

A hydrologic model was built using the hydrological software WBNM. This software is commonly used in NSW and one of the best practice approaches for the estimation of design flows in catchments having no calibration data. In particular, as it was developed based on empirical relationships identified for south-east NSW, hence default parameters will tend to turn rainfall of a given probability into flow of equivalent probability. WBNM was applied to multiple sub-catchments which recognised major delineating features in the catchment including roads, hills and depressions. Figure 2 shows the catchment delineation. Hydrologic modelling work also included the assessment of impervious percentages for sub-catchments (10%).

Rainfalls from ARR 2016 were applied to WBNM in order to develop design flows using the following steps:

1. Ten temporal patterns were run for each storm duration;
2. Peak flows were extracted from each temporal pattern at the downstream end of the catchment;
3. The average peak flow of the ten was calculated for every storm duration; and
4. The temporal pattern giving the closest peak flow value to the average flow was selected for that duration.

Initial and continuous losses consistent with ARR 2016 have been applied (see ARR Hub Output). A Pre burst rainfall depth has been removed from the Initial loss value for each duration (see ARR Hub Output).

HYDRAULIC MODEL

A hydraulic model for the site was then developed using the well known modelling software TUFLOW. The 2D TUFLOW model build was based on ALS data for the location with this data being sourced from the Land and Property Information Service. This topographic data is based on a dense collection of ground strikes which have an average accuracy of +/- 0.15 m (for the first confidence interval). Such topographic data is used for flood studies throughout NSW and again represents best practice for a flood study.

Detailed survey was undertaken for one basin due to the inadequacy of the ALS in that location. Using the ALS and survey data, a 2D TUFLOW model with a grid size of 2m*2m was established. The existing case model incorporates building extents and roughness as per Appendix B of the Campbelltown DCP (Reference 3) with a default manning value of 0.045 instead of 0.035. The culverts were incorporated into the hydraulic model with a blockage of 50% for the 1% AEP. The critical duration assessment has been undertaken using the TUFLOW model with the WBNM inflows. Figure 3 shows the hydraulic model layout.

A Rainfall on Grid TUFLOW model was developed to identify the defined secondary flow path extents. The following steps were followed to calibrate the Rainfall On Grid model and ensure that rainfall was not trapped artificially in 'depressions' caused by inconsistencies in the ALS data:

1. Initially the WBNM inflows were input to the TUFLOW hydraulic model to determine the design flows within creeks and the 270 minute event was determined as the critical storm duration.

2. A Rainfall on Grid TUFLOW model was then designed for the critical storm duration. This model applied rainfall directly on the grid of the hydraulic model using the temporal pattern of the critical storm duration and the ARR 2016 rainfall depths.

3. The Rainfall on Grid model was then adjusted to match the creek flows of Step 1 using specific initial loss and continuous loss values.

After running the 1% AEP event, flood levels were mapped and these have been used to inform proposed building floor levels, under the guidance of Council's DCP (Reference 3).

EXISTING FLOOD CONDITION

Figure 4a and Figure 4b show locations where 1% AEP flow values are provided in Table 1. The flood depth exceeds 1 m in most of the creeks and 0.3 m in all overland flow paths. Flood affectation in terms of depths, extents and level contours is shown for the 1% AEP 270 minute design event on Figure 5a and Figure 5b. Peak flood levels are characterised by a gradient along the site ranging from 78.5 to 51.3 mAHD along the main creek line.

Table 1 Existing Peak Flow Value as shown Figure 4a and Figure 4b

Location	Flow Value m^3/s	Location	Flow Value m^3/s
Q1	7.296	**Q9**	2.70
Q2	0.46	**Q10**	0.99
Q3	0.54	**Q11**	0.92
Q4	0.24	**Q12**	0.61
Q5	1.63	**Q13**	0.20
Q6	3.41	**Q14**	0.18
Q7	2.35	**Q15**	1.12
Q8	0.48	**Q16**	0.37

Peak velocities for the 1% AEP event (Figure 6a and Figure 6b) exceed 1 m/s in many places. This is due to the relatively steep grade of 10% to 3% along flow paths and creeks.

The hydraulic categories, namely floodway, flood storage and flood fringe, are described in the NSW *Floodplain Development Manual* (Reference 4). However, there is no technical definition of hydraulic categorisation that would be suitable for all catchments, and different approaches are used by different consultants and authorities, based on the specific features of the study catchment. For this study, hydraulic categories are defined by the following criteria:

Floodway is defined as areas where:

- the peak value of velocity multiplied by depth (V x D) > 0.25 m^2/s **AND** peak velocity > 0.25 m/s, **OR**
- peak velocity > 1.0 m/s **AND** peak depth > 0.15.

The remainder of the floodplain is either Flood Storage or Flood Fringe,

- Flood Storage comprises areas outside the floodway where peak depth > 0.5 m; and
- Flood Fringe comprises areas outside the floodway where peak depth < 0.5 m.

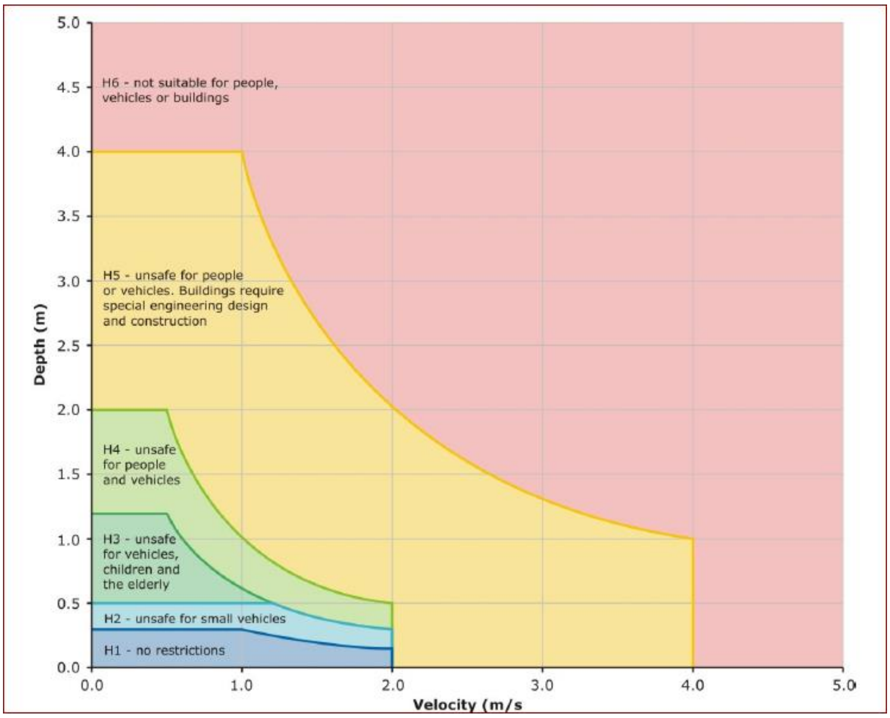
Figure 7 shows the hydraulic categorisation for the 1% AEP design event.

As with hydraulic categories, hazard classification plays an important role in informing floodplain risk management in an area. Previously, hazard classifications were binary – either Low or High Hazard as described in the *Floodplain Development Manual* (Reference 4). However, in recent years there have been a number of developments in the classification of hazard. *Updating National Guidance on Best Practice Flood Risk Management* (Reference 5) provides revised hazard classifications which add clarity to the hazard categories and what they mean in practice. The classification is divided into 6 categories (Table 2 and Diagram 1) which indicate the restrictions on people, buildings and vehicles.

Table 2: Hazard Curves - Vulnerability Thresholds (Reference 5)

Hazard Classification	Description
H1	Relatively benign flow conditions. No vulnerability constraints.
H2	Unsafe for small vehicles.
H3	Unsafe for all vehicles, children and the elderly.
H4	Unsafe for all people and all vehicles.
H5	Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
H6	Unconditionally dangerous. Not suitable for any type of development or evacuation access. All building types considered vulnerable to failure.

