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Proposed Solar Farm, Wollar, New South Wales

Hydrological and Hydraulic Analysis

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1.0 INTRODUCTION

Footprint (NSW) Pty. Ltd. (*Footprint*) has been engaged by ngh environmental Pty. Ltd. to undertake a hydrological and hydraulic analysis in support of a proposed solar farm located approximately 7km south of Wollar Village, in the mid-western region of the Upper Hunter, New South Wales.

The purpose of the analysis is to define the flood behaviour, including depth of inundation and flood velocity, over that part of Wollar Creek within the proposal area and the numerous 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 calculations to determine critical storm durations for the 20%, 10%, 5%, 2% and 1% AEP events.
3. Undertake two-dimensional hydraulic modelling (using HEC-RAS) to determine the depth and extent of flooding over the proposal area for each of the above rainfall events.
4. Preparation of a concise hydrological and hydraulic report defining the methodology and result of the above investigation.

2.0 PROPOSAL AREA

The Wollar Solar Farm proposal is to be located on a property of approximately 800 ha and is located approximately 7km south of Wollar Village, in the mid-western region of the Upper Hunter, New South Wales.

The proposal area includes Lots 22-25, 27, 30, 45, 49-51, 60-63, 69-80, 92, 105-107, 119 and 152-154 of DP 755430, and Lot 1 of DP 650653.

The location and extent of the proposal area in relation to Wollar Village is shown in Figure 1.

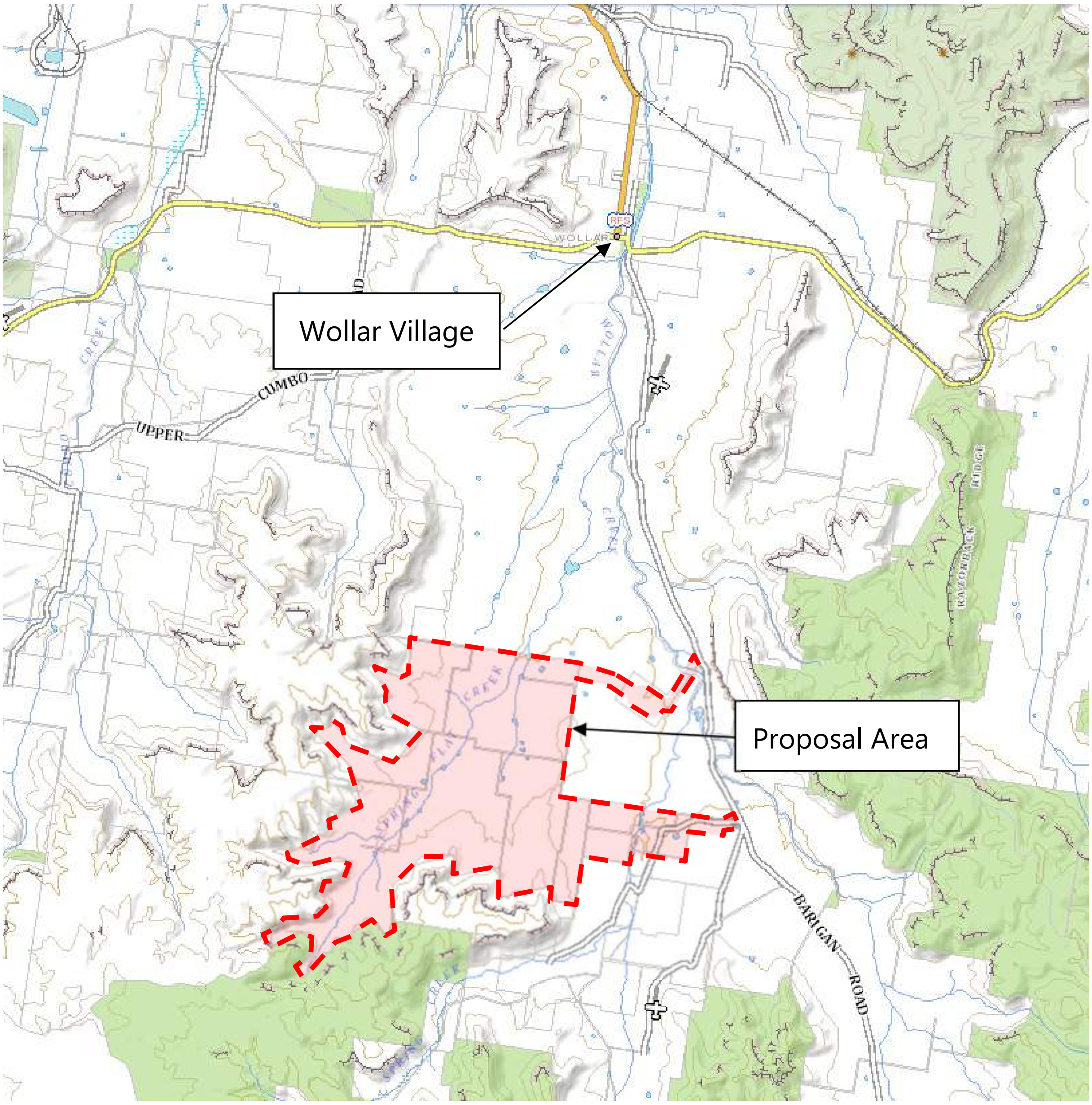


Figure 1: Location and Extent of Proposal Area

The proposal area is traversed by two named watercourses and approximately eight other un-named tributaries. The largest of the watercourses, Wollar Creek, bisects the proposal area on its very eastern edge, whilst Spring Flat Creek traverses the middle of the proposal area in a south-west to north-east direction. Most of the smaller watercourses within the proposal area are tributaries of Spring Flat Creek. Spring Flat Creek discharges into Wollar Creek approximately 2.5km north of the proposal area.

All watercourses within the proposal area would be described as ephemeral and would only contain flowing water during significant rainfall events.

There are approximately 15 dams within the proposal area, mostly located on the watercourses, that are used for stock water.

It is understood that the proposal area has been under agricultural cultivation, including grazing and occasional cropping, since the early 1900's and is predominantly cleared of overstorey vegetation (refer to Figure 2).

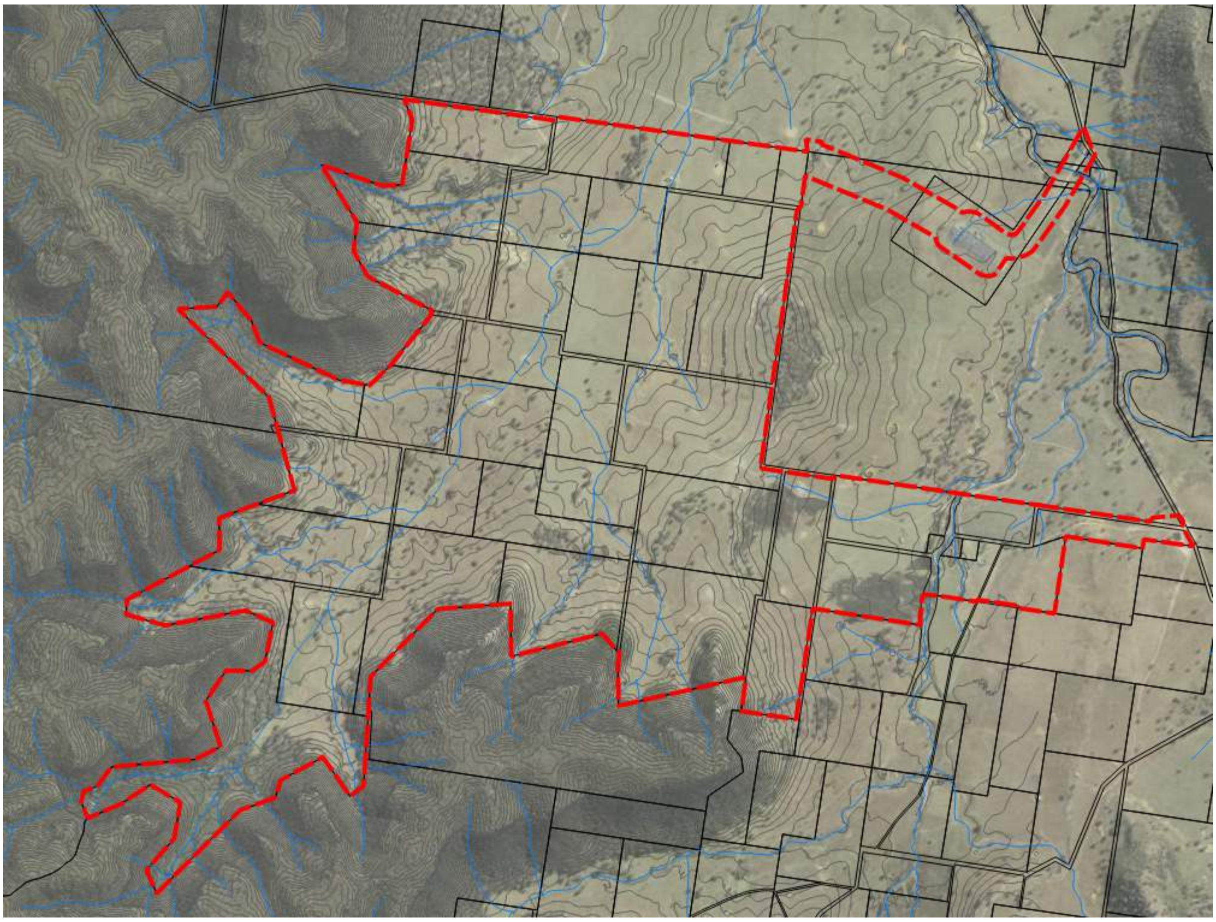


Figure 2: Aerial View of Proposal Area (outlined in red)

The proposal area typically falls from the south-west to the north-east with elevations ranging from about RL400m AHD to RL 540m AHD. On its western and southern flanks, the proposal area is bound by step terrain approaching a 30% gradient with ridgeline elevations ranging from about 600-700m AHD.

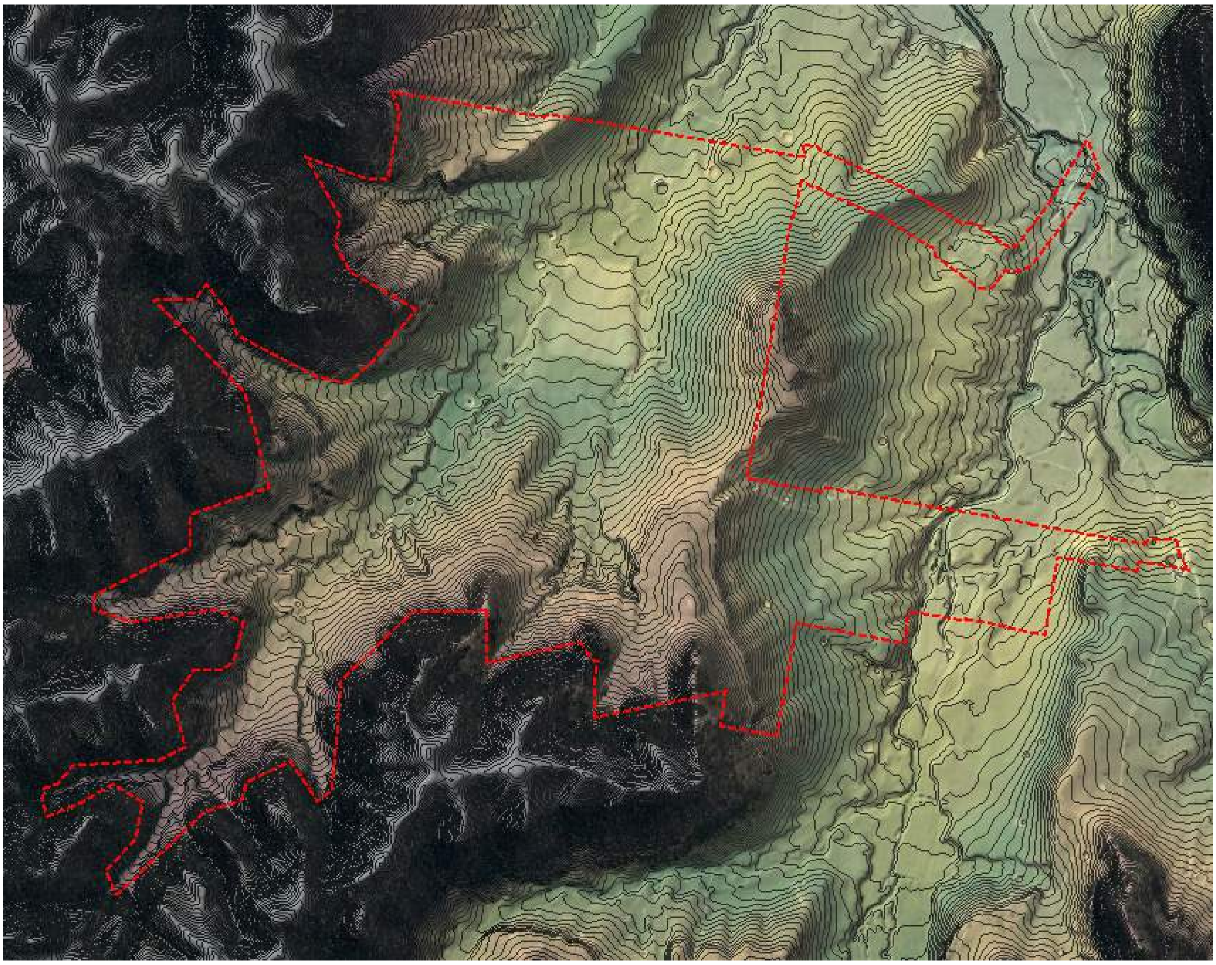


Figure 3: Terrain Analysis over Proposal Area (2m contour interval)

3.0 HYDROLOGICAL MODELLING

3.1. Purpose

Hydrological modelling was conducted to:

i. determine inflow hydrographs for Wollar Creek at the upstream edge of the HEC-RAS two-dimensional direct rainfall hydraulic model
ii. inform the HEC-RAS two-dimensional direct rainfall hydraulic model.

Two separate hydrological models were prepared for the project and included an XP-RAFTS model to determine inflow hydrographs for Wollar Creek and a DRAINS storage routing model to inform the HEC-RAS two-dimensional direct rainfall model.

The primary purpose of the DRAINS hydrological model was to:

iii. determine the critical storm duration for the site, and
iv. 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 (i.e. 1% AEP, 2% AEP)

3.2. XP-RAFTS Hydrological Model

3.2.1. Catchment Areas

The Wollar Creek catchment draining to an outlet on the northern boundary of Lot 2 DP755430 covers an area of approximately 75 hectares and was split into 75 sub-catchments based on topography and homogeneity. Catchment delineation was undertaken using a 25m DEM grid from Geosciences Australia and is shown in Figure 4.

Catchment characteristics (area, area averaged slope, impervious %) were extracted from the DEM and aerial imagery and imported into the XP-RAFTS model.

Flow velocity between sub-catchments was estimated using a simplified HEC-RAS model of Wollar Creek and a 1% AEP flow rate estimated assuming an initial average flow velocity of 1.5m/s. The average velocity during a 1% flood was found to be closer to 2m/s over the channel length and this value conforms well with the two-dimensional HEC-RAS model for the proposal area.

To estimate the flood wave lag between sub-catchments the flow path length was measured in GIS and an average flow velocity of 2m/s adopted.

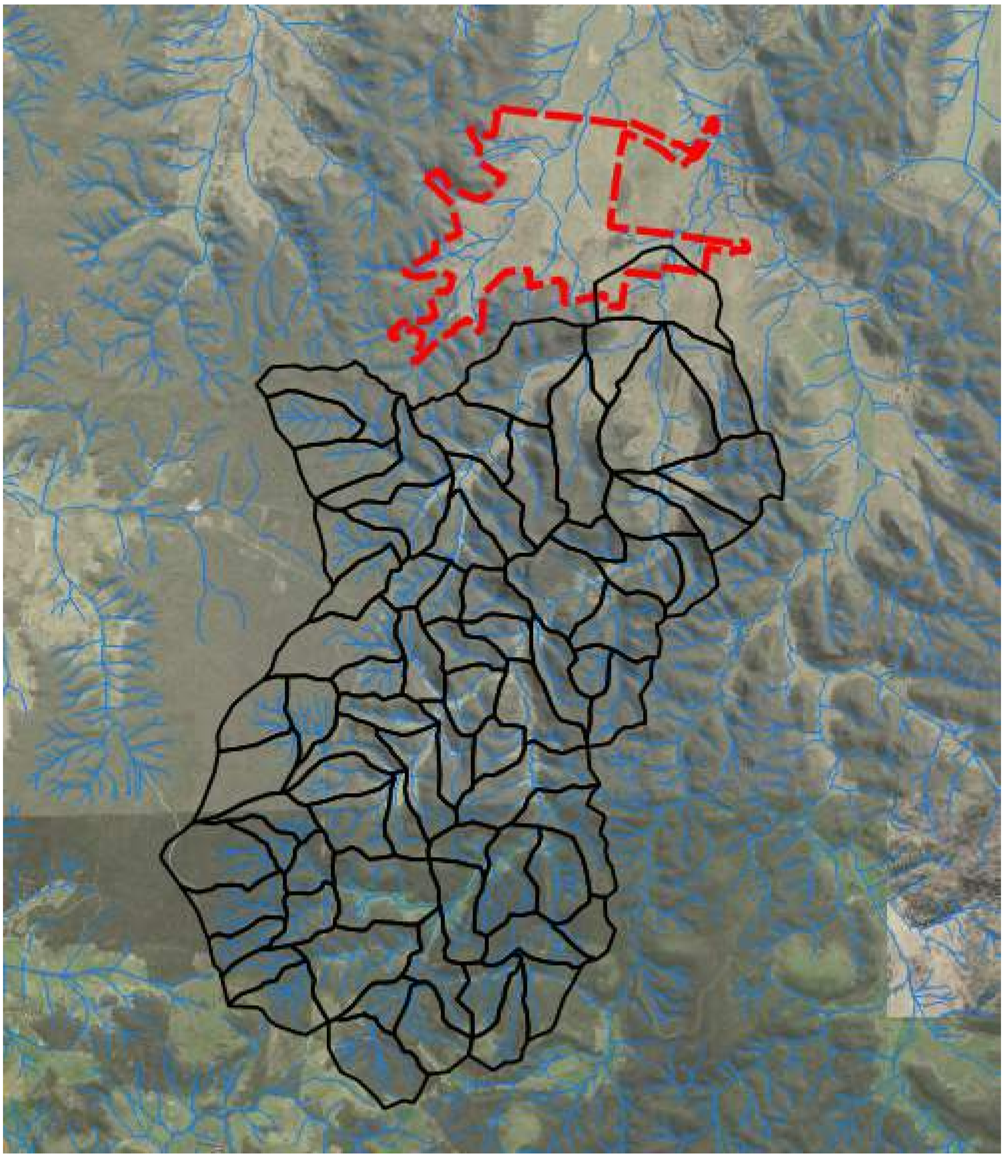


Figure 4 - Wollar Creek Catchment Areas (proposal area shown in red)

3.2.2. XP-RAFTS Modelling Input Parameters

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

Table 1: XP-RAFTS Hydrological Parameters Adopted

Parameter	Value Adopted	Justification/Source
Pervious Area Initial Loss (mm)	30	Recommended value for East Coast South (ECSouth) obtained through ARR 2016 data hub (refer Appendix A)
Pervious Area Continuing Loss (mm/h)	3.2	Recommended value for East Coast South (ECSouth) obtained through ARR 2016 data hub (refer Appendix A)
BX	1	XP-RAFTS Default
Sub-catchment Area (ha)	Varies	As per Figure 4
Impervious Area (%)	0	Based on aerial photography
Sub-catchment Slope (%)	Varies	Varies based on site topography.
Manning's n	0.025 0.06	Rural pasture land Wooded areas.

3.2.3. Rainfall Data

IFD design rainfall depth data and temporal pattern was derived in accordance with Australian Rainfall and Runoff (2016) using the Bureau of Meteorology's 2016 Rainfall IFD on-line Data System.

The temporal patterns for the East Coast South region was used as this covers the site (latitude -32.406, longitude 149.937).

A copy of the rainfall depths for the range of storm durations used can be found in Appendix B. Storm probabilities in ARR2016 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).

The median pre-burst rainfall depths have also been included in Appendix B. These vary according to storm frequency and duration and act to reduce the storm initial loss, on the assumption that the catchment has been wet by pre-burst rainfall preceding the actual storm burst.

No pre-burst rainfall depths are provided on the ARR2016 data hub for storm durations less than 1 hour, or for either the 4.5 hour and 9 hour durations. Therefore, it was assumed that:

- For storm durations of less than 1 hour there was no pre-burst rainfall;
- the 3 hour depth applies for the 4.5 hour storm; and
- the 6 hour depth applies for the 9 hr.

3.2.4. Results

The XP-RAFTS hydrological model was run for storm durations ranging from 30 minutes to 12 hours using a one-minute time step and the results from the critical storm duration and median storm from the ensemble for the range of events modelled are shown in Table 2.

Table 2: XP-RAFTS Hydrological Model Results

Event	Critical Duration	Median Storm from Ensemble	Peak Flow at Outlet (m^3/s)
1% AEP	6 hours	Storm 4	292
2% AEP	4.5 hours	Storm 7	242
5% AEP	6 hours	Storm 7	185
10% AEP	6 hours	Storm 9	147
20% AEP	6 hours	Storm 5	108

The peak flows derived from XP-RAFTS were compared to those derived using the Australian Rainfall and Runoff Regional Flood Frequency Estimation (RFFE) Model and the results are shown in Table 3 and Figure 5.

