Appendix F Hydrological and Hydraulic Analysis

Proposed Forest Glen Solar Farm, Minore, New South Wales

Hydrological and Hydraulic Analysis

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1.0 INTRODUCTION

Footprint (NSW) Pty. Ltd. (*Footprint*) has been engaged by NGH Consulting to undertake a hydrological and hydraulic analysis in support of a proposed solar farm located approximately 16km west of Dubbo, New South Wales.

The purpose of the analysis is to define the flood behaviour, including depth of inundation and flood velocity over the ephemeral watercourses/overland flow paths that traverse the proposal area. The result of the analysis will be used to guide the design with respect to the extent and elevation of proposed solar array infrastructure and to determine the potential impact of this infrastructure on the existing flood behaviour.

1.1. Scope of Works

The scope of works for the project includes:

1. Review available background information including LiDAR data, topographic maps, proposed development plans.
2. Undertake hydrologic modelling to determine critical storm durations for the rainfall on grid two-dimensional model over the subject site for the 5% AEP, 1% AEP and PMF events.
3. Undertake two-dimensional hydraulic modelling (using HEC-RAS) using available LIDAR data (5m DEM) to determine the depth and extent of flooding over the subject site for each of the above rainfall events.
4. Re-run the model in the post development state for the 1% AEP event only by increasing floodplain roughness to account for the proposed solar arrays and any buildings to determine the impact of the proposed development on flood bahaviour.
5. Preparation of a hydrological and hydraulic report, including flood mapping, defining the methodology and results of the above investigations, and providing any recommendations with respect to floodplain management.

2.0 PROPOSAL AREA

The Forest Glen Solar Farm proposal is to be located on Lot 1 DP119811 and Lot 6 DP755102, south of Minore Road, Minore and comprises an area of approximately 789ha. The proposal area is situated approximately 16km west of Dubbo as depicted in Figure 1.

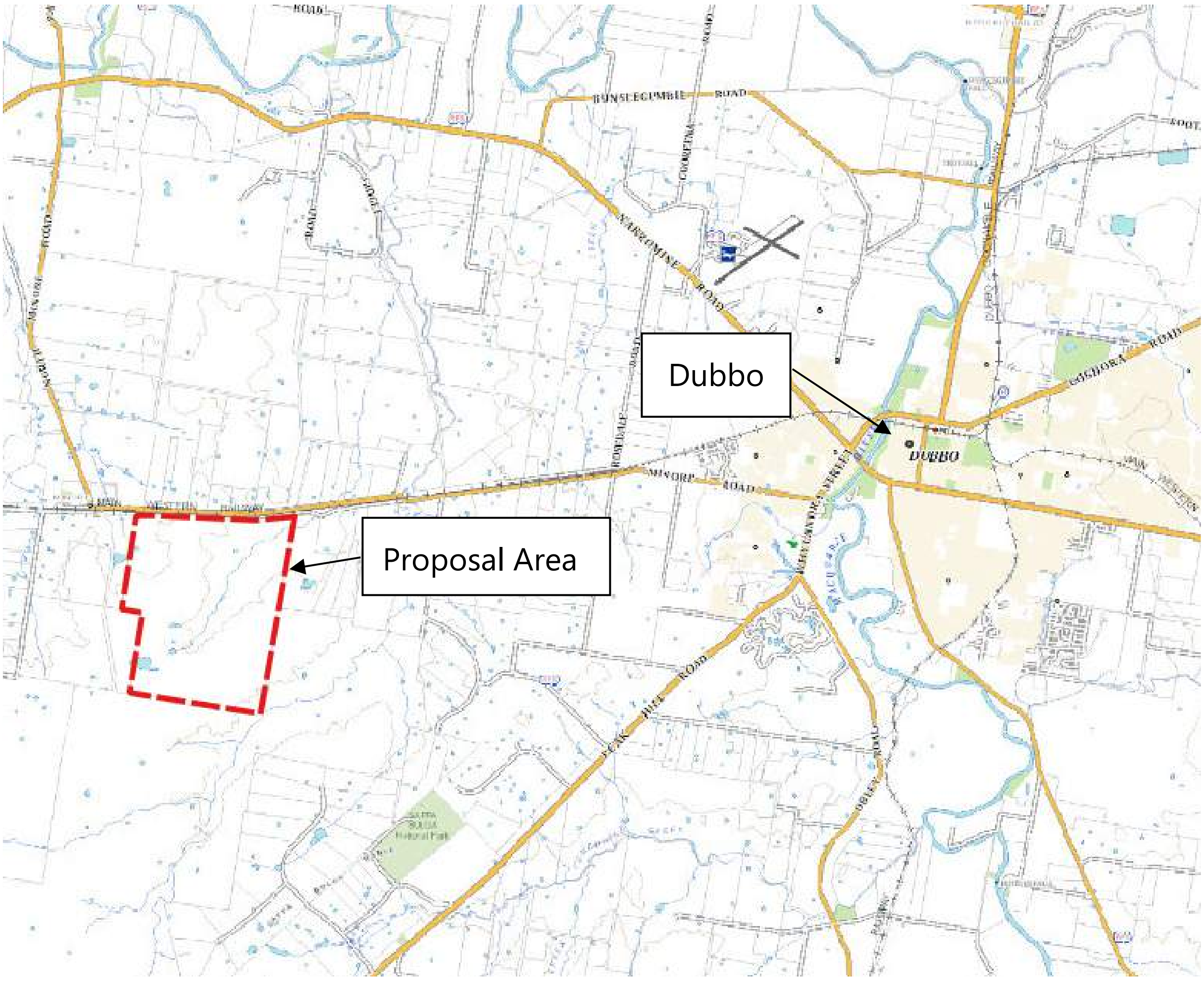


Figure 1: Location and Extent of Proposal Area

The proposal area contains several unnamed watercourses, the larger of which traverses the area in a south-west to north-east direction essentially diagonally bisecting the area into two equal halves. Whylandra Creek passes just to the outside of the south-eastern corner of the proposal area.

All watercourses within the proposal area would be described as ephemeral and, except for existing dams, would only contain flowing water during and shortly after rainfall events.

There are approximately 8 farm dams within the proposal area.

It is understood that the proposal area has been used for agricultural cultivations, including grazing and cropping, and except for of some areas of vegetation in the north-western and south-eastern corners, is mostly cleared of understorey vegetation (refer to Figure 2).

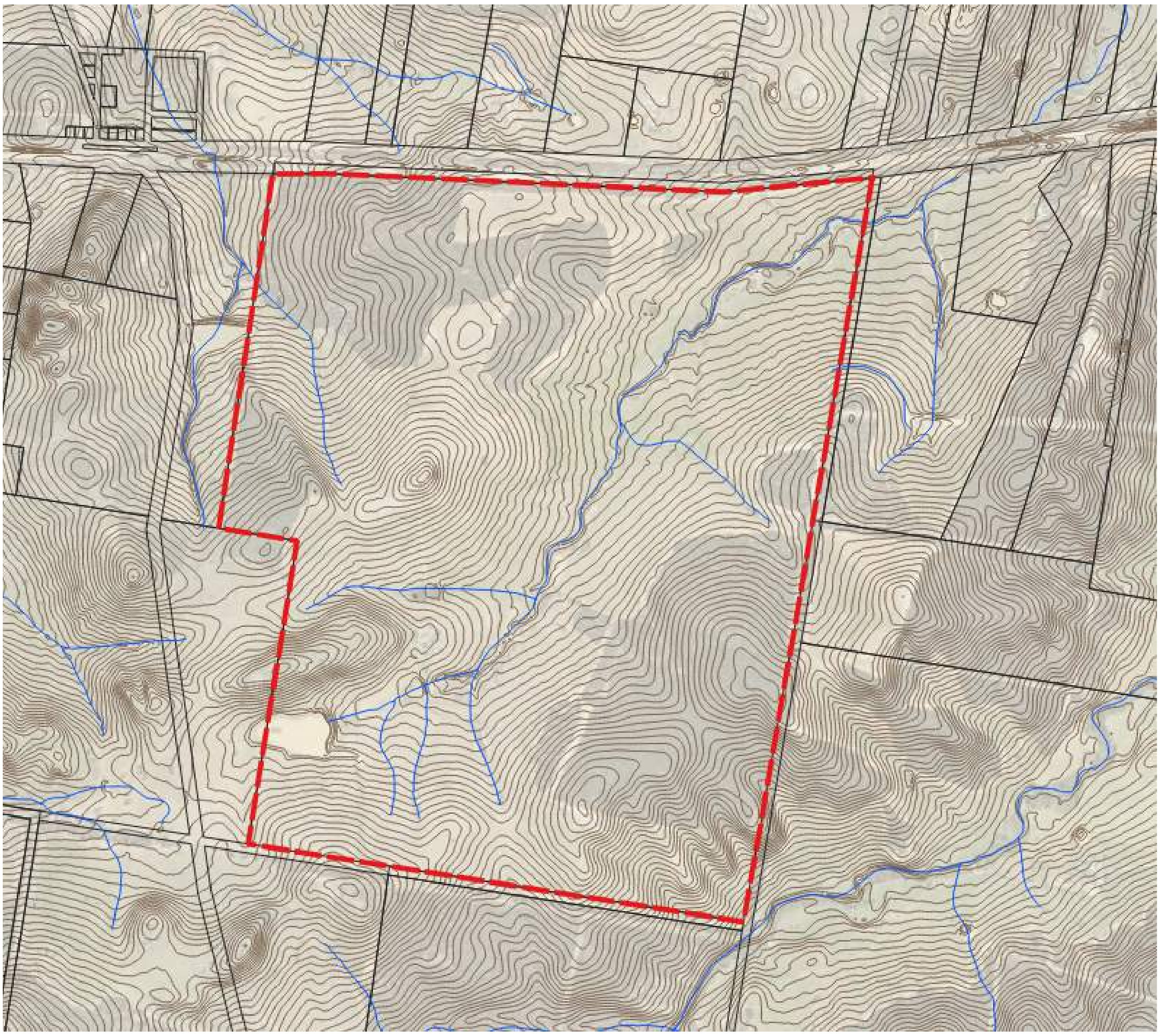


Figure 2: View of Proposal Area (outlined in red)

The proposal area contains a central valley which falls from south-west to north-east with elevation ranging from about 325m AHD to 283m AHD. Either side of the central valley the land fall to the north-western and south-eastern corners.

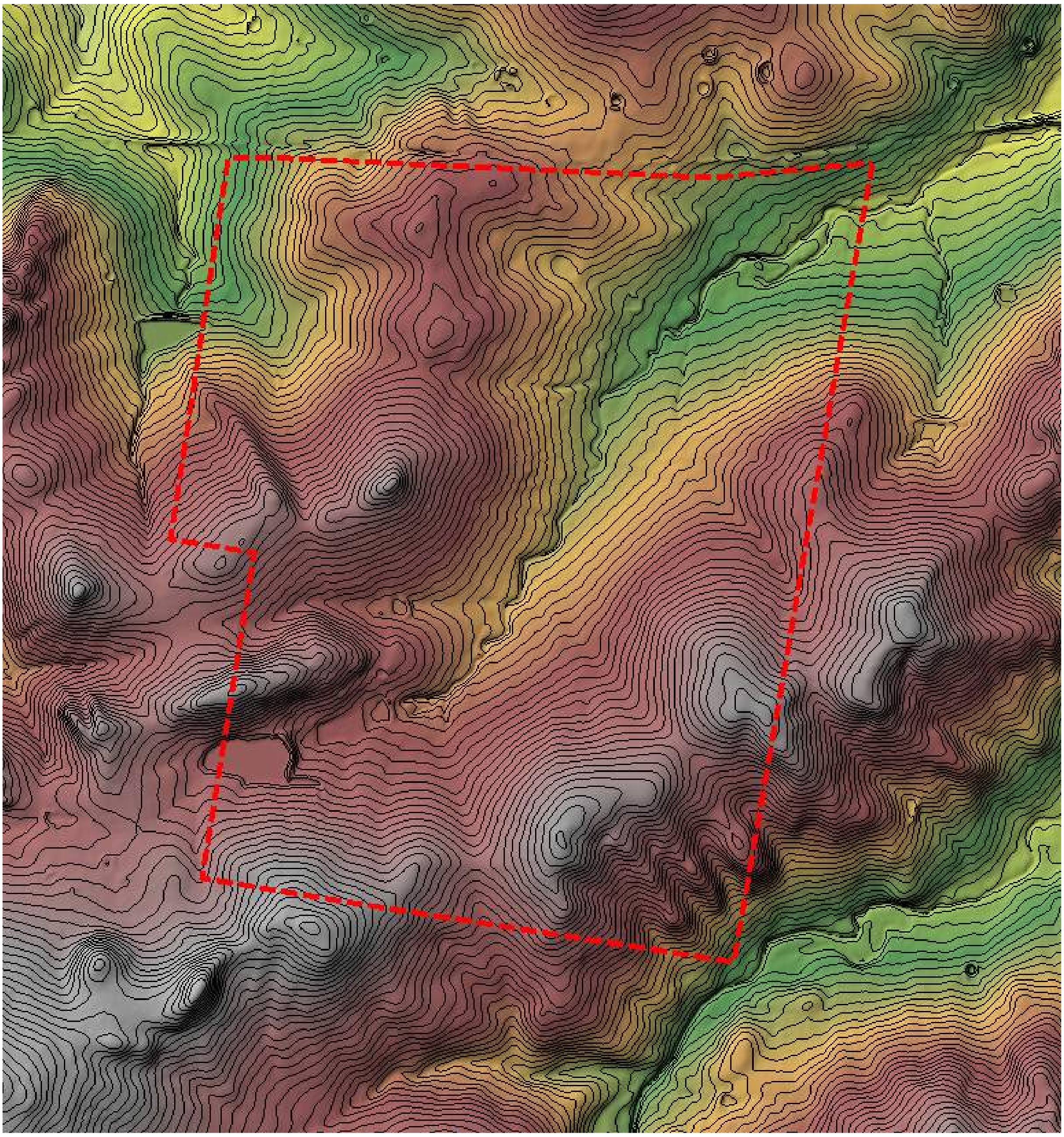


Figure 3: Terrain Analysis over Proposal Area (1m contour interval)

3.0 HYDROLOGICAL MODELLING

3.1. Purpose

Hydrological modelling was conducted to inform the HEC-RAS two-dimensional direct rainfall hydraulic model over the proposal area and to determine peak flow hydrographs arriving in Whylandra Creek at the south-eastern corner of the proposal area.

The primary purposes of the hydrological model were to:

i. determine the critical storm duration for the subject site and external catchment, and
ii. determine the median storm within the ensemble of modelled storms such that the hydraulic modelling could be limited to only one storm for each storm event.

3.2. Model Adoption

Hydrological modelling was conducted in DRAINS using a RAFTS storage routing model.

Storage routing models can model larger catchments using a lumped approach by assuming heterogeneity within the sub-catchment to account for the storage and retardence of flows that occurs within the sub-catchment. Such models account for slope and roughness and use a loss model to produce a hydrograph at the sub-catchment outlet.

The RAFTS hydrological model was chosen because it is widely used and accepted across Australia within the industry and has been shown to be insensitive to initial conditions.

3.3. Catchment Areas

The total catchment area contributing to Whylandra Creek at the south-eastern corner of the proposal area was estimated to be approximately 4005 hectares (40.05km^2) and was determined using the 1 second (approx. 30m) hydro-enforced Digital Elevation Model (DEM) which was obtained through the Australian Foundation Spatial Data web portal.

This overall external catchment was dissected into 8 sub-catchments using hydrologic analysis software package Catchment SIM and ranged in size from 429 to 522 hectares, with an average size of approximately 50 hectares. Sub-catchment slopes were derived by CatchmentSIM using the above terrain data.

The catchment over the proposal area itself was dissected into 5 sub-catchments using hydrologic analysis software CatchmentSIM and 5m LiDAR DEM data available through the Australian Spatial Data web portal. The catchments ranging in size from 127 to 257 hectares which an average catchment area of approximately 220 hectares.

A catchment plan and summary of the sub-catchments is shown in Figure 1.1 in Appendix A.

3.4. Modelling Input Parameters

The parameters adopted for hydrological modelling are shown in Table 1.

Table 1: Hydrological Parameters Adopted

Parameter	Value Adopted	Justification/Source
Pervious Area Initial Loss (mm)	24	Value obtained through ARR data hub (refer Appendix B)
Pervious Area Continuing Loss (mm/h)	0.6	40% of the value obtained through ARR data hub (refer Appendix B) in accordance with recommended NSW loss hierarchy (level 5)
BX	1	RAFTS Default
Sub-catchment Area (ha)	Varies	As per Figure 1.1 in Appendix A
Impervious Area (%)	0	Based on assessment of aerial photography. No directly connected impervious areas
Sub-catchment Slope (%)	Varies	Varies based on site topography.
Manning's n	Varies 0.035 – 0.04	Based on aerial photography and varies from 0.035 for catchments dominated by rural pasture lands to 0.04 for catchment containing a mix of vegetated areas and rural pasture lands. Refer to Figure 1.1 in Appendix A.

3.5. Rainfall Data

3.5.1. Design Rainfall

IFD design rainfall depth data and temporal patterns were derived in accordance with Australian Rainfall and Runoff (2019) using the Bureau of Meteorology's 2019 Rainfall IFD on-line Data System.

The temporal patterns for the Central Slopes (CS) region were used as these cover the subject site (latitude -32.274, longitude 148.476).

A copy of the rainfall depths for the range of storm durations used can be found in Appendix C. Storm probabilities in ARR2019 are now classified in two ways: Very Frequent storms, quantified as 'Exceedances per Year' (EY), and both Frequent and Infrequent storms given as Annual Exceedance Probability (AEP). The 'very frequent' storms have only been used for the 1EY, 0.5EY and the 0.2EY as these are equivalent to the former classifications of 1 in 1 year, 1 in 2 year and 1 in 5 year storms respectively (ARR 2016 state that the 50% AEP and the 20% AEP do not correspond statistically to the 1 in 2 year and 1 in 5 year storms, but rather are equivalent to the 1 in 1.44 year and 1 in 4.48 year storms respectively).

3.5.2. Pre-Burst Rainfall

NSW transformation pre-burst rainfall depths derived from ARR 2019 data hub (refer Appendix D) were adopted in the model.

3.5.3. Probable Maximum Precipitation

The PMF is the response of the catchment to the probable maximum precipitation (PMP) and is the largest flood event that can reasonably be expected to occur at a location.

Estimates of PMP were made using the Generalised Short Duration Method (GSDM) presented in Bureau of Meteorology (2003) and are provided in Table 2. This method is appropriate for estimating extreme rainfall depths for catchments up to 1000km^2 in area and storm durations up to 6 hours and is therefore considered appropriate for the subject catchment. For the subject catchment PMP rainfall depths were limited to a maximum 3 hour duration.

Table 2: Estimate of PMP

Duration (Hours)	PMP Estimate (mm)
0.25	130
0.50	200
0.75	250
1.0	300
1.5	380
2.0	440
2.5	490
3.0	540

Due to the inability of DRAINS (and HEC-RAS) to model spatially variable rainfall no adjustment to the point values above where made.

The hydrological results obtained through modelling point PMP values in lieu of spatially variable PMP values would therefore be slightly higher than actual flows and therefore conservative.

The PMP Calculation spreadsheet is included in Appendix E

3.6. Flow Routing

Flows were routed between each sub-catchment using simple translation with attenuation time based on reach length and an assumed flow velocity of 2.5m/s.

3.7. Results

The DRAINS model was run in ‘standard’ mode for storm durations ranging from 10 minutes to 6 hours for the 5% and 1% AEP events and 15 minutes to 3 hours for the PMF event.

The critical duration and median storm from the ensemble, where applicable, for the range of events modelled are shown in Table 3.

Table 3: Summary of Critical Durations and Storms

Event	Proposal Area (Main Catchment)			Whylandra Creek		
	Critical Duration	Median Storm from Ensemble	Peak Flow at Outlet (m^3/s)	Critical Duration	Median Storm from Ensemble	Peak Flow at Outlet (m^3/s)
5% AEP	3 hours	Storm 8	28.9	4.5 hours	Storm 6	144
1% AEP	2 hours	Storm 10	47.8	3 hours	Storm 7	225
PMF	2 hours	N/A	422	3 hours	N/A	2,140

3.7.1. Comparison to Regional Flood Frequency Model

A comparison of peak flows for the 5% and 1% AEP events from DRAINS were compared to the peak flows obtained through the Regional Flood Frequency Estimation (RFFE) Model for both the proposal area and external catchment and the results are shown in Table 5 and Table 5 respectively, with a copy of the RFFE Model report for each contained in Appendix F.

The comparison shows that peak flows derived by the DRAINS hydrological model are towards the lower confidence limit for the proposal area catchment and close to the mean discharge for the external catchment model.

Analysis of the RFFE results for the proposal area catchment shows that the catchment area is at least an order to magnitude less than the reference catchments used in the RFFE analysis and therefore the results are likely to be skewed towards the higher flows reported.

Given the above the hydrological results obtain through DRAINS modelling is considered suitable for use in the flood model.