Diagram 1: Hazard Classifications (Reference 5)



Hazard categories are often grouped based on consequences. Figure 8 provides the hazard classification for the 1% AEP design event based on Diagram 1.

SENSITIVITY ANALYSIS

The *Floodplain Development Manual* (Reference 4) requires that Flood Studies and Floodplain Risk Management Studies consider the impacts of climate change on flood behaviour. Three scenarios have been modelled:

- low level rainfall increase = 10%,
- medium level rainfall increase = 20%,
- high level rainfall increase = 30%.

Table 3 below provides the increase in peak flood level at specific location within the catchment (Figure 4a and Figure 4b show the locations).

Table 3 Results - Increase in 1% AEP Peak Flood Level (m) due to Climate Change

Location Figure 4a and Figure 4b	% Increase in rainfall		
	10%	20%	30%
H1	0.01	0.02	0.03
H2	0.01	0.03	0.04
H3	0.54	0.69	0.76
H4	0.01	0.02	0.03
H5	0.01	0.02	0.02
H6	0.07	0.09	0.10
H7	0.01	0.02	0.02
H8	0.01	0.02	0.03
H9	0.00	0.00	0.01
H10	0.01	0.03	0.05
H11	0.01	0.02	0.03
H12	0.03	0.06	0.07
H13	0.04	0.08	0.11
H14	0.01	0.02	0.03
H15	0.04	0.08	0.11

The increase is minor for the 30% increased rainfall scenario (below 0.1m) except at St Andrews Road where the culverts have a significant backwater effect and at Dam 2 and 3.

PROPOSED DEVELOPMENT

The proposed development consists of an internal access road layout and buildings. The proposed development is modelled by importing the proposed road TIN into the TUFLOW model.

- At access A (Figure 1b) the proposed TIN has been merged into the road level at St Andrews Road. A new culvert 2m wide by 0.6m high has also been added at that location.
- The building extents are nulled out.
- A set of culverts (Figure 1b) and retention walls have also been added. The culverts are all box culverts 2m wide by 0.6m high except close to the gatehouse where the box culvert is 3m wide and 0.6 m high.

Figure 9 shows the impact (change in 1% AEP flood level) of constructing the new roads and construction of buildings. The figure also shows the location of the proposed buildings relative to overland flow paths and other drainage features as summarised below.

- The Gatehouse is not located close to an overland flow path;
- The Chapel is close to an overland flow path. It has been assumed that the courtyard, the basement and the main building of the chapel are not flooded during a 1% AEP event.
- The Function Room is close to Dam 4;
- The café and shop are located close to Dam 5;
- The Administration building is not located close to an overland flow path;

- The Staff building is not located close to an overland flow path;
- The concrete storage bins building is obstructing a flow path and so create a major depth;
- The area around the staff building and the concrete storage bin building is set at 71.2 mAHD.

Table 4 Floor Planning Level

Building	ID	DCP requirement
The Gatehouse	1	Ground+0.15m
The Chapel	2	Ground+0.15m with a minimum level of 80.53 mAHD
The Function Room	3	Ground+0.15m with a minimum level of 65.23 mAHD
The café and shop	4	Ground+0.15m with a minimum level of 59.93 mAHD
The administration	5	Ground+0.15m
The staff building	6a	Ground+0.15m
The concrete storage bin building	6b	Ground+0.15m with a minimum level of 73.3 mAHD

Table 4 above provides the floor level requirements based on the Campbelltown DCP (Reference 3).

Buildings 2, 3 and 4 are close to dams or overland flow paths. Therefore the floors should be set at the level indicated in Table 4 with a restriction that every opening should be at least 0.15m above the ground.

Building 6b is obstructing a flow path and creates a ponding at the north side, the minimum floor level should be the ground +0.15 with a minimum level of 73.3 mAHD.

As Buildings 1, 5 and 6a are not located close to an overland flow path their floor planning level is defined by the ground elevation+0.15 m requirement.

It should be noted that the ground level could change as a result of construction works and upon completion must be certified that the floor is at least 0.15m above the surrounding ground.

CONCLUSIONS

WMAwater has undertaken a flood study for the proposed development. Based on this the existing 1% AEP flood event has been mapped. Key features of the proposed development have been modelled in the development scenario and recommended floor planning levels have been established.

Please do not hesitate to contact the undersigned for clarification of any of the above.

Yours Sincerely,
WMAwater

Richard Dewar
Director

REFERENCES

1 Macarthur Memorial Park Masterplan, Florence Jacquet, September 2015.
2 Watercourse Assessment, Travers Bushfire & Ecology, September 2013.
3 Campbelltown (Sustainable City) Development Control Plan 2015 (SCDCP 2015).
4 NSW Government, Floodplain Development Manual, April 2005.
5 Updating National Guidance on Best Practice Flood Risk Management; D. McLuckie, M Babister, G Smith, R Thomson, 2014
6 Volume 2, Engineering Design For Development (SCDCP 2019).