Table 3: Comparison of Peak Flows from XP-RAFTS to RFFE Method

AEP	Peak Flow Rate (cumecs)			
	XP-RAFTS	Regional Flood Frequency Estimation Model		
		Discharge	Lower (5%)	Upper (95%)
1%	292	316	133	754
2%	242	235	101	553
5%	185	152	66	351
10%	147	104	45	238
20%	108	66	28	151

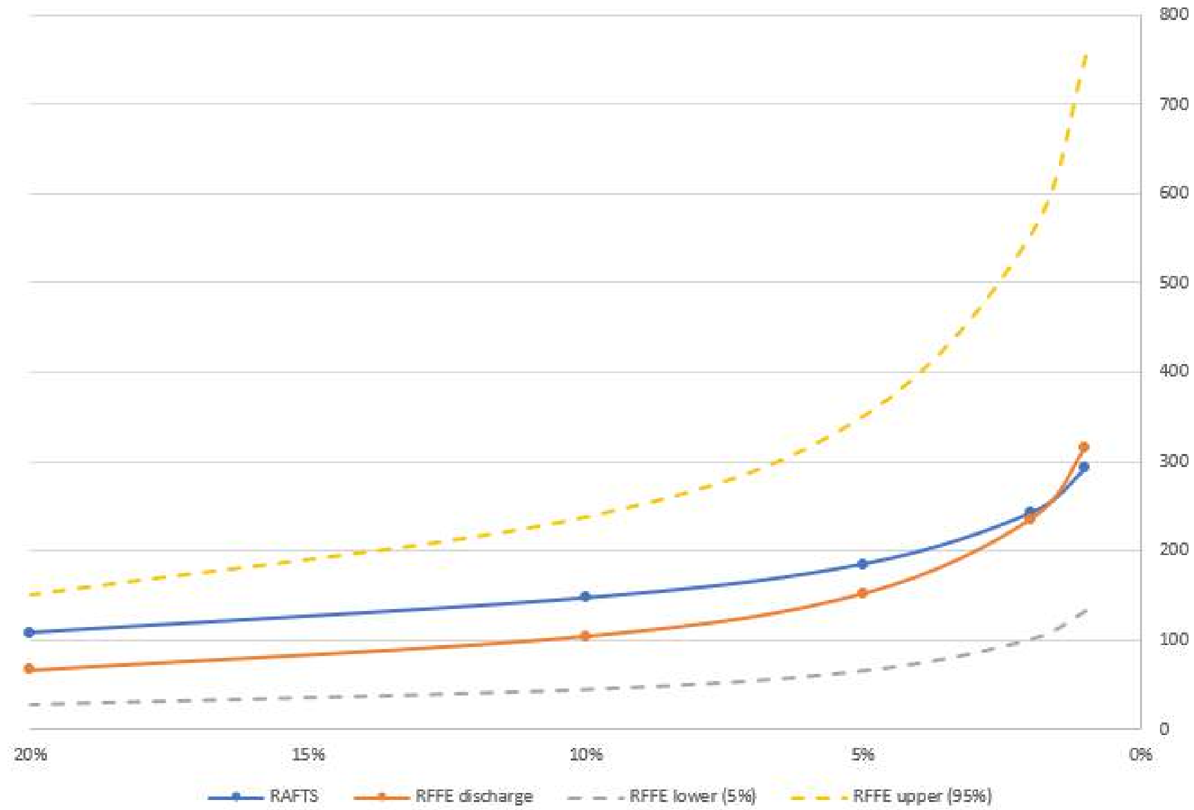


Figure 5: Comparison of peak flows from XP-RAFTS to RFFE Method

The comparison of XP-RAFTS results with the RFFE model showed reasonable correlation with the peak discharge falling close to the RFFE expected discharge and well within the confidence limits for flow estimations based on gauged events from regional catchments. This suggests modelling assumptions are reasonable.

Outputs from the RFFE method for Wollar Creek are included in Appendix C.

3.2.5. Sensitivity Analysis

Analysis was undertaken to check the sensitivity of the adopted velocity of 2m/s used to estimate flood wave propagation.

The model was run using only the 6-hour duration as this duration typically corresponded to the critical storm duration for all events (see Table 2) and the results and shown in Table 4.

The results shown that peak flows are highly sensitive to changes in velocity. Analysis of the velocity data from the two-dimensional model for the site revealed typical flow velocities of 2 to 2.5m/s for the 1% AEP event within the lower reaches of Spring Flat Creek which is considered to have similar topography to that of Wollar Creek and therefore the adopted value of 2m/s is considered reasonable.

Velocities for the more frequent events (i.e. lower peak flows) are likely to be lower, however, for consistency, a single value was adopted for all modelled events.

Table 4: Results of Sensitivity Analysis

Event	Peak Flow at Outlet (m^3/s)		
	V = 0.75m/s	V = 1.5m/s	V=3m/s
1% AEP	167 (Storm 7)	257 (Storm 4)	316 (Storm 9)
2% AEP	134 (Storm 7)	212 (Storm 5)	275 (Storm 9)
5% AEP	93 (Storm 7)	160 (Storm 5)	206 (Storm 8)
10% AEP	69 (Storm 1)	121 (Storm 8)	166 (Storm 5)
20% AEP	46 (Storm 5)	81 (Storm 5)	132 (Storm 5)

3.3. DRAINS Hydrological Model

3.3.1. 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.

3.3.2. Catchment Areas

The total catchment area contributing Spring Flat Creek at the northern boundary of the proposal area was estimated to be approximately 1,390 hectares (13.9km^2) and was determined using 1m Digital Elevation Models (DEM) covering the areas which were obtained through the Australian Foundation Spatial Data web portal.

The overall catchment was dissected into 12 sub-catchments ranging in size from 54 to 207 hectares.

Table 5: Summary of Catchment Areas

Catchment	Area (ha)
1	74
2	142
3	95
4	161
5	154
6	54
7	207
8	119
9	68
10	72
11	106
12	138
TOTAL	1,390

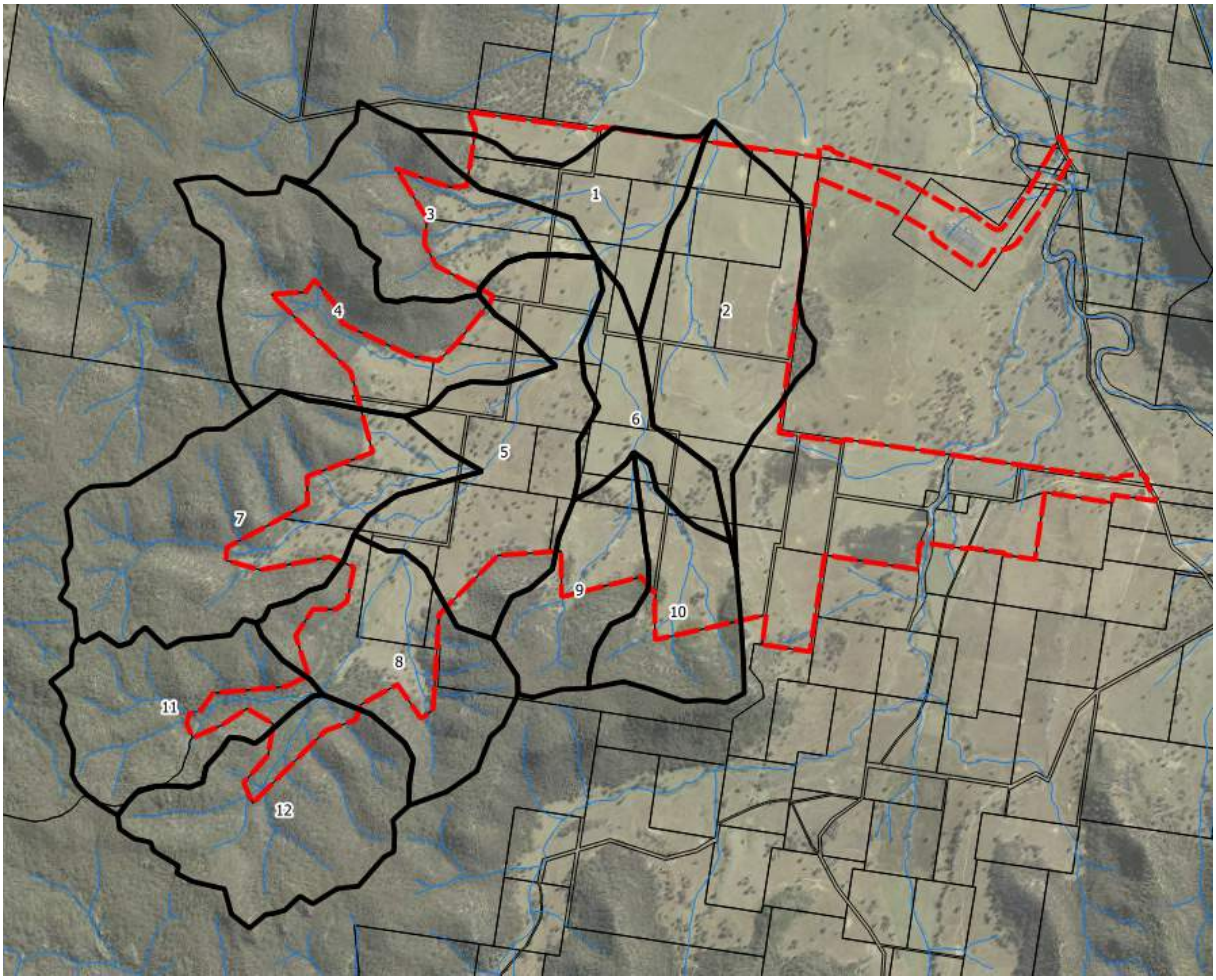


Figure 6: Sub-catchment Plan

3.3.3. DRAINS Modelling Input Parameters

The parameters adopted for DRAINS hydrological modelling are shown in Table 6.

Table 6: DRAINS Hydrological Parameters Adopted

Parameter	**Value Adopted**	**Justification/Source**
Pervious Area Initial Loss (mm)	30	Recommended value for East Coast South (ECSouth) obtained through ARR 2016 data hub (refer Appendix A)
Pervious Area Continuing Loss (mm/h)	3.2	Recommended value for East Coast South (ECSouth) obtained through ARR 2016 data hub (refer Appendix A)
BX	1	RAFTS Default
Sub-catchment Area (ha)	Varies	As per Figure 6 & Table 5
Impervious Area (%)	0	Based on aerial photography
Sub-catchment Slope (%)	Varies	Varies based on site topography.
Manning's n	Varies 0.025 – 0.06	Varies from 0.025 for rural pasture lands to 0.06 for wooded areas.

3.3.4. Rainfall Data

Rainfall data as per Section 3.2.3 was adopted.

3.3.5. Results

The DRAINS hydrological model was run for storm durations ranging from 20 minutes to 12 hours and the results from the critical storm duration and median storm from the ensemble for the range of events modelled are shown in Table 7.

Table 7: DRAINS Hydrological Model Results

Event	Critical Duration	Median Storm from Ensemble	Peak Flow at Outlet (m^3/s)
1% AEP	6 hours	Storm 5	123
2% AEP	3 hours	Storm 6	100
5% AEP	2 hours	Storm 7	71
10% AEP	90 minutes	Storm 8	48
20% AEP	2 hours	Storm 6	34

4.0 HYDRAULIC MODELLING

Hydraulic modelling was conducted using an unsteady direct rainfall two-dimensional HEC-RAS model (Version 5.0.5) which covered the entire catchment draining to the proposal area. Inflow hydrographs derived from XP-RAFTS were applied to this model to account for flows generated in Wollar Creek upstream of the model domain.

4.1.1. Two-Dimensional Domain

A digital elevation model (DEM) of the proposal area was established using a series of 2m gridded digital elevation models (gulgong2015.tif) sourced from www.elevation.fsdf.org.au.

A two-dimensional flow area (i.e. active cells) was defined over the entire catchment to simulate the rainfall-runoff process. The extent of the two-dimensional flow area is shown in Figure 7.

The 2m 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 contours banks and dam walls. An example of the grid refinement undertaken using breaklines is shown in Figure 8.

The two-dimensional flow area was assigned a default Manning's n value of 0.025 which is considered representative of the current condition of the land (grazed agricultural land). The Manning's n value was increased in areas of vegetation to represent light brush (0.04) and heavy brush (0.06) as shown in Figure 9.

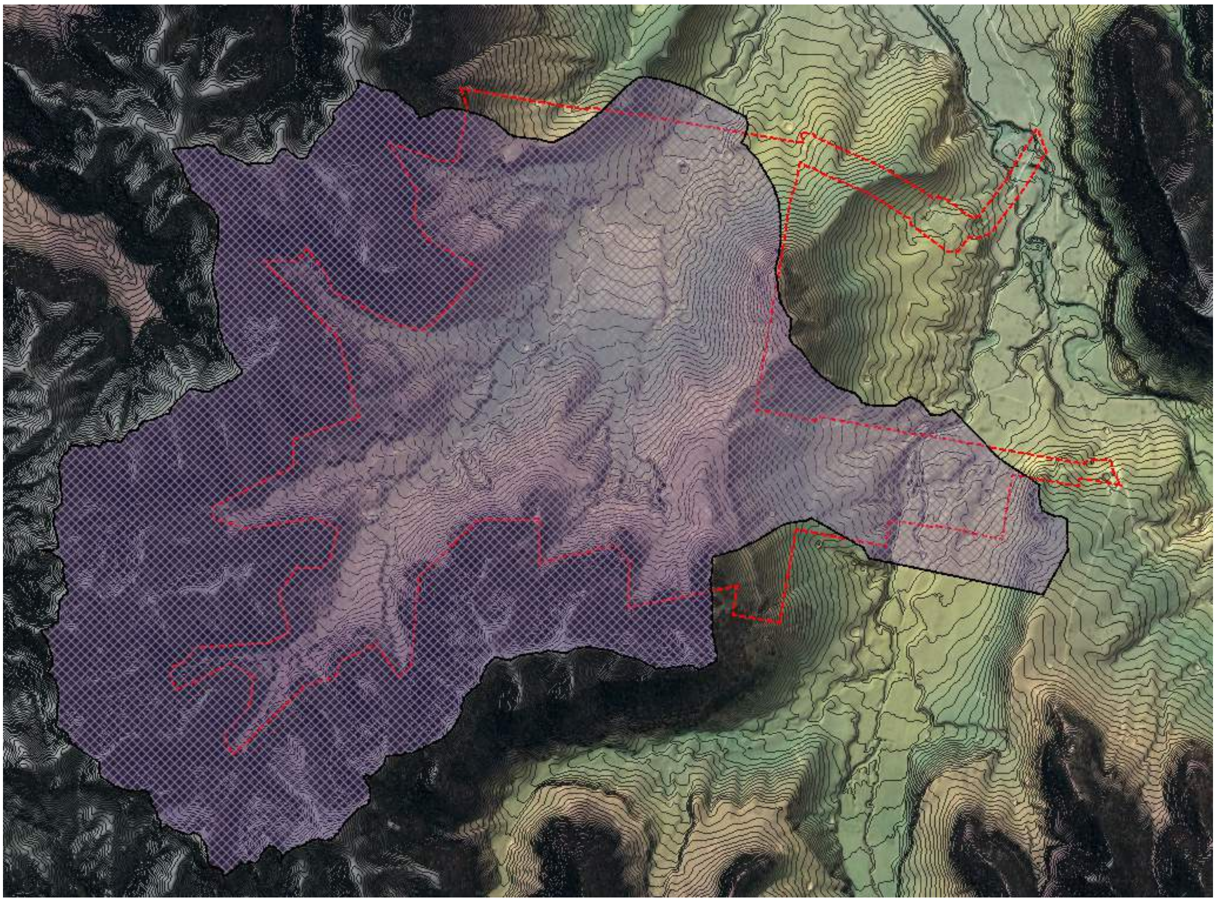


Figure 7: Two-Dimensional Flow Area

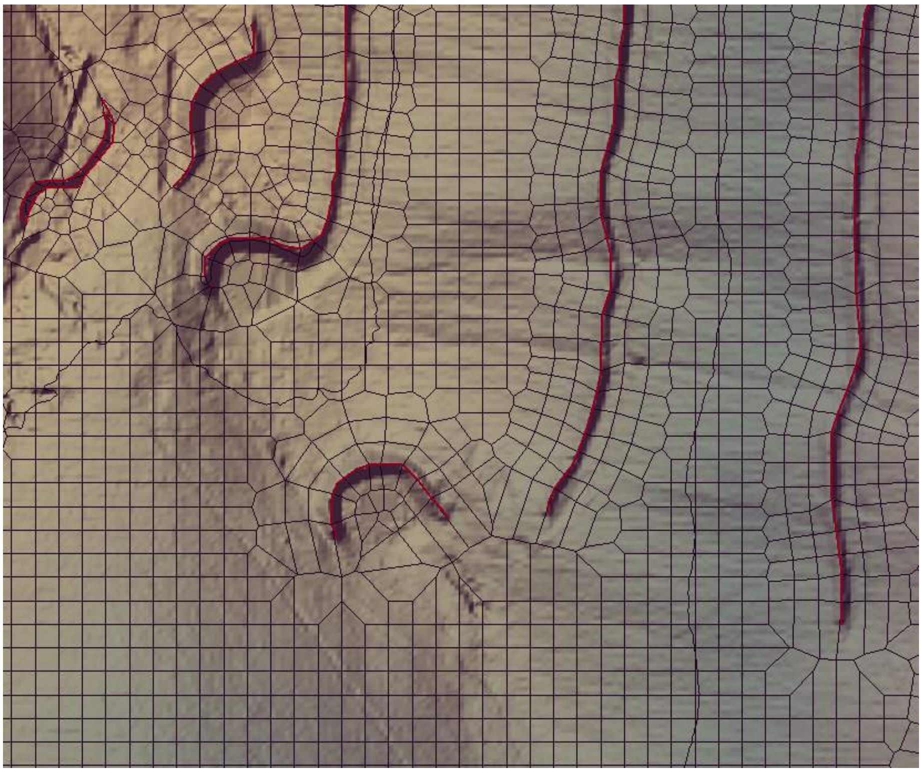


Figure 8: Example of Grid Refinement Using Breaklines

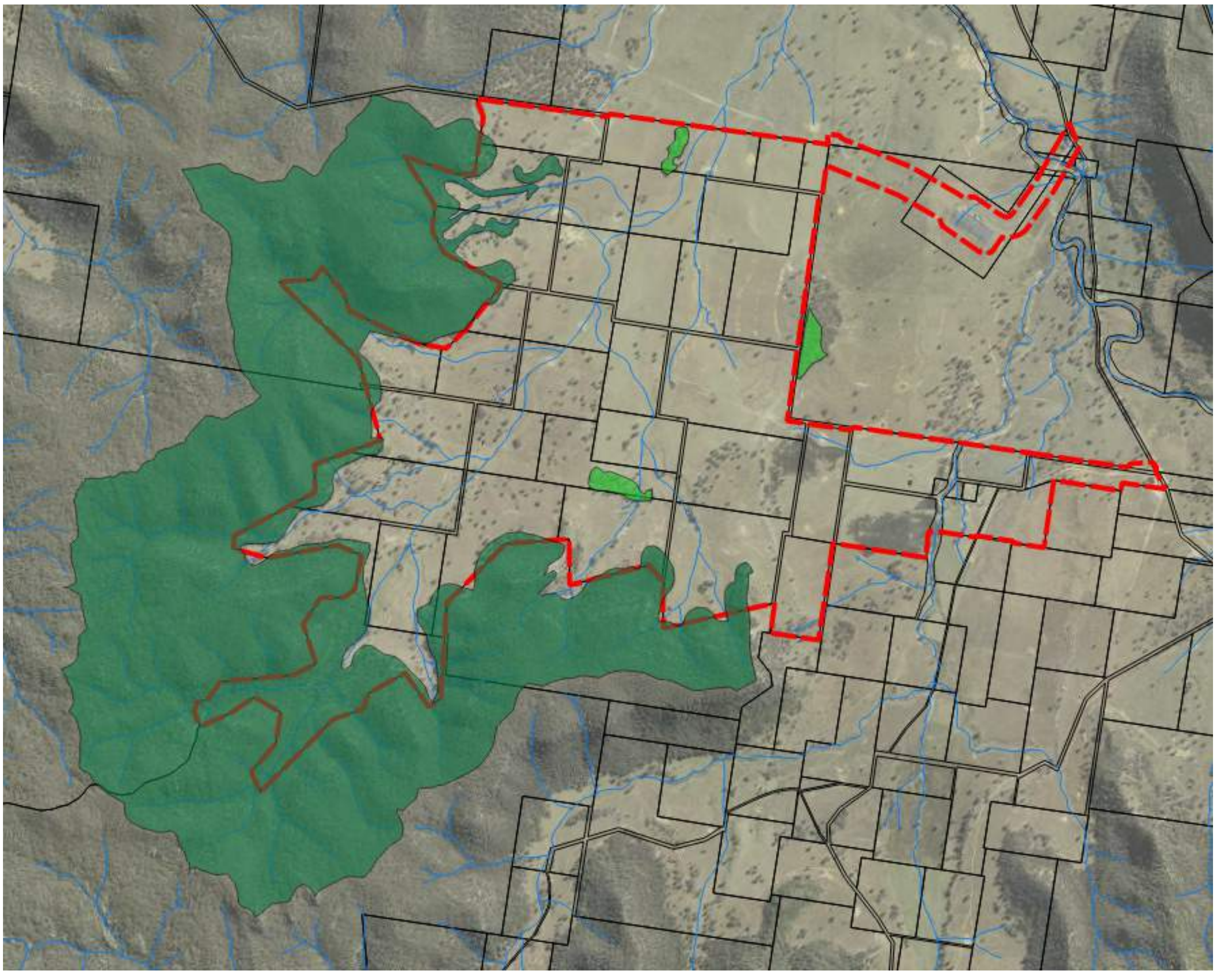


Figure 9: Manning's n Value Adopted (light green = 0.04, dark green = 0.06)

4.1.2. 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 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 shown in Table 7 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 storm event is shown in Figure 10.