Table 4: Comparison to RFFE Model – Proposal Area

AEP	Peak Flow Rate (cumecs)			
	DRAINS	Regional Flood Frequency Estimation Model		
		Discharge	Lower (5%)	Upper (95%)
5%	28.9	44.9	19.7	103
1%	47.8	92.2	39.7	215

Table 5: Comparison to RFFE Model – External Catchment

AEP	Peak Flow Rate (cumecs)			
	DRAINS	Regional Flood Frequency Estimation Model		
		Discharge	Lower (5%)	Upper (95%)
5%	144	117	51.1	268
1%	225	240	103	561

4.0 HYDRAULIC MODELLING

Hydraulic modelling was conducted using an unsteady direct rainfall two-dimensional HEC-RAS model (Version 5.0.7) which covered the proposal area with an inflow boundary representing flows in Whylandra Creek on the south-eastern corner of the site.

4.1. Two-Dimensional Domain

A digital elevation model (DEM) of the entire catchment areas draining to the subject site was established using a series of 5m gridded digital elevation models (Dubbo201301.asc) sourced from www.elevation.fsdf.org.au.

A two-dimensional flow area (i.e. active cells) was defined over the catchment area draining to the proposal area to simulate the rainfall-runoff process. The extent of the two-dimensional flow area is shown in Figure 4.

The 5m DEM grid was imported into HEC-RAS and used as the basis for development of a 10m x 10m terrain model. The DEM grid was further refined where required by applying breaklines to enforce abrupt changes in geometry, such as along existing watercourses.

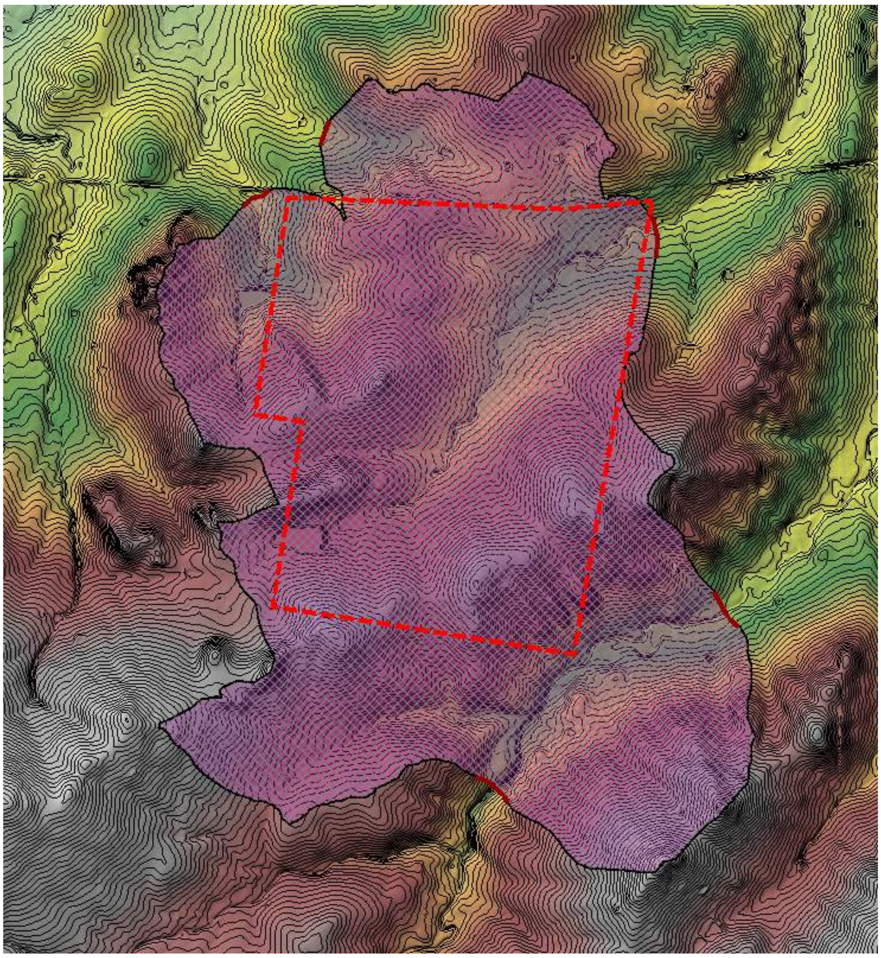


Figure 4: Two-Dimensional Flow Area

4.2. Manning's Roughness

Manning's roughness values adopted for design event modelling are shown in Figure 2.1 in Appendix G.

4.3. Direct Rainfall Boundary Condition

The direct rainfall boundary condition applies precipitation directly to the surface of the grid to perform two-dimensional hydraulic calculations.

The current limitation of HEC-RAS 5.0.7 means that precipitation can only be used to apply rainfall excess (rainfall minus losses due to interception/infiltration) directly to the two-dimensional grid.

Rainfall excess hyetographs for each of the critical duration median storm events for the proposal area catchment shown in Table 3 were generated in Microsoft Excel by subtracting initial losses plus pre-burst rainfall (where applicable) from the design rainfall data starting from the beginning of the data set. An example of this for the 1% AEP, 1-hour storm event is shown in Figure 5.

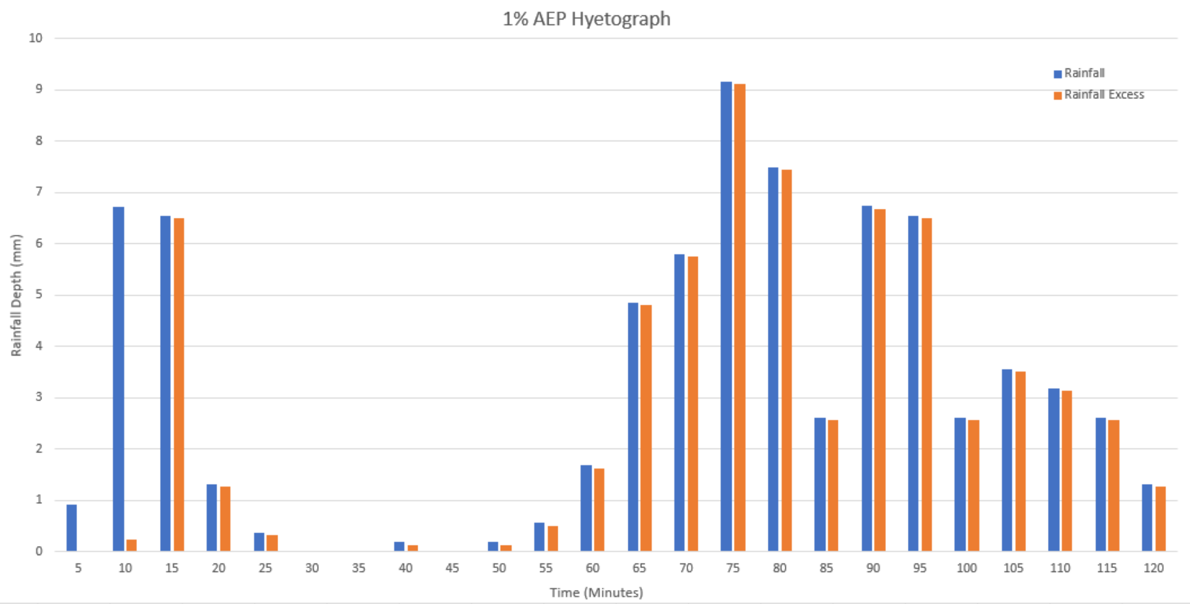


Figure 5: 1% AEP Hyetograph

4.3.1. Downstream Boundary Condition

Flows leaving the two-dimensional area were defined with a normal depth downstream boundary condition with a friction slope approximating the gradient of the land at the location of the boundary. The friction slope method uses the Manning's equation to compute a normal depth for each given flow, based on the cross section underneath the two-dimensional boundary condition line and is computed on a per cell basis.

4.4. Results

The HEC-RAS model was run in unsteady mode with variable timestep controlled by Courant conditions using the diffusion wave computational method. The pre-development results are provided in Appendix H and include the mapping shown in Table 6.

The results include the mapping of flood hazard vulnerability in accordance with Book 6, Chapter 7 of Australian Rainfall and Runoff (2019) as described further in Section 4.4.1.

Table 6: Summary of Pre-Development Results

Figure	Description
Figure 3.1	Maximum Flood Levels and Depths – 5% AEP
Figure 3.2	Maximum Flood Velocities – 5% AEP
Figure 3.3	Maximum Flood Hazard – 5% AEP
Figure 4.1	Maximum Flood Levels and Depths – 1% AEP
Figure 4.2	Maximum Flood Velocities – 1% AEP
Figure 4.3	Maximum Flood Hazard – 1% AEP
Figure 5.1	Maximum Flood Levels and Depths – PMF
Figure 5.2	Maximum Flood Velocities – PMF
Figure 5.3	Maximum Flood Hazard – PMF

4.4.1. Hazard Vulnerability

The flood hazard vulnerability over the subject site was mapped in accordance with Table 6.7.4 of Australian Rainfall and Runoff (2019) and is shown in Figures 3.3, 4.3 and 5.3 in Appendix H for the 5%AEP, 1%AEP and PMF events respectively.

Table 6.7.3 of Australian Rainfall and Runoff (below) describes the hazard thresholds for community interaction with floodwaters.

Table 6.7.3. Combined Hazard Curves - Vulnerability Thresholds (Smith et al, 2014)

Hazard Vulnerability Classification	Description
H1	Generally safe for vehicles, people and buildings.
H2	Unsafe for small vehicles.
H3	Unsafe for vehicles. children and the elderly.
H4	Unsafe for vehicles and people.
H5	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure.

4.4.2. Results Discussion

The results of the pre-development flood assessment demonstrates that flooding is generally isolated to mapped watercourses and other existing depressions over the site with the flood extents generally contained in relatively narrow bands over these areas. As expected, the flood extent in the PMF event becomes more widespread and results in deeper flows that impact a much larger portion of the site.

The hazard mapping shows that flooding within the proposal area is primarily classified as a H1 hazard vulnerability in the 5% AEP and 1% AEP events, except for flooding within the more major unnamed water and existing dames which reach up to H5 classification. As expected, hazard increases significantly over the proposal area in the PMF event.

5.0 IMPACT OF PROPOSED WORKS

5.1. Proposal Description

The proposal involves the construction, operation and decommissioning of a ground mounted PV solar array which would generate approximately 110 Megawatts (DC) to be supplied directly to the national electricity grid.

The Proposal would provide enough clean, renewable energy for about 40,000 average NSW homes while displacing approximately 164,000 metric tons of carbon dioxide annually. The proposal site is approximately 789 hectares of which approximately 444 hectares would be developed for the solar farm and associated infrastructure (Development Footprint).

One existing Essential Energy transmission line transects the site and would be used to connect the solar farm to the national electricity grid.

The primary access point during construction and operation for light and heavy vehicles would be off Delroy Road, north of the site.

Key development and infrastructure components would include:

- 150,000-200,000, PV modules on tracking systems
- Internal access roads, typically 4m wide minimum. Approximately 37,570m of track in total
- 1 watercourse crossing for internal access roads
- A Battery and Energy Storage System (BESS) with a capacity of approximately 25MWh (i.e., 25MW power output for one hour).
- Approximately 20-25 Power Conversion Units (PCUs) composed of two inverters, a transformer and associated control equipment to convert DC energy generated by the solar panels to 33kV AC energy.
- An onsite 132kV substation containing two transformers and associated switchgear to facilitate connection to the national electricity grid via the existing 132kV transmission line onsite.
- Underground power cabling to connect solar panels, combiner boxes and PCUs.
- Underground auxiliary cabling for power supplies, data services and communications.
- Buildings to accommodate a site office, 33kV switchgear, protection and control facilities, maintenance facilities and staff amenities.
- Perimeter security fencing up to 2.3m high.

In total, the construction phase of the proposal is expected to take 12 to 18 months, and the facility would be expected to operate for around 35 years or extended pending further approvals. Up to five fulltime equivalent operations and maintenance staff and service contractors would operate the facility.

At the end of its operational life, the facility would be decommissioned. Underground cables buried at 500mm deep and greater would likely remain in situ after decommissioning.

The Proposal would require subdivision of Deposited Plan Lots within the proposal site for lease and purchase agreement purposes with the involved landowner.

5.2. Hydraulic Modelling

An assessment of the impact of the proposed permanent infrastructure on flooding was undertaken by increasing the surface roughness over the proposed development footprint to account for solar array infrastructure and buildings.

Typical solar array modules consist of a frame supported by piers at a typical grid spacing of 5-6m. The addition of the solar arrays and their associated infrastructure will result in an increase in surface roughness over the site, from grazed/cropped pasture to a regular grid of steel piers.

The change in floodplain roughness associated with the proposed solar arrays was assessed using the Modified Cowan Method for Floodplain Roughness and is shown in Table 7. It should be noted that only n_3 (effect of obstructions) has been modified to represent the change in roughness associated with the solar array piers, all other variables remain at pre-development values which are variable across the site and hence have remained at n_b, n_1 etc.

It demonstrates that the roughness is anticipated to slightly increase because of the proposed development.

Table 7: Modified Cowan Method for Estimation of Floodplain Roughness

Roughness Component	**Existing (Grazed Pasture)**	**Proposed (Solar Array)**
Floodplain Material (n_b)	n_b	n_b
Degree of Irregularity (n_1)	n_1	n_1
Variation in Floodplain Cross Section (n_2)	n_2	n_2
Effect of Obstructions (n_3)	0.000	0.003[1]
Amount of Vegetation (n_4)	n_4	n_4
Change in Roughness (n)	0.000	0.003

[1] Based on an obstruction of 2.5% of the available flow area (i.e. 150mm piers at 5-6m intervals)

The increase in roughness was applied to the pre-development roughness values shown in Figure 2.1 in Appendix G over the extent of the proposed solar array footprint. The post development roughness is shown on Figure 2.2 in Appendix I.

The area nominated for the proposed substation, battery storage and O&M facilities, including parking areas was assigned a Manning's n value of 3 to reflect the impact of the proposed buildings and structures in these areas.

It should be noted that the proposed development would include a network of access roads and these would be constructed from gravel and within the floodplain itself would be constructed at the existing surface level so as not to result in adverse impact on flood behaviour.

In accordance with the Modified Cowan Method of Floodplain Roughness gravel has a similar floodplain roughness to that of the surrounding pre-development floodplain roughness. On this basis, and considering the fact these tracks are likely to be less than 10m in width and therefore not well represented by the model, the marginal increase in floodplain roughness associated with the proposed road network has not been included in the post development model.

Furthermore, watercourse crossings have not been included in the model as fords or bridges, which minimise any hydraulic impact, have been recommended (see Section 6.4).

The post development hydraulic model is therefore considered to be representative of the development as proposed and therefore reflective of the hydraulic impacts associated with the development.

The hydraulic model was re-run to assess the impact of an increase in surface roughness on flood behaviour for the 1% AEP event and the results in included in Figures 6.1, 6.2 and 6.3 in Appendix H.

The results in Figures 6.1, 6.2 and 6.3 demonstrate that there is not predicted to be a significant impact on flood behaviour within the floodplain as a result of the proposed works, with flood levels, depths, velocities and hazards remaining relatively unchanged.

This is better demonstrated in Figures 7.1 and 7.2 (Appendix H) which show the change in maximum flood level and peak flood velocity resulting from the proposed development. These figures show that peak flood levels and velocities over most of the proposal area are anticipated to remain unchanged, due primarily to the infrastructure being located outside of areas subject to flooding.

The most significant change observed is that in proximity of the proposed substation and battery energy storage system where a significant increase in flood extent (was dry now wet) is predicted. This increase in flood extent is because of rainfall falling directly on the proposed area and being unable to runoff due to the artificially high Manning's n value of 3.0 adopted. In reality, any building or structures on the land would allow water to readily runoff without ponding. The above is also shown to result in a slight reduction in flood levels (up to about 100mm) perpetuating for some distance downstream of the area.

Further, velocities over the proposal area are shown to largely remain in the range of plus or minus 0.25m/s and therefore should not result in any adverse impact to the stability of the bed and banks of existing waterways.

6.0 FLOOD MANAGEMENT RECOMMENDATIONS

6.1. Buildings and Structures

All buildings and structures (including solar arrays) associated with the proposal should be located outside high hazard areas (H5 and above) where they may be vulnerable to structural damage and have significant impact on flood behaviour.

The finished floor level of all buildings should be a minimum of 500mm above the 1% AEP flood level.

6.2. Flood Management

As the proposal area is flood affected it is recommended that:

i. Flood warning signs and flood level indicators should be placed on each approach to any proposed watercourse crossings that is subject to inundation.
ii. A Business Floodsafe Plan be prepared for the development to ensure the safety of employees during flood events in general accordance with the NSW SES "Business Floodsafe Toolkit and Plan"

6.3. Solar Array Field

For fixed solar panel modules, the mounting height of the module frames should be designed such that the lower edge of the frame is clear of the predicted 1% AEP flood level plus 500mm freeboard so as not to impact on existing flood behaviour and to prevent the infrastructure from being damaged from flooding.

For solar tracking modules, the tracking axis should be located above the 1%AEP flood level plus 500mm freeboard, and the modules rotated to the horizontal during significant flood events to provide maximum clearance to the predicted flood level.

Where located in the floodplain the solar array mounting piers should be designed to withstand the forces of floodwater (including any potential debris loading) up to the 1% AEP flood event, giving regard to the depth and velocity of floodwaters. Post development 1% AEP flood levels and velocities are included in Figures 6.1 and 6.2 respectively in Appendix H.

6.4. Electrical Infrastructure

All electrical infrastructure, including power conversions stations and the proposed substation, should be located above the 1% AEP flood level plus appropriate freeboard (min 500mm).

Where electrical cabling is required to be constructed below the 1% AEP flood level it should be capable of continuous submergence in water.

6.5. Perimeter Fencing

Wherever possible security fencing within the floodplain should be avoided or minimised. Where required security fencing should be constructed in a manner which does not adversely affect the flow of floodwater and should be designed to withstand the forces of floodwater or collapse in a controlled manner to prevent impediment to floodwater.

Fencing across the primary watercourse traversing the proposal area should be avoided in preference to creating two separate fenced compounds on either side of the watercourse.

6.6. Watercourse Crossings

Watercourses on the subject site have been classified by the Strahler System in accordance with the Guidelines for Riparian Corridors on Waterfront Land (DPI Water, 2012) and are shown in Figure 8.1 in Appendix J. Any road crossings on watercourses within the subject site should be of the type defined in Table 2 of this same document (see extract below).

Table 2. Riparian corridor matrix

Stream order	Vegetated Riparian Zone (VRZ)	RC off-setting for non RC uses	Cycleways and paths	Detention basins		Stormwater outlet structures and essential services	Stream realignment	Road crossings		
				Only within 50% outer VRZ	Online			Any	Culvert	Bridge
1st	10m	•	•	•	•	•	•	•		
2nd	20m	•	•	•	•	•		•		
3rd	30m	•	•	•		•			•	•
4th +	40m	•	•	•		•			•	•

Any proposed crossings (vehicular or service) of existing watercourses on the subject site should be designed in accordance with the following guidelines, and, in the case of vehicular crossings should preferably consist of bed level crossings constructed flush with the bed of the watercourse on first and second order watercourses to minimise any hydraulic impact:

i. Guidelines for Watercourse Crossings on Waterfront land (NSW DPI, 2012)
ii. Guidelines for Laying Pipes and Cable in Watercourses on Waterfront Land (NSW DPI, 2012)

6.7. Access Roads

Within the floodplain access roads should be constructed as close to natural ground levels as possible so as not to form an obstruction to floodwaters.

The surface treatment of roads should be designed giving regard to the velocity of floodwaters to minimise potential for scouring during flood events.

6.8. Erosion Management

Any areas of existing erosion within the proposed development footprint should be appropriately treated prior to the erection of solar array modules to ensure their ongoing stability.

For further information refer to Saving Soil: A Landowners Guide to Preventing and Repairing Soil Erosion, NSW DPI (2009) available at
https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0008/270881/saving-soil-complete.pdf

7.0 SEAR'S COMPLIANCE

The Department of Planning and Environment issued environmental assessment requirements (SEARs) for the preparation of an Environmental Impact Assessment (EIS) for the proposed development on 30 October 2020, which included requirements from the Biodiversity, Conservation and Science Directorate of the NSW Department of Planning, Industry and Environment pertaining to flooding. Table 8 below demonstrates how this report addresses the OEH SEAR's requirements with respect to flooding.

Table 8: Assessment of Compliance with SEAR's

OEH Requirement	**Response**
10. The EIS must map the following features relevant to flooding as described in the Floodplain Development Manual 2005 (NSW Government 2005), including:	
a. Flood Prone Land.	Flood Prone Land for the 5% AEP, 1% AEP and PMF have been defined over the proposal area as defined in Section 4.4 of this report.
b. Flood Planning Area, the area below the flood planning level.	Whilst an important tool in the management of flood risk the delineation of a flood planning areas is not considered relevant for the proposed development as the development does not comprise filling or habitable structures within the floodplain. Notwithstanding, Section 6.3 recommends setting proposal solar array panels a minimum of 500mm above the 1% AEP flood level.
c. Hydraulic Categorisation (floodways and flood storage areas).	Hydraulic categorisation is not considered relevant for the proposed development as they are a tool to assist in the preparation of appropriate floodplain risk management plans. The Floodplain Development Manual (2005) states that "they are not to be used for assessment of development proposals on an isolated or individual basis".