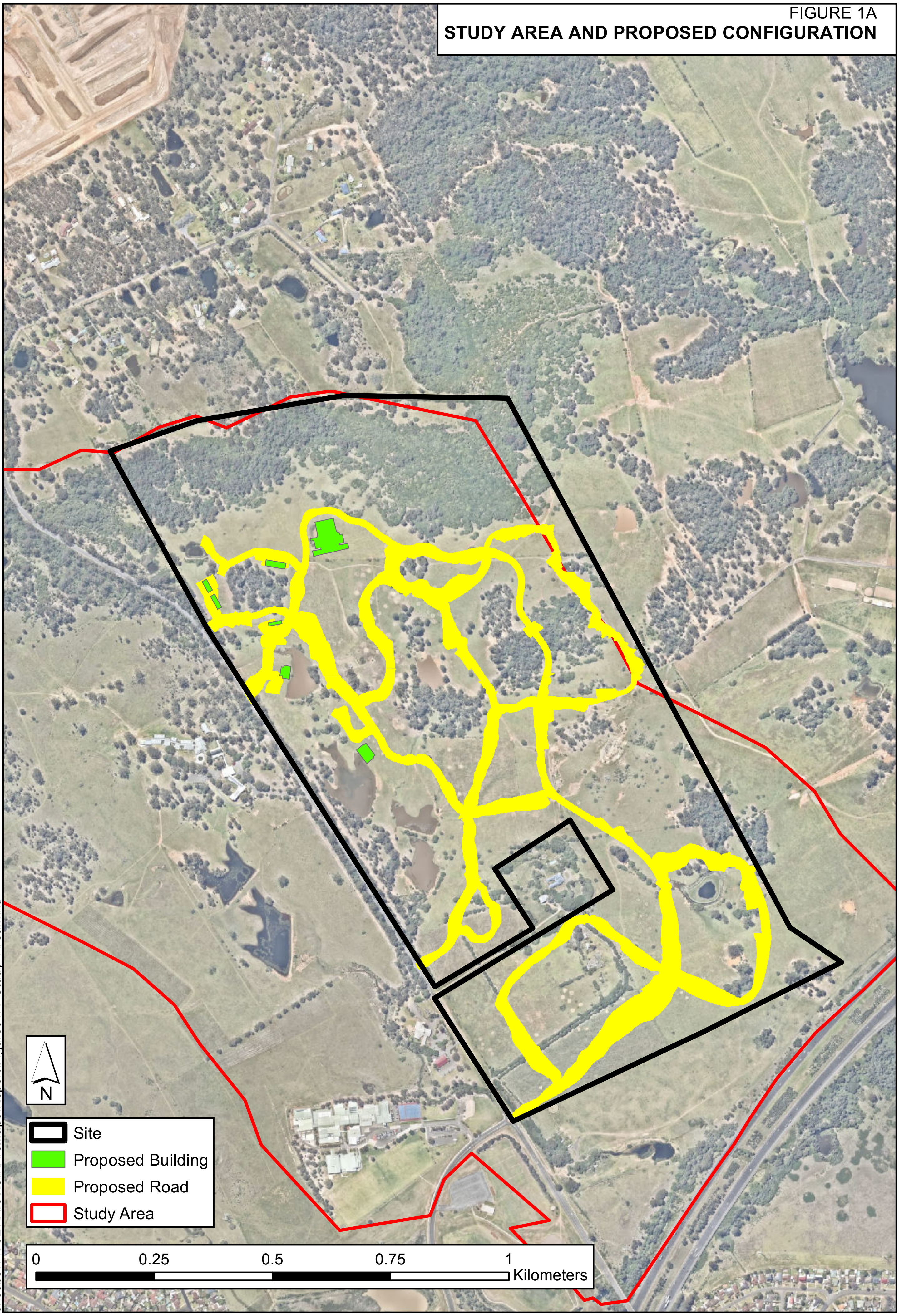


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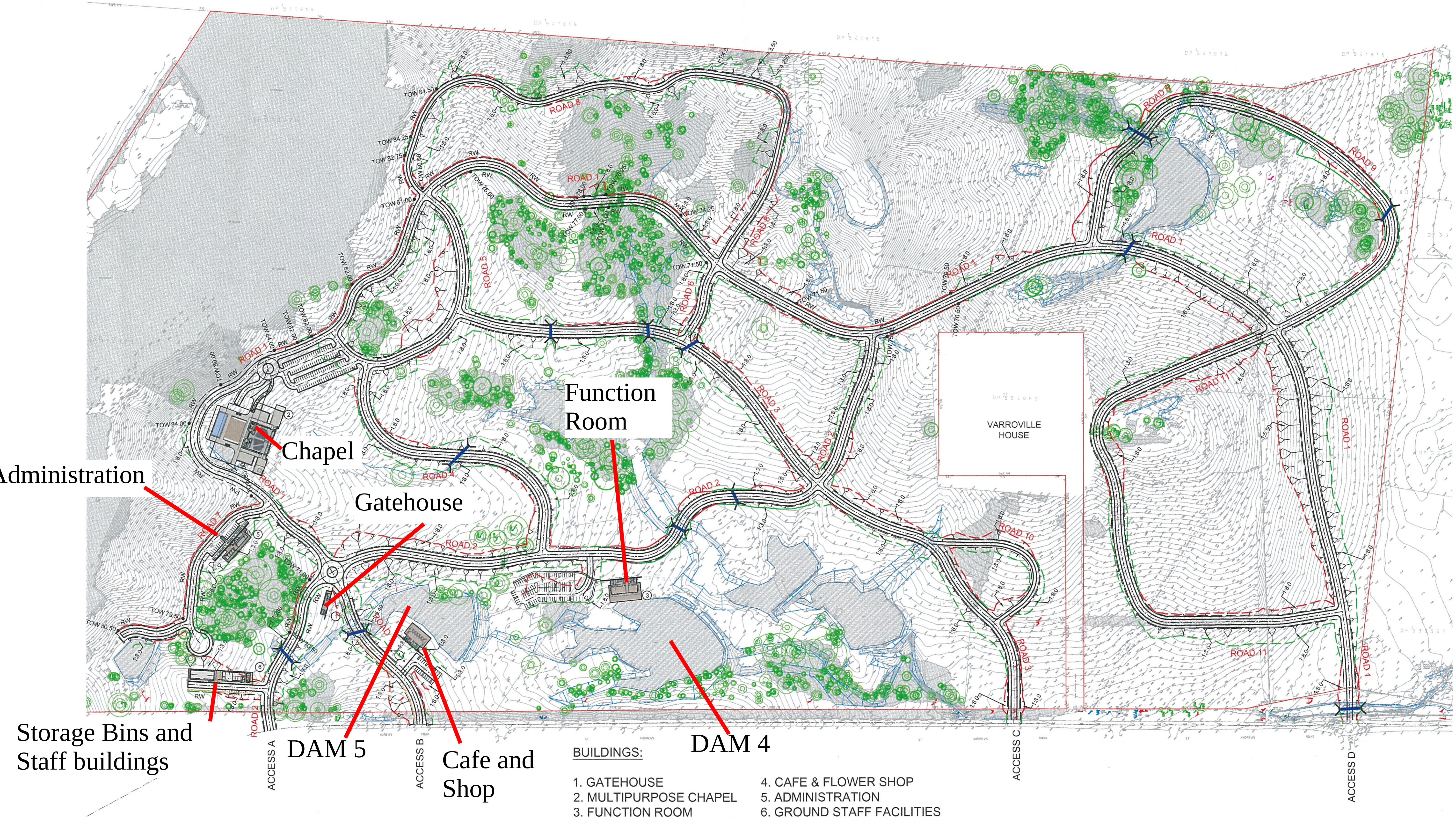
FIGURE 1B
PROPOSED DESIGN