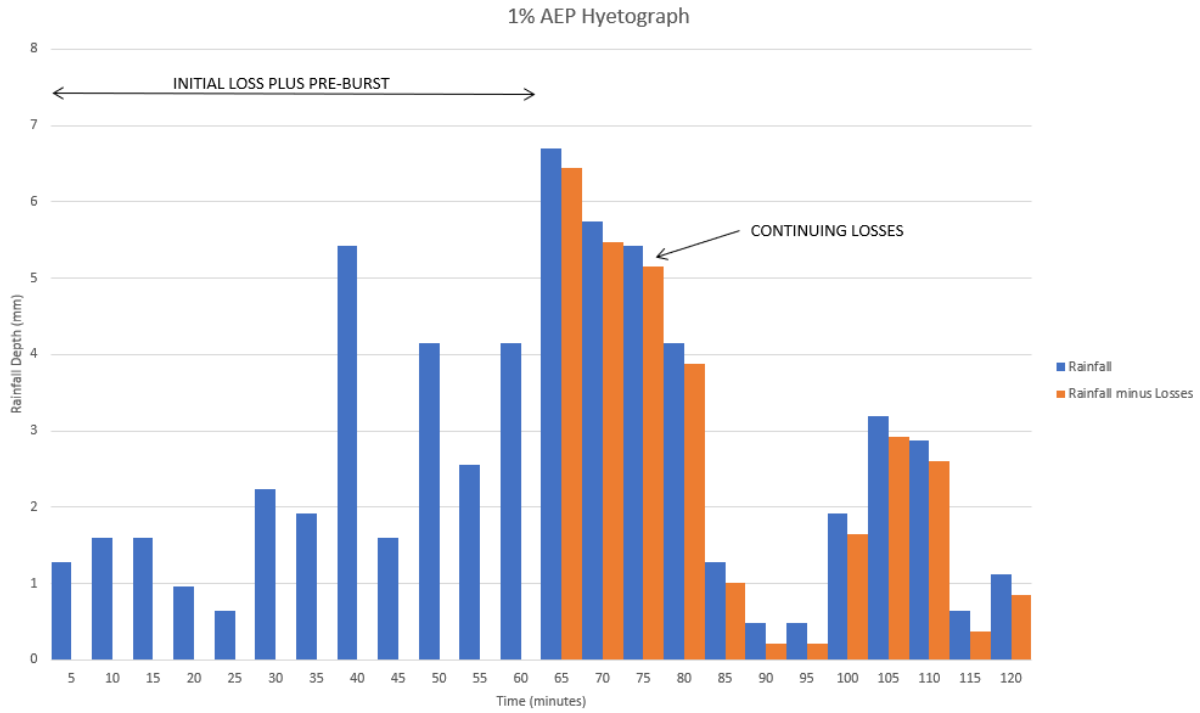


Figure 10: 1% AEP Hyetograph

4.1.3. Upstream Boundary Condition

The hydrographs derived using XP-RAFTS were used to define the upstream boundary condition within Wollar Creek for each of the modelled events.

Hydrographs for each event are contained in Appendix E.

The upstream boundary was extended along the upstream face of the two-dimensional domain across Wollar Creek over enough length to enable the model to appropriately distribute the flow to the cells that are wet. At any given timestep, only a portion of the boundary condition line may be wet, thus only the cells in which the water surface elevation is higher than their outer boundary face terrain will receive water.

4.1.4. 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.

The location of upstream and downstream boundary conditions are shown in Figure 11.

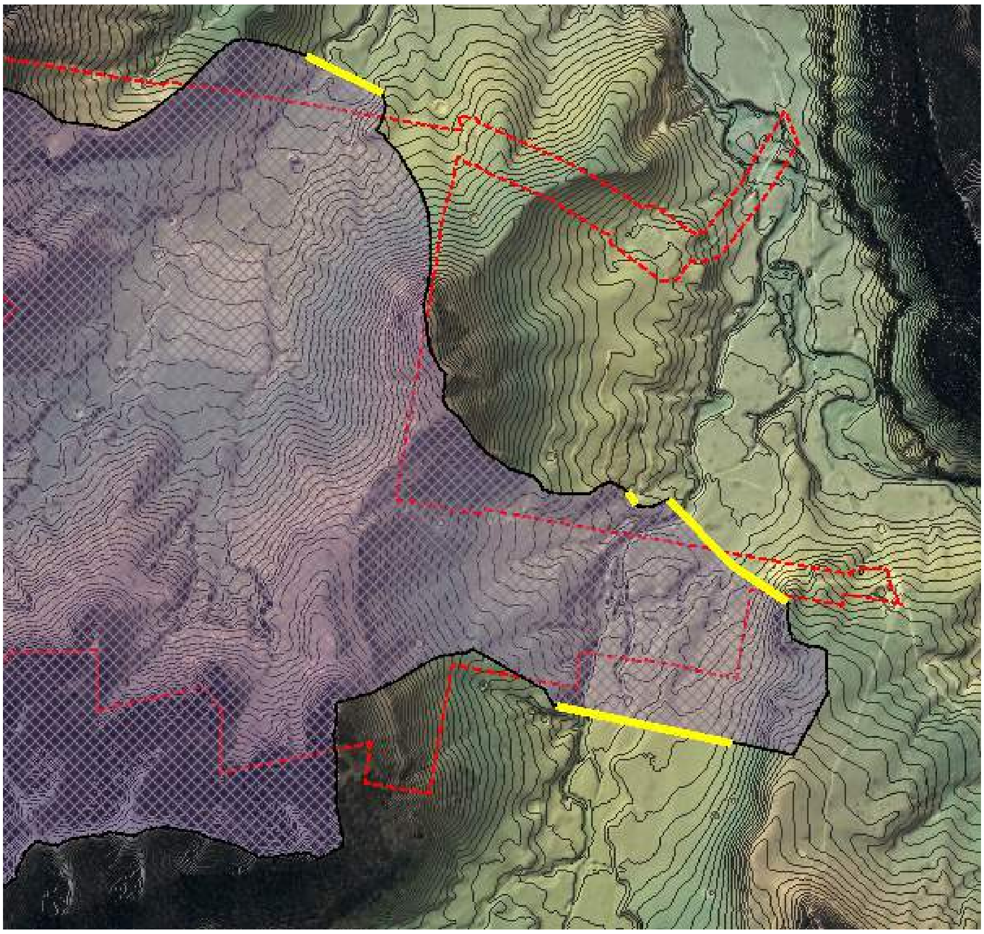


Figure 11: Location of Boundary Conditions (Shown in Yellow)

4.2. Results

Results of the hydraulic modelling are included in Appendix F and include the following:

Figure 1.1 – Existing 1% AEP Flood Levels and Depths

Figure 1.2 – Existing 1% AEP Flood Velocities

Figure 2.1 – Existing 2% AEP Flood Levels and Depths

Figure 2.2 – Existing 2% AEP Flood Velocities

Figure 3.1 – Existing 5% AEP Flood Levels and Depths

Figure 3.2 – Existing 5% AEP Flood Velocities

Figure 4.1 – Existing 10% AEP Flood Levels and Depths

Figure 4.2 – Existing 10% AEP Flood Velocities

Figure 5.1 – Existing 20% AEP Flood Levels and Depths

Figure 5.2 – Existing 20% AEP Flood Velocities

The results show that significant flow depth (up to about 1.2m outside existing dams) is expected to occur along Spring Flat Creek in the 1% AEP event with velocities approaching 4m/s in places. Elsewhere, in the un-named tributaries of Spring Flat Creek flow depths do not typically exceed 0.3m in the 1% AEP event however velocities remain reasonably high and are typically in the 2-3 m/s range.

4.3. Hazard Vulnerability

The flood hazard vulnerability over the proposal area was mapped in accordance with Table 6.7.4 of Australian Rainfall and Runoff (2016) and the results are included in Appendix F and include the following:

Figure 1.3 – Existing 1% AEP Flood Hazard

Figure 2.3 – Existing 2% AEP Flood Hazard

Figure 3.3 – Existing 5% AEP Flood Hazard

Figure 4.3 – Existing 10% AEP Flood Hazard

Figure 5.3 – Existing 20% AEP Flood Hazard

The mapping shows that flows along Spring Flat Creek within the watercourse are typically categorised as H4 and H5 in the 1% AEP event and would therefore be unsuitable for development. Along most other watercourses within the proposal area flows are typically categorised as H4 and H5 in the upper reaches were grades are steep and the channel is confined and reduce to H1-H3 in the lower flatter reaches where flood depths and velocities reduce.

Table 6.7.3 of Australian Rainfall and Runoff (below) describes the hazard thresholds for interaction with floodwaters. In the context of this project structural damage to solar array infrastructure could be expected for areas categorised as either H5 or H6 and development in these areas should ideally be avoided.

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. Comparison of Results

Flow hydrographs on Spring Flat Creek at the downstream boundary of the two-dimensional hydraulic model were compared to those of the DRAINS model and are shown in Figure 12.

The comparison shows good correlation between the two sets of data with similar hydrograph shape. Peak flows from the hydraulic model tend to have slightly higher peaks (up to about 20%) which typically occur in the order of 15 minutes earlier than those from the DRAINS model. Probable causes of these differences are likely associated with the simplified method used by DRAINS in routing flows between catchment and/or surface roughness which leads to reduced peak flows when compared to the HEC-RAS model.

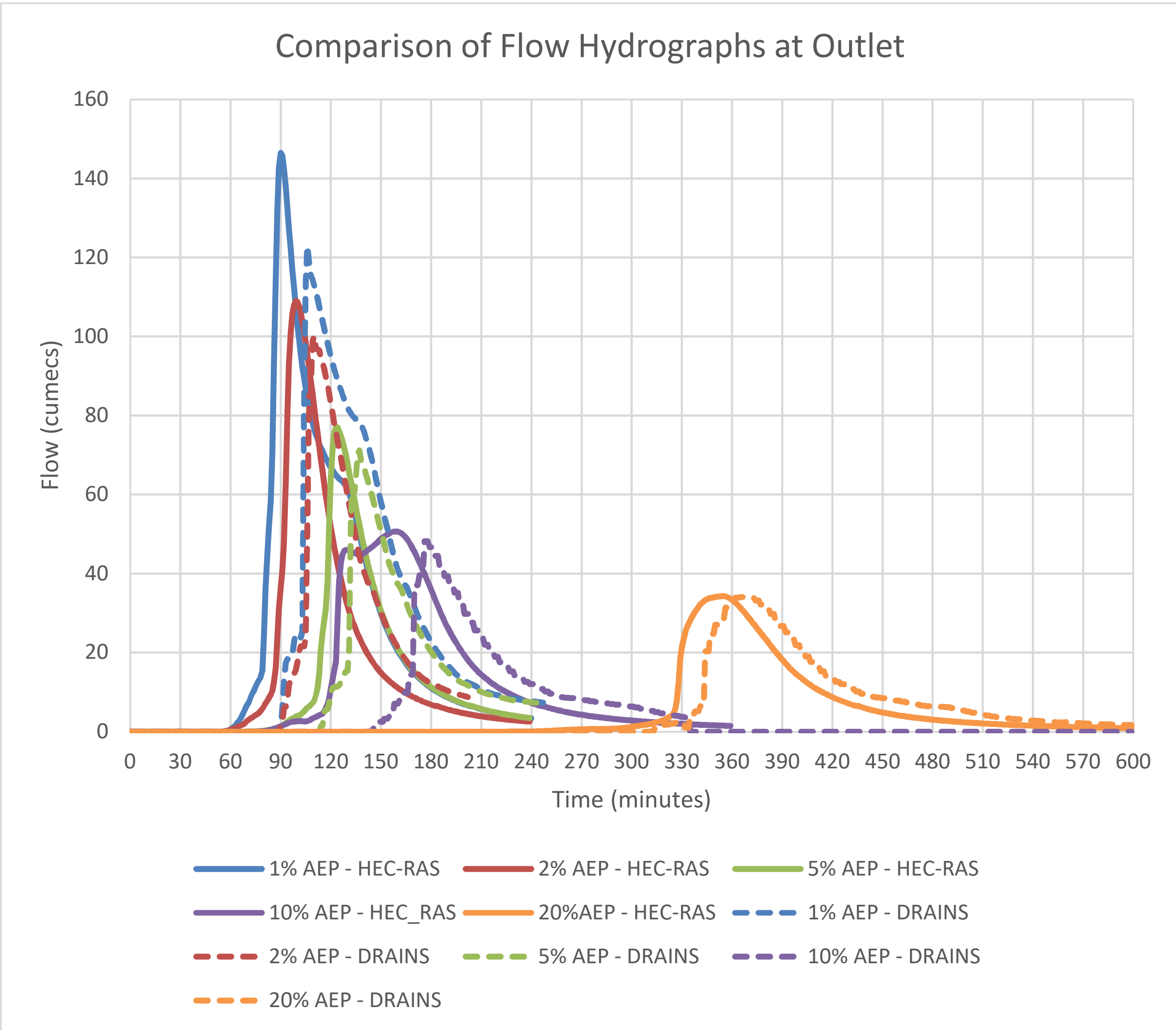


Figure 12: Comparison of Flood Hydrographs

The peak flows derived from both the hydrological (DRAINS) and hydraulic (HEC-RAS) models at the outlet on Spring Flat Creek were also compared to those derived using the Australian Rainfall and Runoff Regional Flood Frequency Estimation (RFFE) Model and the results are shown in Table 8 and Figure 13.

Table 8: Comparison of Peak Flows to Regional Flood Frequency Estimation Model

AEP	Peak Flow Rate (cumecs)				
	RAFTS	HEC-RAS	Regional Flood Frequency Estimation Model		
			Discharge	Lower (5%)	Upper (95%)
20%	34	34	25	11	58
10%	48	51	40	17	91
5%	71	77	58	25	134
2%	100	109	90	39	211
1%	123	146	121	51	288

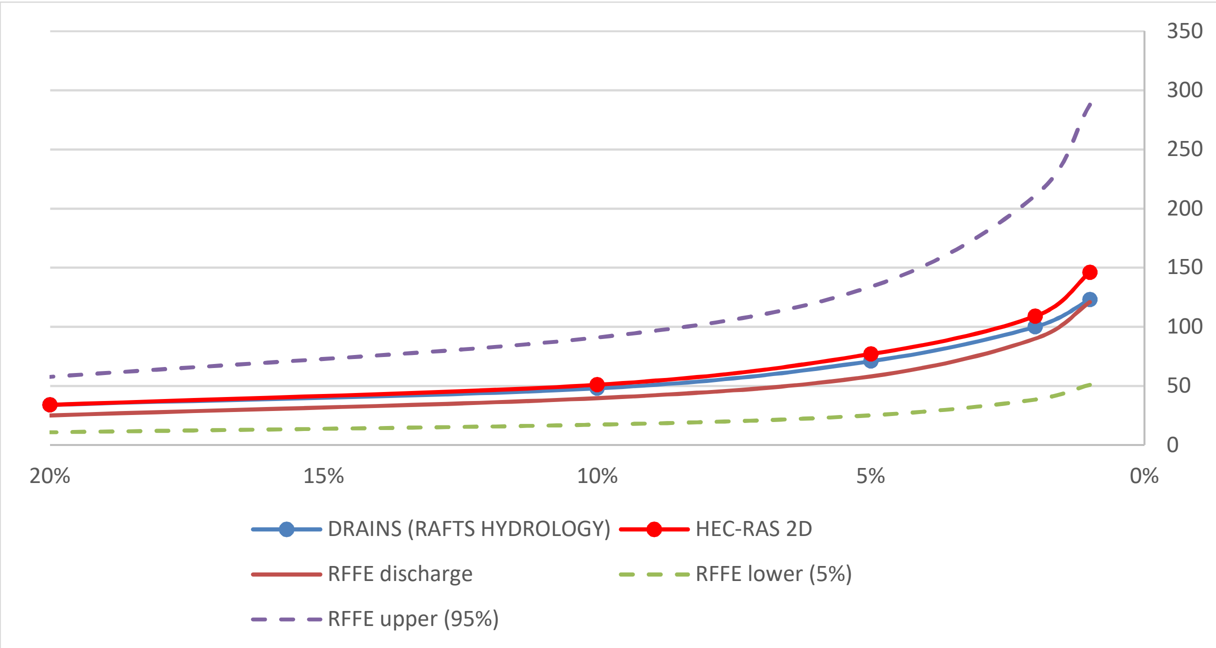


Figure 13: Comparison of Peak flows to Regional Flood Frequency Estimation Model

The comparison of results with the RFFE model show good correlation with the peak discharge for both the DRAINS and HEC-RAS models falling close to the RFFE expected discharge and well within the confidence limits for flow estimations based on gauged events from regional catchments.

Outputs from the RFFE method for the site are included in Appendix D.

5.0 IMPACT OF PROPOSED WORKS

5.1. Proposal Description

The proposed Wollar Solar Farm involves the construction, operation and decommissioning of a ground-mounted PV solar array. Up to 290 MW (AC) of renewable energy would be generated and supplied directly to the national electricity grid. The proposal area is approximately 878 ha and would consist of associated infrastructure occupying around half (458ha) the area.

The proposed Wollar Solar Farm comprises the following key items of infrastructure:

- Approximately 922,432 photovoltaic solar panels mounted on either fixed or tracking systems, both of which are considered feasible:
    - Fixed-tilted structures in a north orientation at an angle of 32 degrees or
    - East-west horizontal tracking systems
- Approximately 58 power conversion units (PCU) composed of two inverters, a transformer and associated control equipment to convert DC electricity generated in the solar panels to 33 kV AC electricity
- Steel mounting frames with piled foundations.
- An onsite 330kV substation containing 2 transformers and associated switch gear to facilitate connection to the national electricity grid via the existing 330kV transmission line onsite.
- Underground power cabling to connect solar panels, combiner box and PCU's.
- Underground auxiliary cabling for power supplies, data services and communications.
- Buildings to accommodate a site office, protection and control facilities, maintenance facilities and staff amenities.
    - Up to 2km of access track off Barigan Road to the site via the existing TransGrid substation access road, which would require construction of an access road between the Wollar substation and the proposed onsite substation
- Internal access tracks for construction and maintenance activities
- Space for future energy storage facility with a capacity of up to 30MWh and comprising lithium ion batteries with inverters
- Perimeter security fencing up to 2.3 m high

- Native vegetation planting to provide visual screening for specific viewers, if any are required

During the construction phase, temporary ancillary facilities would be established on the site and may include:

- Laydown areas
- Construction site offices and amenities
- Car and bus parking areas for construction staff.

Construction access to the site is proposed along the existing TransGrid Wollar substation access road via Barigan Road, which incorporates an existing concrete causeway crossing at Wollar Creek.

Operational access to the solar farm is to be provided off Barigan Road via Maree Road and un existing un-named track, which incorporates an existing culvert crossing of Wollar Creek.

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

Table 9: Modified Cowan Method for Estimation of Floodplain Roughness

Roughness Component	Existing (Grazed Pasture)	Proposed (Solar Array)
Floodplain Material (n_b)	0.020	0.020
Degree of Irregularity (n_1)	0.001	0.001
Variation in Floodplain Cross Section (n_2)	N/A	N/A
Effect of Obstructions (n_3)	0.000	0.003[1]
Amount of Vegetation (n_4)	0.004	0.004
Total (n)	0.025	0.028

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

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

The distribution and extent of Manning's n values adopted for assessment of the proposed development are shown in Figure 14. Note the absence of shaded reflects areas where the model default value (0.025) exists.

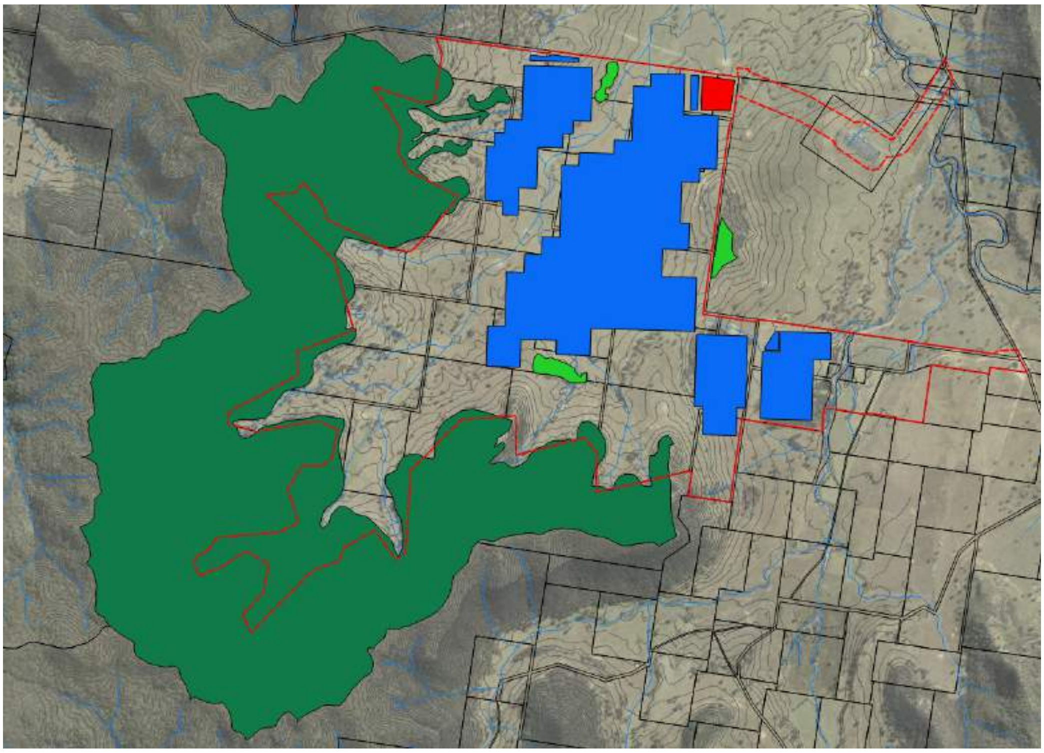


Figure 14: Post Development Manning's n Value Adopted (blue = 0.028, light green = 0.04, dark green = 0.06, red = 3.0)

It should be noted that the proposed development would include a network of access roads and these would be constructed from dirt (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 floodplain roughness of 0.026, which is only marginally higher than the adopted predevelopment value. On this basis, and considering the fact these tracks are likely to be less than 5m 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, 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 F.

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 F) which show the change in maximum flood level and peak flood velocity resulting from the proposed development.

The analysis of the results in Figure 7.1 shows that a maximum increase in flood level of 33mm is expected as a result of the proposed development whilst a maximum decrease of 123mm is expected. Importantly the modelling demonstrates that changes in peak flood levels are limited to within the proposal area and are therefore not anticipated to adversely affect adjoining properties.

Figure 7.2 shows that changes in peak velocity resulting from the proposed development are typically 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. It should be noted that localised increases in floodplain velocity in close proximity to piers for the proposed solar array are likely and piers should therefore be located outside areas subject to high velocity flows.

6.0 FLOOD MANAGEMENT RECOMMENDATIONS

6.1. 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 F.

6.2. 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.

6.3. 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 Spring Flat Creek should be avoided in preference to creating two separate fenced compounds on either side of the creek.

6.4. Watercourse Crossings

Watercourses within the proposal area 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 15. Any new road crossings on watercourses within the proposal area should be of the type defined in Table 2 of this same document (see extract below).