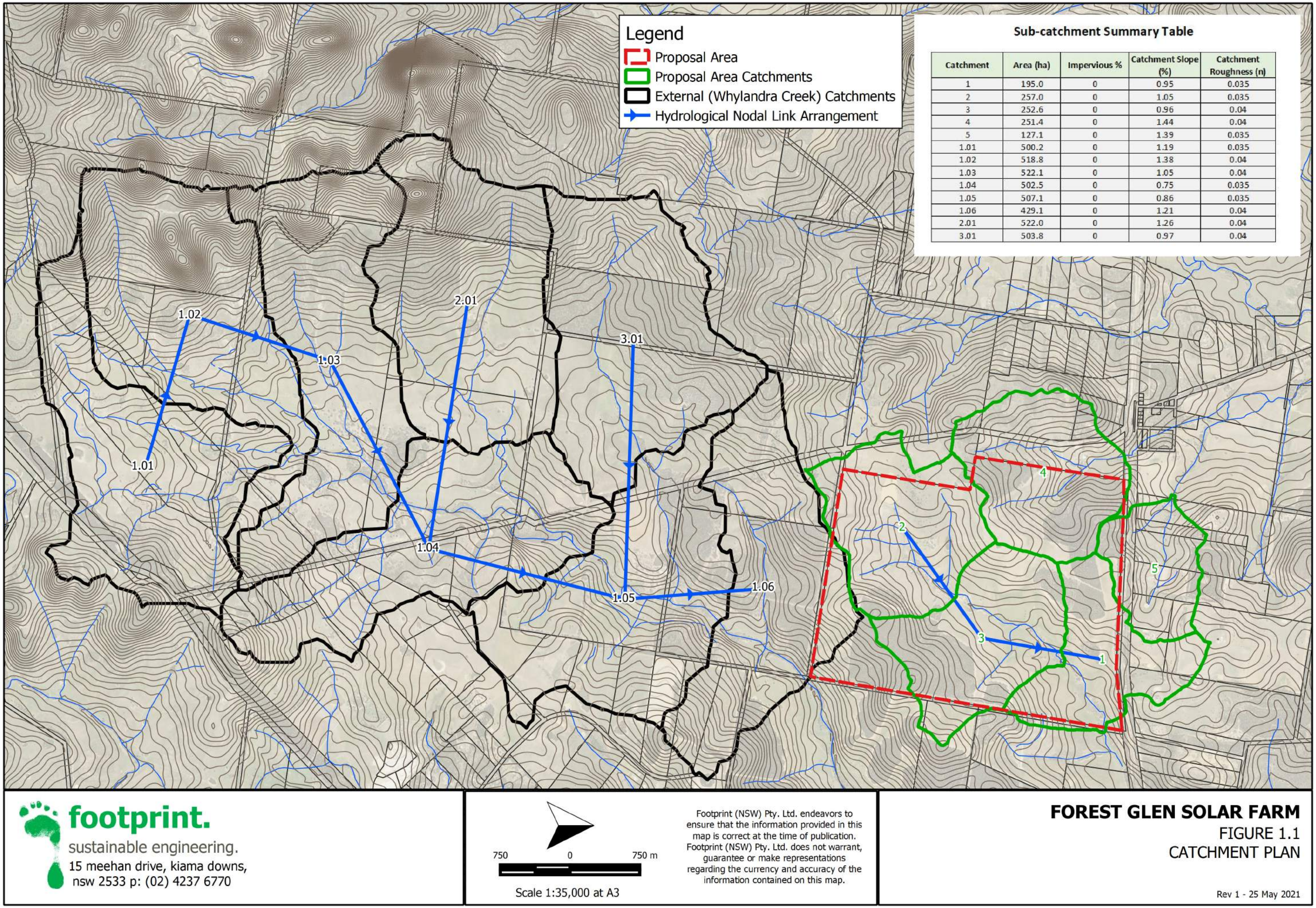
OEH Requirement	Response
d. Flood Hazard.	Flood Hazard Categorisation for all design storm events modelled was undertaken in accordance with Table 6.7.4 of Australian Rainfall and Runoff (2016) and is included in Section 4.4.1 of this report.
11. The EIS must describe the flood assessment and modelling undertaken in determining the design flood levels for events, including a minimum of the 5% AEP, 1% AEP flood levels and the PMF, or equivalent extreme event.	The methodology and modelling undertaken in determining flood levels and velocities is described in details in Sections 3.0 and 4.0 of this report.
12. The EIS must model the effect of the proposed development (including fill) on the flood behaviour under the following scenarios:	
a. Current flood behaviour for a range of design events as identified in 15 above. This includes the 0.5% and 0.2% year flood events as proxies for assessing sensitivity to an increase in rainfall intensity of flood producing rainfall events due to climate change.	The impact of the proposed development on flood behaviour is described in detail in Section 0 of this report. Modelling for 1% AEP only was undertaken and shows minimal impact on existing flood behaviour. It is not considered necessary to model the 0.5% and 0.2% AEP events as proxies for assessing the sensitivity to an increase in rainfall intensity as the proposed development is relatively insensitive to flooding and will incorporate measures (such a solar array panels being a minimum of 500mm above the 1% AEP flood level) to minimise flood damages to proposed infrastructure.
13. Modelling in the EIS must consider and document:	
a. Existing Council flood studies in the area and examine consistency to the flood behaviour documented in these studies.	No existing studies are known to exist within proximity of the proposal area.
b. The impact on existing flood behaviour for a full range of flood events including up to the probably maximum flood, or equivalent extreme flood.	The impact of existing flood behaviour up to the PMF event has been included in this assessment

OEH Requirement	Response
c. Impacts of the development on flood behaviour resulting in detrimental changes in potential flood affection of other developments or land. This may include redirection of flow, flow velocities, flood levels, hazard categories and hydraulic categories	Section 0 of this report demonstrates that the impacts of the proposed development are very minor change in flood level and velocity within the proposal area. Importantly the modelling demonstrates that changes in peak flood levels are largely limited to within the proposal area and are therefore not anticipated to adversely affect adjoining properties
d. Relevant provision of the NSW Floodplain Development Manual 2005	This report is considered to address the relevant provisions of the NSW Floodplain Development Manual.
14. The EIS must assess the impacts on the proposed development on flood behaviour including:	
a. Whether there will be detrimental increases in the potential flood affectation of other properties, assets and infrastructure.	The post development modelling presented in Section 0 shows that the proposed development will have negligible impact on existing flood behaviour, and negligible change in flood behaviour of other properties, assets or infrastructure.
b. Consistency with Council Floodplain Risk Management Plans	No known Floodplain Risk Management Plan exists for the proposal area.
c. Consistency with any Rural Floodplain Management Plan	No known Rural Floodplain Management Plans exist for the proposal area.
d. Compatibility with the flood hazard of the land	The development is compatible with the flood hazard of the site as infrastructure proposed as part of the development is typically located on low flood hazard land.
e. Compatibility with the hydraulic functions of flow conveyance in floodways and storage in flood storage areas of the land.	The layout of proposed infrastructure has been undertaken in consideration of flood risk with development located outside land subject to mainstream flooding and where located within the floodplain typically located on land with low associated flood risk.

OEH Requirement	Response
f. Whether there will be adverse effect to beneficial inundation of the floodplain environment, on, adjacent to or downstream of the site.	The proposed development will not result in any change to the current flooding regime on the proposal area and beneficial inundation of the floodplain environment will continue to occur.
g. Whether there will be direct or indirect increase in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.	Section 0 indicates that changes in peak velocity resulting from the proposed development are expected to be in the range of plus or minus 0.25m/s which will ensure the stability of the bed and banks of existing watercourses and minimise further erosion potential. Further Section 6.8 recommends that any areas of existing erosion within the proposed development footprint should be appropriately treated prior to the erection of solar array modules to ensure their ongoing stability
h. Any impacts the development may have upon existing community emergency management arrangements for flooding. These matters are to be discussed with the NSW SES and Council.	No known community emergency management arrangement exists in proximity of the proposal area.
i. Whether the proposal incorporates specific measures to manage risk to life from flood. These matters are to be discussed with the NSW SES and Council.	Recommendations regarding specific measures to manage the risk to life from flooding and evacuation are provided in Section 6.2 and include flood warning signs for watercourse crossings and preparation of a Business Floodsafe Plan. Whilst not discussed with the NSW SES or Council they are considered standard flood management measures.
j. Emergency management, evacuation and access, and contingency measures for the development considering the full range of flood risk (based upon the probable maximum flood or an equivalent extreme flood event). These matters are to be discussed with and have the support of Council and the NSW SES.	
k. Any impacts the development may have on the social and economic costs to the community as consequence of flooding.	The proposed development is not anticipated to have any adverse impact on the social and economic costs to the community as a result of flooding.

APPENDIX A

Catchment Plan



Sub-catchment Summary Table

Catchment	Area (ha)	Impervious %	Catchment Slope (%)	Catchment Roughness (n)
1	195.0	0	0.95	0.035
2	257.0	0	1.05	0.035
3	252.6	0	0.96	0.04
4	251.4	0	1.44	0.04
5	127.1	0	1.39	0.035
1.01	500.2	0	1.19	0.035
1.02	518.8	0	1.38	0.04
1.03	522.1	0	1.05	0.04
1.04	502.5	0	0.75	0.035
1.05	507.1	0	0.86	0.035
1.06	429.1	0	1.21	0.04
2.01	522.0	0	1.26	0.04
3.01	503.8	0	0.97	0.04

footprint.
sustainable engineering.
15 meehan drive, kiama downs,
nsw 2533 p: (02) 4237 6770

FOREST GLEN SOLAR FARM
FIGURE 1.1
CATCHMENT PLAN

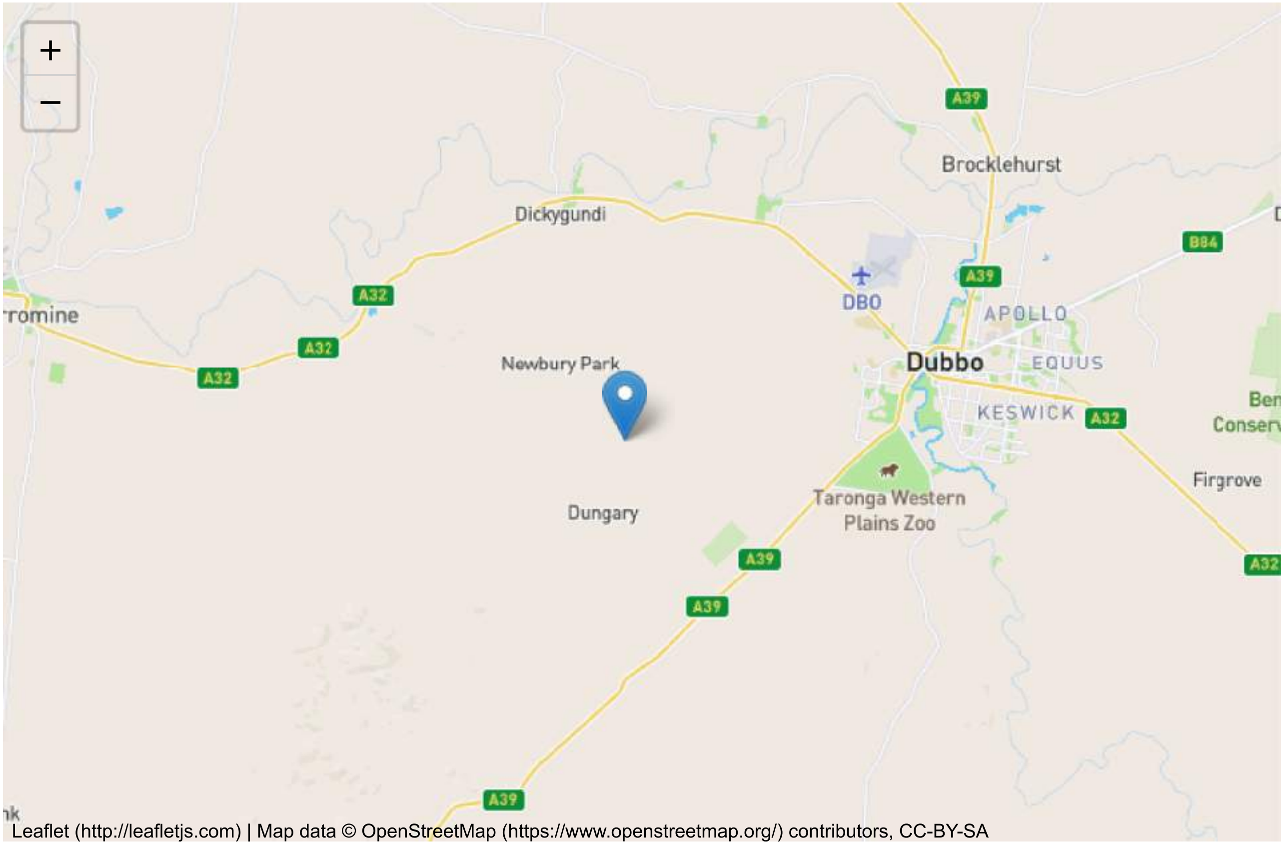
Rev 1 - 25 May 2021

APPENDIX B
ARR Hub Data

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	148.476
Latitude	-32.274
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Probability Neutral Burst Initial Loss (./nsw_specific)	show



Data

River Region

Division	Murray-Darling Basin
River Number	22
River Name	Macquarie-Bogan Rivers

Layer Info

Time Accessed	18 January 2021 10:34AM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^b - c\log_{10}Duration\right)Duration^{-d} + eArea^f Duration^g\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
Central NSW	0.265	0.241	0.505	0.321	0.00056	0.414	-0.021	0.015	-0.00033

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26 \text{ x } 10^{-3} \text{ x } Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141 \text{ x } Area^{0.213} \text{ x } 10^{-0.021\frac{(Duration-180)^2}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	18 January 2021 10:34AM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. The continuing storm loss information from the ARR Datahub provided below should only be used where relevant under the loss hierarchy (level 5) and where used is to be multiplied by the factor of 0.4.

ID	21818.0
Storm Initial Losses (mm)	24.0
Storm Continuing Losses (mm/h)	1.5

Layer Info

Time Accessed	18 January 2021 10:34AM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/CS.zip)

code	CS
Label	Central Slopes

Layer Info

Time Accessed	18 January 2021 10:34AM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_CS.zip)

code	CS
arealabel	Central Slopes

Layer Info

Time Accessed	18 January 2021 10:34AM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-32.274428&longitude=148.476232&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	18 January 2021 10:34AM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	1.7 (0.071)	1.3 (0.039)	1.0 (0.026)	0.8 (0.017)	0.7 (0.012)	0.5 (0.009)
90 (1.5)	0.7 (0.027)	1.0 (0.028)	1.2 (0.028)	1.4 (0.027)	1.1 (0.017)	0.8 (0.011)
120 (2.0)	1.0 (0.033)	1.1 (0.026)	1.1 (0.023)	1.2 (0.021)	1.4 (0.022)	1.6 (0.022)
180 (3.0)	1.1 (0.034)	1.0 (0.022)	0.9 (0.017)	0.8 (0.013)	1.1 (0.014)	1.2 (0.015)
360 (6.0)	1.2 (0.029)	2.4 (0.043)	3.2 (0.048)	3.9 (0.052)	8.4 (0.094)	11.7 (0.116)
720 (12.0)	0.0 (0.000)	3.0 (0.045)	4.9 (0.063)	6.8 (0.075)	9.5 (0.088)	11.6 (0.094)
1080 (18.0)	0.0 (0.000)	0.7 (0.010)	1.2 (0.014)	1.7 (0.017)	4.8 (0.040)	7.1 (0.052)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	3.2 (0.025)	5.6 (0.038)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.4 (0.002)	0.6 (0.004)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	18 January 2021 10:34AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	18 January 2021 10:34AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.001)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	18 January 2021 10:34AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	15.3 (0.643)	11.3 (0.342)	8.6 (0.218)	6.1 (0.132)	9.6 (0.174)	12.2 (0.197)
90 (1.5)	12.5 (0.466)	13.1 (0.351)	13.5 (0.302)	13.8 (0.266)	14.7 (0.239)	15.4 (0.223)
120 (2.0)	14.2 (0.484)	15.4 (0.381)	16.3 (0.337)	17.1 (0.304)	19.4 (0.291)	21.2 (0.283)
180 (3.0)	13.5 (0.411)	14.2 (0.314)	14.7 (0.273)	15.2 (0.242)	20.7 (0.278)	24.8 (0.297)
360 (6.0)	12.6 (0.313)	20.6 (0.375)	25.9 (0.397)	30.9 (0.411)	41.2 (0.460)	48.8 (0.486)
720 (12.0)	7.0 (0.143)	16.7 (0.251)	23.1 (0.294)	29.2 (0.322)	41.5 (0.384)	50.7 (0.415)
1080 (18.0)	4.9 (0.088)	10.8 (0.145)	14.7 (0.168)	18.5 (0.183)	28.1 (0.232)	35.3 (0.257)
1440 (24.0)	0.6 (0.010)	4.4 (0.055)	7.0 (0.074)	9.4 (0.086)	17.9 (0.136)	24.2 (0.162)
2160 (36.0)	0.0 (0.000)	2.5 (0.029)	4.2 (0.040)	5.8 (0.048)	9.4 (0.064)	12.1 (0.072)
2880 (48.0)	0.0 (0.000)	1.2 (0.013)	2.0 (0.018)	2.8 (0.022)	7.4 (0.047)	10.9 (0.060)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	1.7 (0.010)	3.0 (0.015)

Layer Info

Time Accessed	18 January 2021 10:34AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	36.3 (1.523)	29.7 (0.901)	25.4 (0.643)	21.2 (0.461)	38.3 (0.698)	51.0 (0.827)
90 (1.5)	32.9 (1.222)	42.2 (1.133)	48.4 (1.086)	54.3 (1.047)	65.0 (1.054)	73.0 (1.053)
120 (2.0)	31.8 (1.089)	40.4 (0.999)	46.1 (0.954)	51.6 (0.917)	61.3 (0.918)	68.5 (0.914)
180 (3.0)	46.3 (1.410)	49.4 (1.090)	51.5 (0.952)	53.4 (0.851)	67.6 (0.909)	78.2 (0.937)
360 (6.0)	25.7 (0.640)	40.9 (0.745)	51.0 (0.782)	60.6 (0.805)	84.7 (0.947)	102.7 (1.022)
720 (12.0)	21.1 (0.429)	39.2 (0.590)	51.2 (0.652)	62.7 (0.692)	83.0 (0.768)	98.3 (0.804)
1080 (18.0)	18.7 (0.339)	30.7 (0.413)	38.6 (0.441)	46.2 (0.458)	65.2 (0.538)	79.3 (0.577)
1440 (24.0)	9.5 (0.159)	17.3 (0.216)	22.4 (0.237)	27.3 (0.251)	44.4 (0.338)	57.1 (0.382)
2160 (36.0)	5.7 (0.087)	13.4 (0.151)	18.4 (0.176)	23.3 (0.193)	37.1 (0.253)	47.4 (0.282)
2880 (48.0)	5.0 (0.071)	11.3 (0.119)	15.5 (0.138)	19.5 (0.150)	26.0 (0.165)	31.0 (0.171)
4320 (72.0)	1.4 (0.018)	4.6 (0.045)	6.8 (0.055)	8.8 (0.062)	20.5 (0.118)	29.2 (0.146)

Layer Info

Time Accessed	18 January 2021 10:34AM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	**RCP 8.5**
2030	**0.972 (4.9%)**	0.847 (4.2%)	**1.052 (5.3%)**
2040	**1.225 (6.2%)**	1.127 (5.7%)	**1.495 (7.6%)**
2050	**1.452 (7.3%)**	1.406 (7.1%)	**1.971 (10.1%)**
2060	**1.653 (8.4%)**	1.685 (8.6%)	**2.480 (12.9%)**
2070	**1.827 (9.3%)**	1.963 (10.1%)	**3.023 (15.9%)**
2080	**1.974 (10.1%)**	2.241 (11.6%)	**3.599 (19.2%)**
2090	**2.095 (10.8%)**	2.518 (13.1%)	**4.208 (22.8%)**

Layer Info

Time Accessed	18 January 2021 10:34AM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	**50.0**	**20.0**	**10.0**	**5.0**	**2.0**	**1.0**
60 (1.0)	19.0	12.0	12.2	13.9	11.9	9.6
90 (1.5)	19.3	12.6	11.5	11.7	10.3	8.4
120 (2.0)	18.9	12.8	11.6	11.9	10.1	7.2
180 (3.0)	18.1	12.9	12.3	13.0	10.7	6.9
360 (6.0)	19.7	13.6	12.0	10.8	9.0	4.9
720 (12.0)	21.4	15.0	13.0	11.4	9.9	5.5
1080 (18.0)	22.7	17.1	16.3	15.1	12.9	7.5
1440 (24.0)	25.5	20.3	19.7	19.3	15.8	7.4
2160 (36.0)	26.9	21.5	21.1	21.8	18.4	10.0
2880 (48.0)	27.3	22.1	21.7	24.0	19.9	14.7
4320 (72.0)	28.0	24.1	24.9	27.5	22.5	15.9

Layer Info

Time Accessed	18 January 2021 10:34AM
Version	2018_v1

Note	As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.