NORTH

Warren Smith & Partners
35 YEARS OF SERVICE

5162001 - MACARTHUR MEMORIAL PARK
RETAINING WALL LEVELS [1]
6-JUN-17

FIGURE 2
WBNM CATCHMENT DELINEATION

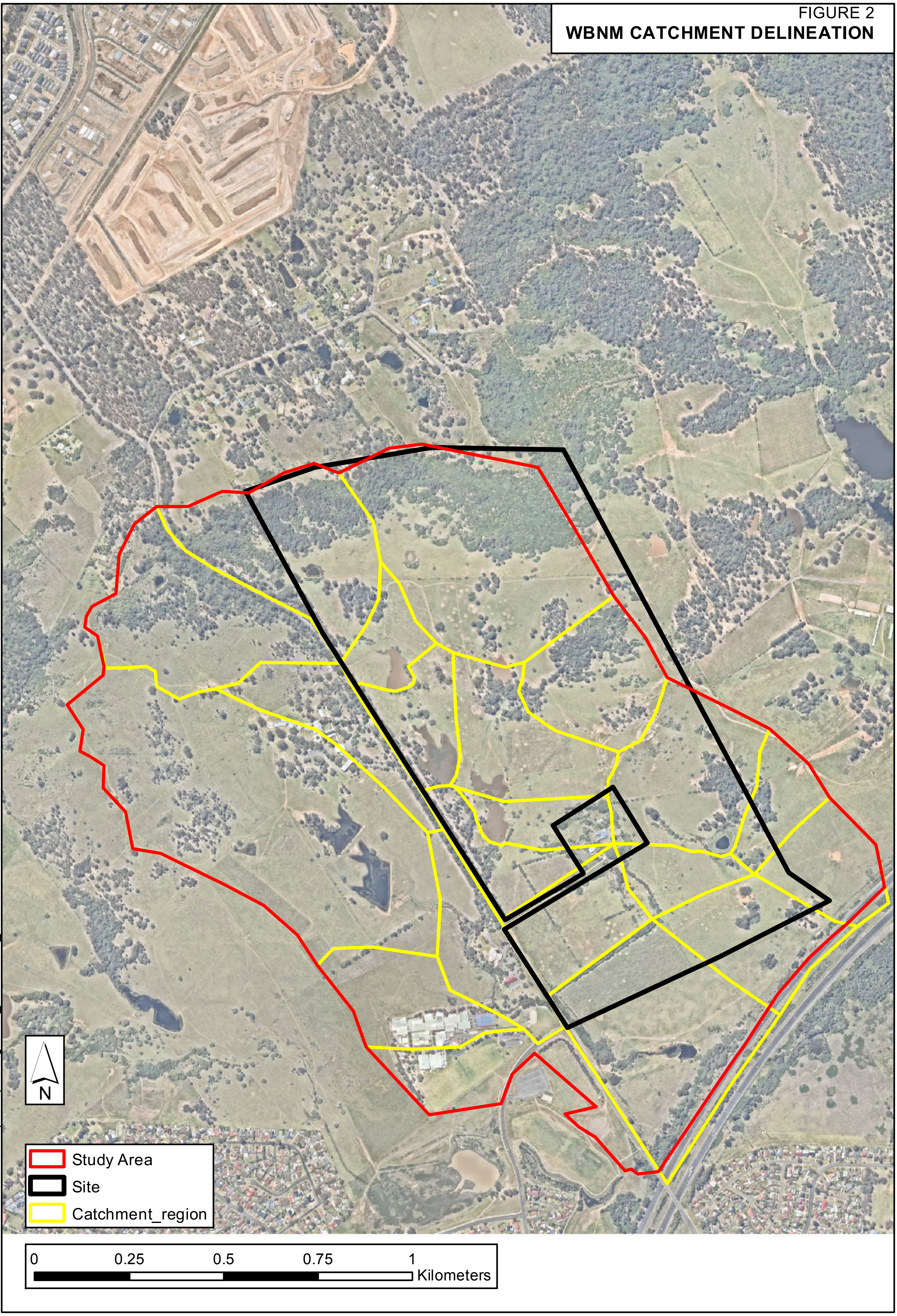


FIGURE 3
HYDRAULIC MODEL LAYOUT

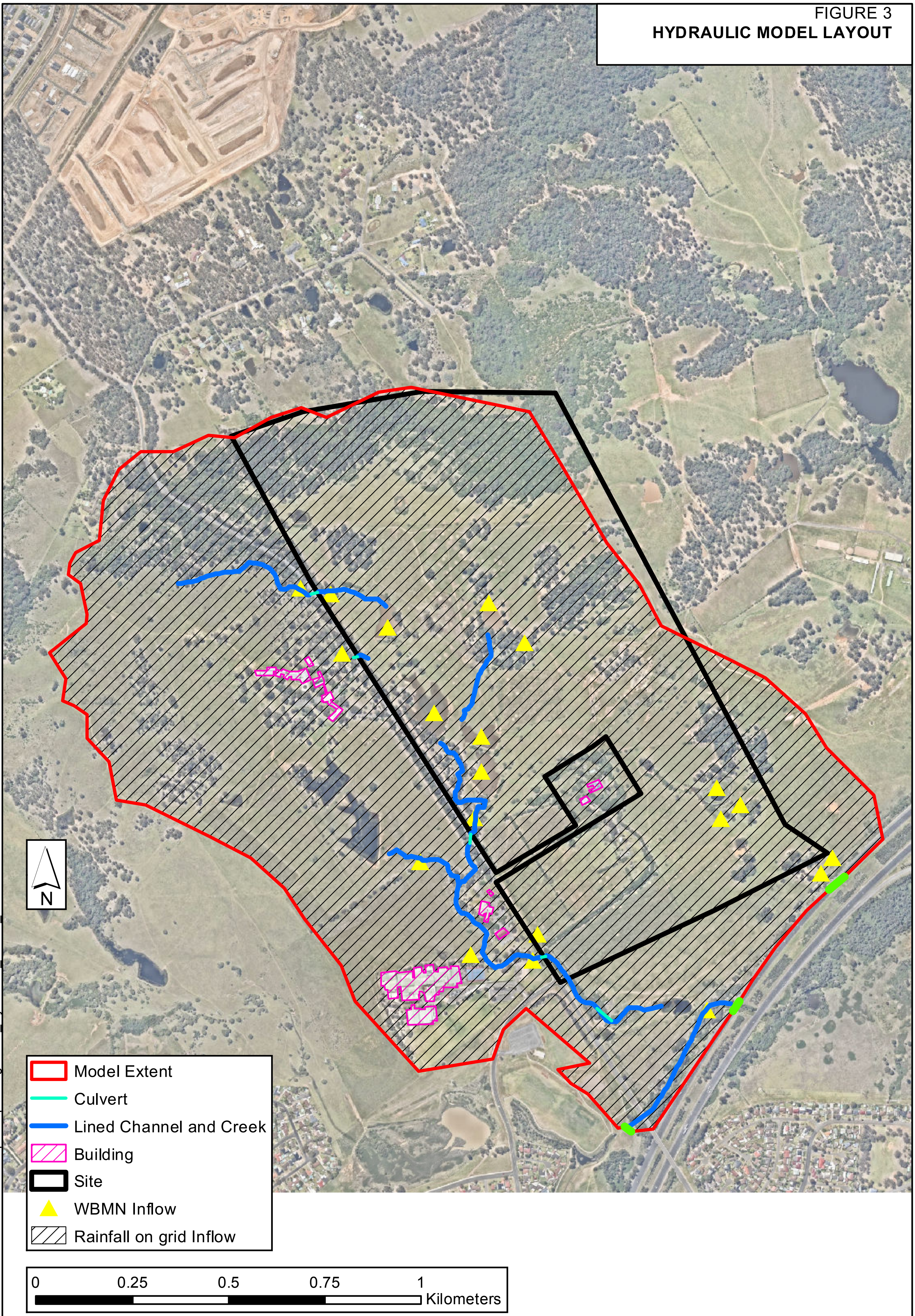


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FIGURE 4A
FLOOD INFORMATION LOCATION