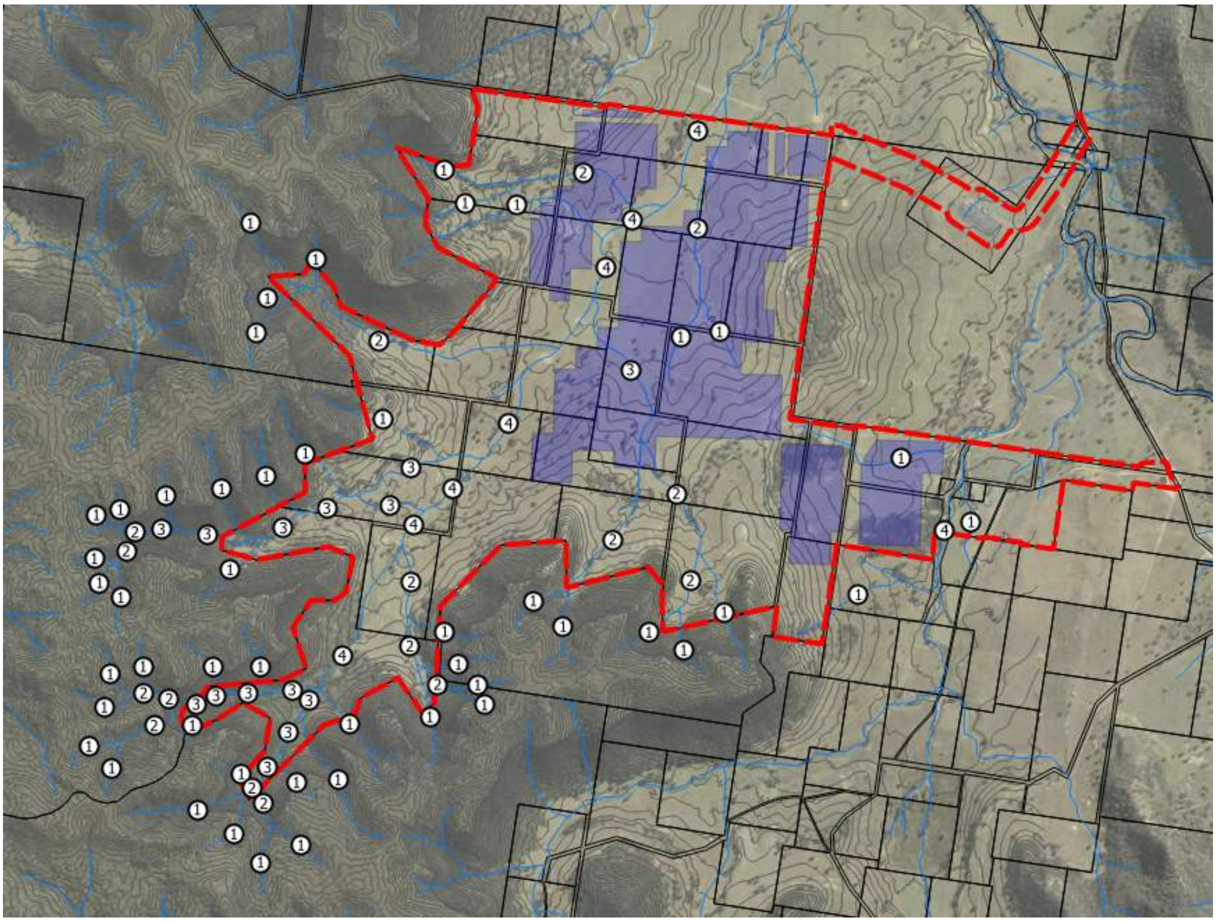


Figure 15: Stream Order

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 proposal area 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)

It should be noted that both construction and operational access to the proposed solar farm will utilise existing crossings on Wollar Creek as noted in Section 5.1 and therefore no new crossing on Wollar Creek is required as part of the proposed development.

6.5. 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

6.6. Flood Management

As operational access to the site will utilise an existing low-level crossing within Wollar Creek that will become inundated in flood events (up to approximately 2.0m in the 1% AEP event) it is recommended that:

i. Flood warning signs and flood level indicators should be placed on each approach to the existing low-level crossing (as shown in Figure 16).
ii. A flood refuge building or structure be provided within the proposal area on the western side of Wollar Creek, such that in the event the Wollar Creek crossing is not trafficable any staff on-site have access to a weatherproof, flood free structure to seek temporary refuge.
iii. 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"

Figure 16: Recommended Flood Warning and Flood Level Indicator Signs

7.0 SEAR'S COMPLIANCE

The Secretary of 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 04 May 2018, which included requirements from the Office of Environmental and Heritage (OEH) pertaining to flooding.

OEH Requirement	**Response**
14. 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 all design storm events modelled (20% AEP, 10% AEP, 5% AEP, 2% AEP and 1% AEP) has been defined over the proposal area as defined in Section 4.2 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 6.1 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".

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 4.3 of this report.
15. 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.
16. The EIS must model the effect of the proposed Wollar Solar Project (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 5.0 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.
17. Modelling in the EIS must consider and document:	
18. 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.

19. The impact on existing flood behaviour for a full range of flood events including up to the probably maximum flood, or equivalent extreme flood.	Due to the nature of the proposed development impact assessment was undertaken for the 1% AEP event only and showed only very minor changes in flood level and velocity. On this basis assessment of the impact on other events included in the design model runs was not considered to be warranted.
20. 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 5.0 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 limited to within the proposal area and are therefore not anticipated to adversely affect adjoining properties
21. Relevant provision of the NSW Floodplain Development Manual 2005	This report is considered to address the relevant provisions of the NSW Floodplain Development Manual.
22. The EIS must assess the impact on the proposed Wollar Solar Project 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 5.2 shows that the proposed development will have negligible impact on existing flood behaviour, and no 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 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 very low associated flood risk.
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 5.2 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 6.5 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.	

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.	Recommendations regarding specific measures to manage the risk to life from flooding and evacuation are provided in Section 6.6 and include flood warning signs, a flood refuge structure and preparation of a Business Floodsafe Plan. Whilst not discussed with the NSW SES or Council they are considered standard flood management measures.
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.

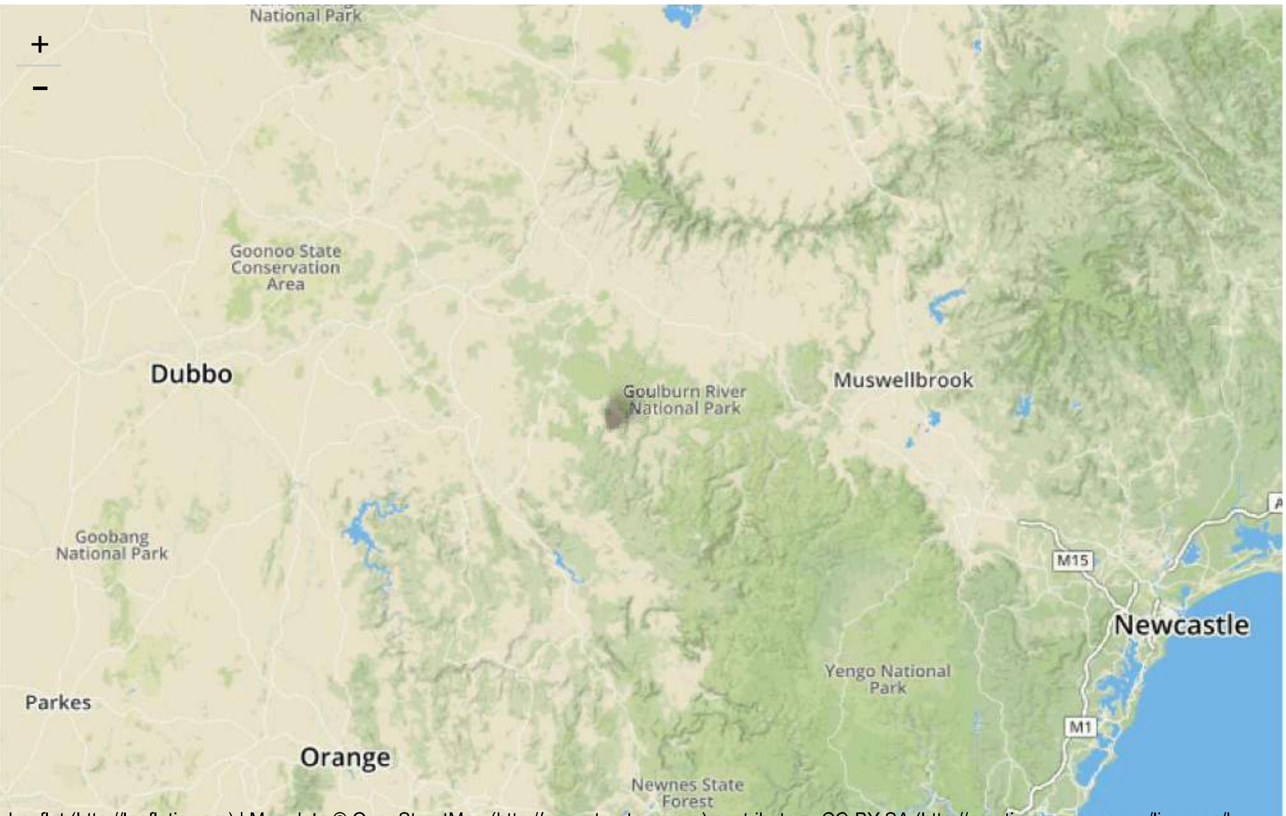
APPENDIX A

BOM ARR 2016 Hub Data

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	149.937
Latitude	-32.406
Selected Regions (clear)	
Storm Losses	show
Temporal Patterns	show



Leaflet (http://leafletjs.com) | Map data © OpenStreetMap (http://openstreetmap.org) contributors, CC-BY-SA (http://creativecommons.org/licenses/by-sa/2.0/), Imagery © Mapbox (http://mapbox.com)

Region Information

Data Category	**Region**
River Region	Hunter River
ARF Parameters	SE Coast
Temporal Patterns	East Coast South

Data

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

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

id	14090.0
Storm Initial Losses (mm)	30.0
Storm Continuing Losses (mm/h)	3.2

Layer Info

Time Accessed	18 June 2018 03:49PM
Version	2016_v1

Temporal Patterns | Download (.zip) (./temporal_patterns/tp/ECsouth.zip)

code	ECsouth
Label	East Coast South

Layer Info

Time Accessed	18 June 2018 03:49PM
Version	2016_v2

BOM IFD Depths

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-32.406356&longitude=149.937034&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

No data	No data found at this location!

Layer Info

Time Accessed	18 June 2018 03:49PM

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)	0.9 (0.040)	0.8 (0.028)	0.8 (0.023)	0.8 (0.019)	0.8 (0.018)	0.9 (0.017)
90 (1.5)	1.0 (0.039)	0.8 (0.024)	0.7 (0.017)	0.5 (0.012)	0.3 (0.006)	0.2 (0.003)
120 (2.0)	1.0 (0.037)	0.8 (0.022)	0.6 (0.015)	0.5 (0.011)	0.5 (0.010)	0.5 (0.009)
180 (3.0)	2.0 (0.064)	1.6 (0.041)	1.4 (0.030)	1.2 (0.023)	0.7 (0.012)	0.4 (0.005)
360 (6.0)	0.6 (0.017)	1.3 (0.025)	1.7 (0.029)	2.1 (0.032)	4.6 (0.060)	6.5 (0.076)
720 (12.0)	0.0 (0.000)	0.6 (0.009)	0.9 (0.013)	1.3 (0.015)	4.1 (0.042)	6.3 (0.056)
1080 (18.0)	0.0 (0.000)	1.8 (0.025)	3.0 (0.035)	4.1 (0.042)	7.9 (0.068)	10.8 (0.081)
1440 (24.0)	0.0 (0.000)	0.3 (0.004)	0.5 (0.005)	0.7 (0.006)	5.0 (0.039)	8.3 (0.056)
2160 (36.0)	0.0 (0.000)	0.1 (0.001)	0.1 (0.001)	0.2 (0.002)	1.6 (0.010)	2.6 (0.015)
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 June 2018 03:49PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Download TXT (downloads/1529300995.txt) Generating PDF... (downloads/1529300995.pdf)

APPENDIX B

ARR 2016 IFD Data

Australian Government
Bureau of Meteorology

Location

Label: Not provided

Latitude: -32.406 [Nearest grid cell: 32.4125 (S)]

Longitude: 149.937 [Nearest grid cell: 149.9375 (E)]

IFD Design Rainfall Depth (mm)

Issued: 31 July 2018

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

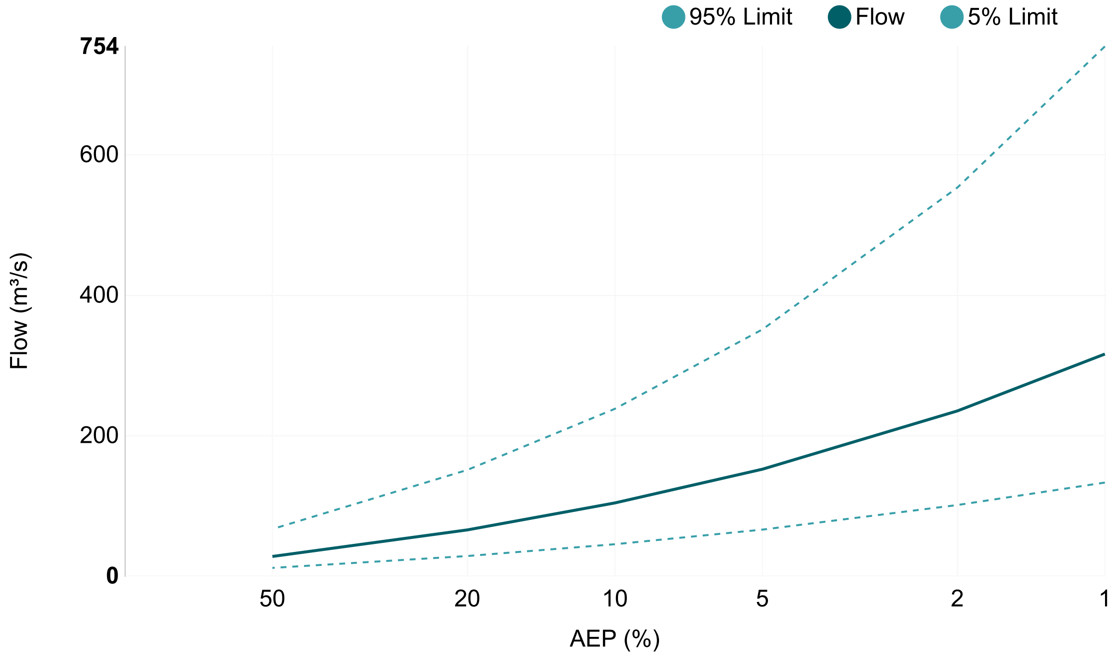
	Annual Exceedance Probability (AEP)						
Duration	**63.2%**	**50%#**	**20%***	**10%**	**5%**	**2%**	**1%**
1 min	1.81	2.01	2.65	3.10	3.56	4.18	4.68
2 min	3.00	3.33	4.37	5.10	5.83	6.71	7.36
3 min	4.17	4.62	6.08	7.09	8.11	9.37	10.3
4 min	5.24	5.81	7.64	8.92	10.2	11.9	13.1
5 min	6.20	6.87	9.05	10.6	12.1	14.1	15.7
10 min	9.78	10.9	14.3	16.8	19.3	22.7	25.5
15 min	12.1	13.5	17.8	20.9	24.0	28.4	31.9
30 min	16.3	18.1	23.9	28.0	32.1	37.9	42.4
1 hour	20.4	22.6	29.8	34.9	40.0	46.7	52.0
1.5 hour	22.9	25.4	33.4	39.0	44.6	52.0	57.7
2 hour	24.8	27.5	36.1	42.1	48.1	56.0	62.1
3 hour	27.7	30.7	40.3	47.0	53.6	62.4	69.3
6 hour	33.9	37.6	49.4	57.7	65.8	77.2	86.2
9 hour	38.4	42.6	56.3	65.8	75.3	89.0	100
12 hour	42.0	46.7	61.9	72.6	83.4	99.2	112
24 hour	52.1	58.2	78.2	92.7	108	130	149
48 hour	63.4	71.1	97.0	116	137	168	194
72 hour	69.9	78.5	108	130	153	189	219
96 hour	74.3	83.5	115	138	163	201	233
120 hour	77.6	87.1	119	143	168	207	240
144 hour	80.2	90.0	123	146	171	210	243
168 hour	82.4	92.4	125	148	171	210	243

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.

APPENDIX C

RFFE Method Results – Wollar Creek

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	27.8	11.5	66.8
20	65.6	28.4	151
10	104	45.2	238
5	152	66.0	351
2	235	101	553
1	316	133	754

Statistics

Variable	Value	Standard Dev
Mean	3.357	0.532
Standard Dev	0.987	0.132
Skew	0.124	0.027

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

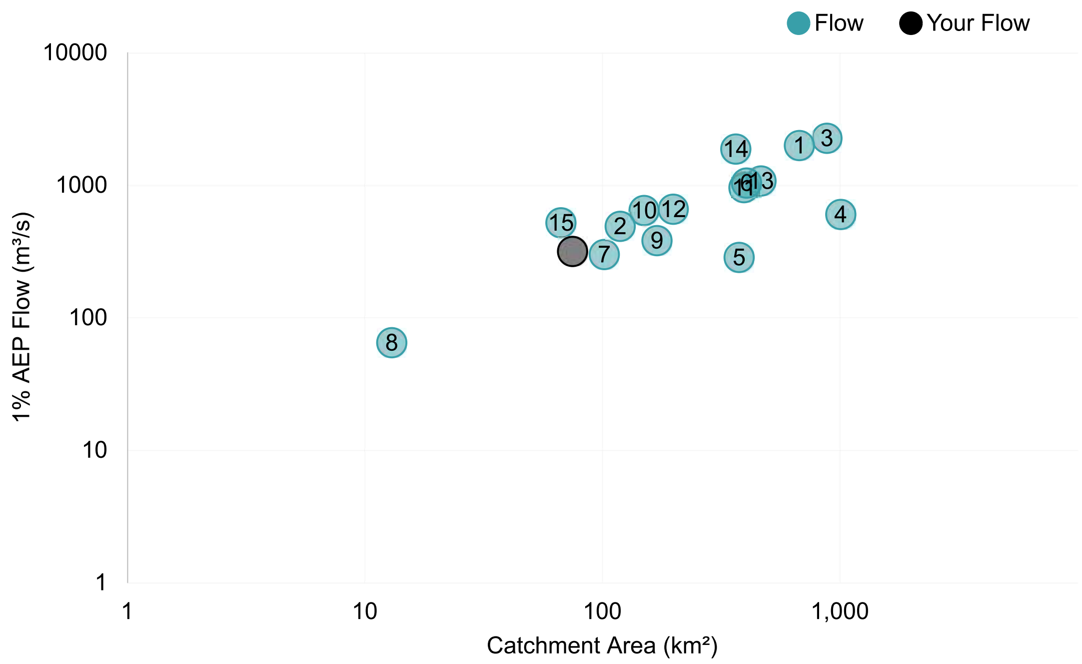
Correlation

Correlation

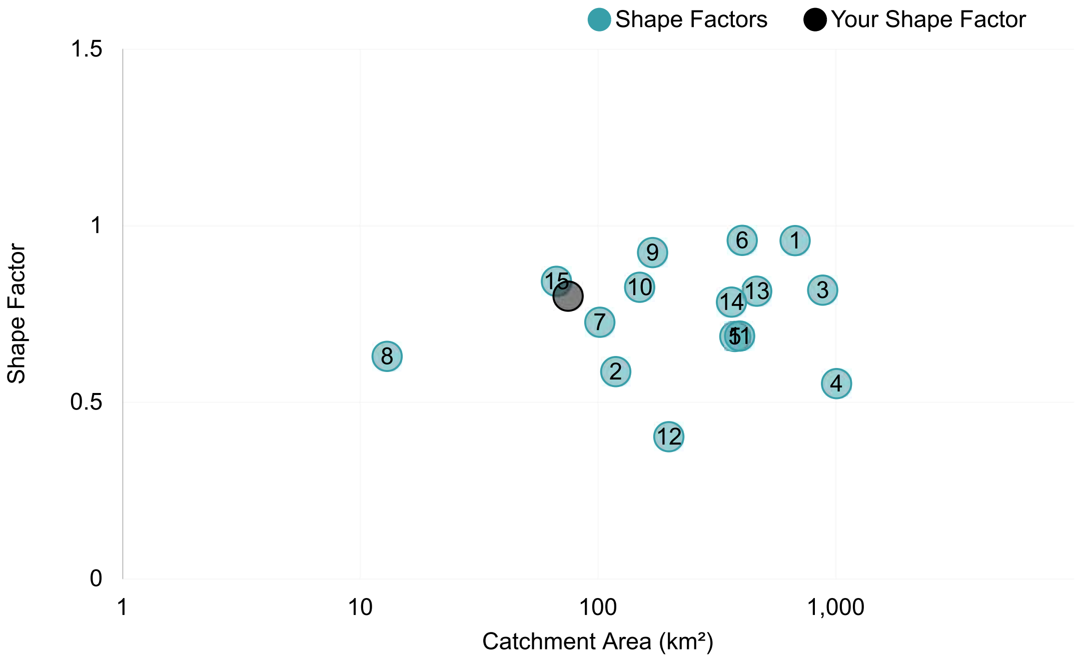
1.000		
-0.330	1.000	
0.170	-0.280	1.000