Download TXT (downloads/eb522084-8398-4478-bf9f-6d4bb435f661.txt)

Download JSON (downloads/28733c04-425a-42d7-9d57-b3fb6f87a6ef.json)

Generating PDF... (downloads/ab2a6dfd-6180-490b-9320-f943bec4db61.pdf)

APPENDIX C

Rainfall Depths

Australian Government
Bureau of Meteorology

Location

Label: Not provided

Latitude: -32.2744 [Nearest grid cell: 32.2625 (S)]

Longitude:148.4762 [Nearest grid cell: 148.4875 (E)]

IFD Design Rainfall Depth (mm)

Issued: 18 January 2021

Rainfall depth for Durations, Exceedance per Year (EY), and Annual Exceedance Probabilities (AEP).
FAQ for New ARR probability terminology

	Annual Exceedance Probability (AEP)						
Duration	**63.2%**	**50%#**	**20%***	**10%**	**5%**	**2%**	**1%**
1 min	1.90	2.15	2.96	3.53	4.10	4.90	5.53
2 min	3.21	3.65	5.08	6.08	7.07	8.35	9.33
3 min	4.43	5.04	6.99	8.35	9.70	11.5	12.9
4 min	5.53	6.27	8.66	10.3	12.0	14.3	16.0
5 min	6.51	7.37	10.1	12.1	14.1	16.7	18.8
10 min	10.1	11.4	15.6	18.6	21.7	25.9	29.3
15 min	12.5	14.1	19.3	23.0	26.8	32.1	36.3
20 min	14.2	16.0	22.0	26.3	30.6	36.7	41.5
25 min	15.5	17.6	24.2	28.9	33.7	40.3	45.6
30 min	16.7	18.8	26.0	31.1	36.2	43.3	49.0
45 min	19.2	21.7	30.0	35.9	41.9	50.0	56.4
1 hour	21.0	23.8	33.0	39.4	46.0	54.8	61.7
1.5 hour	23.7	26.9	37.3	44.6	51.9	61.7	69.4
2 hour	25.7	29.2	40.5	48.4	56.2	66.8	75.0
3 hour	28.9	32.8	45.3	54.1	62.8	74.4	83.5
4.5 hour	32.6	36.9	50.7	60.3	69.9	82.8	92.9
6 hour	35.5	40.2	54.9	65.2	75.4	89.4	100
9 hour	40.2	45.2	61.4	72.7	83.9	99.8	113
12 hour	43.8	49.2	66.5	78.6	90.6	108	122
18 hour	49.3	55.3	74.3	87.6	101	121	138
24 hour	53.4	59.8	80.1	94.4	109	131	150
30 hour	56.6	63.3	84.8	100.0	115	139	160
36 hour	59.2	66.2	88.7	105	121	146	168
48 hour	63.2	70.6	94.9	112	130	158	182
72 hour	68.4	76.6	103	123	142	174	200
96 hour	71.7	80.4	109	130	151	185	213
120 hour	74.0	83.3	114	136	158	193	222

144 hour	76.0	85.6	117	140	163	199	228
168 hour	77.6	87.5	120	144	168	203	233

Note:
The 50% AEP IFD **does not** correspond to the 2 year Average Recurrence Interval (ARI) IFD. Rather it corresponds to the 1.44 ARI.
* The 20% AEP IFD **does not** correspond to the 5 year Average Recurrence Interval (ARI) IFD. Rather it corresponds to the 4.48 ARI.

This page was created at **10:36 on Monday 18 January 2021 (AEDT)**

APPENDIX D

Pre-burst Rainfall Depths

Table E1: NSW Transformation Pre-Burst Rainfall Depths

Storm Duration		Pre-Burst Rainfall Depth (mm)	
		AEP (%)	
min	**hrs**	**5**	**1**
<60[1]	<1	9.9	14.2
60	1	9.9	14.2
90	1.5	12.1	15.4
120	2	11.9	16.6
180	3	10.8	16.9
270[2]	4.5	11.9	17.9
360	6	13	18.9

[1] 60 minute losses adopted
[2] Value interpolated between 180 minute and 360 minute values

APPENDIX E
PMP Calculations

GSDM Calculation Sheet

Location Information				
Catchment	Forest Glen Solar	Area (km2)	40	
State	NSW	Duration Limit (hrs)	3	
Latitude	-32.3265	Longitude	148.4601	
Proportion of Area Considered:				
Smooth S= (0.0 - 1.0)	0	Rough R= (0.0-1.0)	1	
Elevation Adjustment Factor (EAF)				
Mean Elevation (m AHD)			330	
Adjustment for Eelvation (-0.05 per 300m above 1500m)			0	
EAF = (0.85-1.00)			1	
Moisture Adjustment Factor (MAF)				
MAF = (0.40 - 1.00)			0.71	
PMP Values				
Duarion (hrs)	Initial Depth - Smooth	Initial Depth - Rough	PMP Estimate	Rounded PMP Estimate (nearest 10mm)
0.25		190	135	130
0.50		275	195	200
0.75		350	249	250
1.0		420	298	300
1.5		535	380	380
2.0		625	444	440
2.5		695	493	490
3.0		755	536	540

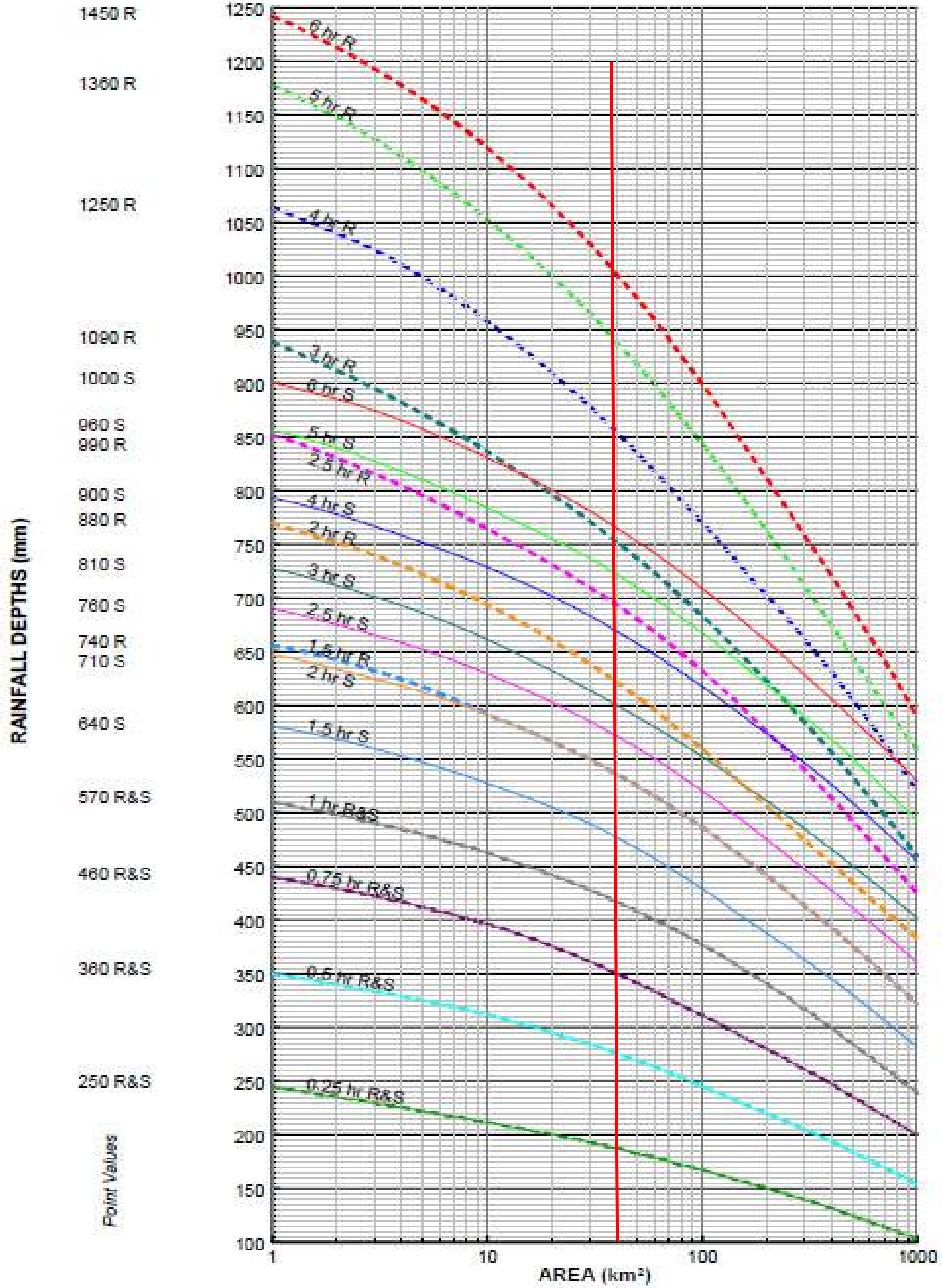
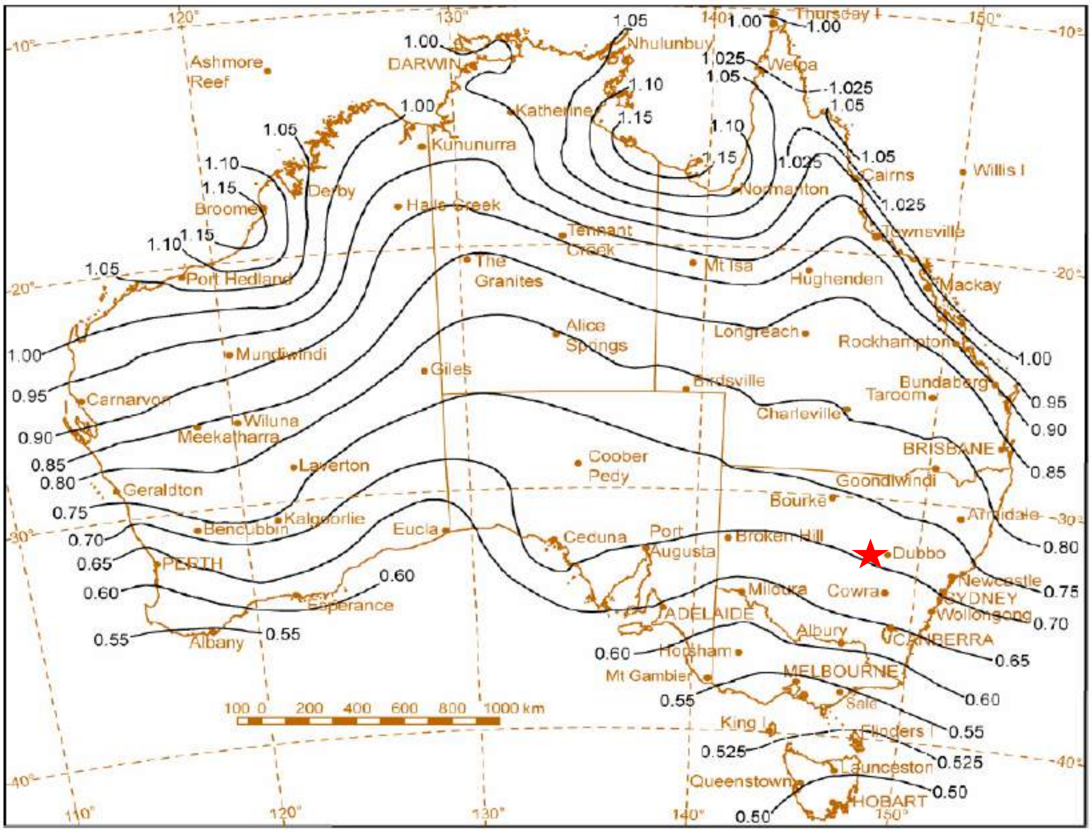


Figure 4: Depth-Duration-Area Curves of Short Duration Rainfall

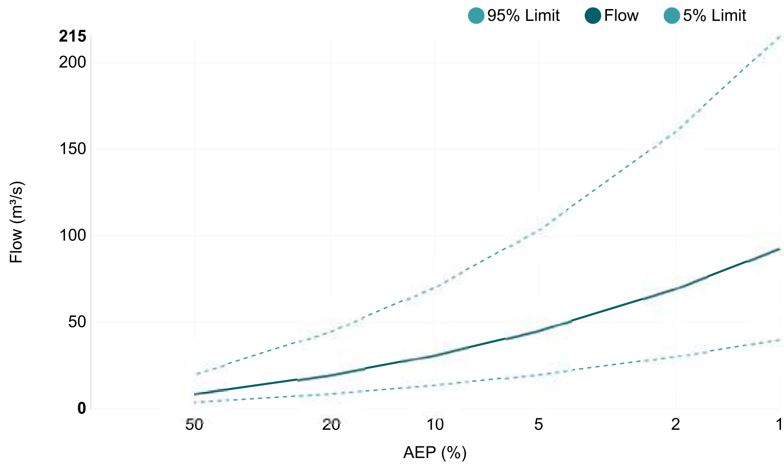


120°
130°
140°
150°
10°
20°
30°
40°
110°
Ashmore Reef
DARWIN
Nhulunbuy
Thursday I
Weipa
Katherine
Kununurra
Derby
Broome
Halls Creek
Tennant Creek
Normanton
Cairns
Willis I
Townsville
Mt Isa
Hughenden
Mackay
Port Hedland
The Granites
Alice Springs
Longreach
Rockhampton
Mundiwindi
Giles
Birdsville
Bundaberg
Taroom
Carnarvon
Wiluna
Meekatharra
Charleville
BRISBANE
Laverton
Coober Pedy
Goondiwindi
Geraldton
Bourke
Armidale
Bencubbin
Kalgoorlie
Eucla
Ceduna
Port Augusta
Broken Hill
Dubbo
PERTH
Newcastle
SYDNEY
Wollongong
Mildura
Cowra
Esperance
ADELAIDE
Albury
CANBERRA
Albany
Horsham
Mt Gambier
MELBOURNE
Sale
King I
Flinders I
Launceston
Queenstown
HOBART
100 0 200 400 600 800 1000 km
1.00
1.05
1.10
1.15
1.025
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.525
0.50

APPENDIX F

RFFE Method Results

Results | Regional Flood Frequency Estimation Model



AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	8.27	3.44	19.7
20	19.5	8.43	44.7
10	30.7	13.4	70.2
5	44.9	19.7	103
2	69.1	30.0	160
1	92.2	39.7	215

Statistics

Variable	Value	Standard Dev
Mean	2.118	0.523
Standard Dev	1.016	0.109
Skew	0.076	0.026

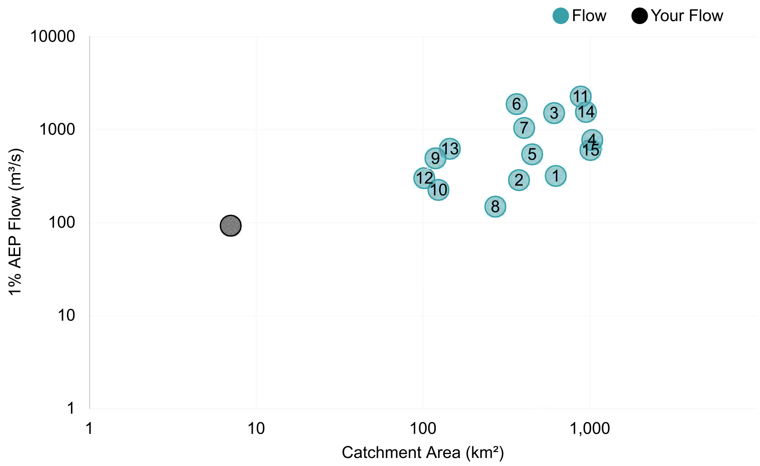
Note: These statistics come from the nearest gauged catchment. Details.

Correlation

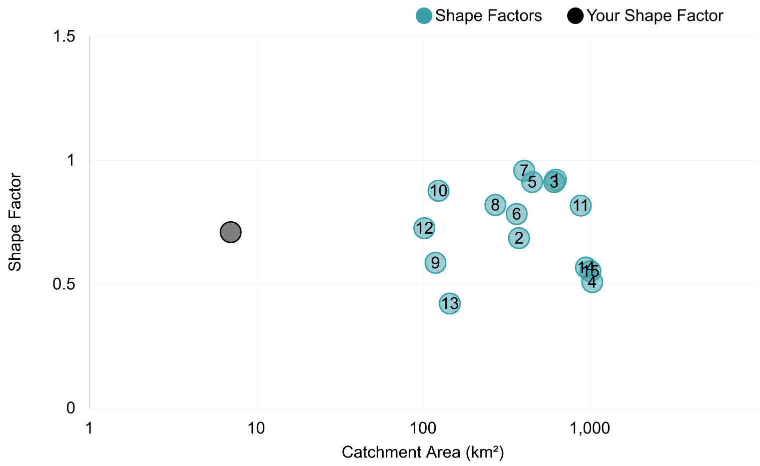
1.000		
-0.330	1.000	
0.170	-0.280	1.000

Note: These statistics are common to each region. Details.

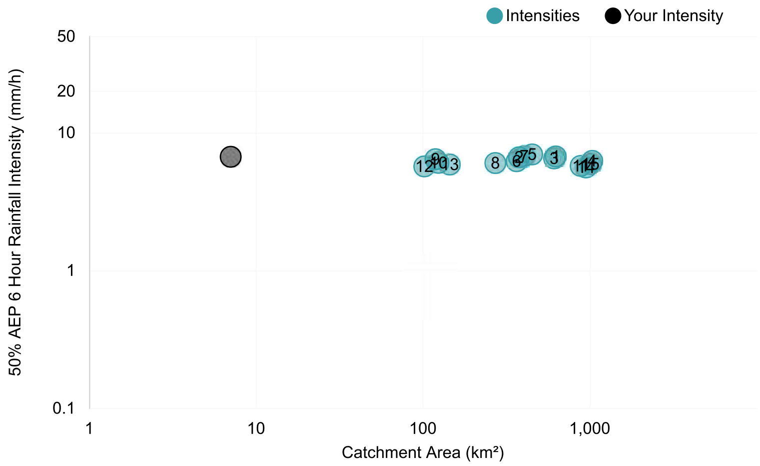
1% AEP Flow vs Catchment Area



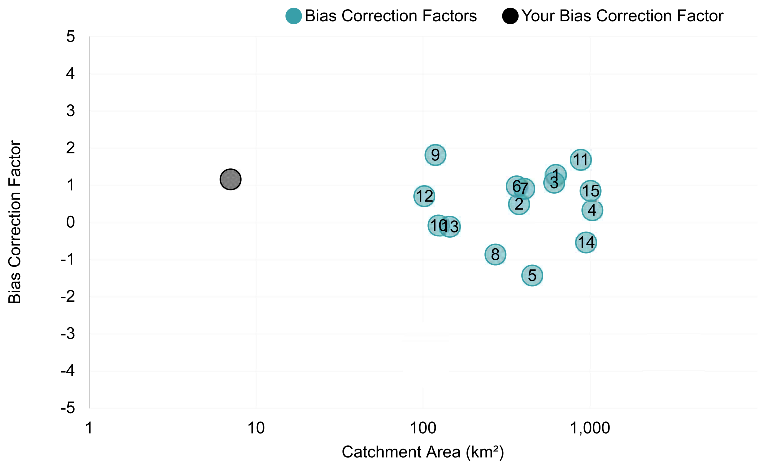
Shape Factor vs Catchment Area



Intensity vs Catchment Area



Bias Correction Factor vs Catchment Area



Download

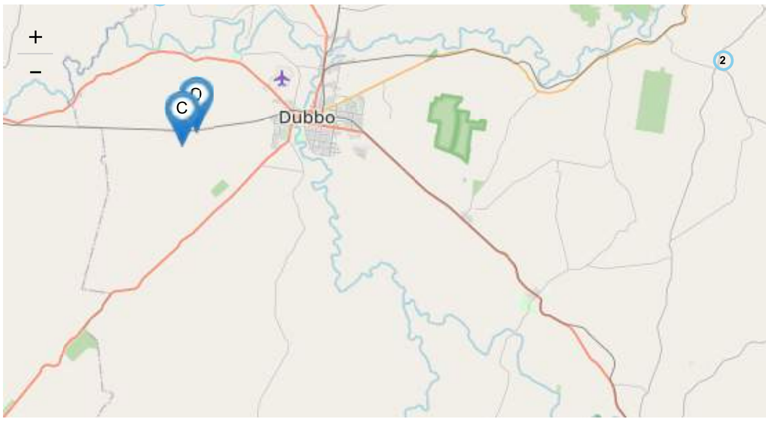
TXT Nearby JSON

Input Data

Date/Time	2021-01-28 11:14

Input Data

Catchment Name	Catchment1
Latitude (Outlet)	-32.2616
Longitude (Outlet)	148.49305
Latitude (Centroid)	-32.27317
Longitude (Centroid)	148.4785
Catchment Area (km^2)	7.05
Distance to Nearest Gauged Catchment (km)	13.45
50% AEP 6 Hour Rainfall Intensity (mm/h)	6.692849
2% AEP 6 Hour Rainfall Intensity (mm/h)	14.858391
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast
Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	0.71
Interpolation Method	Natural Neighbour
Bias Correction Value	1.155



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Method by Dr Ataur Rahman and Dr Khaled Haddad from Western Sydney University for the Australian Rainfall and Runoff Project. Full description of the project can be found at the project page (http://arr.ga.gov.au/revision-projects/project-list/projects/project-5) on the ARR website. Send any questions regarding the method or project here (mailto:admin@arr-software.org).