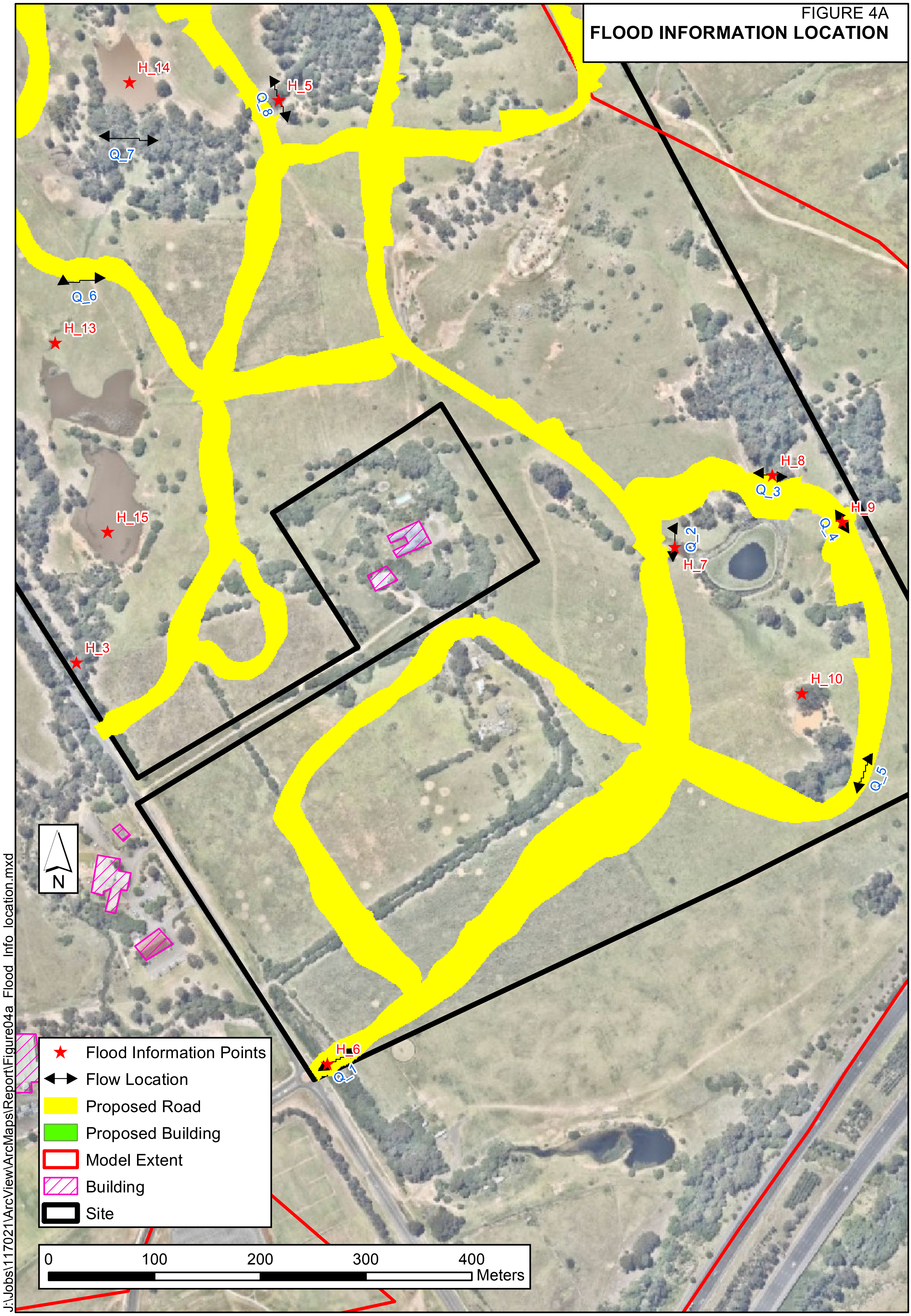

FIGURE 4B
FLOOD INFORMATION LOCATION

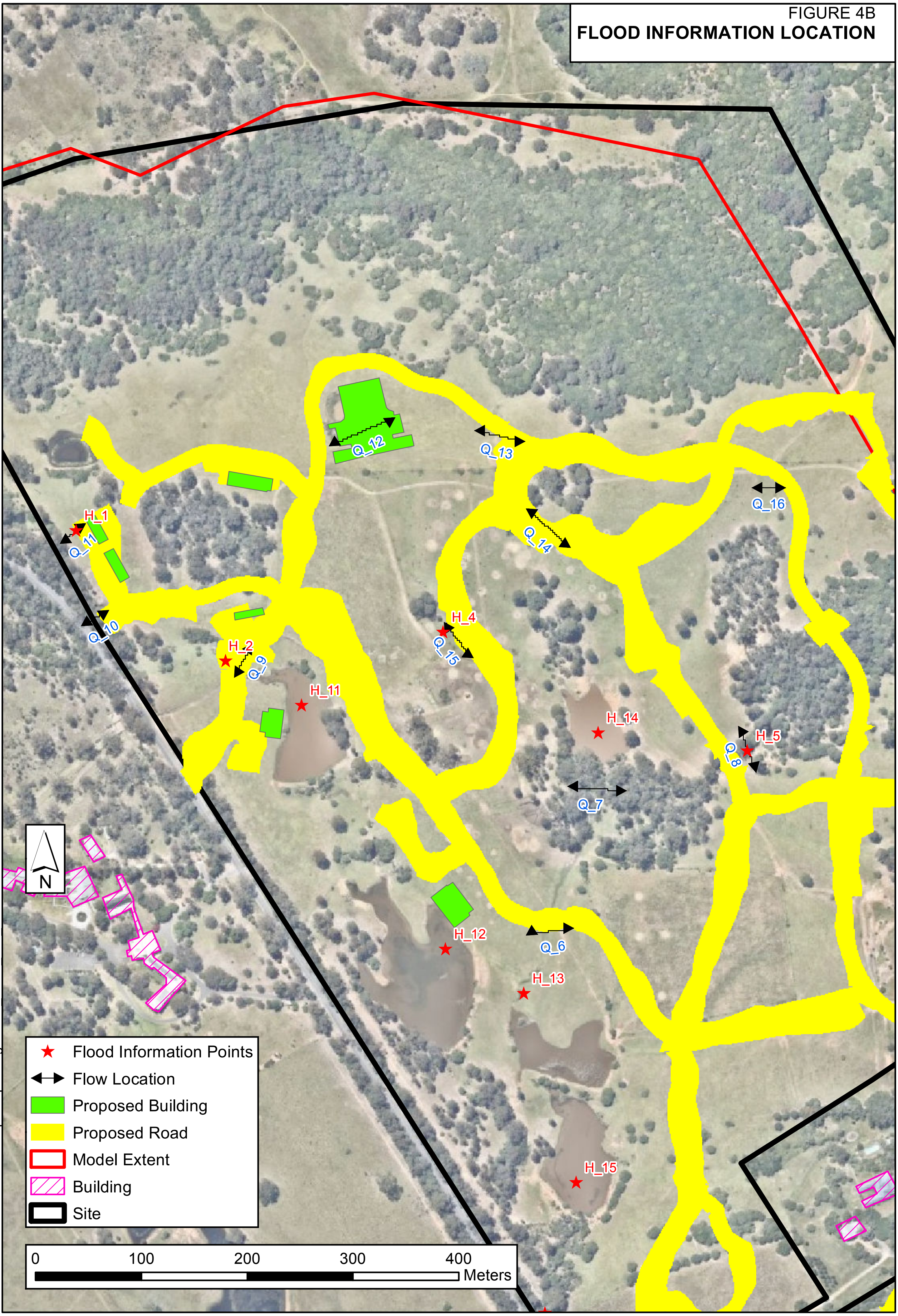

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FIGURE 5A

EXISTING SCENARIO

PEAK FLOOD DEPTH AND LEVEL CONTOUR - 1% AEP

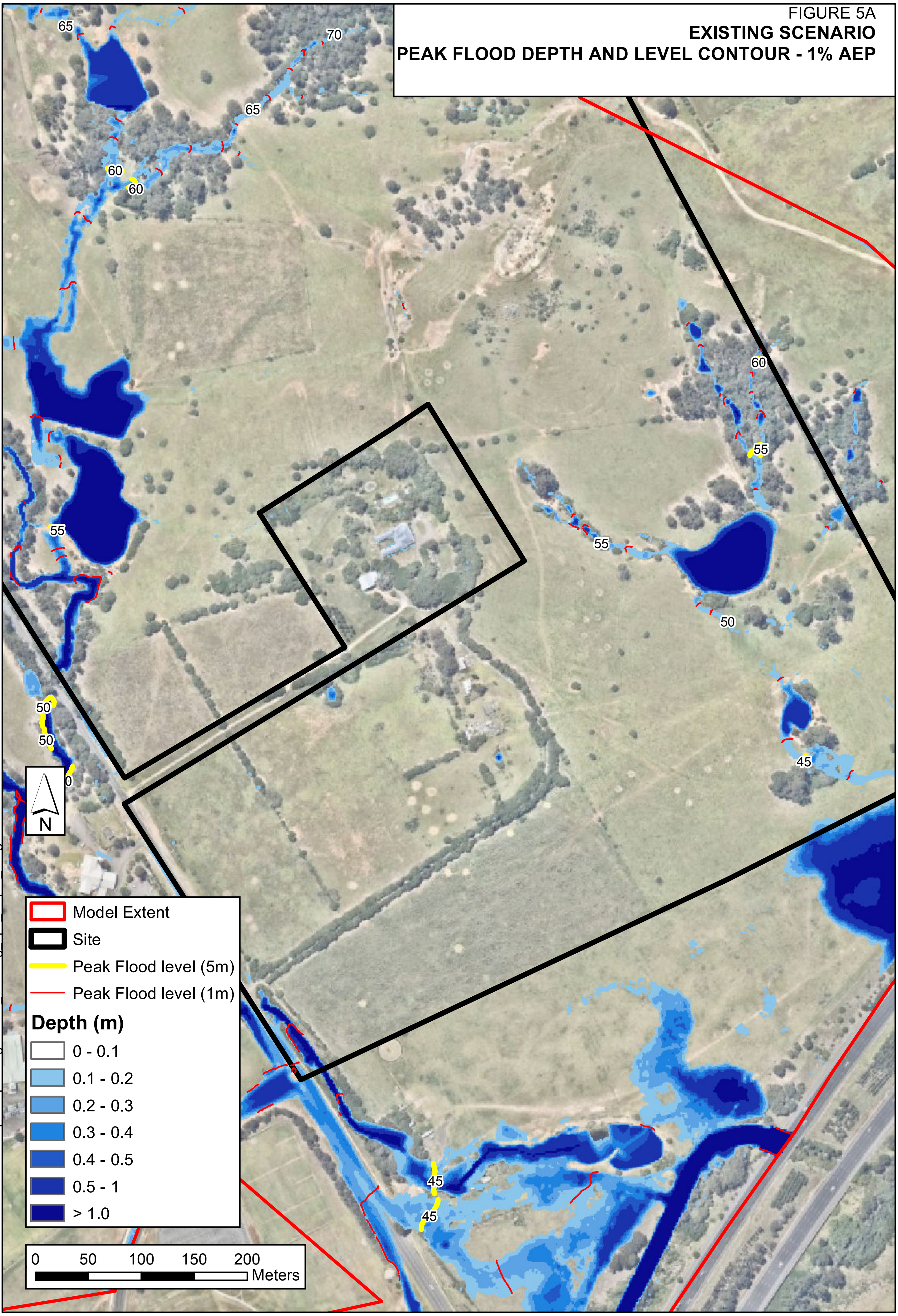