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

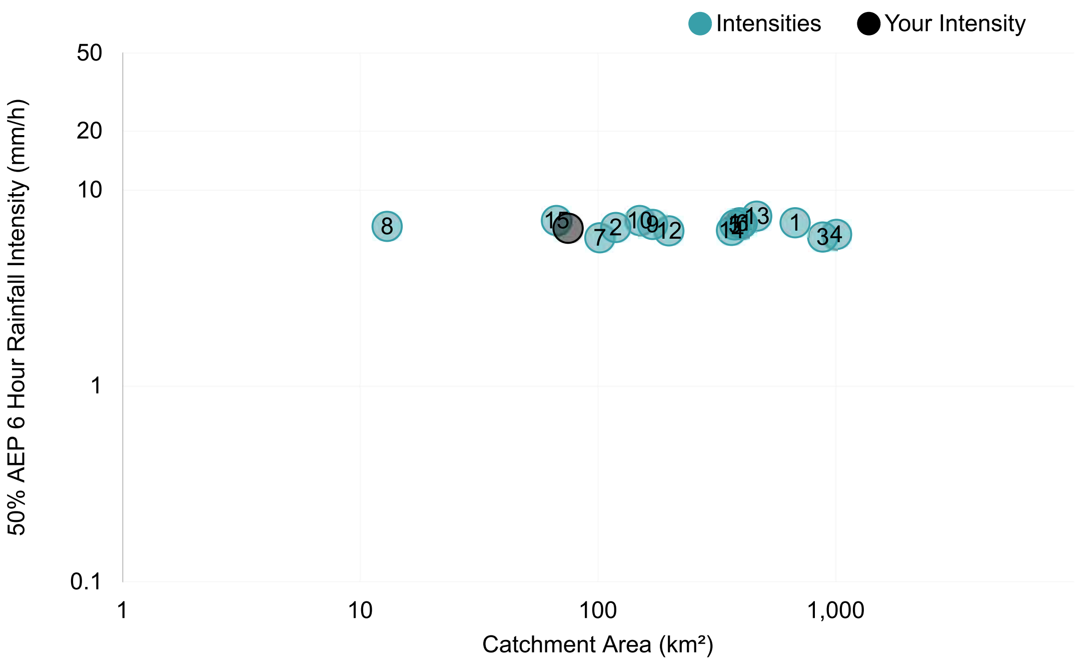
1% AEP Flow vs Catchment Area



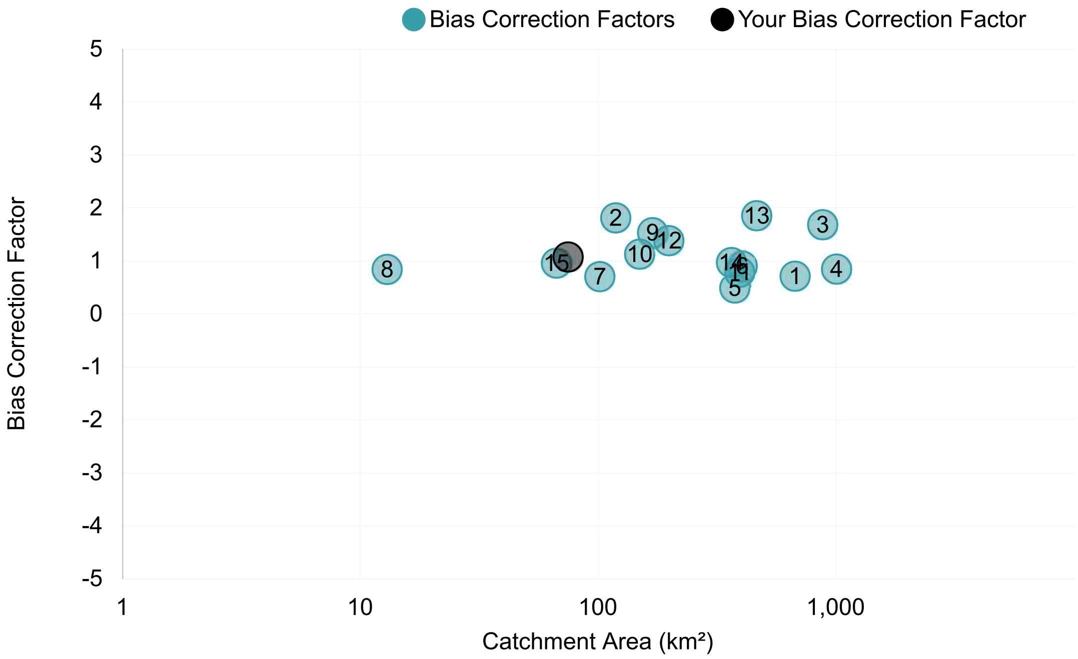
Shape Factor vs Catchment Area



Intensity vs Catchment Area



Bias Correction Factor vs Catchment Area



Download

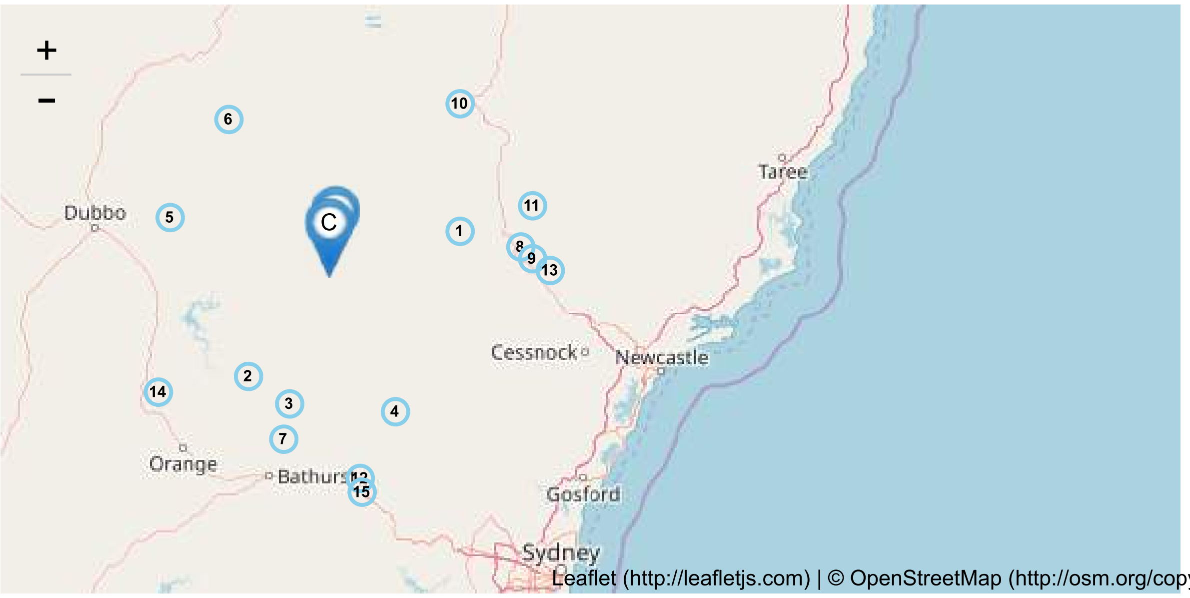
TXT PDF Nearby JSON

Input Data

Date/Time	2018-11-20 09:46
Catchment Name	Wollar Creek
Latitude (Outlet)	-32.425
Longitude (Outlet)	149.951
Latitude (Centroid)	-32.479
Longitude (Centroid)	149.915
Catchment Area (km^2)	75.0
Distance to Nearest Gauged Catchment (km)	66.98
50% AEP 6 Hour Rainfall Intensity (mm/h)	6.374829
2% AEP 6 Hour Rainfall Intensity (mm/h)	12.879383
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast

Input Data

Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	0.8
Interpolation Method	Natural Neighbour
Bias Correction Value	1.073



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).

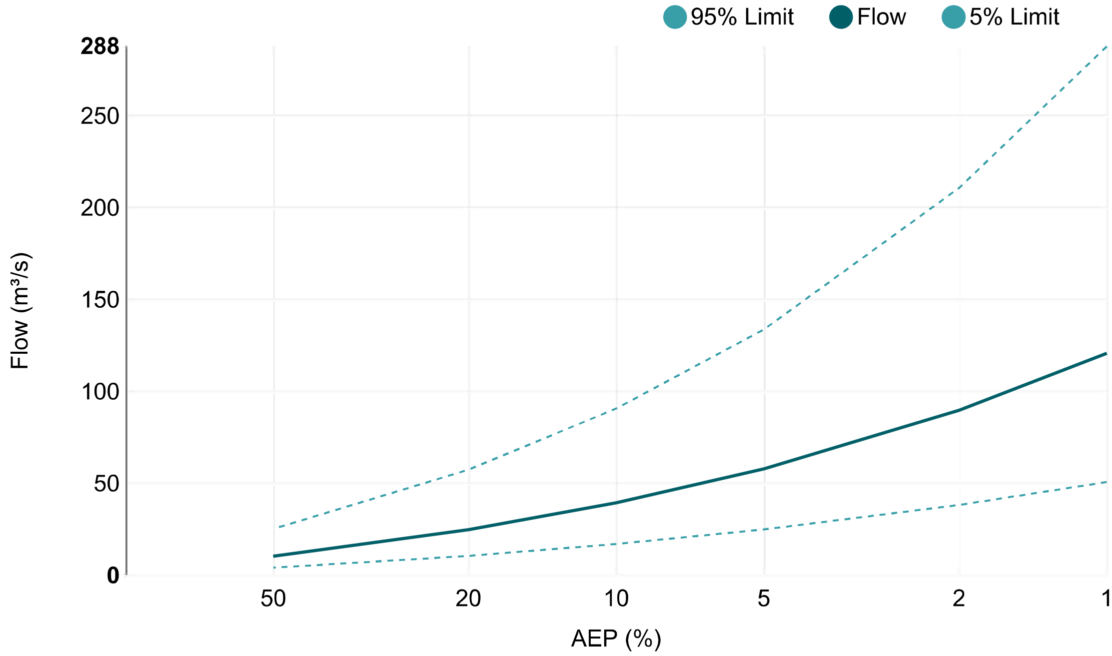
ENGINEERS AUSTRALIA (http://www.engineersaustralia.org.au)

WESTERN SYDNEY UNIVERSITY (http://www.uws.edu.au)

APPENDIX D

RFFE Method Results – 2D HEC-RAS Model

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	10.6	4.39	25.5
20	25.1	10.8	57.7
10	39.7	17.3	91.0
5	58.1	25.2	134
2	90.0	38.5	211
1	121	51.0	288

Statistics

Variable	Value	Standard Dev
Mean	2.396	0.532
Standard Dev	0.987	0.132
Skew	0.124	0.027

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

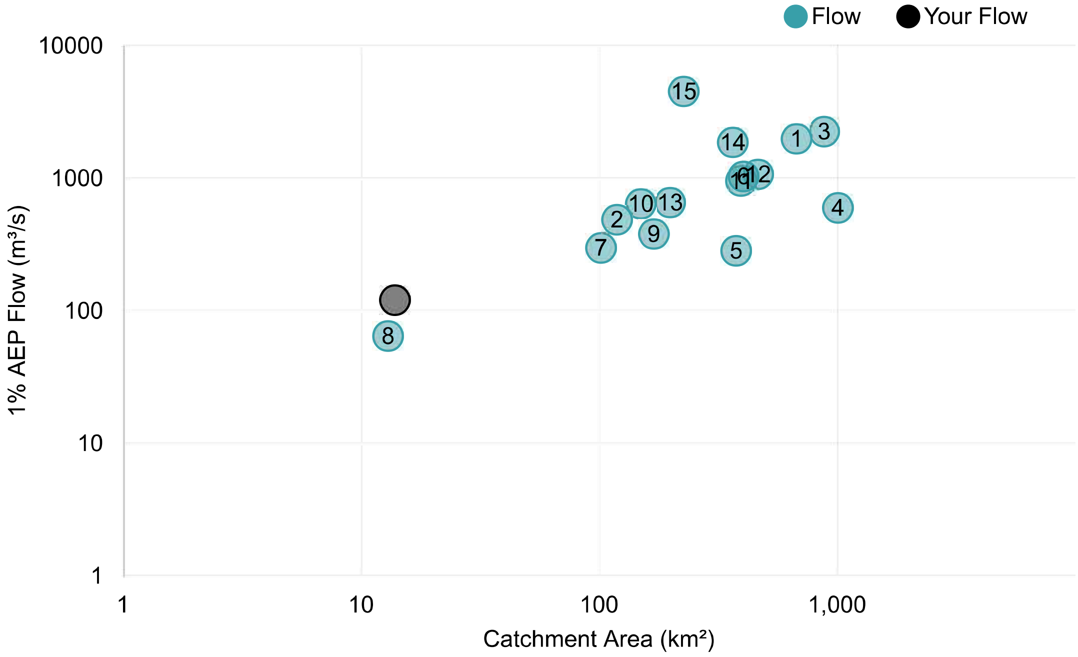
Correlation

Correlation

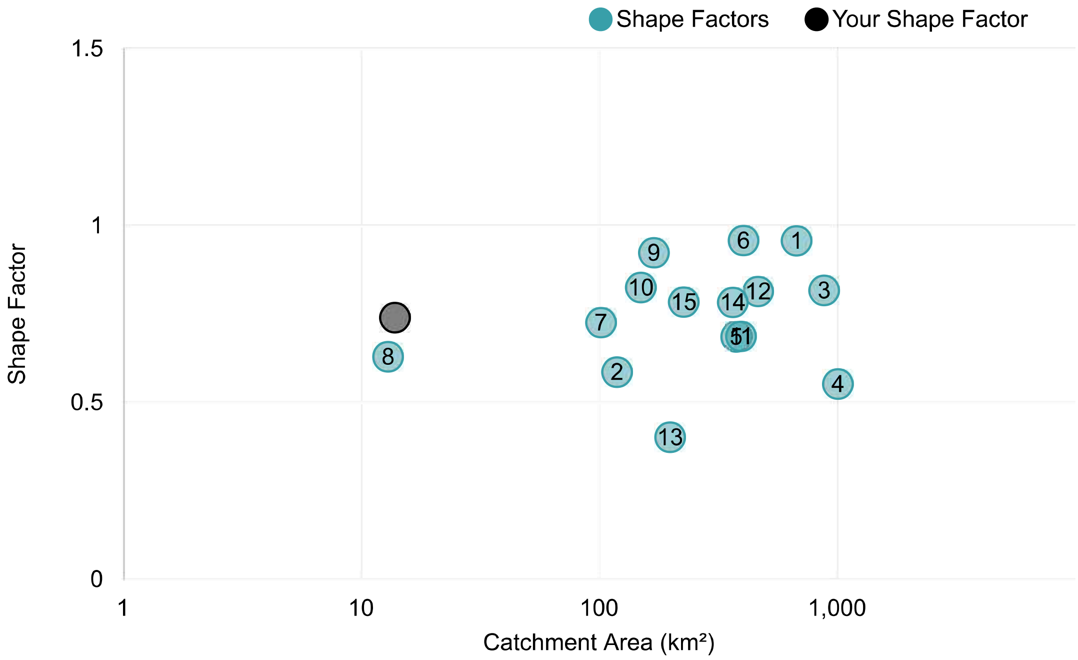
1.000		
-0.330	1.000	
0.170	-0.280	1.000

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

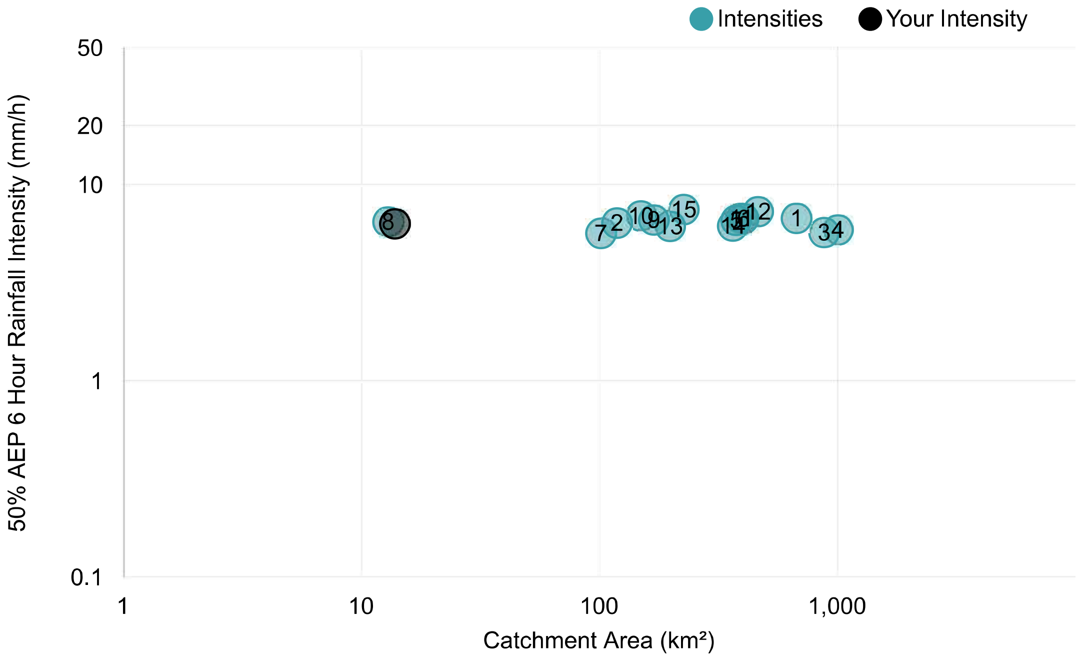
1% AEP Flow vs Catchment Area



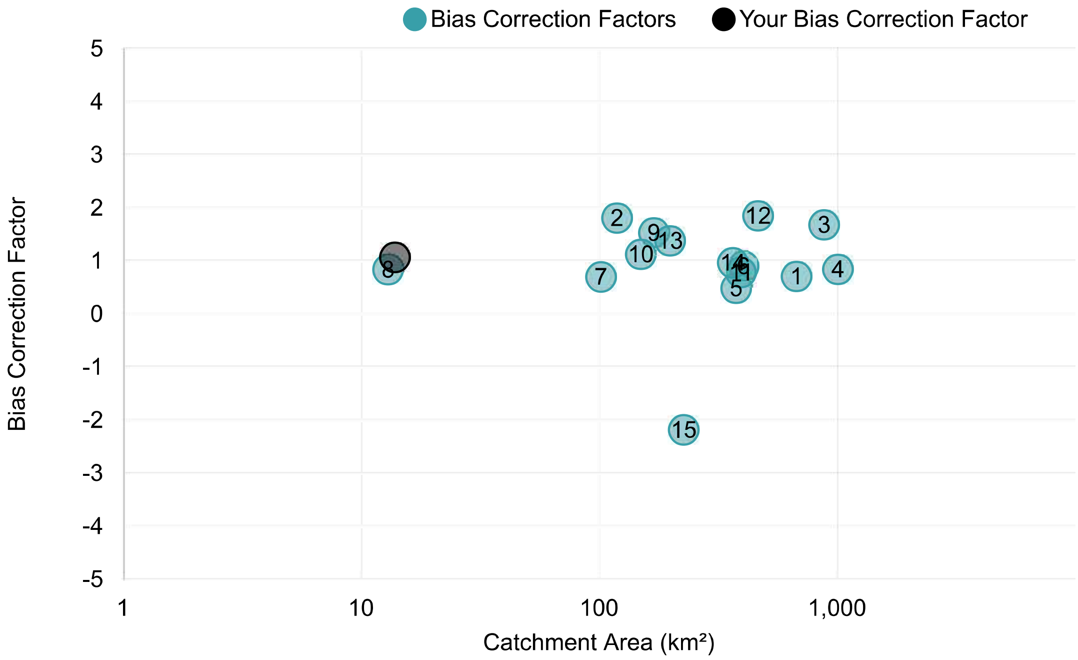
Shape Factor vs Catchment Area



Intensity vs Catchment Area



Bias Correction Factor vs Catchment Area



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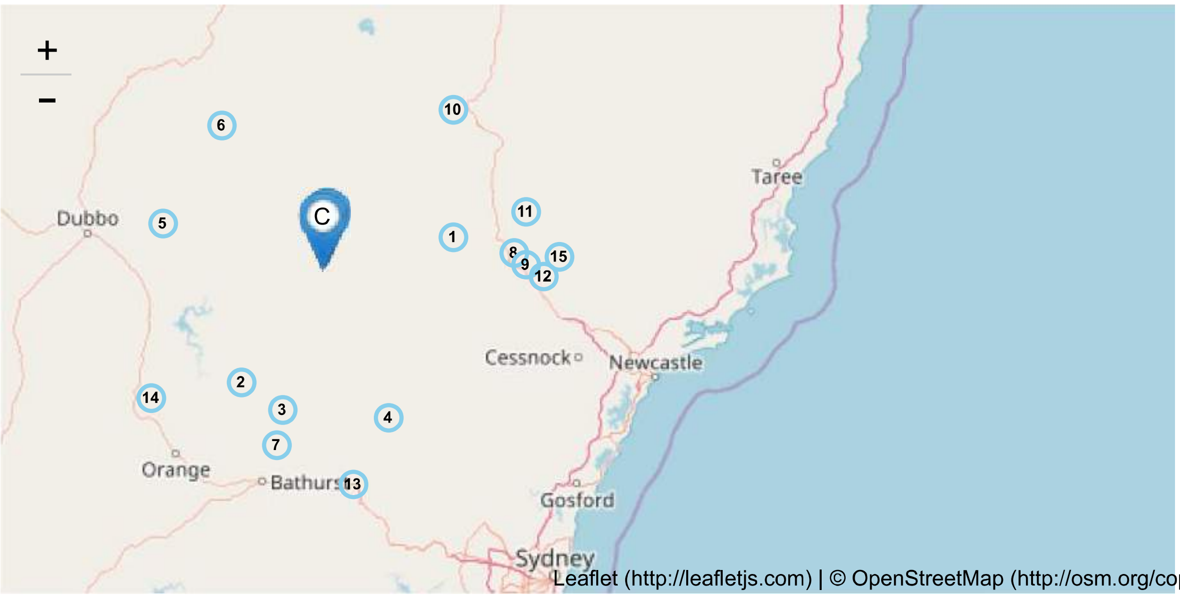
TXT PDF Nearby JSON

Input Data

Date/Time	2018-06-19 16:37
Catchment Name	Catchment1
Latitude (Outlet)	-32.405298
Longitude (Outlet)	149.937489
Latitude (Centroid)	-32.42483
Longitude (Centroid)	149.919674
Catchment Area (km^2)	13.89
Distance to Nearest Gauged Catchment (km)	67.69
50% AEP 6 Hour Rainfall Intensity (mm/h)	6.3775
2% AEP 6 Hour Rainfall Intensity (mm/h)	12.952581
Rainfall Intensity Source (User/Auto)	Auto
Region	East Coast

Input Data

Region Version	RFFE Model 2016 v1
Region Source (User/Auto)	Auto
Shape Factor	0.74
Interpolation Method	Natural Neighbour
Bias Correction Value	1.07