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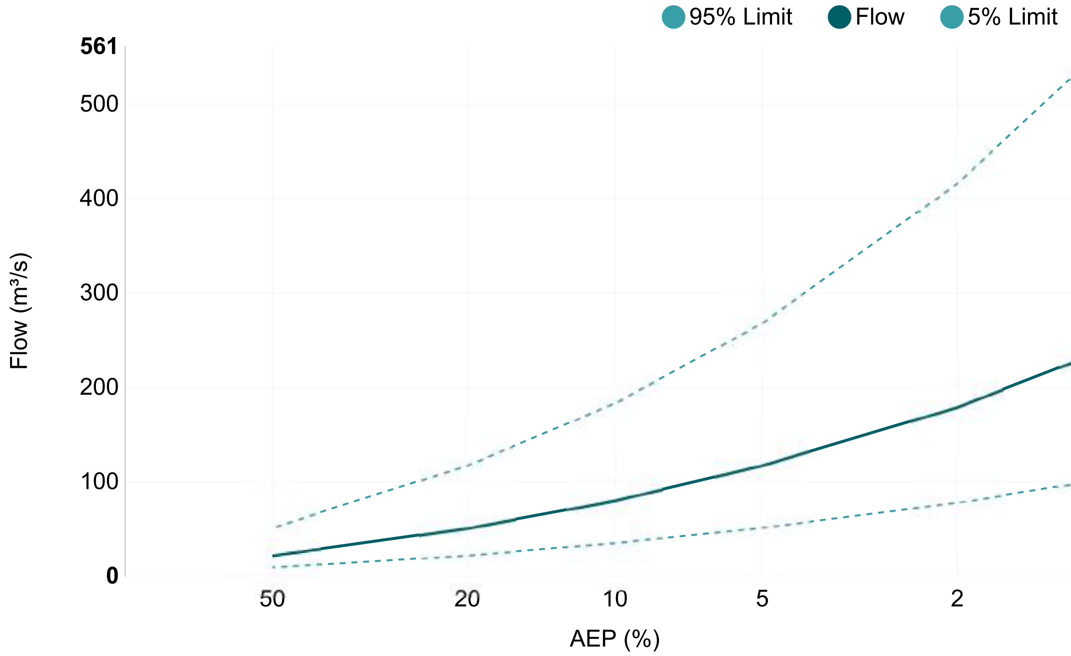
Results | Regional Flood Frequency Estimation Model



AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	21.6	8.94	51.6
20	50.7	21.9	117
10	79.9	34.9	183
5	117	51.1	268
2	179	77.7	416
1	240	103	561

Statistics

Variable	Value	Standard Dev
Mean	3.061	0.523
Standard Dev	1.016	0.109
Skew	0.076	0.026

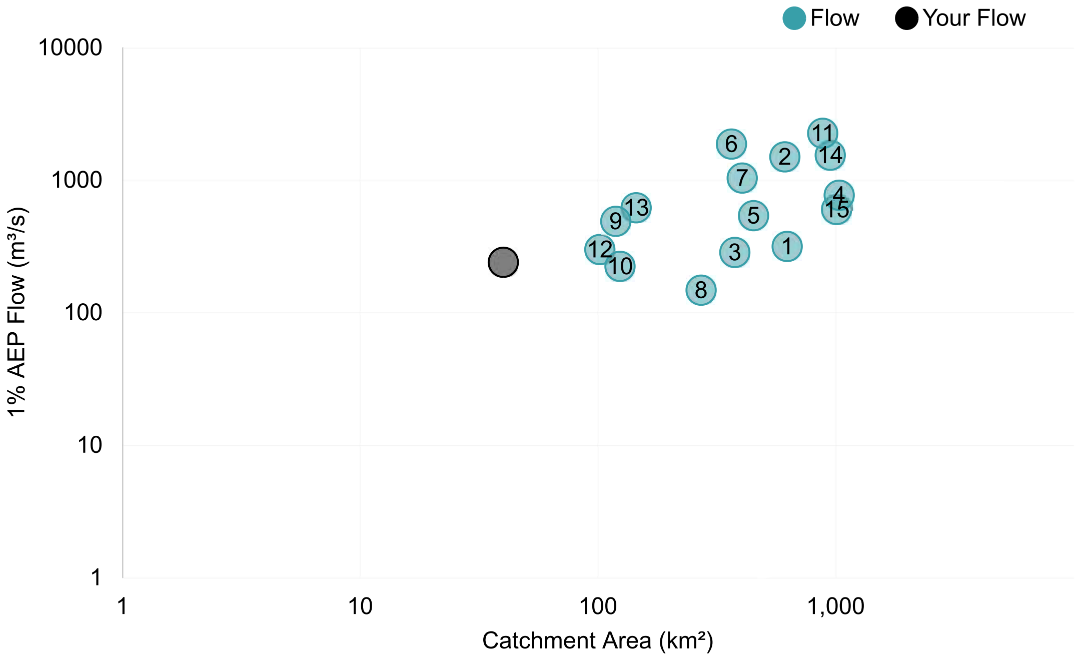
Note: These statistics come from the nearest gauged catchment. Details.

Correlation

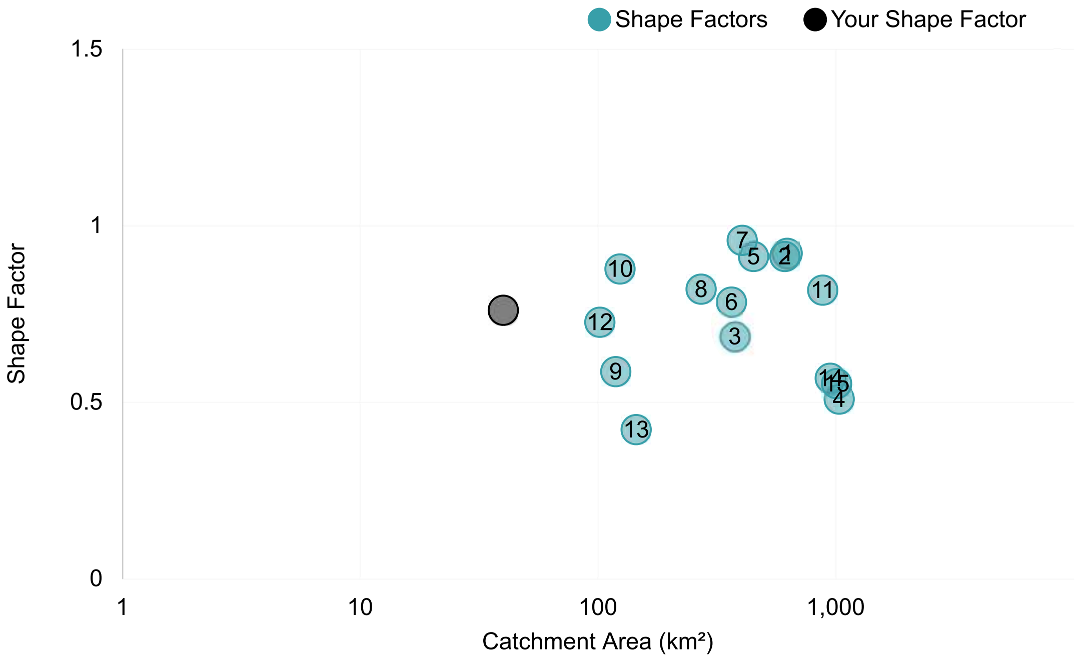
Correlation		
1.000		
-0.330	1.000	
0.170	-0.280	1.000

Note: These statistics are common to each region. Details.

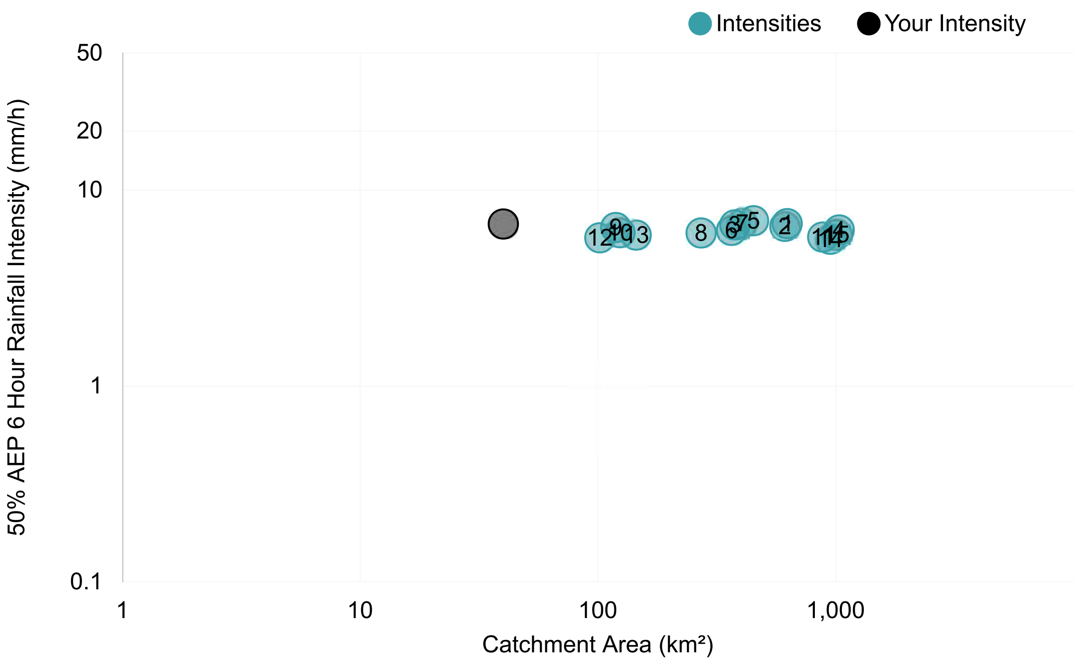
1% AEP Flow vs Catchment Area



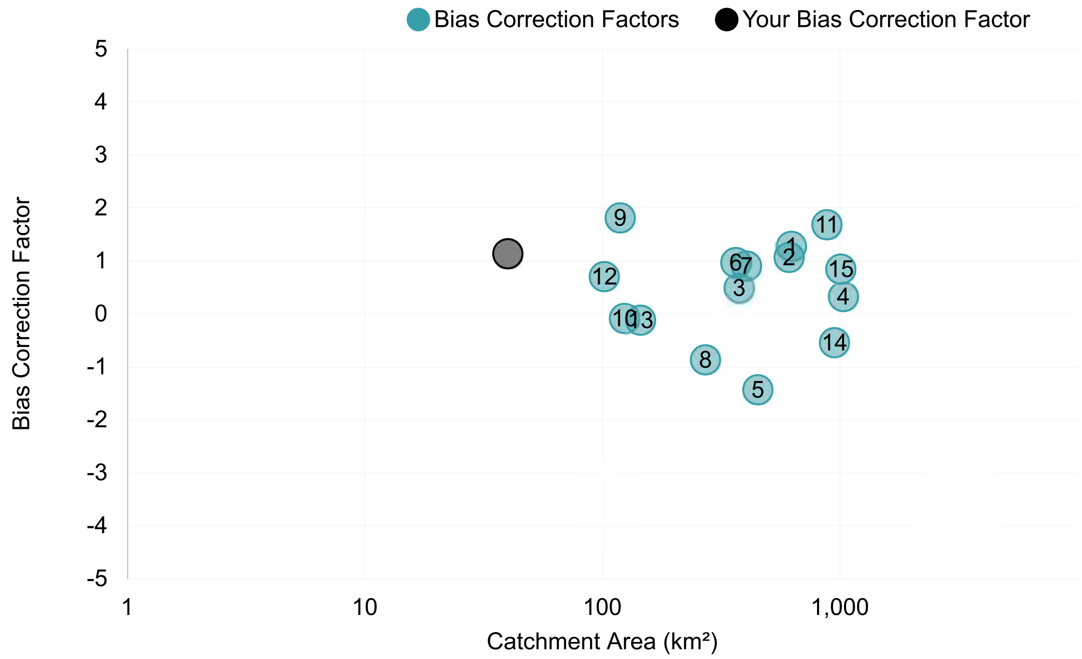
Shape Factor vs Catchment Area



Intensity vs Catchment Area



Bias Correction Factor vs Catchment Area



Download

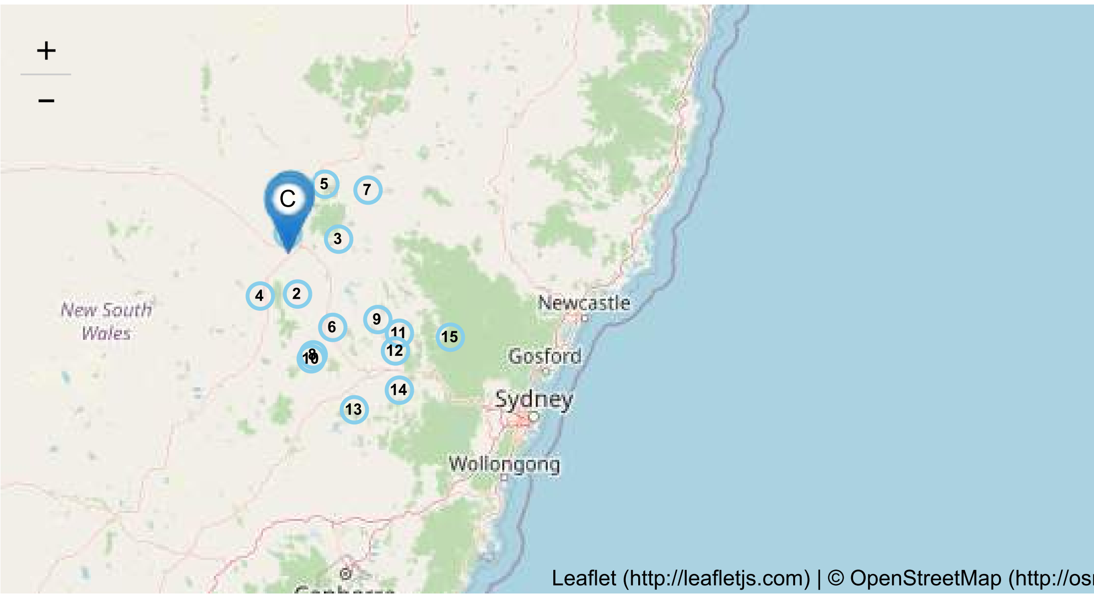
TXT Nearby JSON

Input Data

Date/Time	2021-01-18 17:15
Catchment Name	Forest Glen SF External
Latitude (Outlet)	-32.29048
Longitude (Outlet)	148.487963
Latitude (Centroid)	-32.326489
Longitude (Centroid)	148.460135
Catchment Area (km^2)	40.05
Distance to Nearest Gauged Catchment (km)	16.47
50% AEP 6 Hour Rainfall Intensity (mm/h)	6.701657
2% AEP 6 Hour Rainfall Intensity (mm/h)	14.798915
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast

Input Data

Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	0.76
Interpolation Method	Natural Neighbour
Bias Correction Value	1.134



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Method by Dr Ataur Rahman and Dr Khaled Haddad from Western Sydney University for the Australian Rainfall and Runoff Project. Full description of the project can be found at the project page (http://arr.ga.gov.au/revision-projects/project-list/projects/project-5) on the ARR website. Send any questions regarding the method or project here (mailto:admin@arr-software.org).

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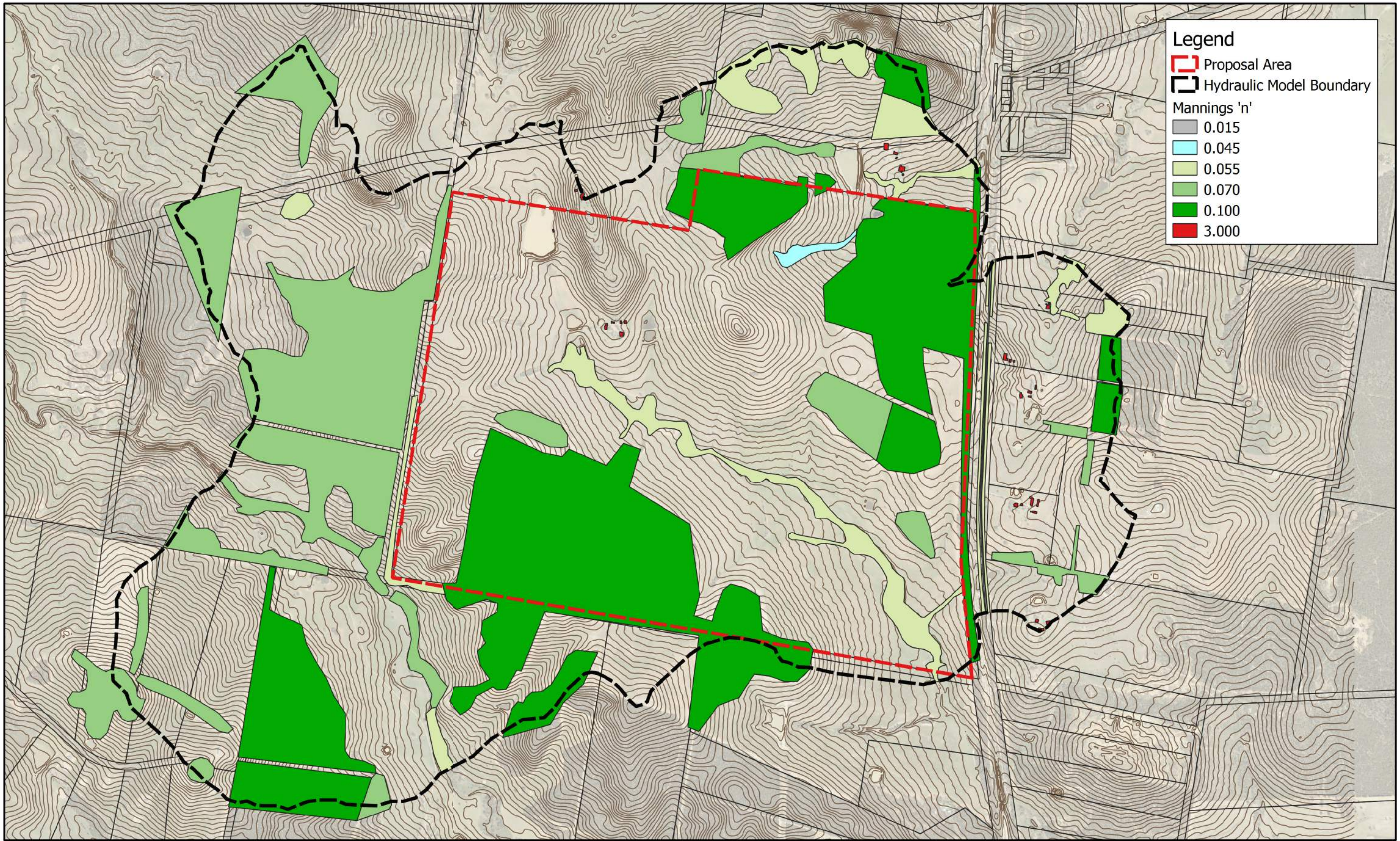
APPENDIX G

Pre-Development Mannings Values



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sustainable engineering.
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400 0 400 m