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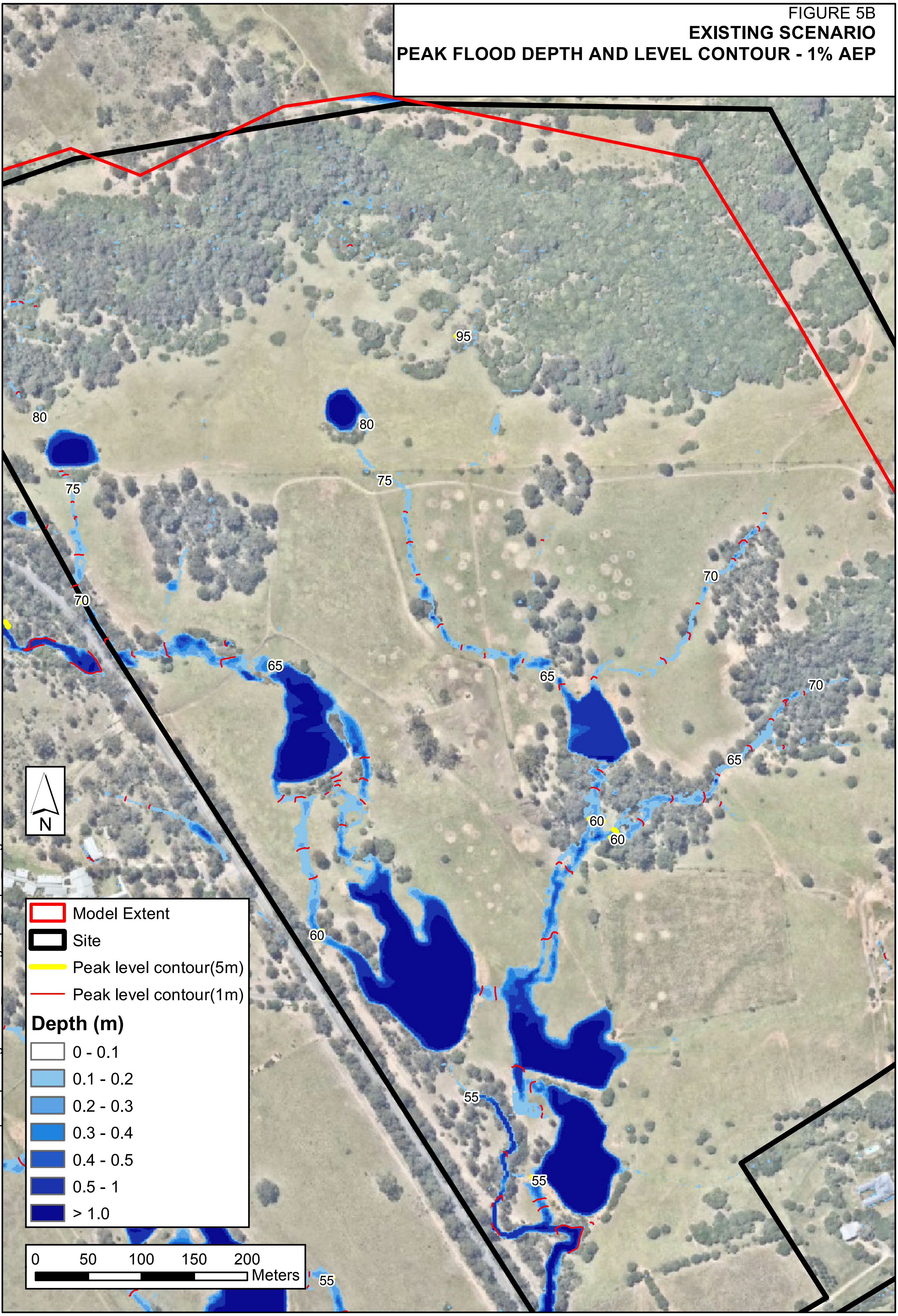
FIGURE 5B
EXISTING SCENARIO
PEAK FLOOD DEPTH AND LEVEL CONTOUR - 1% AEP



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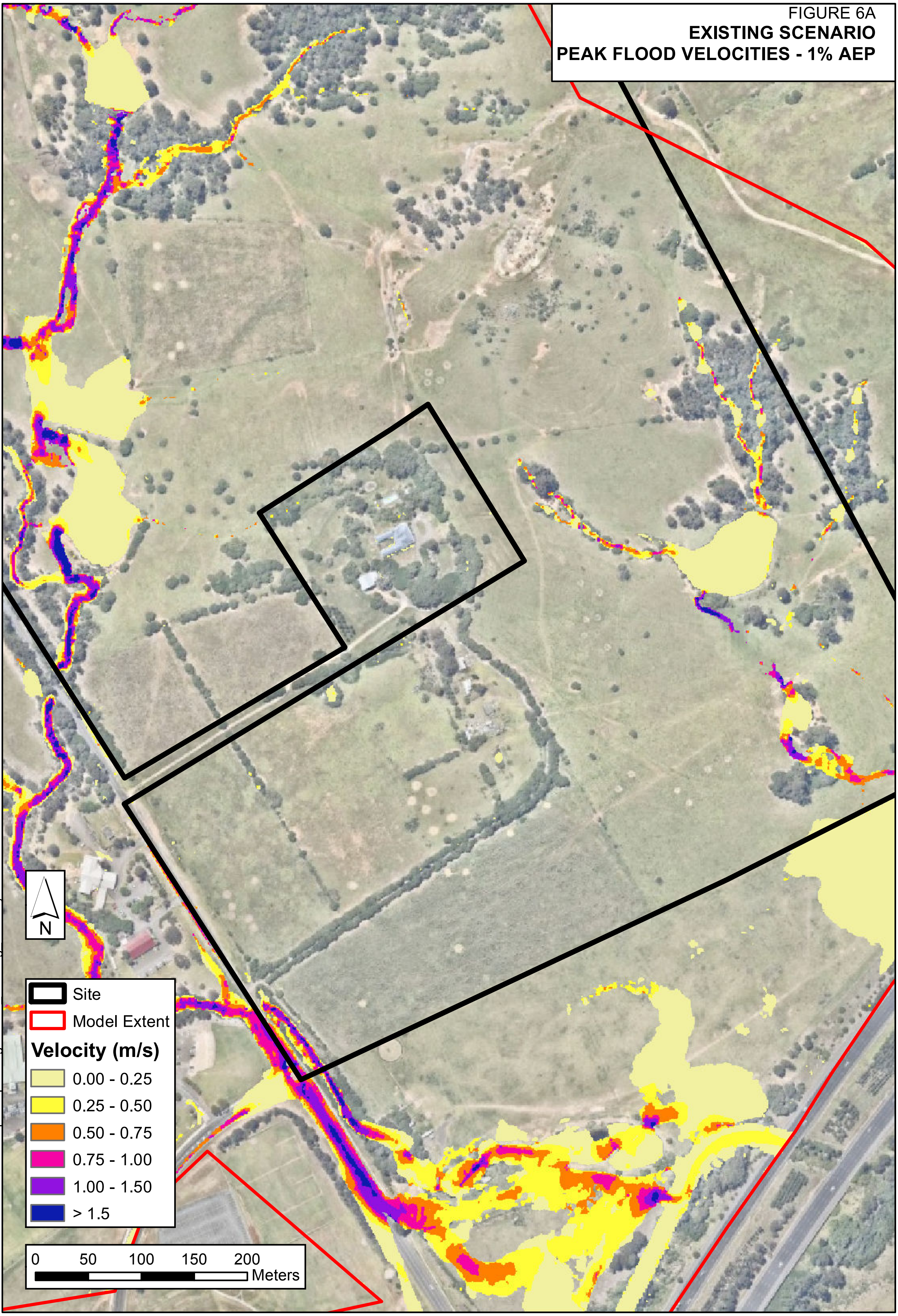