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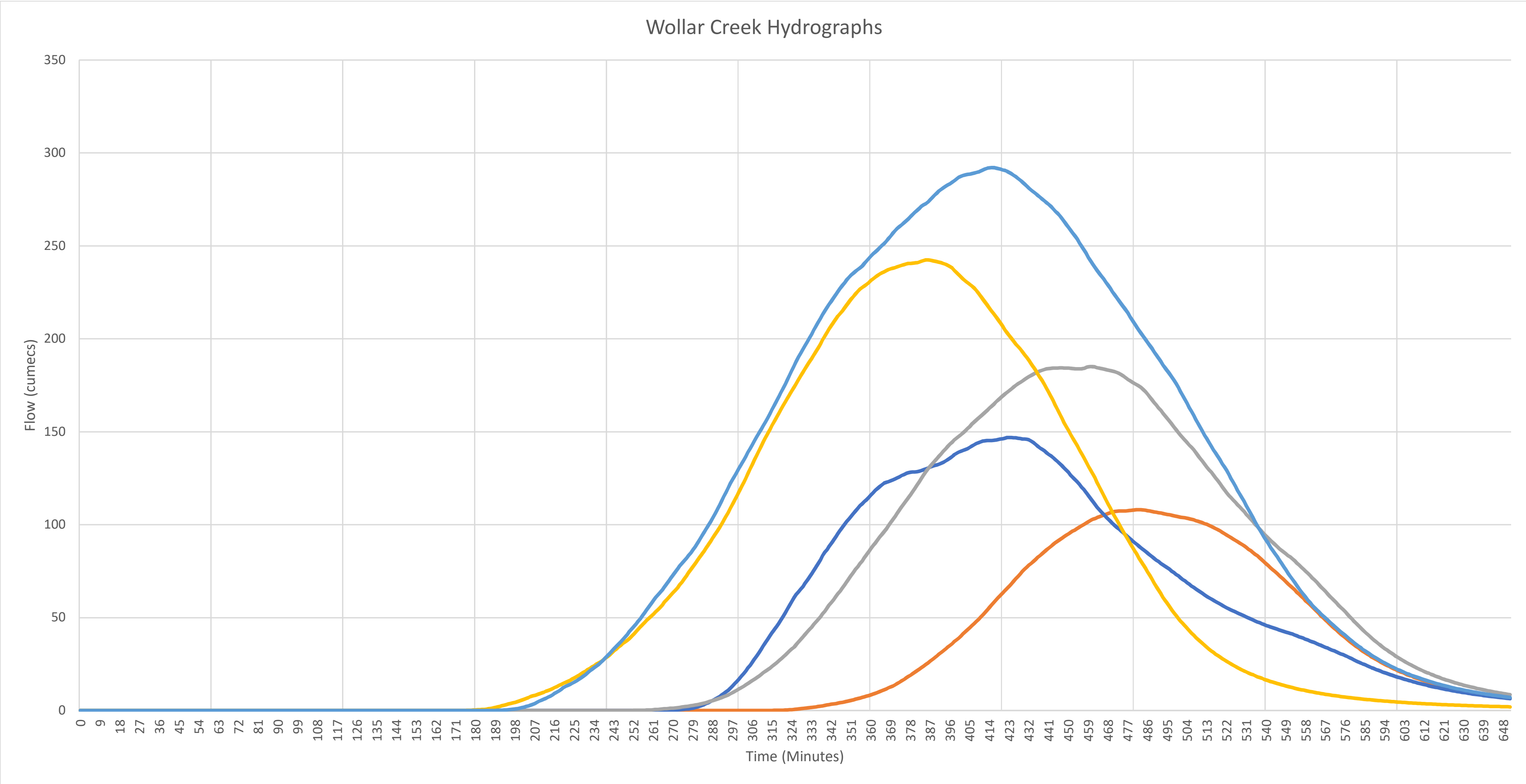
Method by Dr Ataur Rahman and Dr Khaled Haddad from Western Sydney University for the Australian Rainfall and Runoff Project. Full description of the project can be found at the project page (http://arr.ga.gov.au/revision-projects/project-list/projects/project-5) on the ARR website. Send any questions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

ENGINEERS AUSTRALIA (http://www.engineersaustralia.org.au)

WESTERN SYDNEY UNIVERSITY (http://www.uws.edu.au)

APPENDIX E

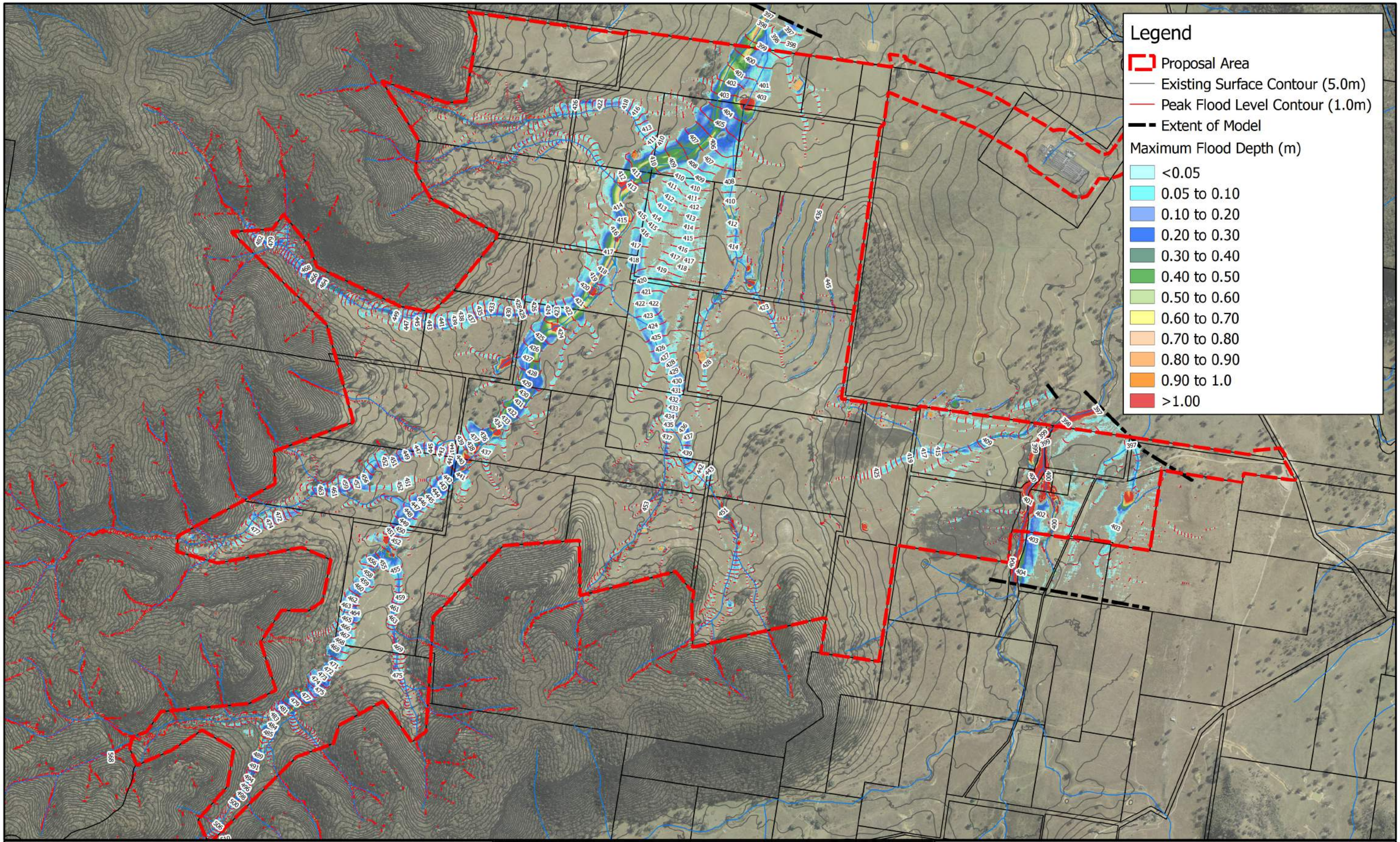
Wollar Creek Hydrographs



Wollar Creek Hydrographs
Flow (cumecs)
Time (Minutes)
350
300
250
200
150
100
50
0

APPENDIX F

Flood Mapping



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200 0 200 400 600 m

Scale 1:20,000 at A3

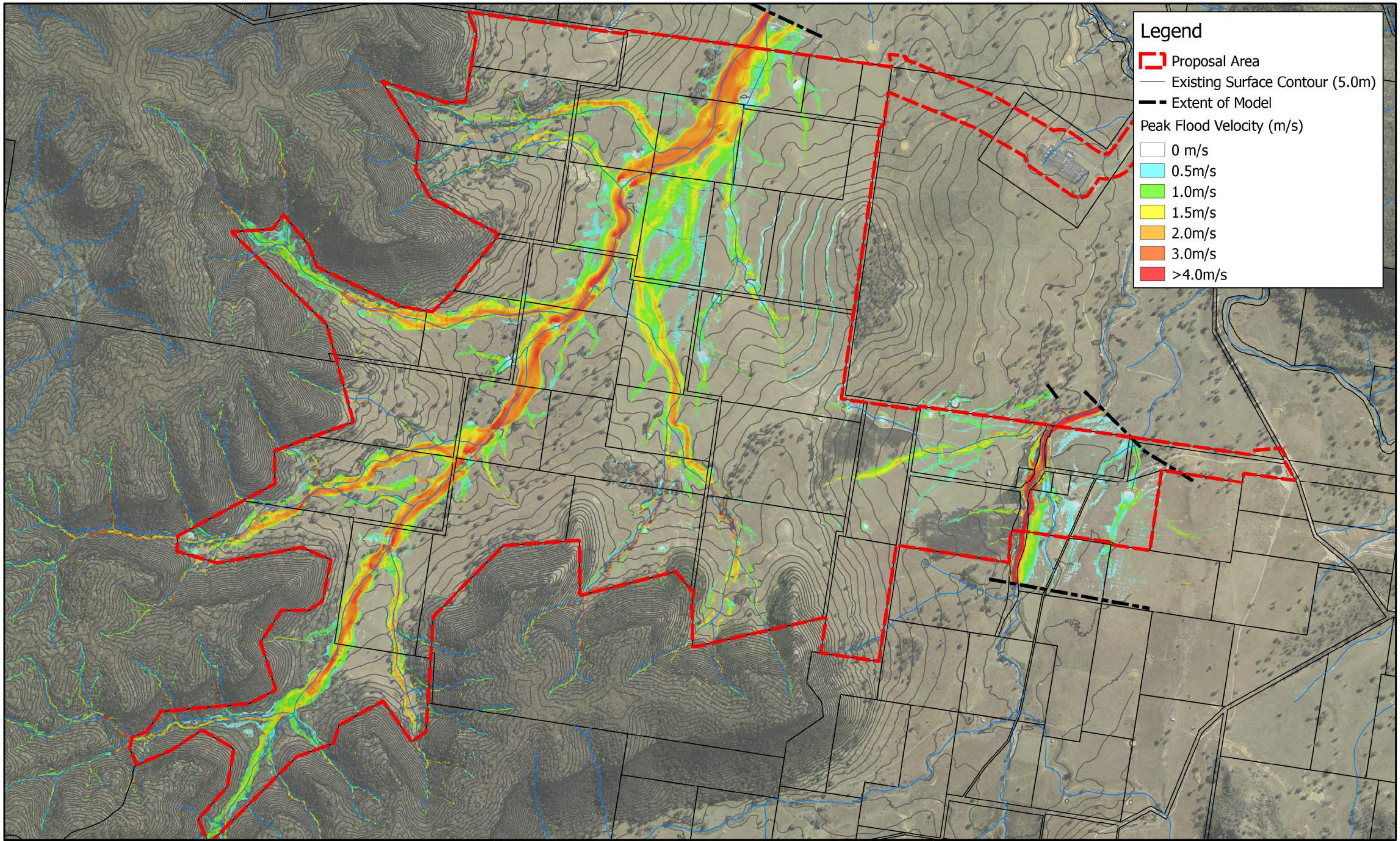
WOLLAR SOLAR FARM

HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 1.1

Existing 1% AEP Maximum Flood Levels and Depths

Rev 2 - 19 November 2018



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WOLLAR SOLAR FARM

HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 1.2

Existing 1% AEP Peak Flood Velocities

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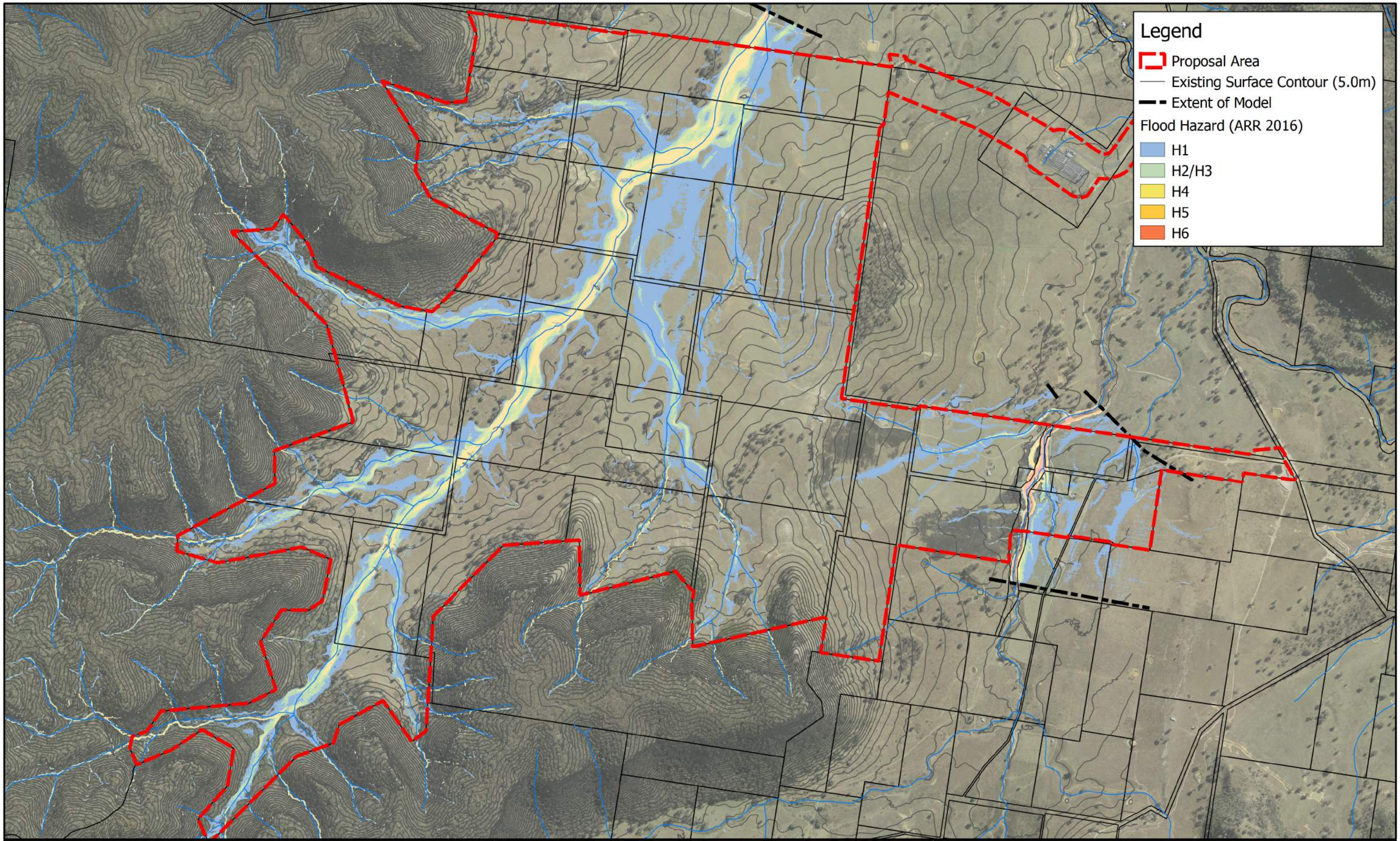

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WOLLAR SOLAR FARM

HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 1.3

Existing 1% AEP Flood Hazard

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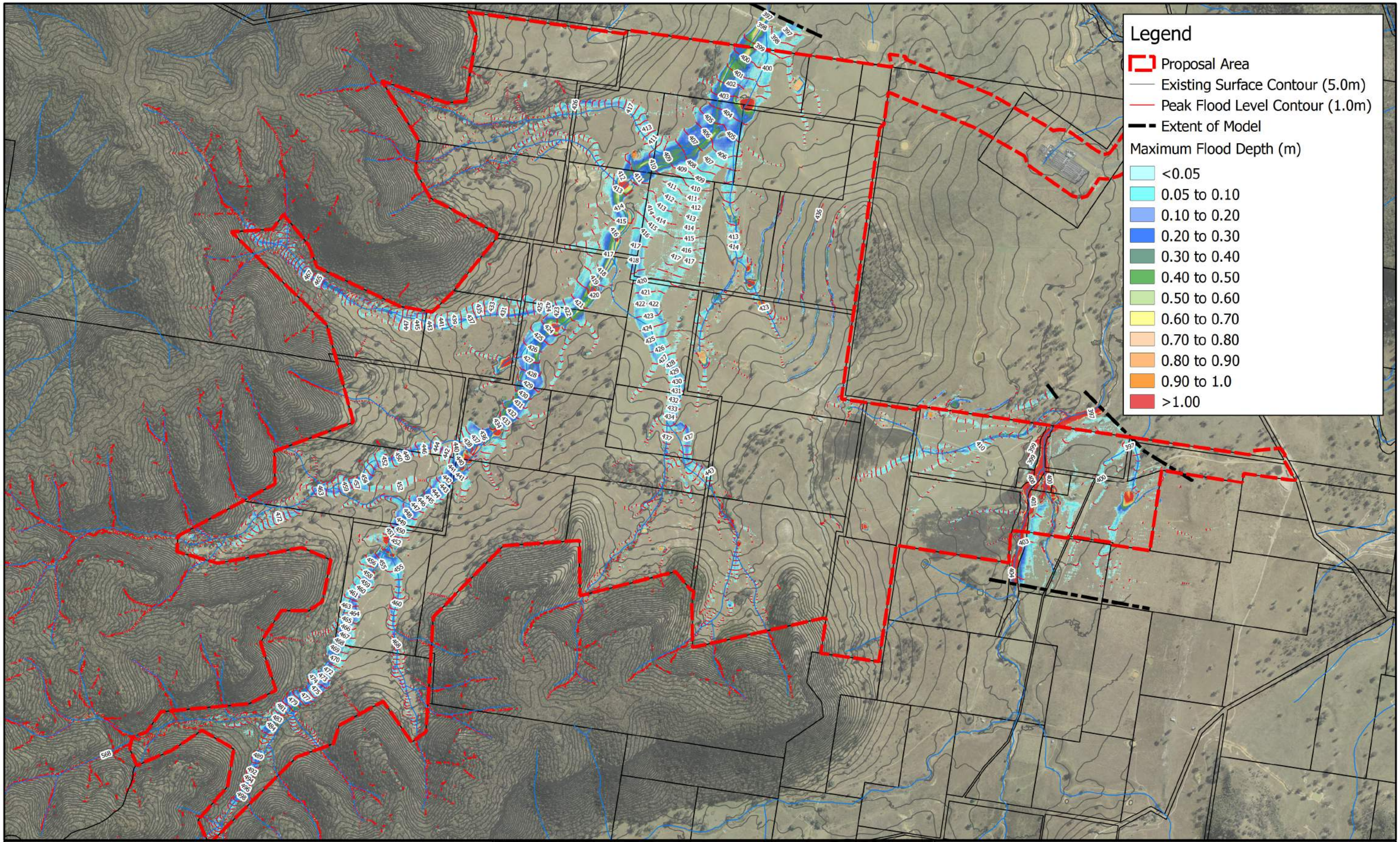

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WOLLAR SOLAR FARM

HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 2.1

Existing 2% AEP Maximum Flood Levels and Depths

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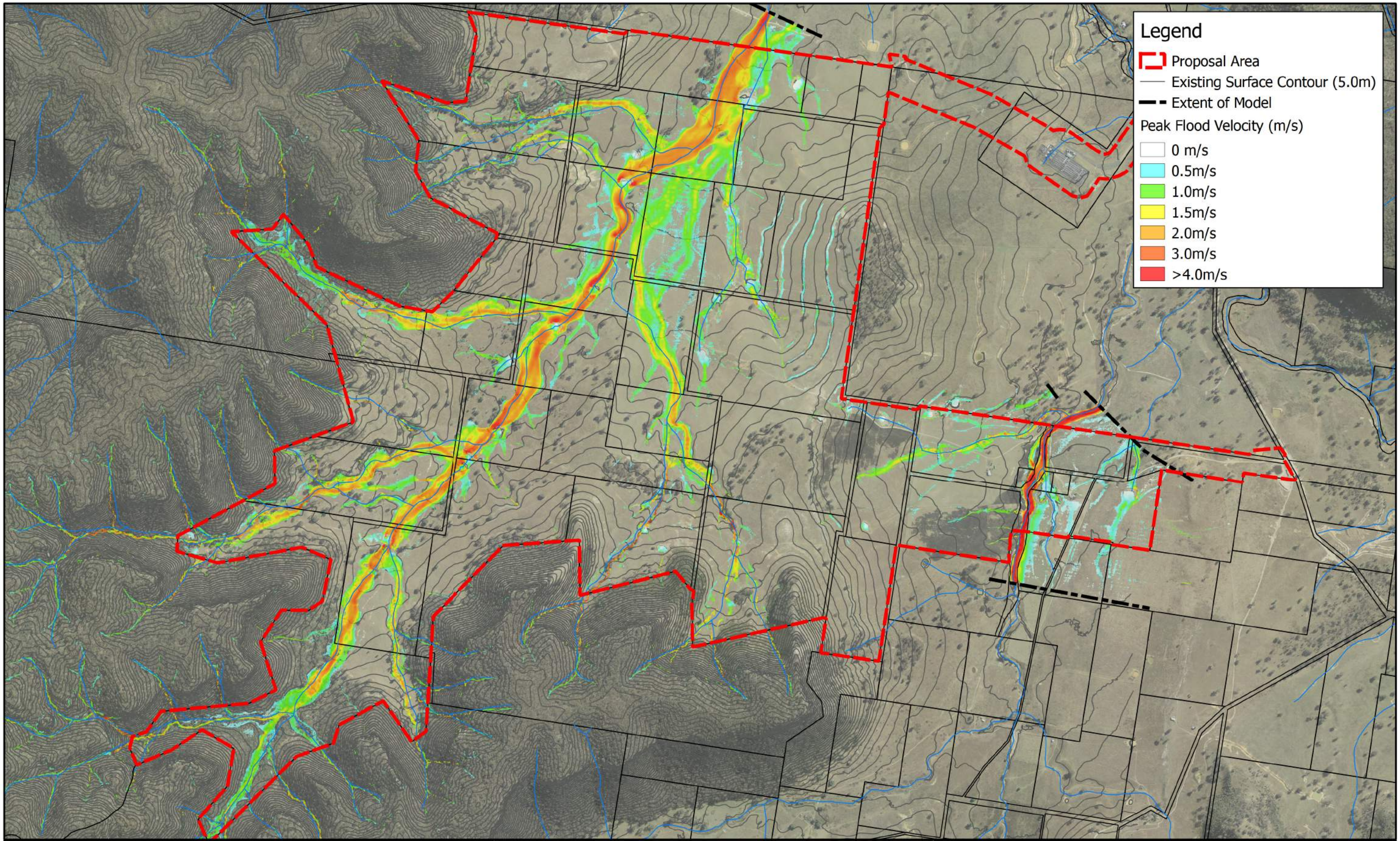