Scale 1:20,000 at A3

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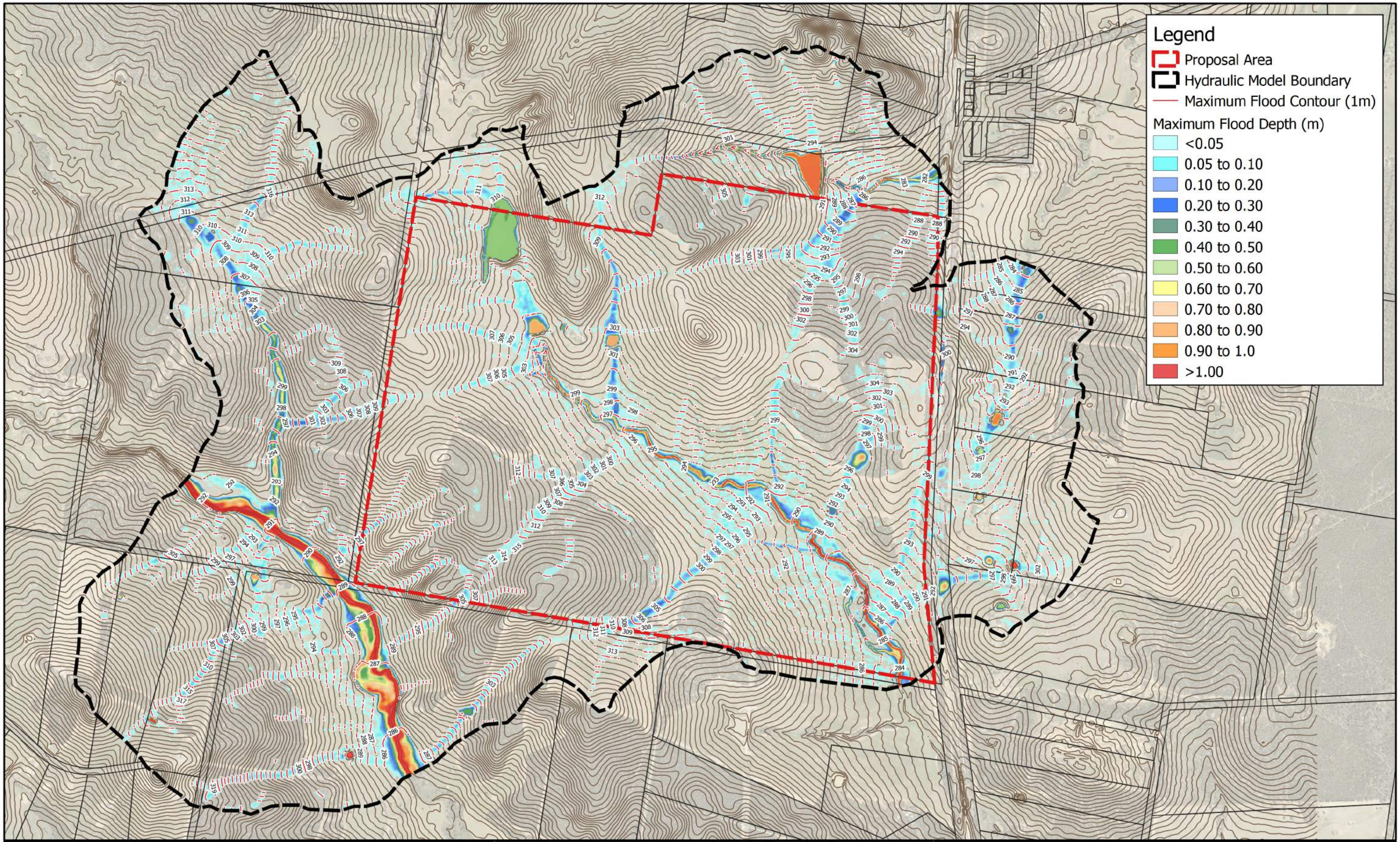
FIGURE 2.1

PRE-DEVELOPMENT CATCHMENT ROUGHNESS

Rev 1 - 25 May 2021

APPENDIX H
Flood Mapping



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Scale 1:20,000 at A3

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FIGURE 3.1

PRE-DEVELOPMENT 5% AEP MAXIMUM FLOOD LEVELS AND DEPTHS

Rev 1 - 25 May 2021

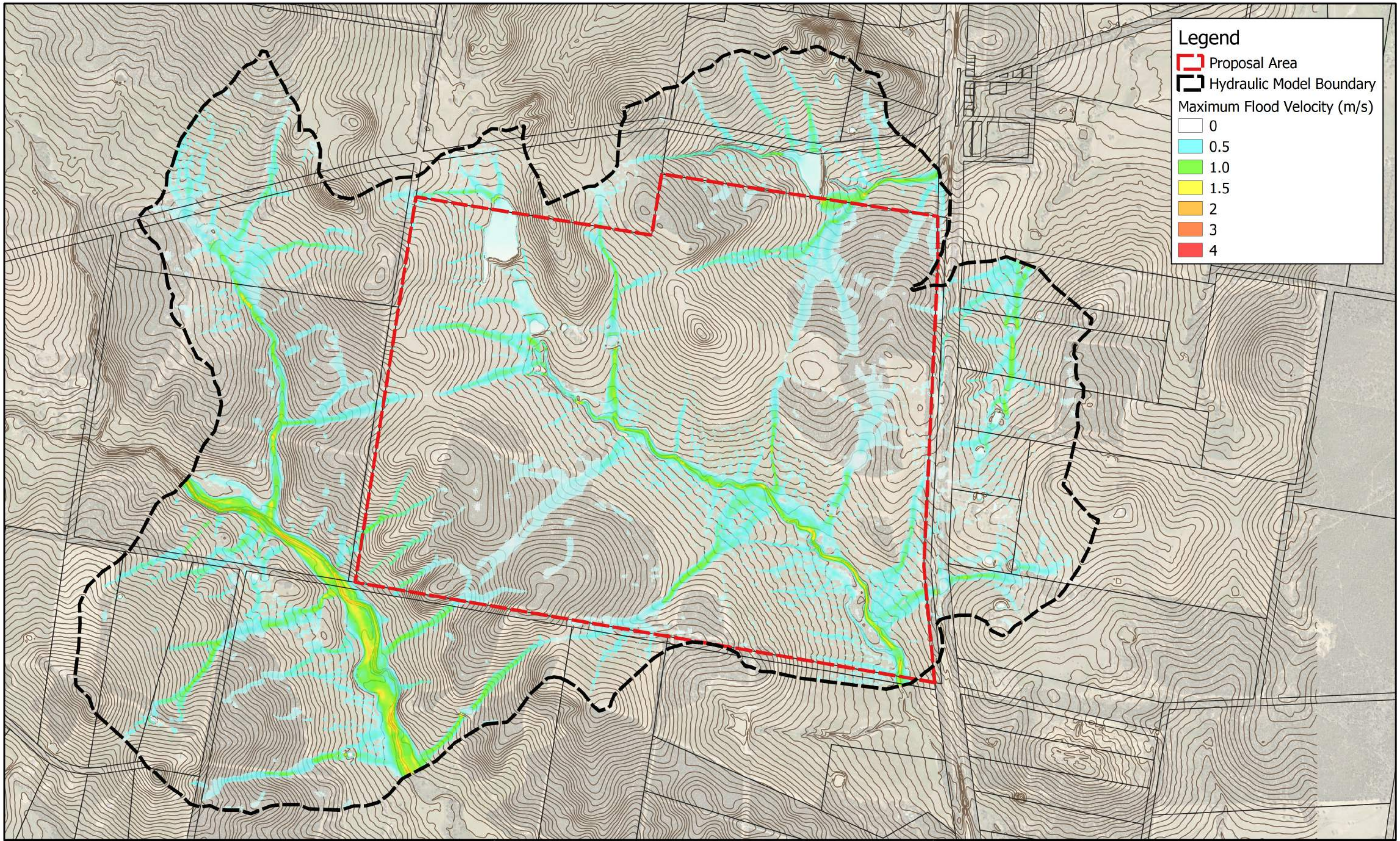

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FIGURE 3.2

PRE-DEVELOPMENT 5% AEP MAXIMUM FLOOD VELOCITIES

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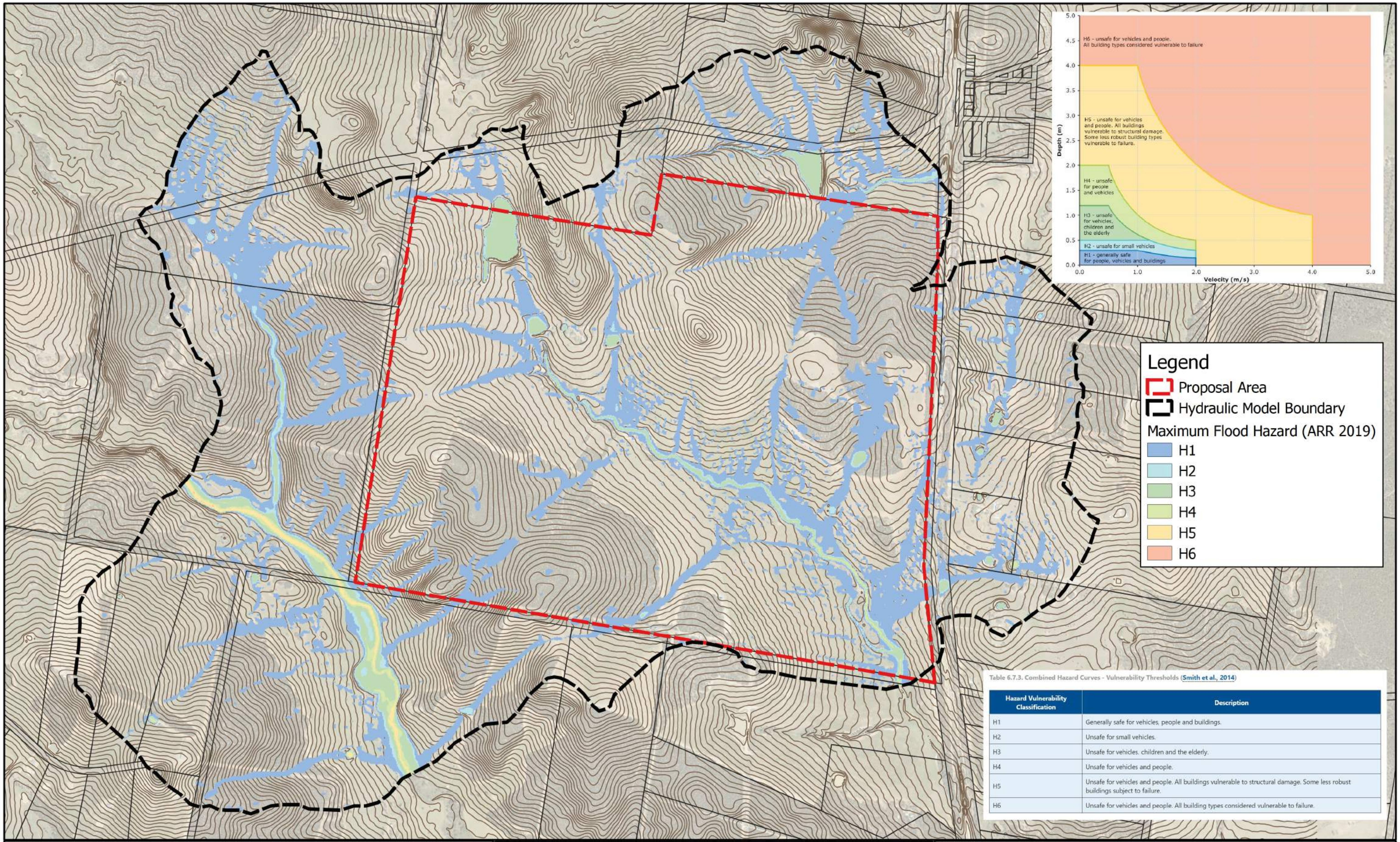

Table 6.7.3. Combined Hazard Curves - Vulnerability Thresholds (Smith et al., 2014)

Hazard Vulnerability Classification	Description
H1	Generally safe for vehicles, people and buildings.
H2	Unsafe for small vehicles.
H3	Unsafe for vehicles. children and the elderly.
H4	Unsafe for vehicles and people.
H5	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure.

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FIGURE 3.3

PRE-DEVELOPMENT 5% AEP MAXIMUM FLOOD HAZARD (ARR 2019)

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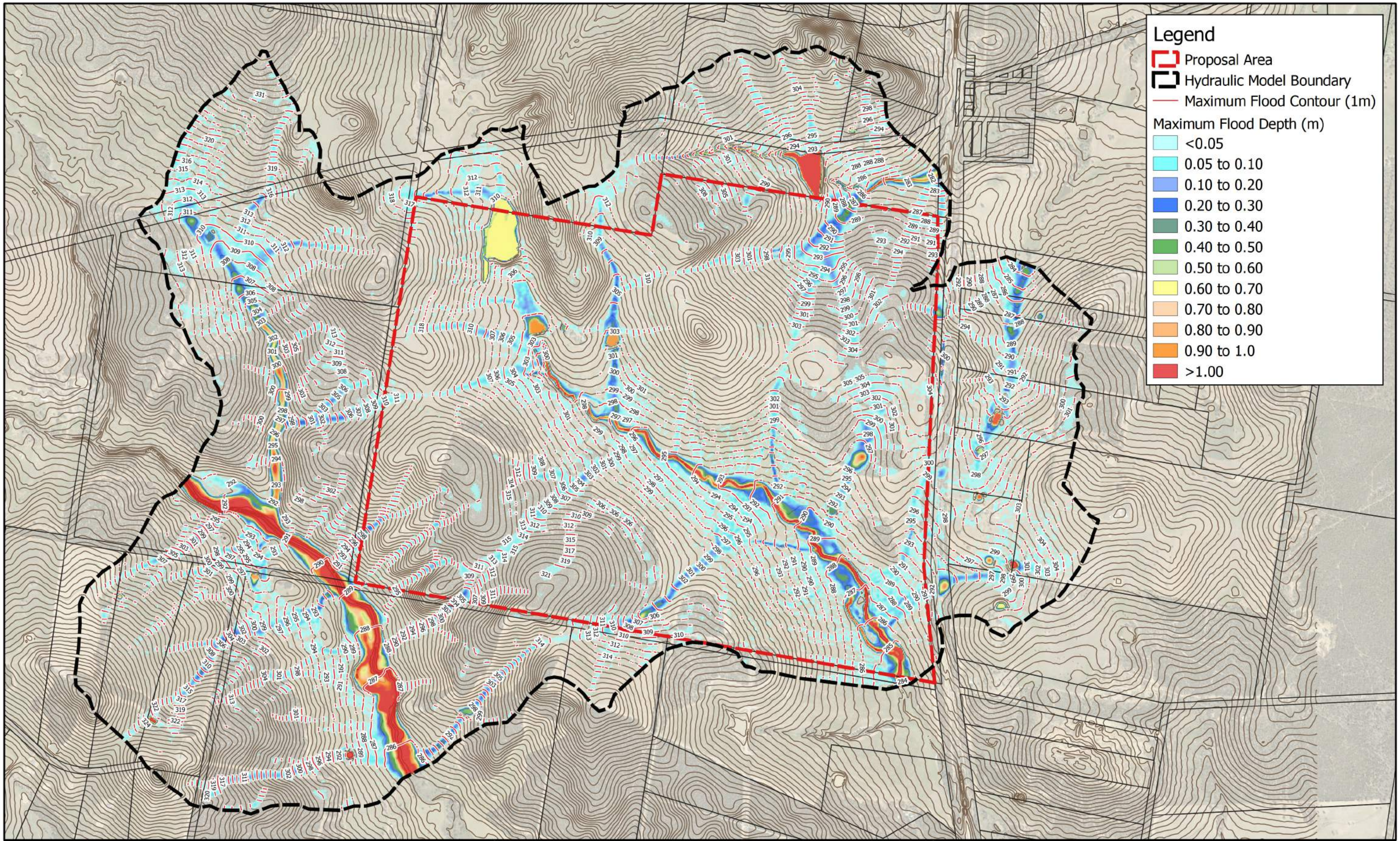

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400 0 400 m

Scale 1:20,000 at A3

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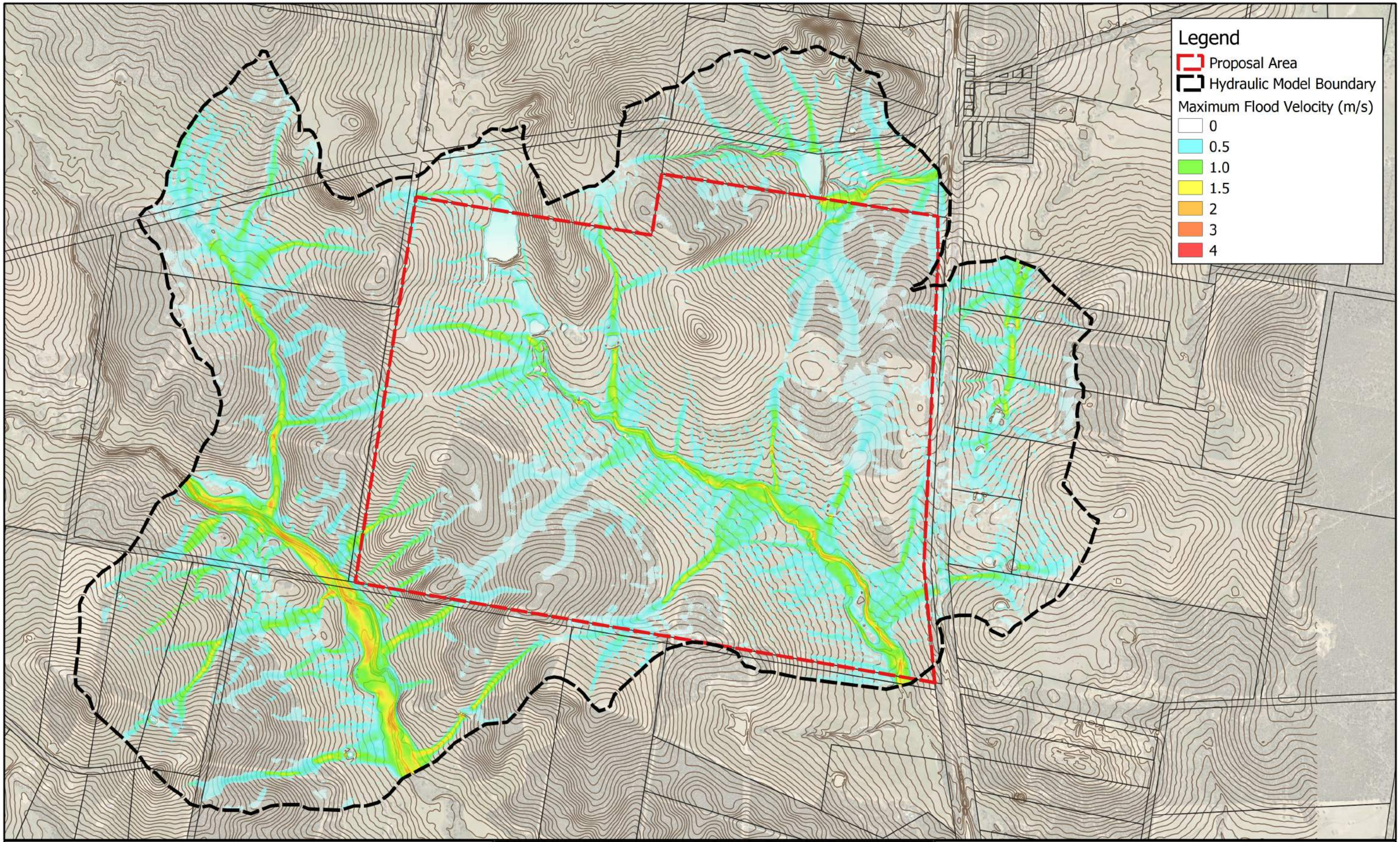
FIGURE 4.1

PRE-DEVELOPMENT 1% AEP MAXIMUM FLOOD LEVELS AND DEPTHS

Rev 1 - 25 May 2021



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400 0 400 m

Scale 1:20,000 at A3

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FIGURE 4.2

PRE-DEVELOPMENT 1% AEP MAXIMUM FLOOD VELOCITIES

Rev 1 - 25 May 2021

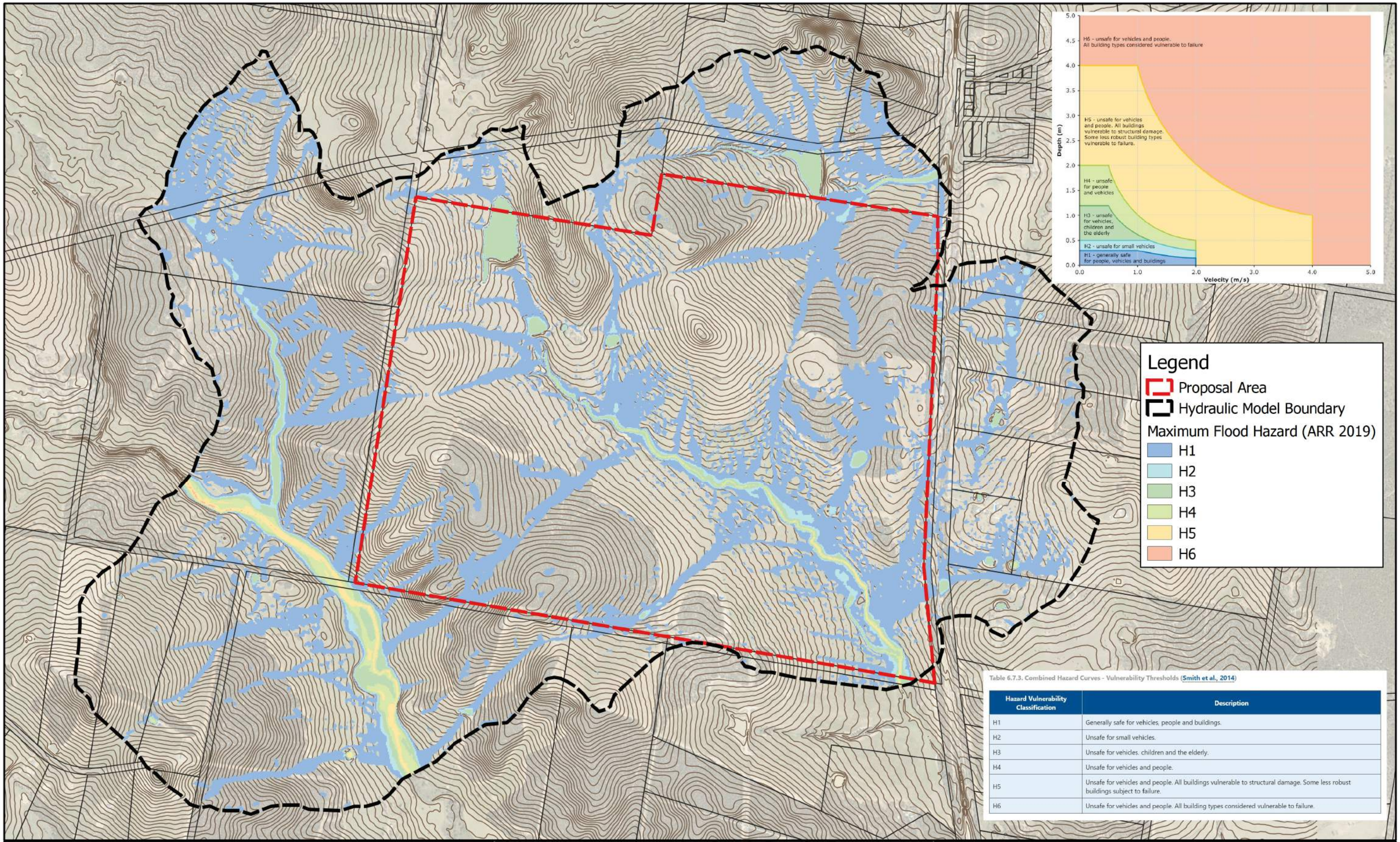

Table 6.7.3. Combined Hazard Curves - Vulnerability Thresholds (Smith et al., 2014)

Hazard Vulnerability Classification	Description
H1	Generally safe for vehicles, people and buildings.
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H3	Unsafe for vehicles. children and the elderly.
H4	Unsafe for vehicles and people.
H5	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure.