FIGURE 6A
EXISTING SCENARIO
PEAK FLOOD VELOCITIES - 1% AEP

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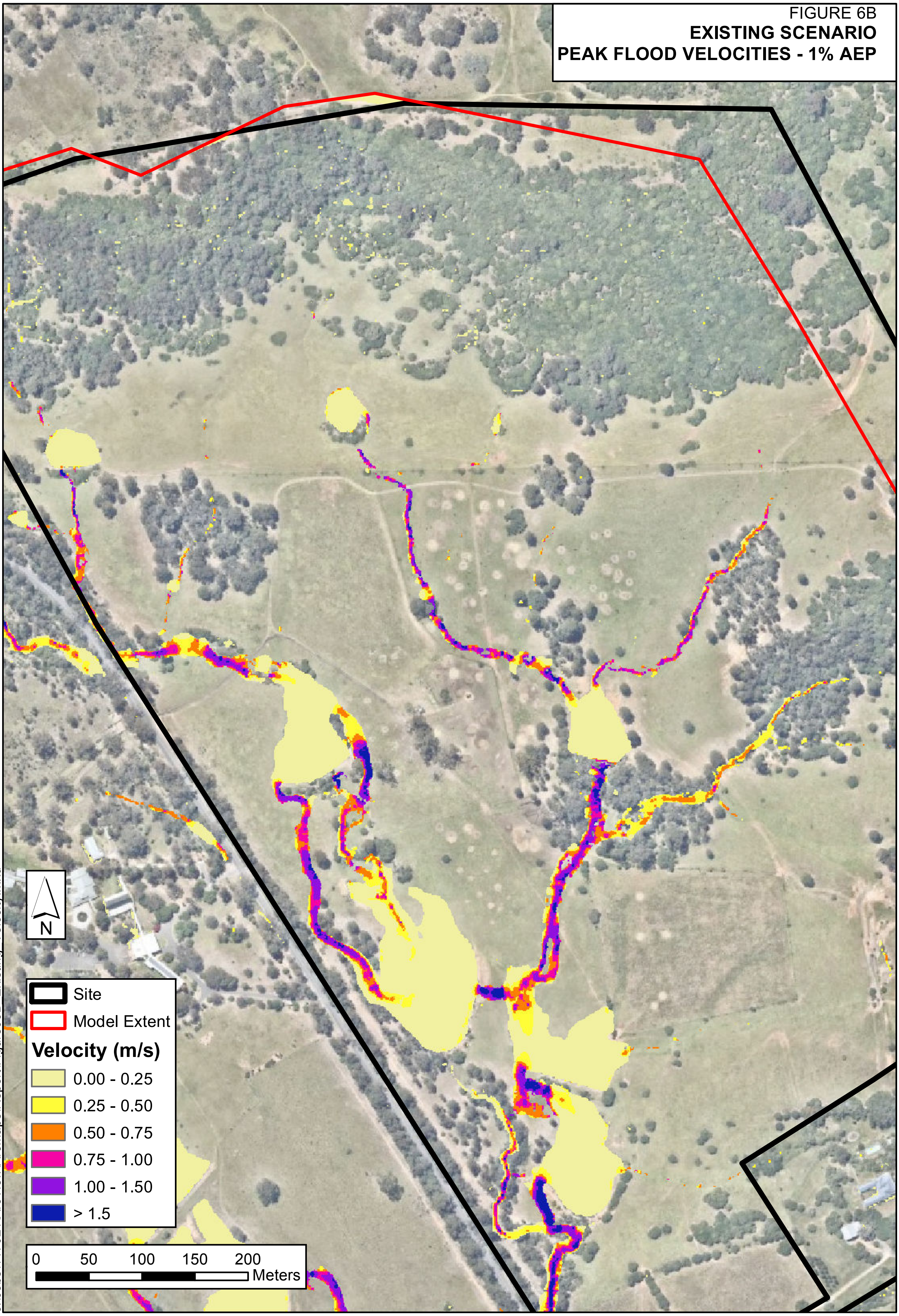

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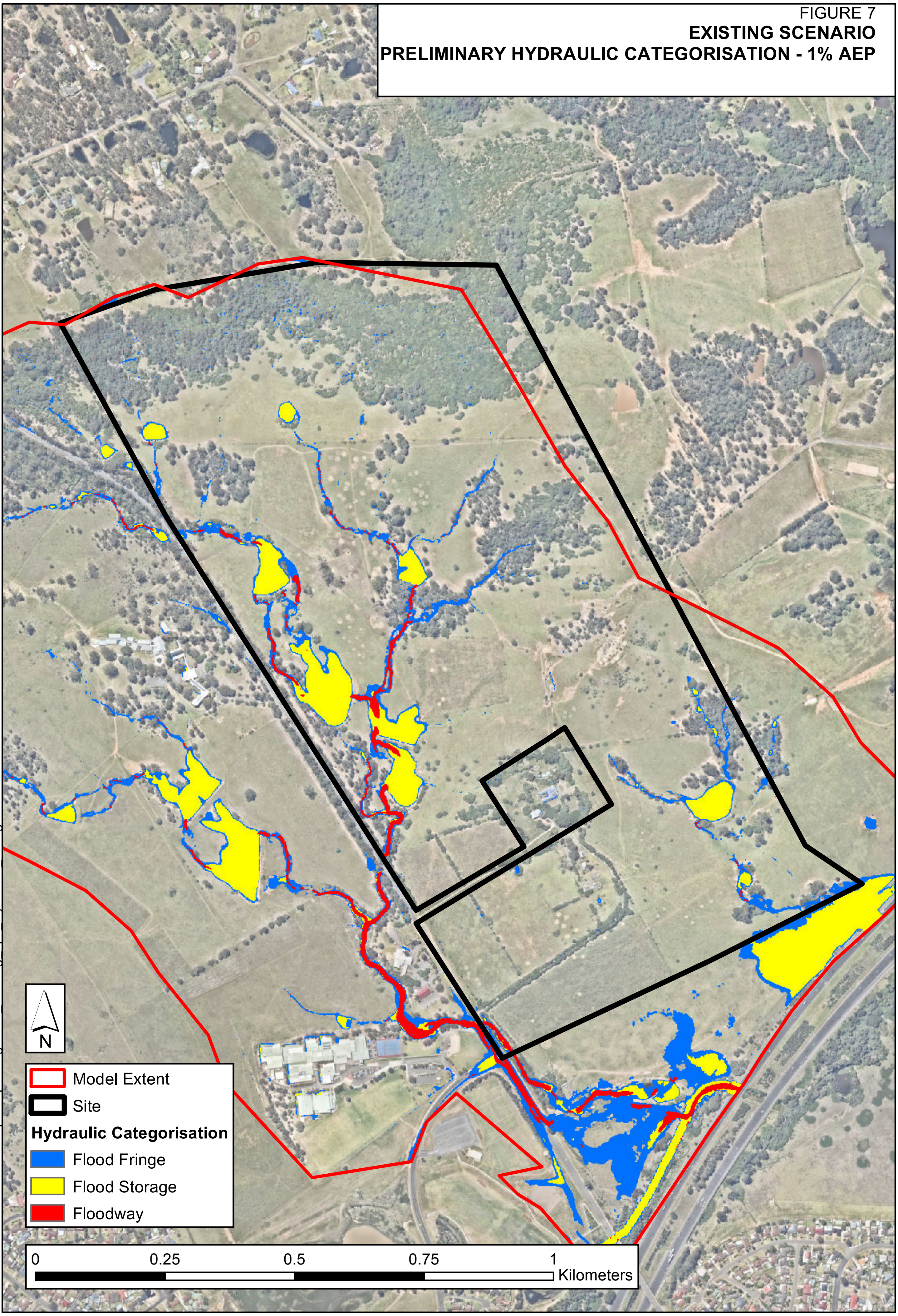
FIGURE 7
EXISTING SCENARIO
PRELIMINARY HYDRAULIC CATEGORISATION - 1% AEP