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200 0 200 400 600 m

Scale 1:20,000 at A3

WOLLAR SOLAR FARM

HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 2.2

Existing 2% AEP Peak Flood Velocities

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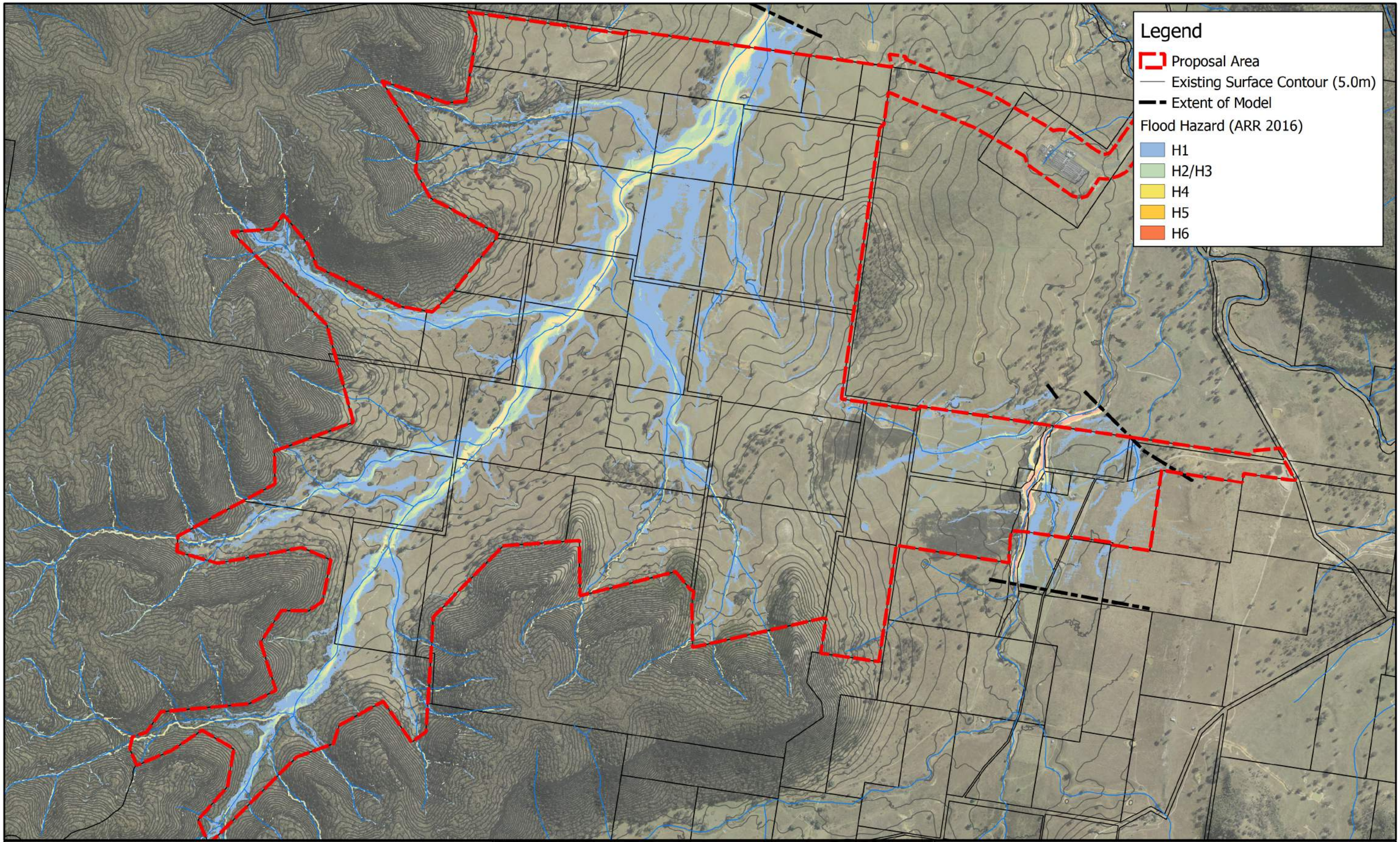

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200 0 200 400 600 m

Scale 1:20,000 at A3

WOLLAR SOLAR FARM

HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 2.3

Existing 2% AEP Flood Hazard

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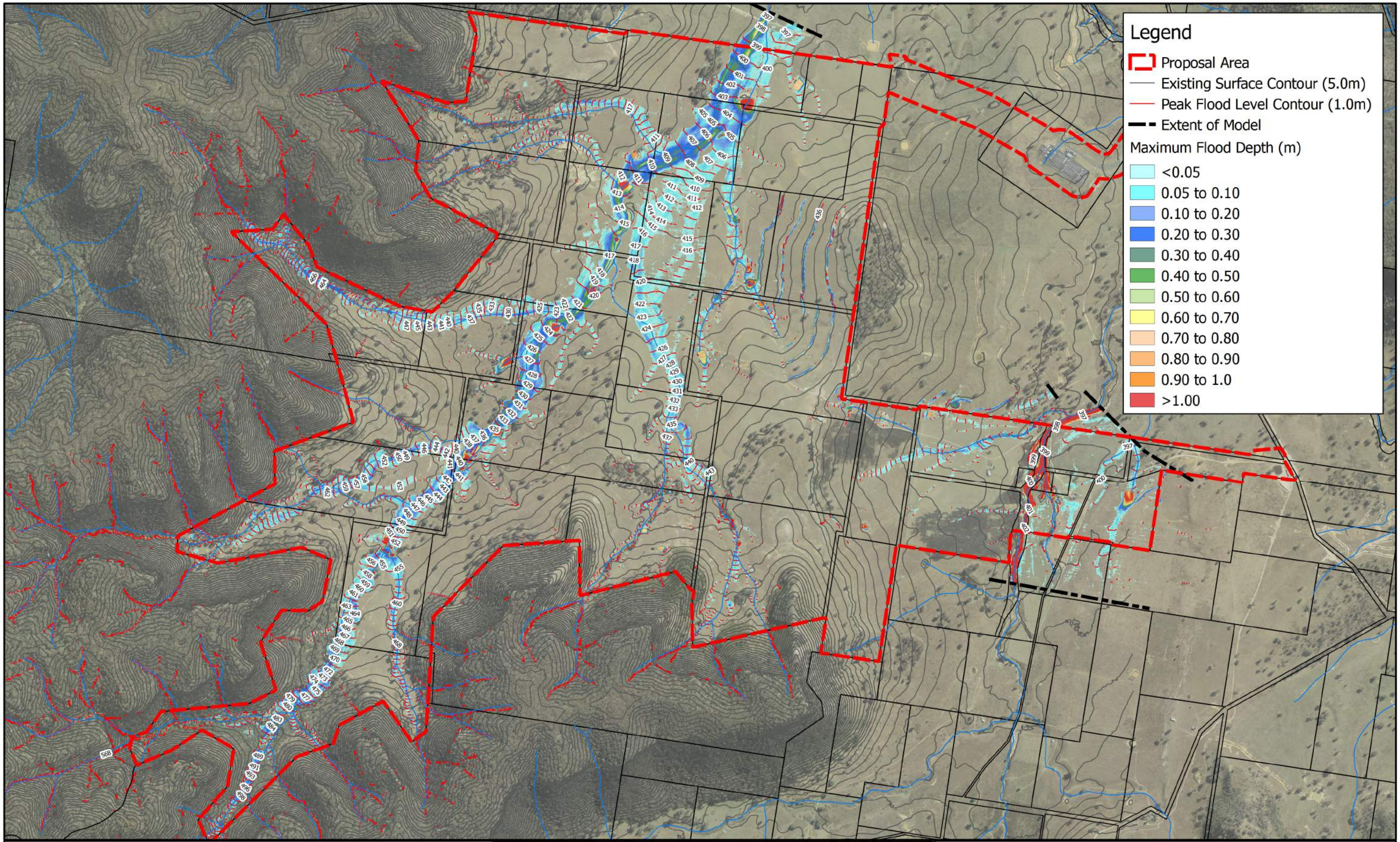

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Scale 1:20,000 at A3

WOLLAR SOLAR FARM

HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 3.1

Existing 5% AEP Maximum Flood Levels and Depths

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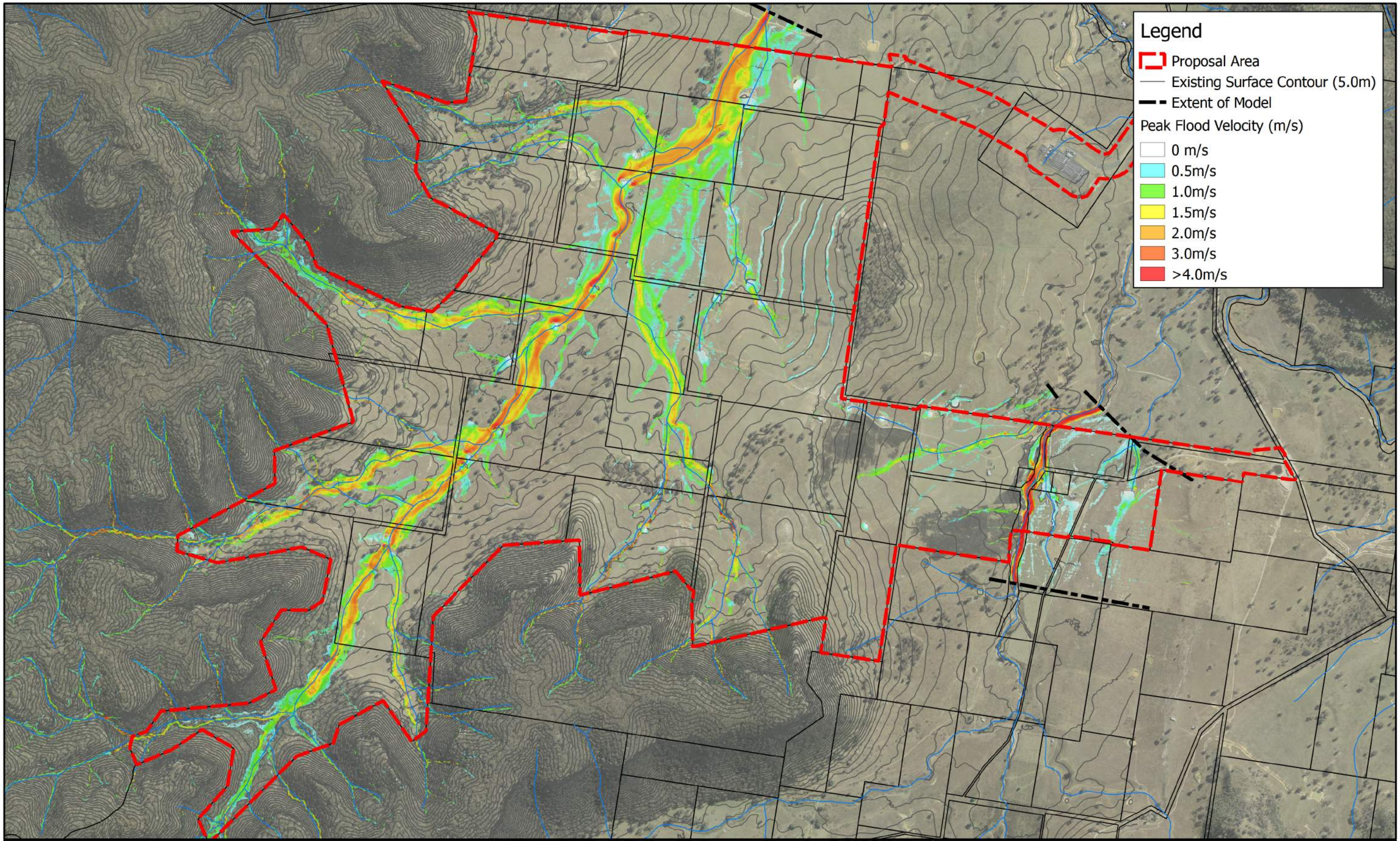

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200 0 200 400 600 m

Scale 1:20,000 at A3

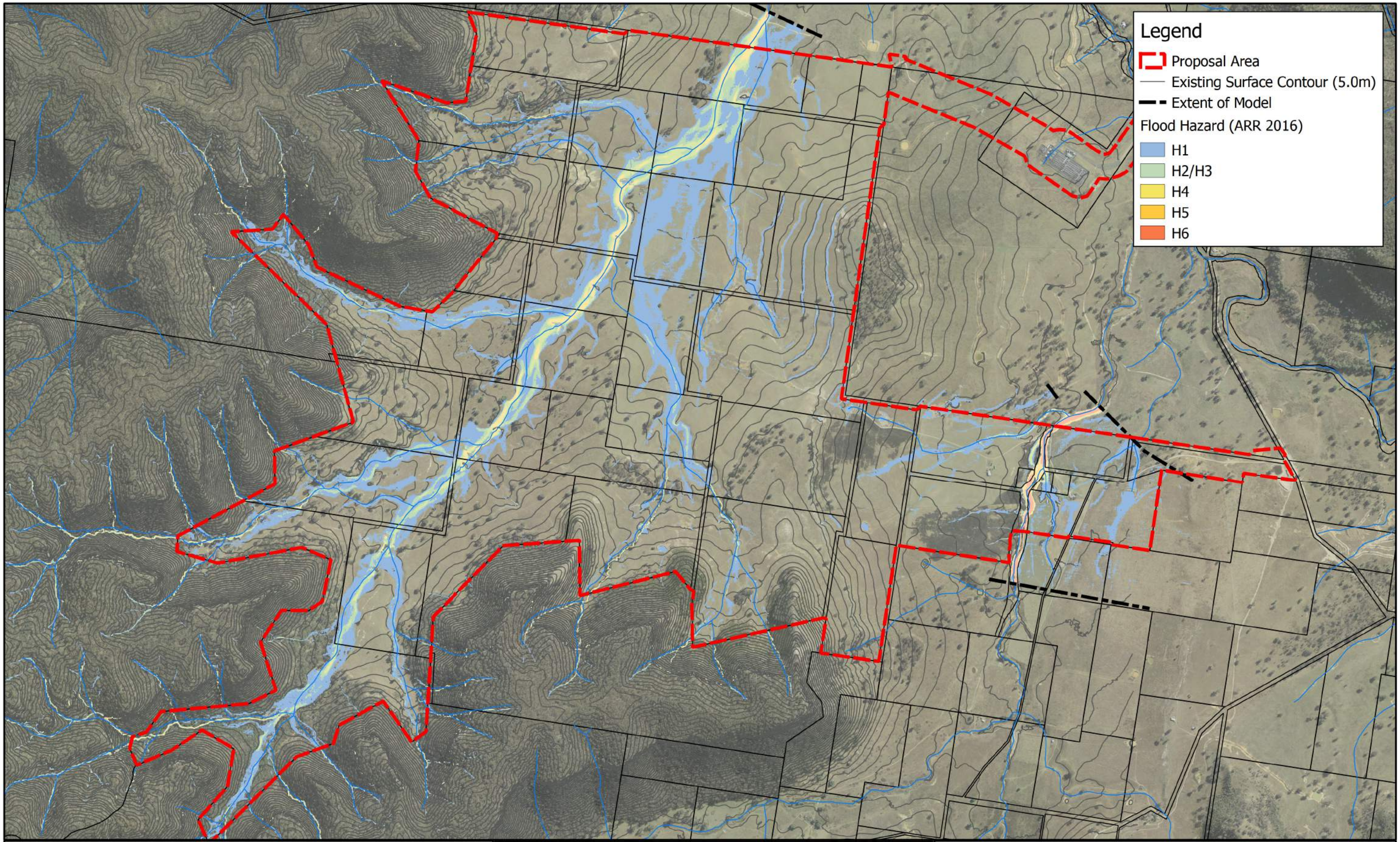
WOLLAR SOLAR FARM

HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 3.2

Existing 5% AEP Peak Flood Velocities

Rev 2 - 19 November 2018



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200 0 200 400 600 m

Scale 1:20,000 at A3

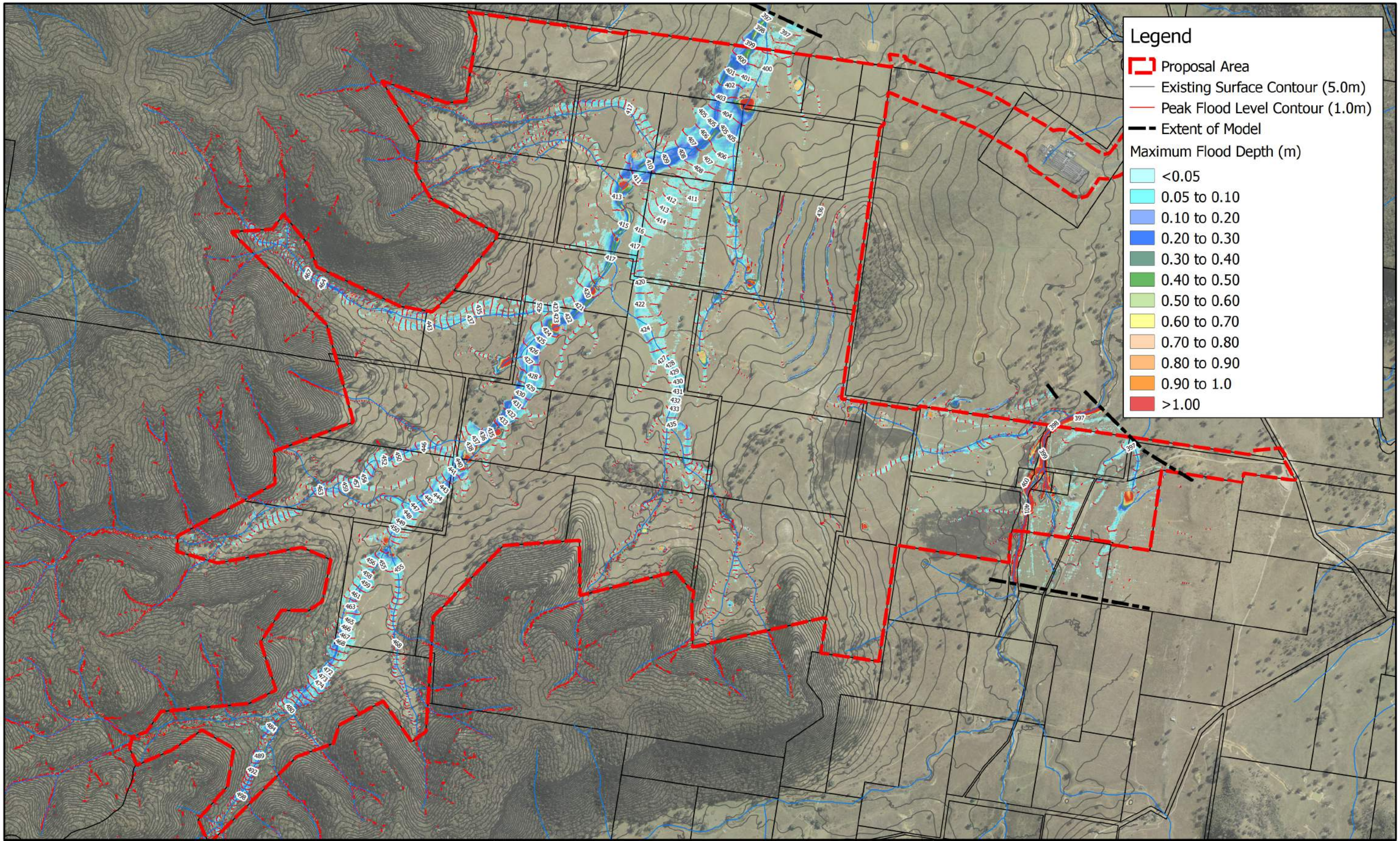
WOLLAR SOLAR FARM

HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 3.3

Existing 5% AEP Flood Hazard

Rev 2 - 19 November 2018



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Scale 1:20,000 at A3

WOLLAR SOLAR FARM

HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 4.1

Existing 10% AEP Maximum Flood Levels and Depths

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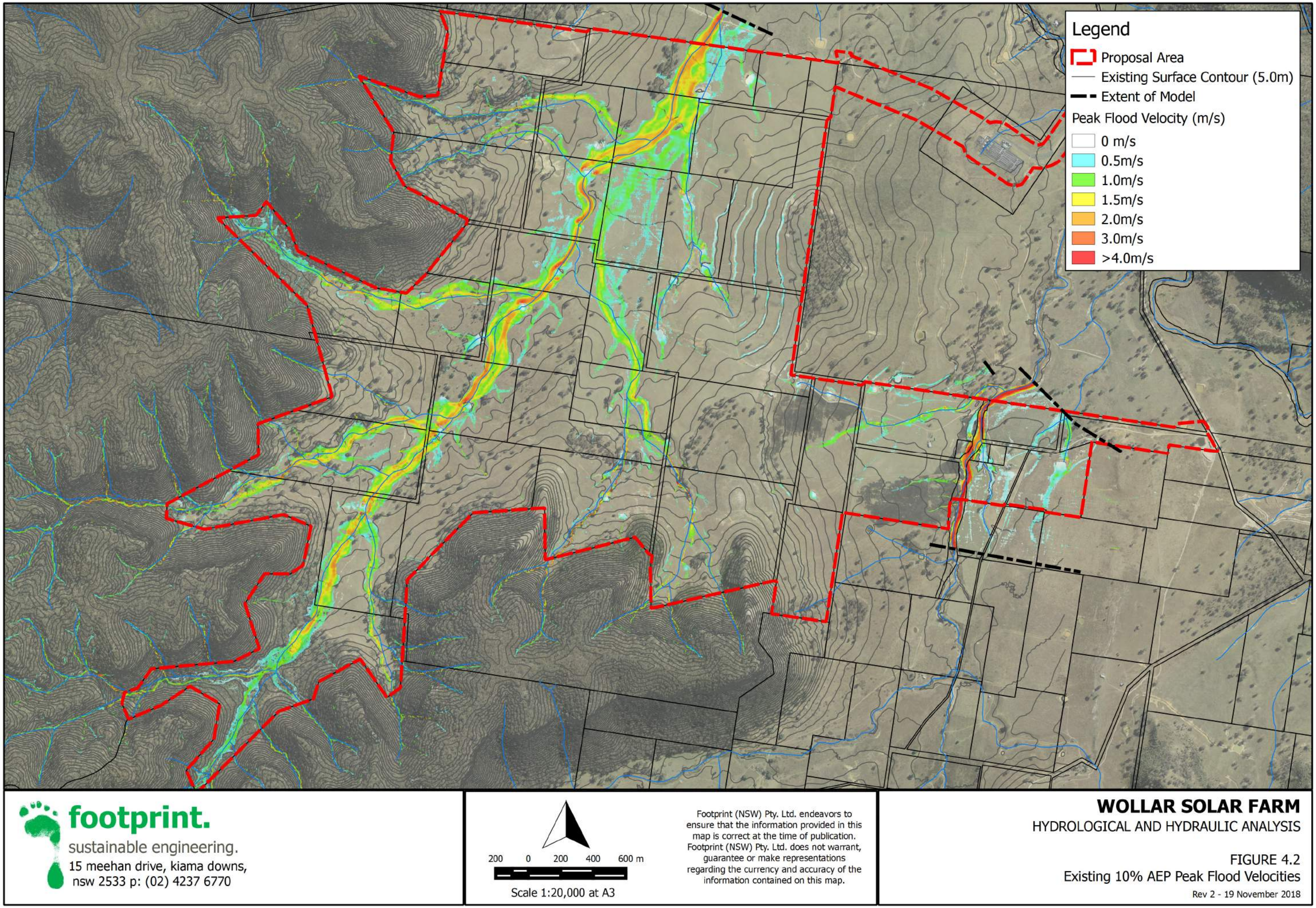