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nsw 2533 p: (02) 4237 6770

400 0 400 m

Scale 1:20,000 at A3

FOREST GLEN SOLAR FARM

FIGURE 4.3

PRE-DEVELOPMENT 1% AEP MAXIMUM FLOOD HAZARD (ARR 2019)

Rev 1 - 25 May 2021

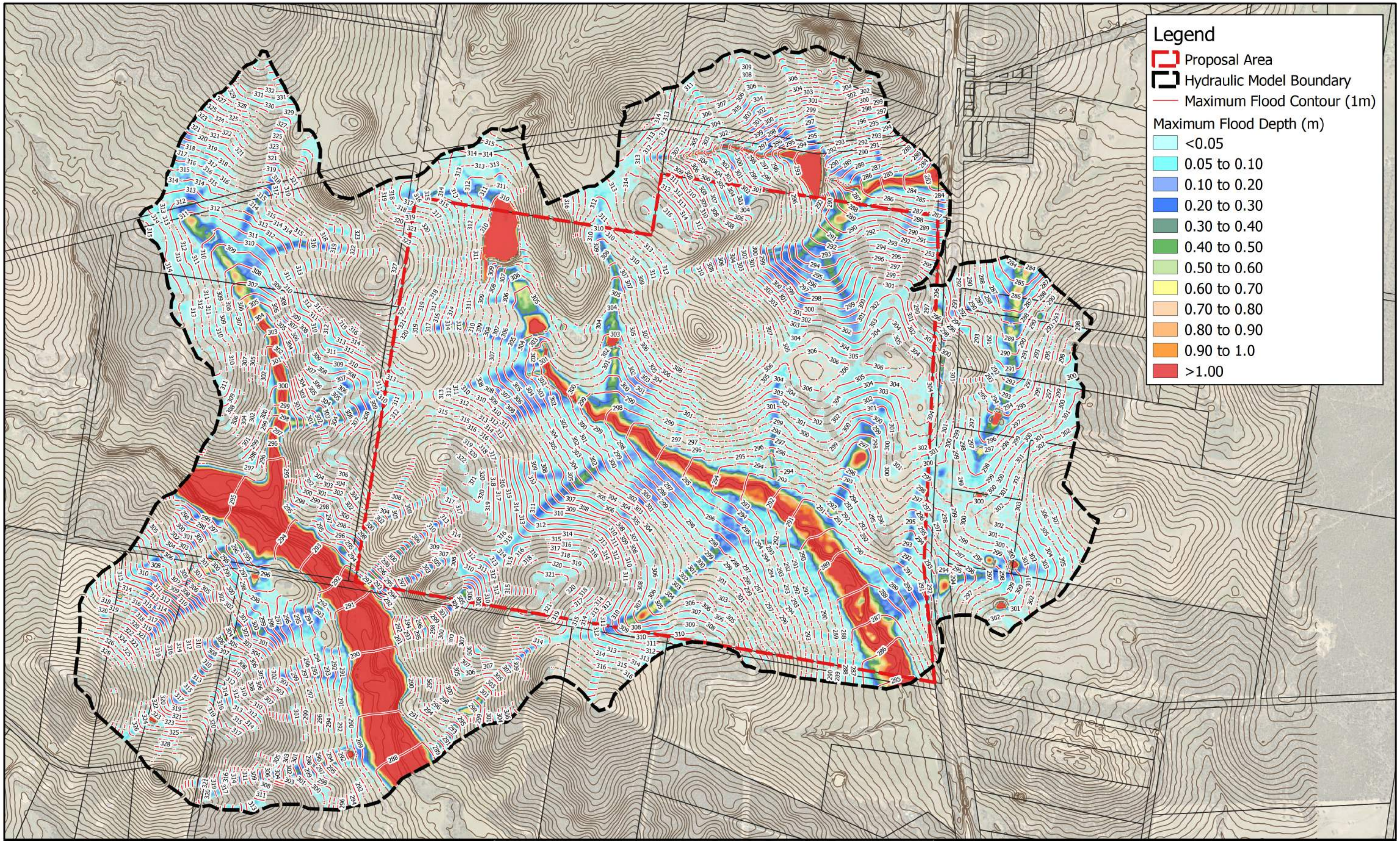

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FIGURE 5.1

PRE-DEVELOPMENT PMF MAXIMUM FLOOD LEVELS AND DEPTHS

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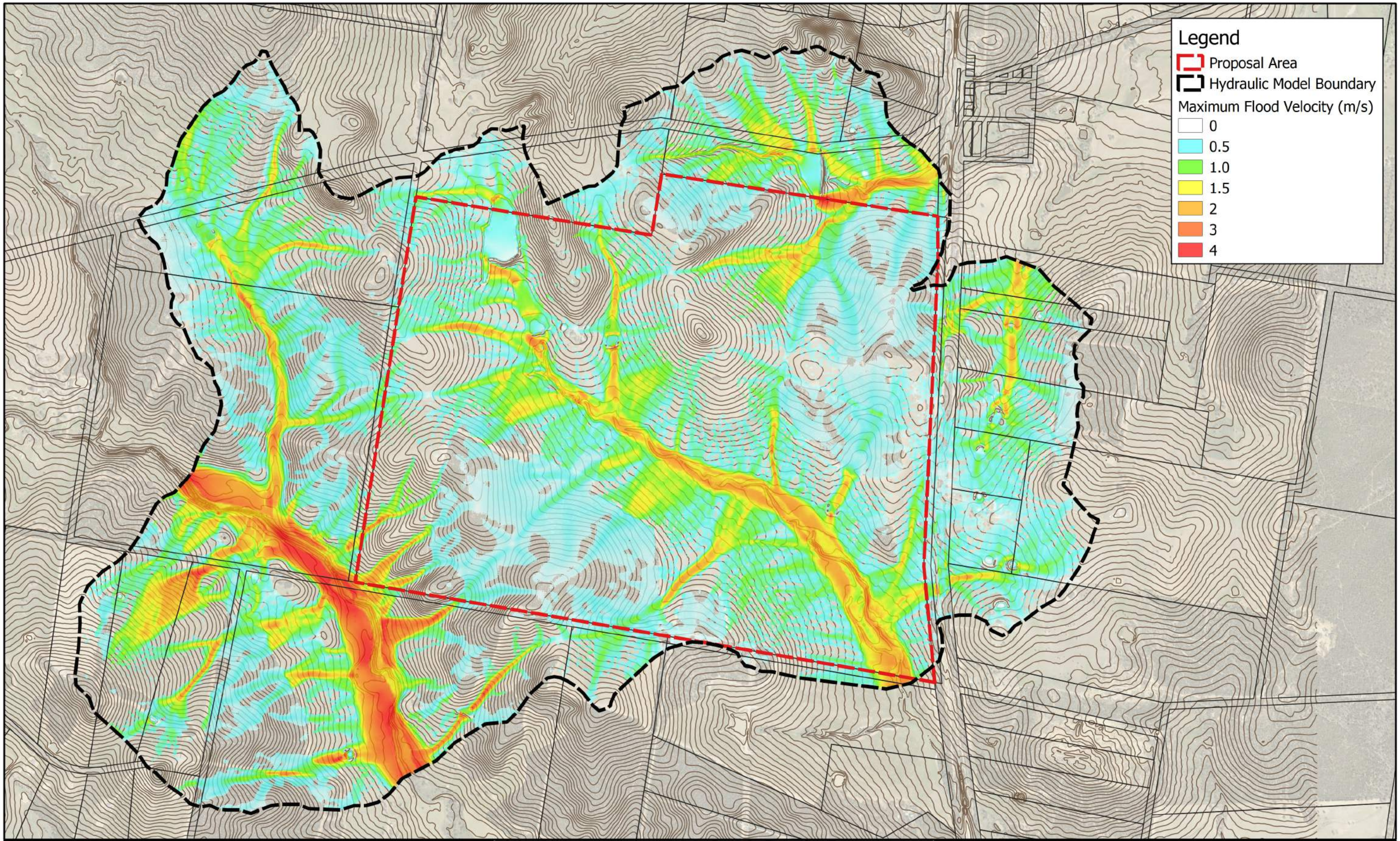

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nsw 2533 p: (02) 4237 6770

400 0 400 m

Scale 1:20,000 at A3

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FIGURE 5.2

PRE-DEVELOPMENT PMF MAXIMUM FLOOD VELOCITIES

Rev 1 - 25 May 2021

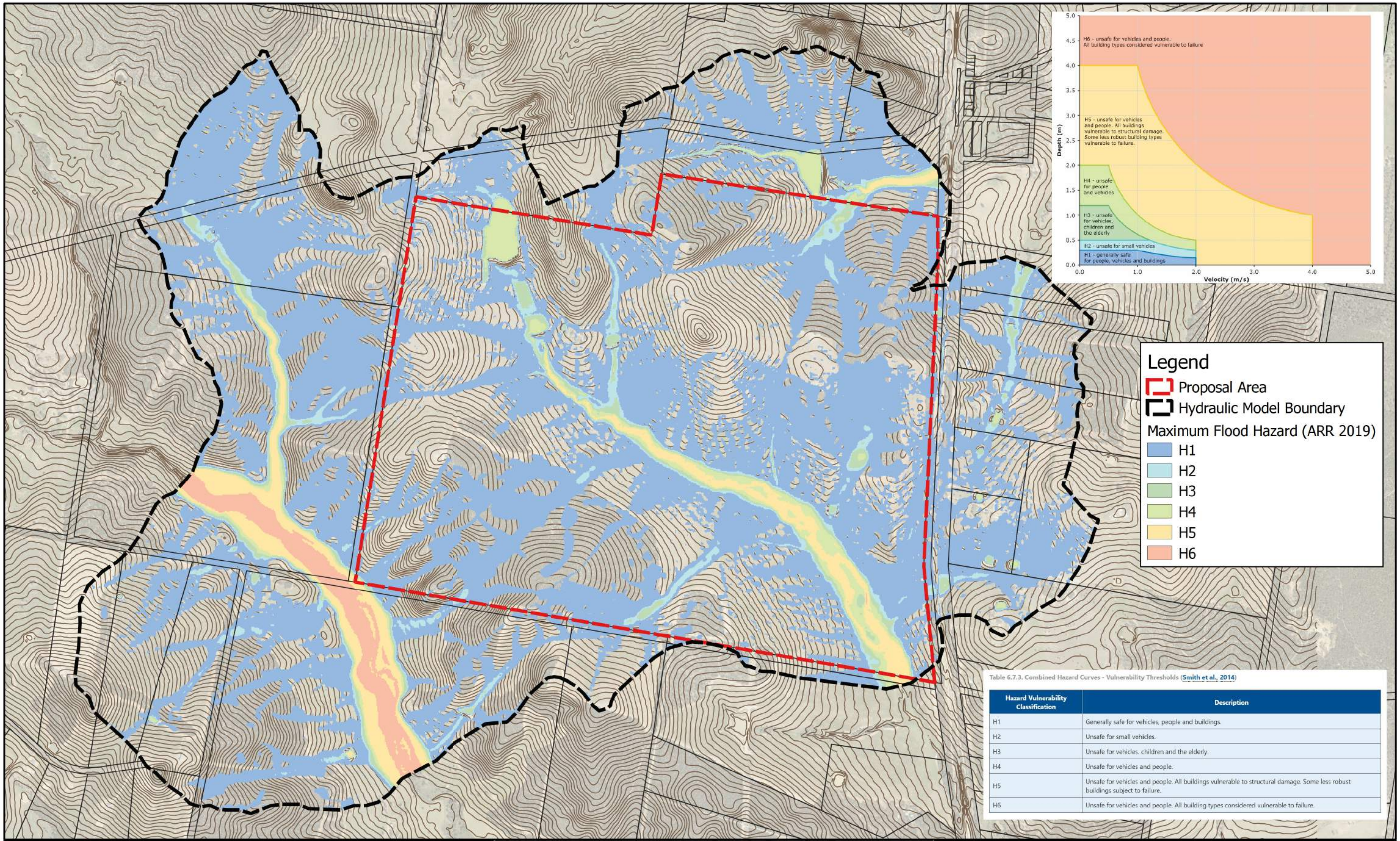

Table 6.7.3. Combined Hazard Curves - Vulnerability Thresholds (Smith et al., 2014)

Hazard Vulnerability Classification	Description
H1	Generally safe for vehicles, people and buildings.
H2	Unsafe for small vehicles.
H3	Unsafe for vehicles. children and the elderly.
H4	Unsafe for vehicles and people.
H5	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure.

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FIGURE 5.3

PRE-DEVELOPMENT PMF MAXIMUM FLOOD HAZARD (ARR 2019)

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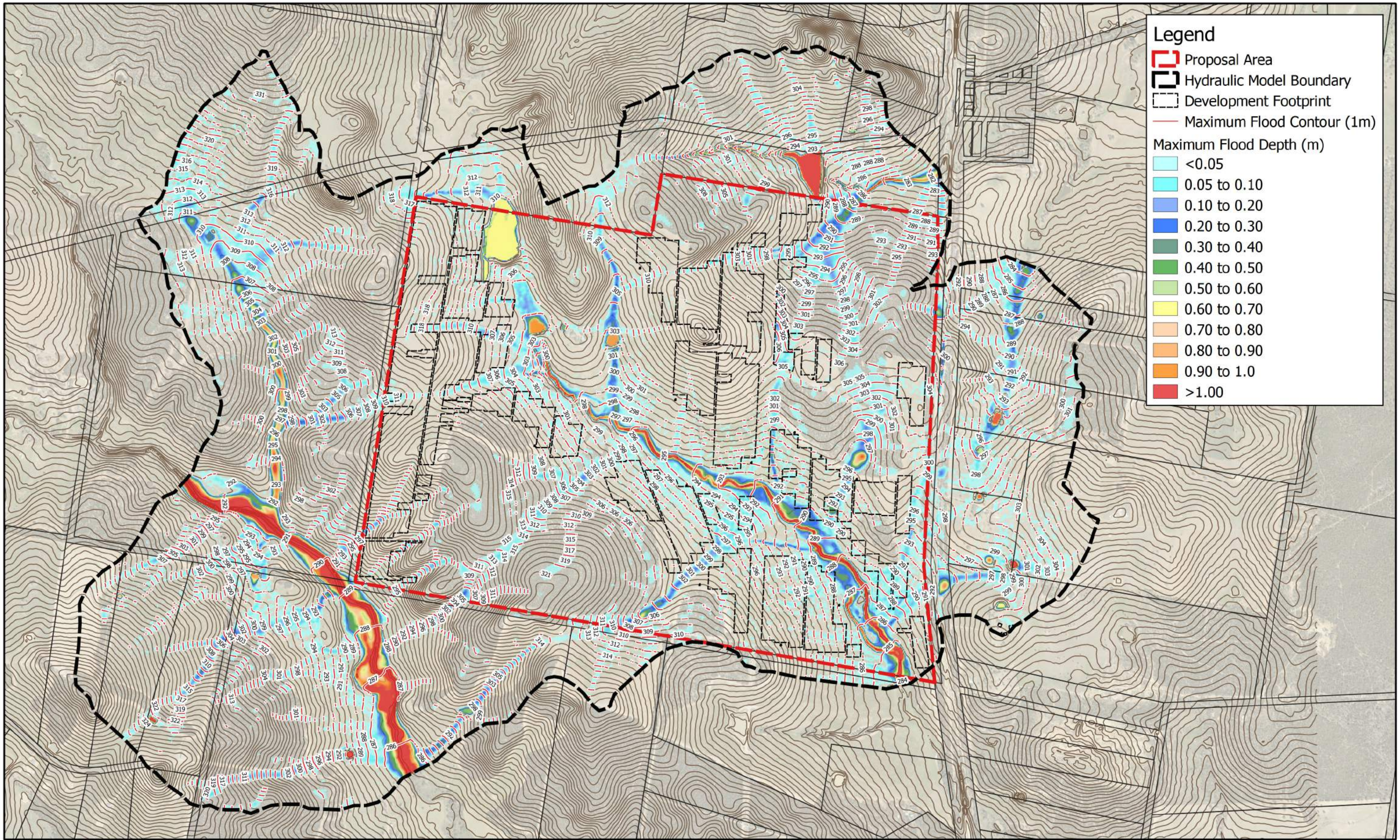

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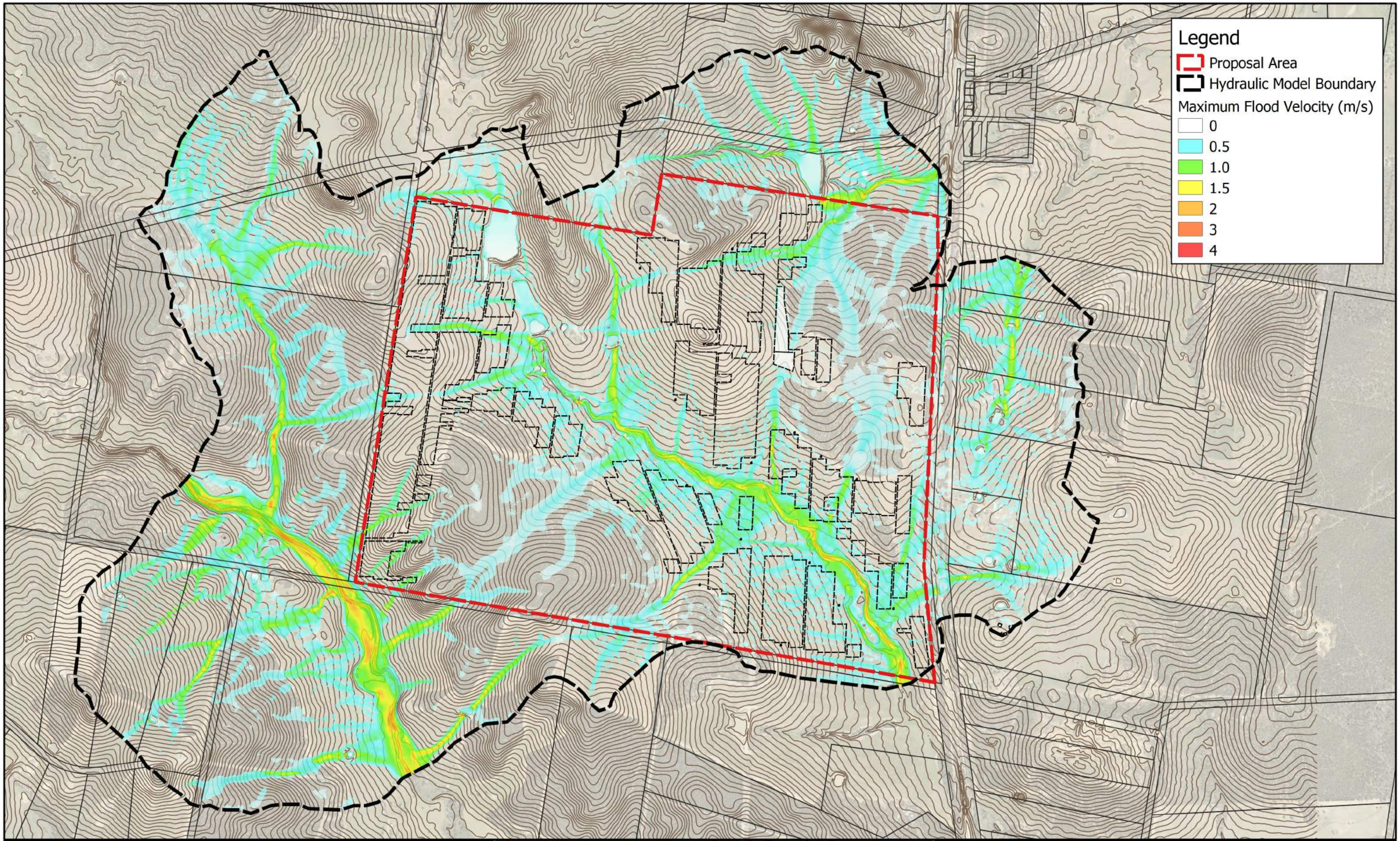
FIGURE 6.1