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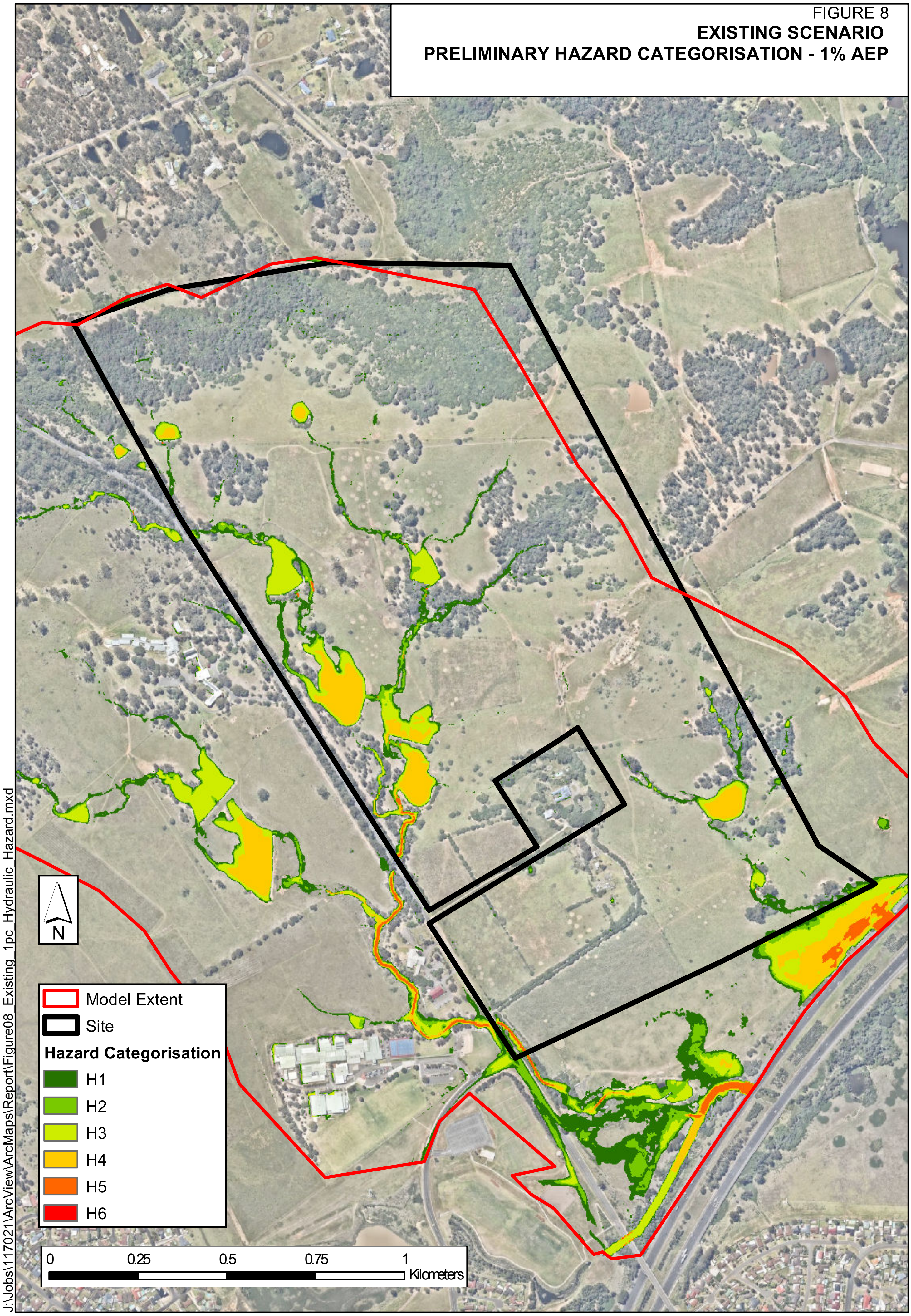

FIGURE 8
EXISTING SCENARIO
PRELIMINARY HAZARD CATEGORISATION - 1% AEP
N
Model Extent
Site
Hazard Categorisation
H1
H2
H3
H4
H5
H6
0
0.25
0.5
0.75
1
Kilometers
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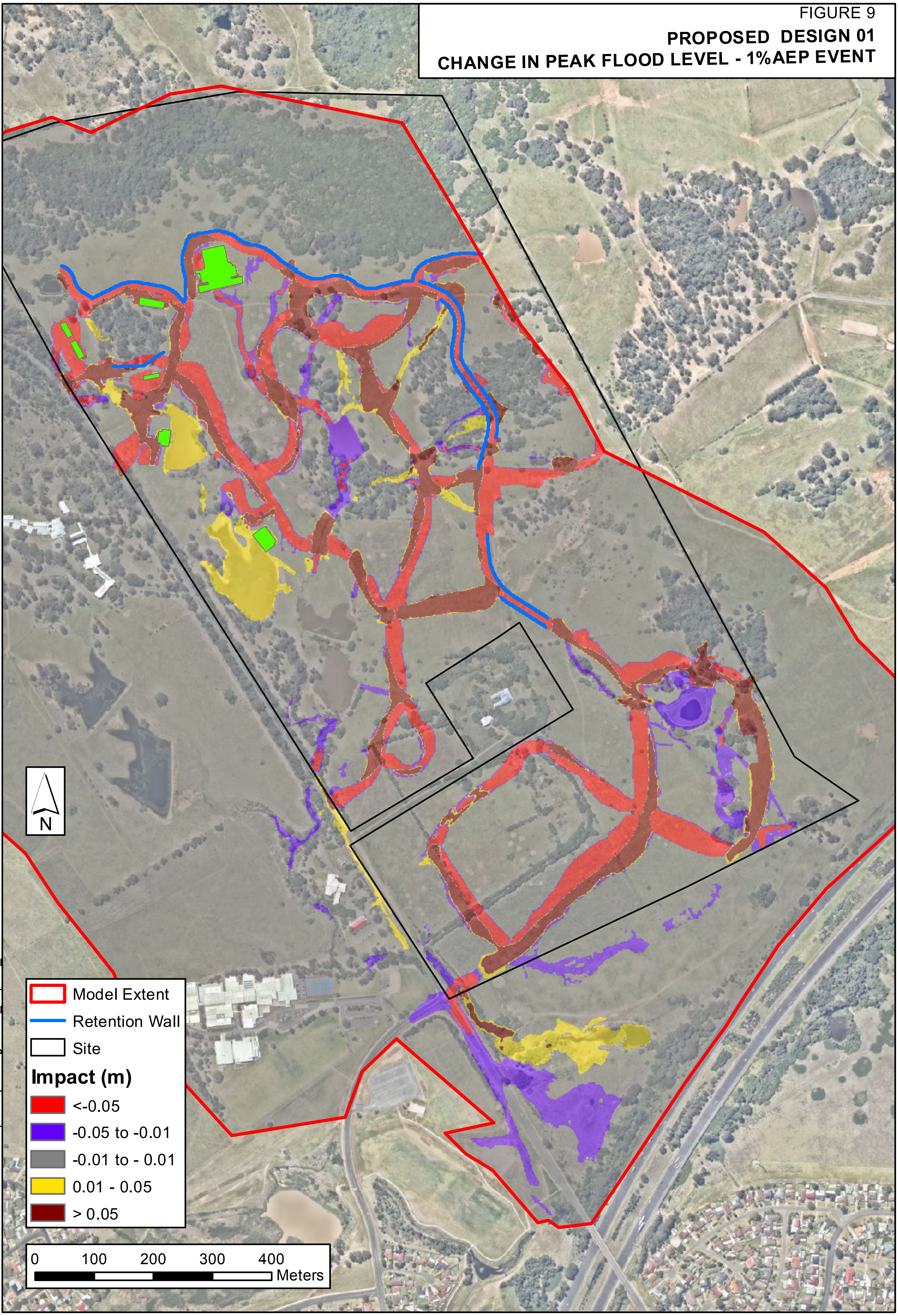
FIGURE 9

PROPOSED DESIGN 01
CHANGE IN PEAK FLOOD LEVEL - 1%AEP EVENT



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