POST DEVELOPMENT 1% AEP MAXIMUM FLOOD LEVELS AND DEPTHS

Rev 1 - 25 May 2021



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400 0 400 m
Scale 1:20,000 at A3

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FOREST GLEN SOLAR FARM

FIGURE 6.2

POST DEVELOPMENT 1% AEP MAXIMUM FLOOD VELOCITIES

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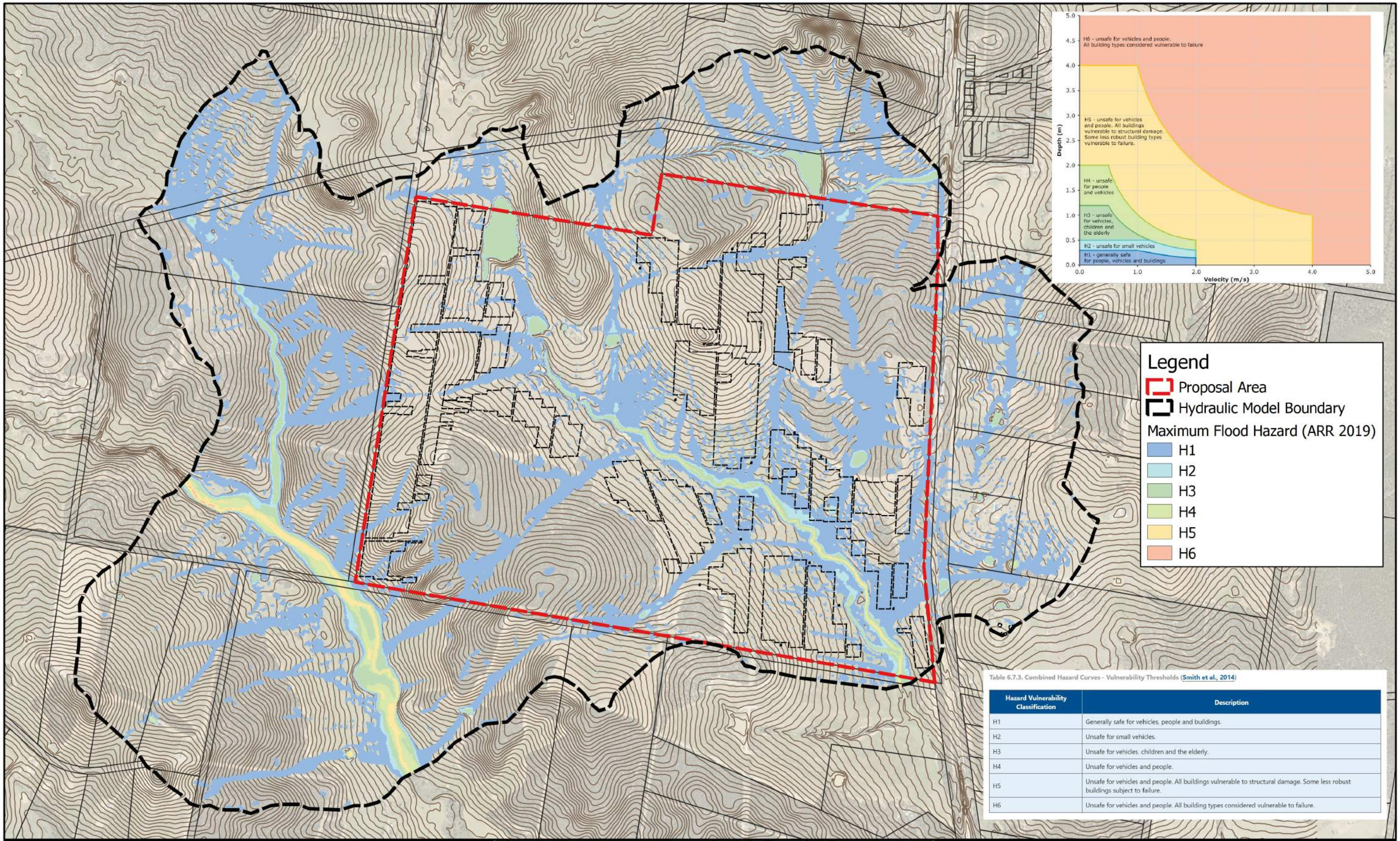

Table 6.7.3. Combined Hazard Curves - Vulnerability Thresholds (Smith et al., 2014)

Hazard Vulnerability Classification	Description
H1	Generally safe for vehicles, people and buildings.
H2	Unsafe for small vehicles.
H3	Unsafe for vehicles. children and the elderly.
H4	Unsafe for vehicles and people.
H5	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure.

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400 0 400 m

Scale 1:20,000 at A3

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FIGURE 6.3

POST DEVELOPMENT 1% AEP MAXIMUM FLOOD HAZARD (ARR 2019)

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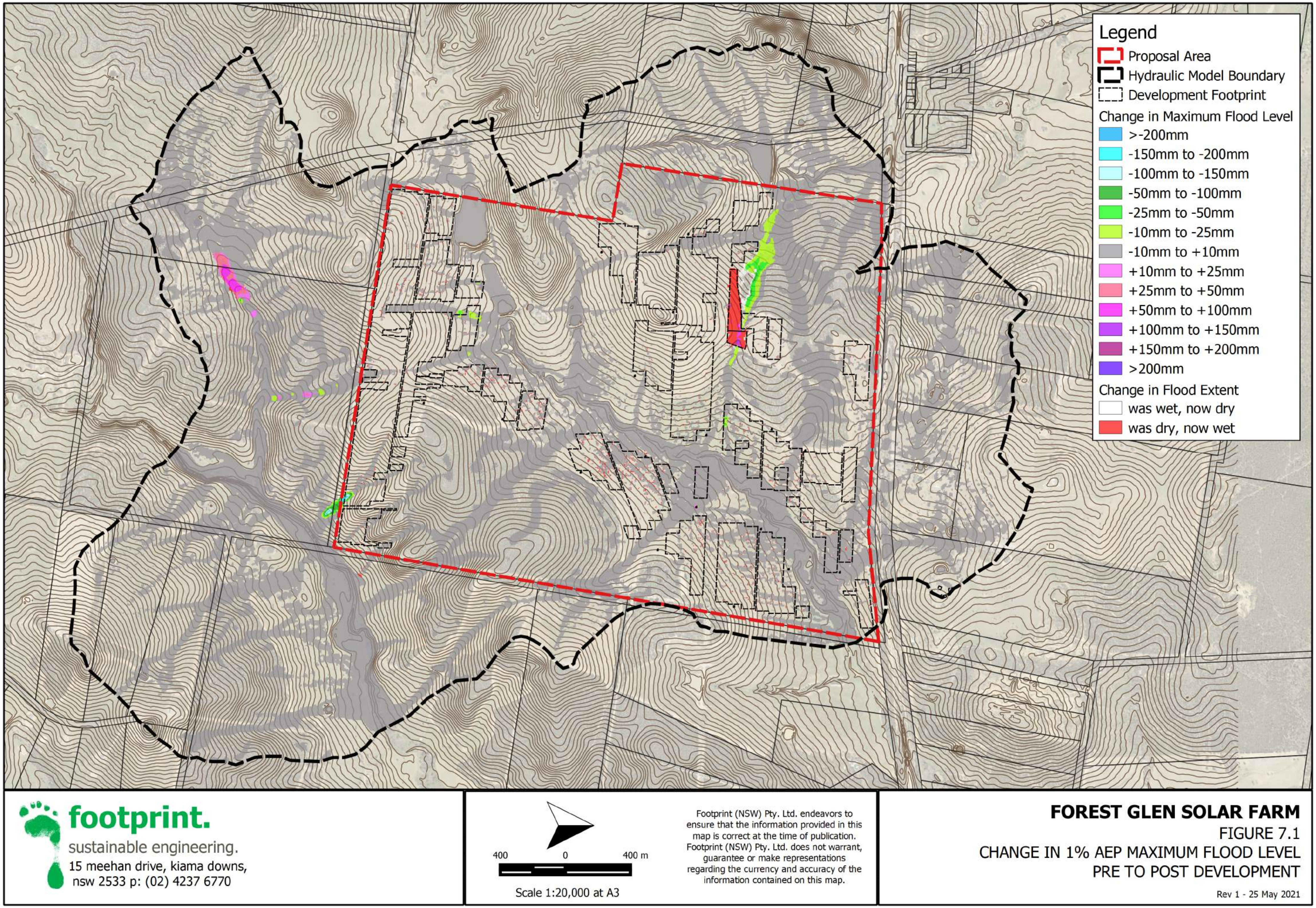

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FIGURE 7.1

CHANGE IN 1% AEP MAXIMUM FLOOD LEVEL PRE TO POST DEVELOPMENT

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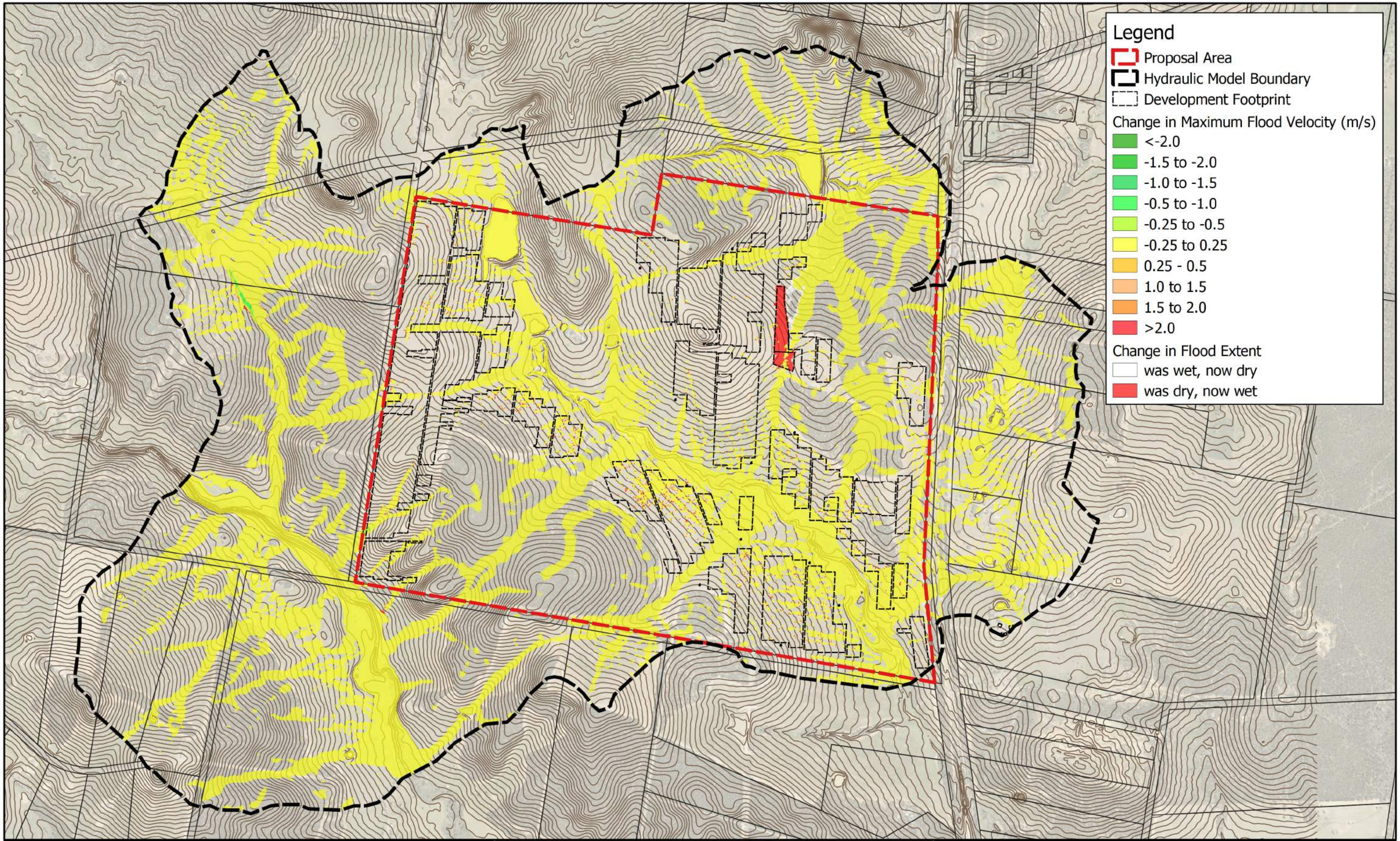

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FIGURE 7.2

CHANGE IN 1% AEP MAXIMUM FLOOD VELOCITY PRE TO POST DEVELOPMENT

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APPENDIX I

Post Development Mannings Values

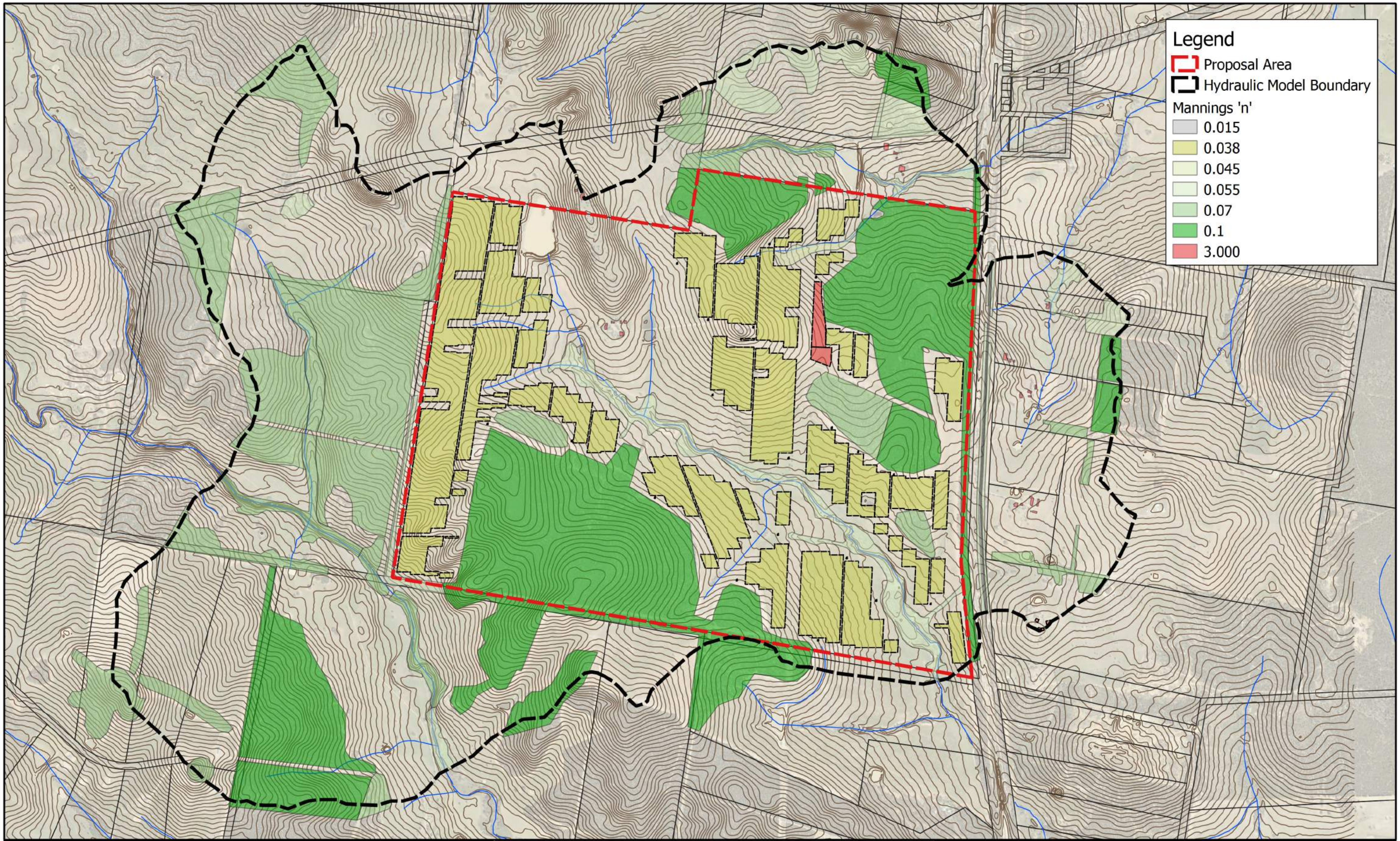

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FIGURE 2.2

POST DEVELOPMENT CATCHMENT ROUGHNESS

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APPENDIX J

Stream Classification

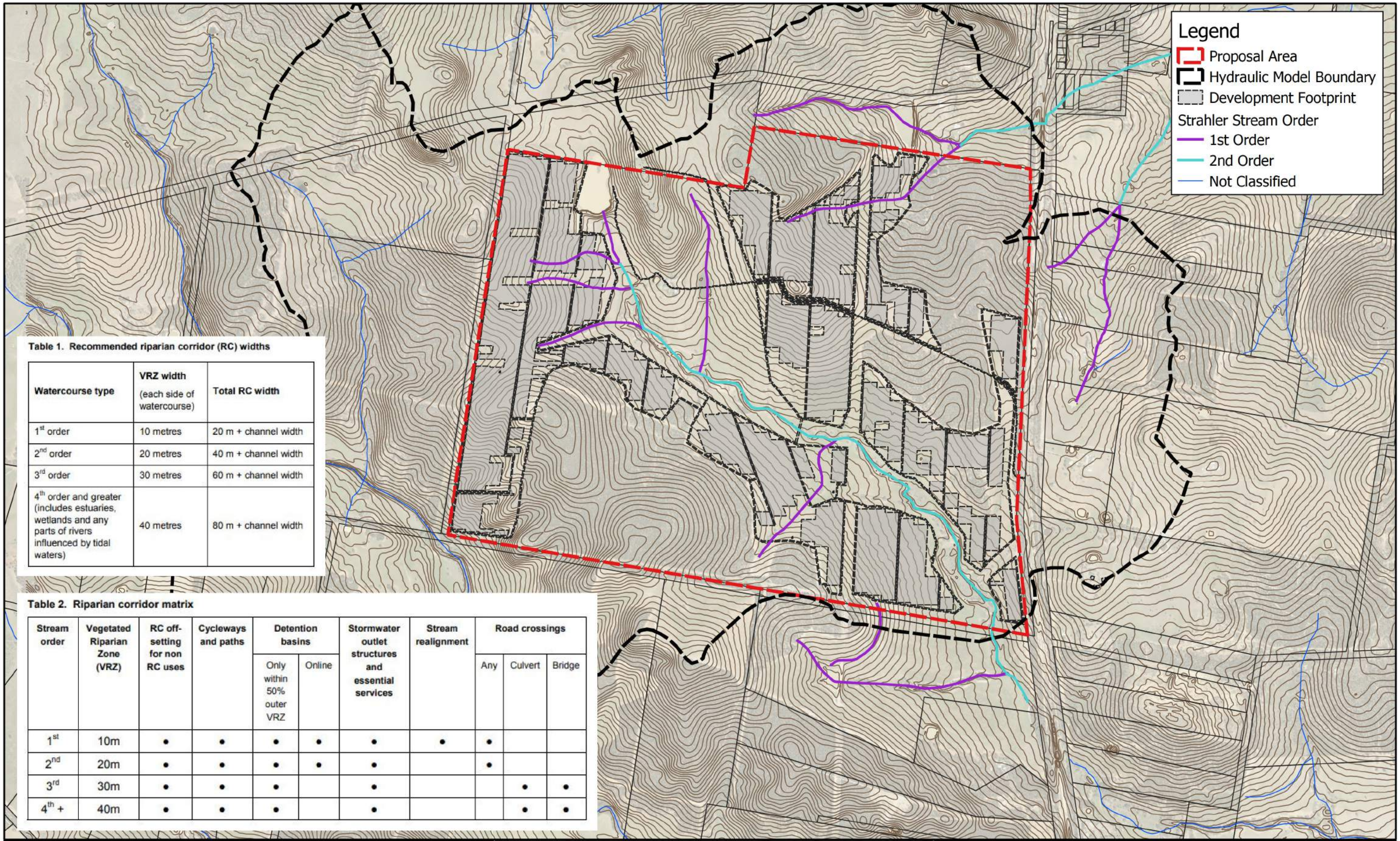

Table 1. Recommended riparian corridor (RC) widths

Watercourse type	VRZ width (each side of watercourse)	Total RC width
1st order	10 metres	20 m + channel width
2nd order	20 metres	40 m + channel width
3rd order	30 metres	60 m + channel width
4th order and greater (includes estuaries, wetlands and any parts of rivers influenced by tidal waters)	40 metres	80 m + channel width

Table 2. Riparian corridor matrix

Stream order	Vegetated Riparian Zone (VRZ)	RC off-setting for non RC uses	Cycleways and paths	Detention basins		Stormwater outlet structures and essential services	Stream realignment	Road crossings		
				Only within 50% outer VRZ	Online			Any	Culvert	Bridge
1st	10m	•	•	•	•	•	•	•		
2nd	20m	•	•	•	•	•		•		
3rd	30m	•	•	•		•			•	•
4th +	40m	•	•	•		•			•	•

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400 0 400 m

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FIGURE 8.1

STREAM CLASSIFICATION

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