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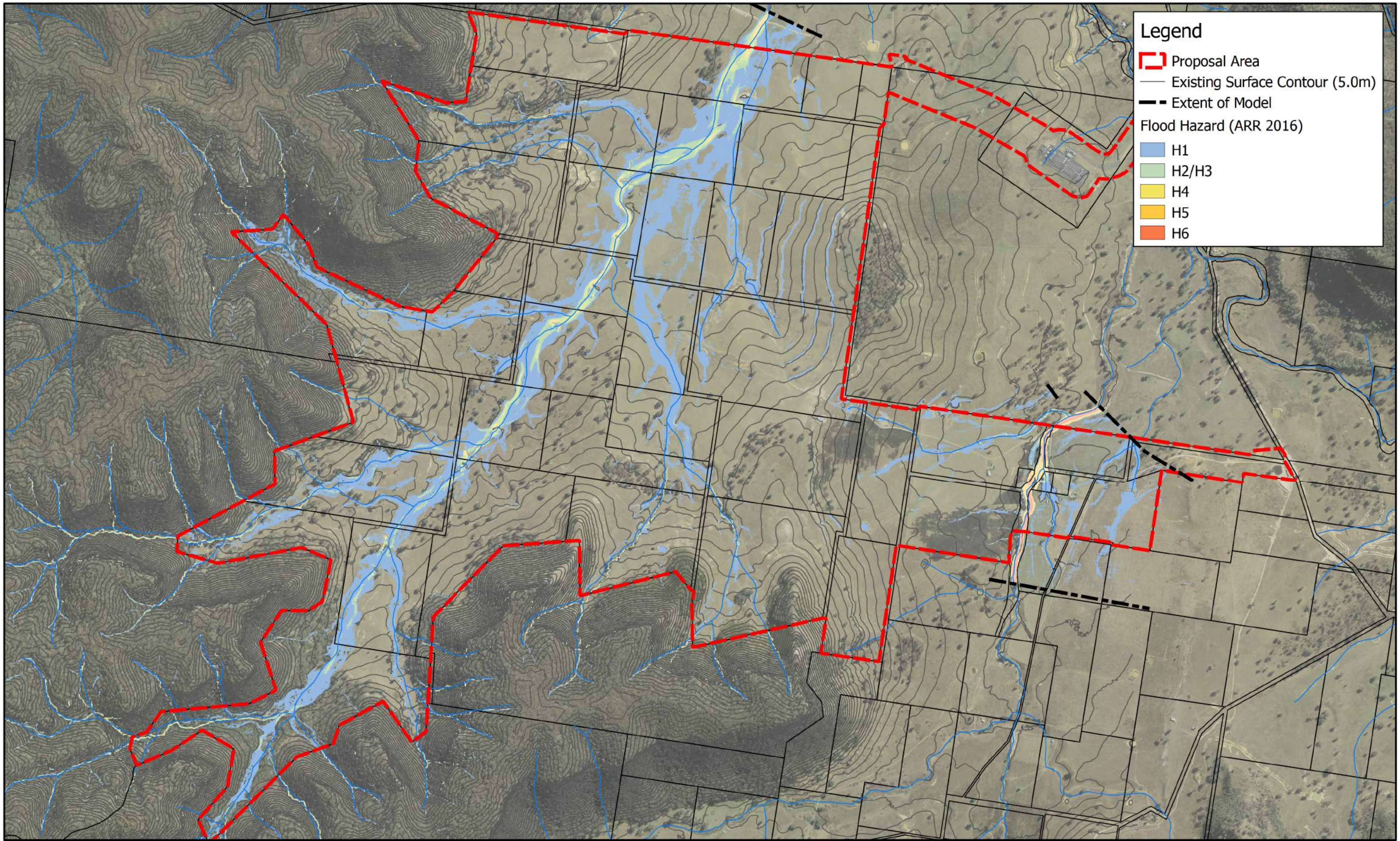
WOLLAR SOLAR FARM

HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 4.2

Existing 10% AEP Peak Flood Velocities

Rev 2 - 19 November 2018



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200 0 200 400 600 m

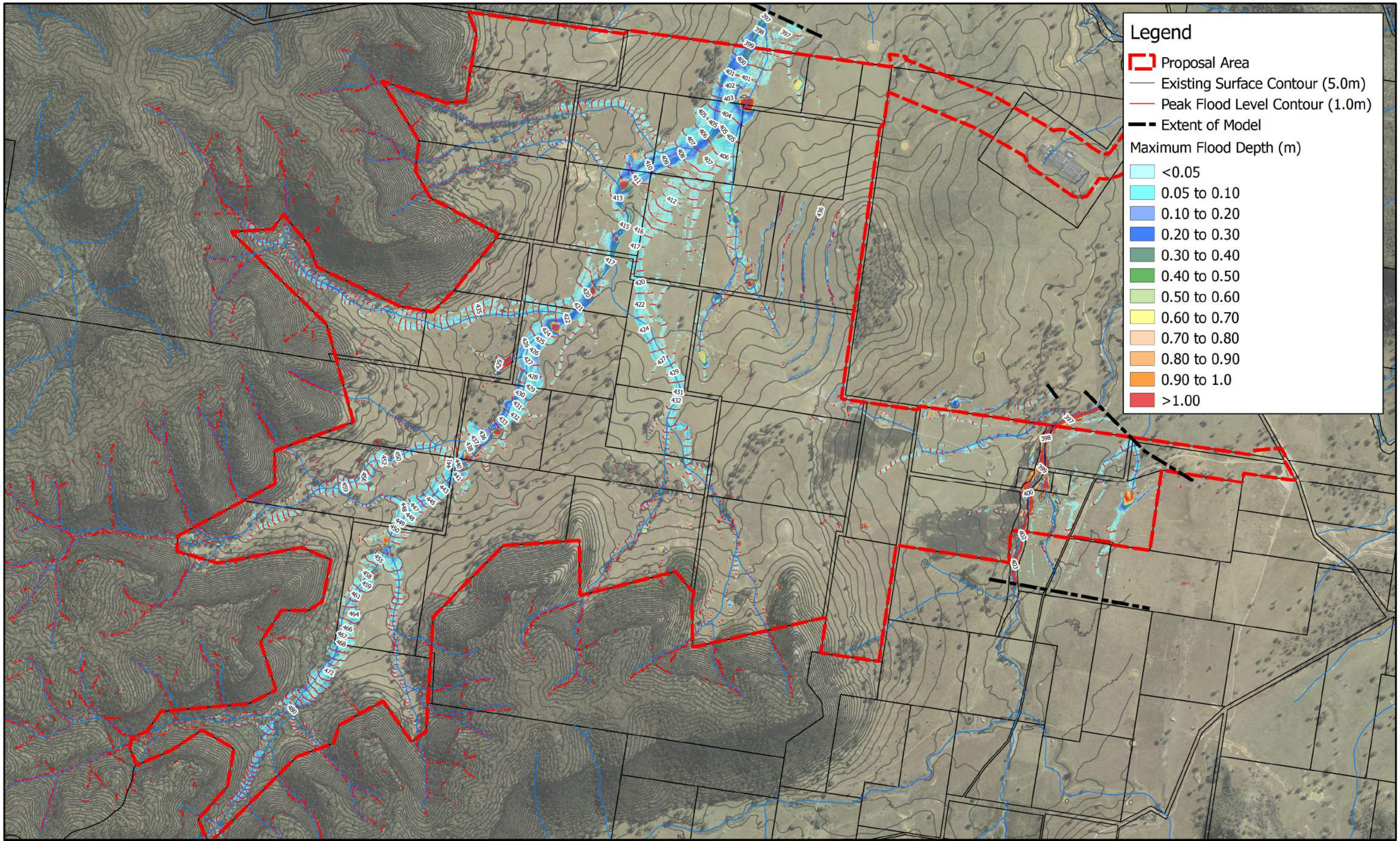
Scale 1:20,000 at A3

WOLLAR SOLAR FARM

HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 4.3
Existing 10% AEP Flood Hazard

Rev 2 - 19 November 2018



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WOLLAR SOLAR FARM

HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 5.1

Existing 20% AEP Maximum Flood Levels and Depths

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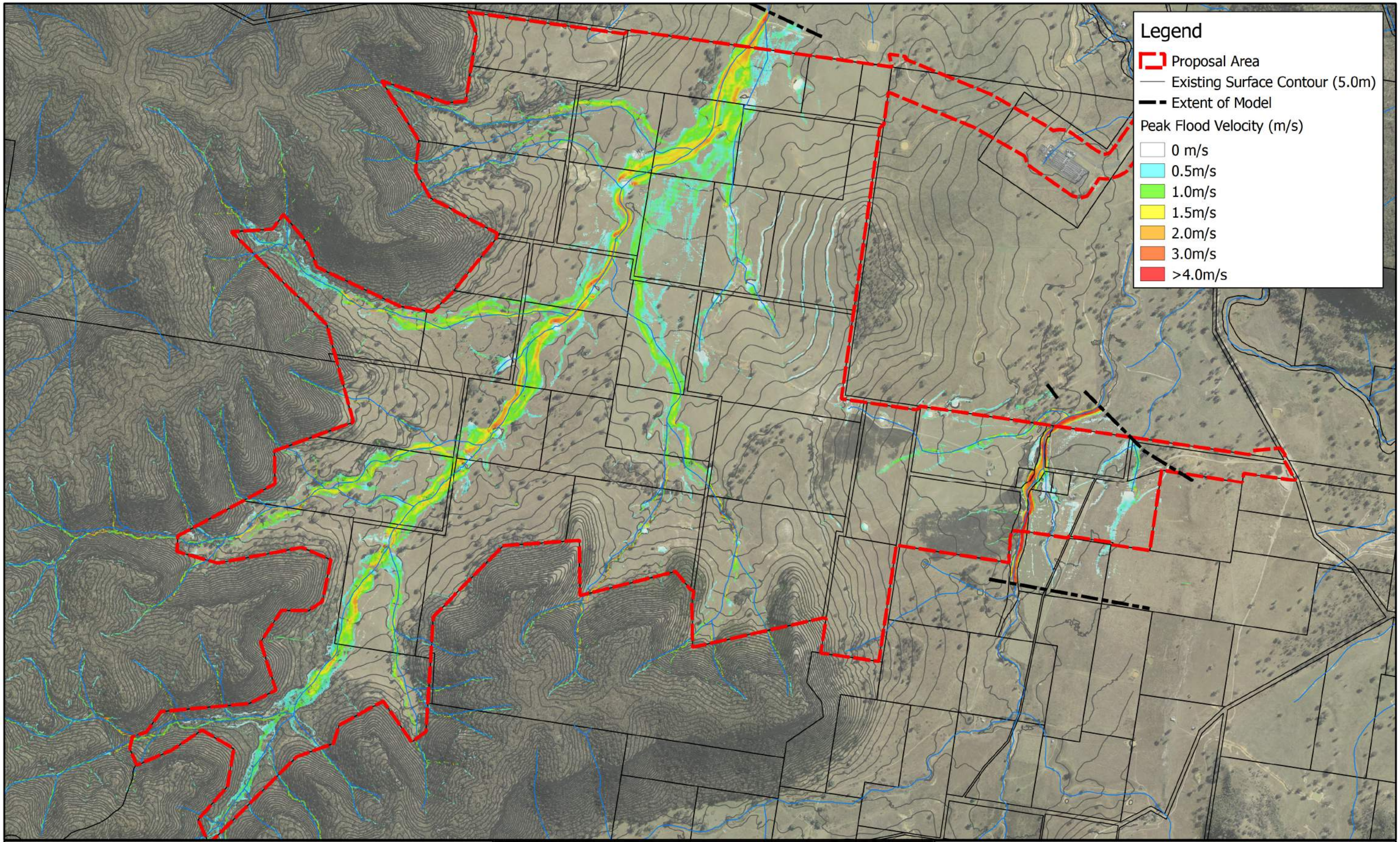

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WOLLAR SOLAR FARM

HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 5.2

Existing 20% AEP Peak Flood Velocities

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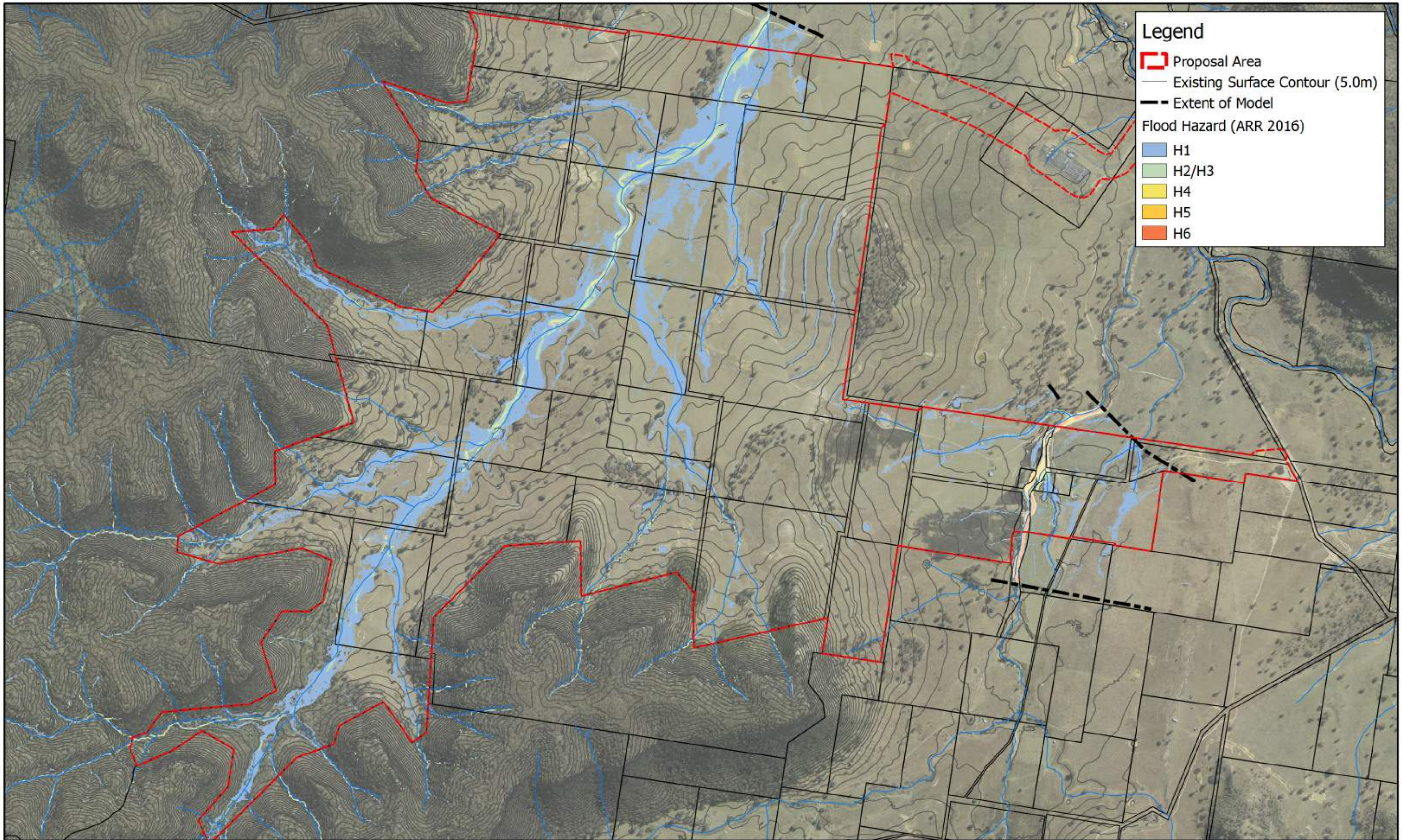

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WOLLAR SOLAR FARM

HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 5.3

Existing 20% AEP Flood Hazard

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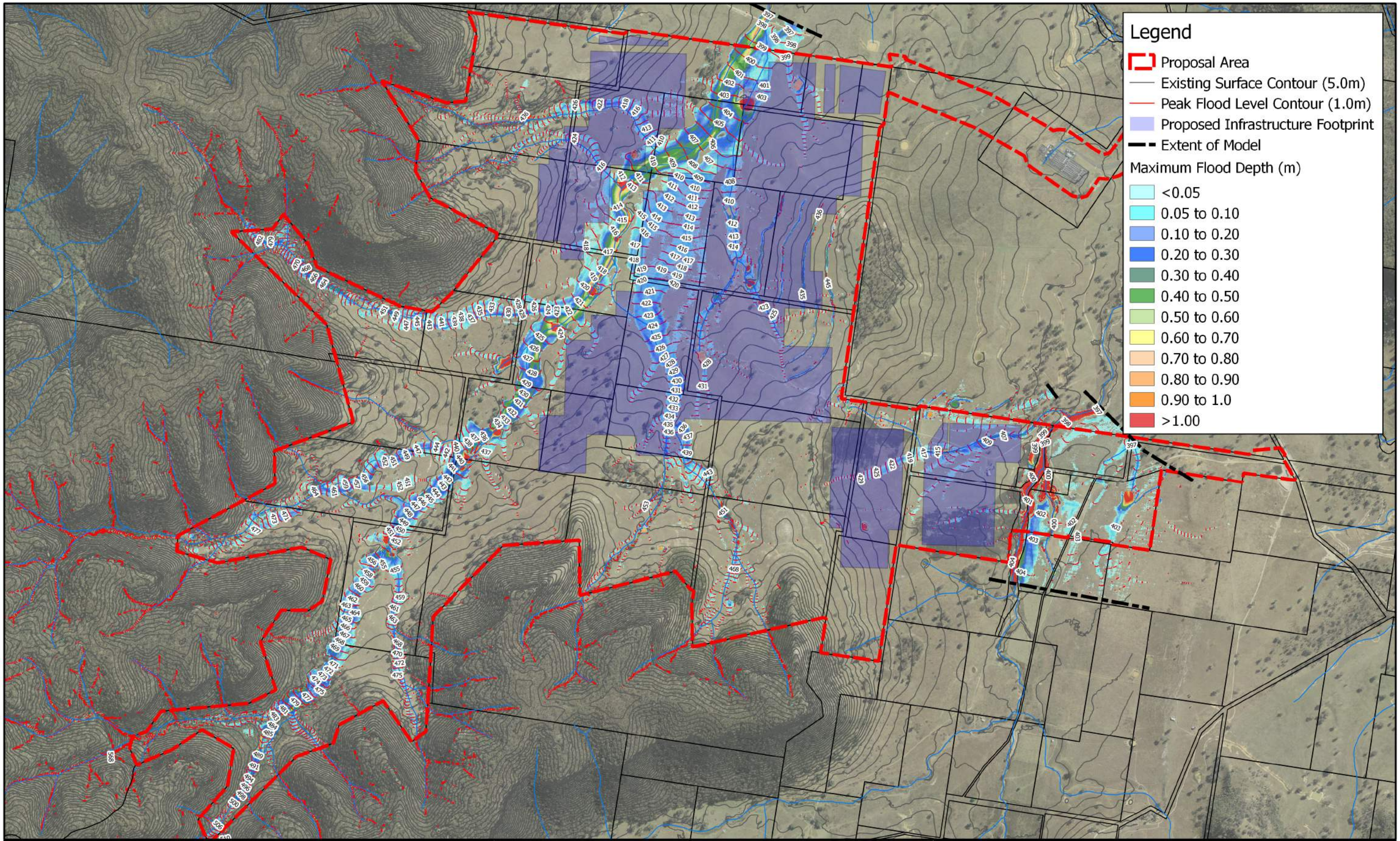

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WOLLAR SOLAR FARM

HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 6.1

Proposed 1% AEP Maximum Flood Levels and Depths

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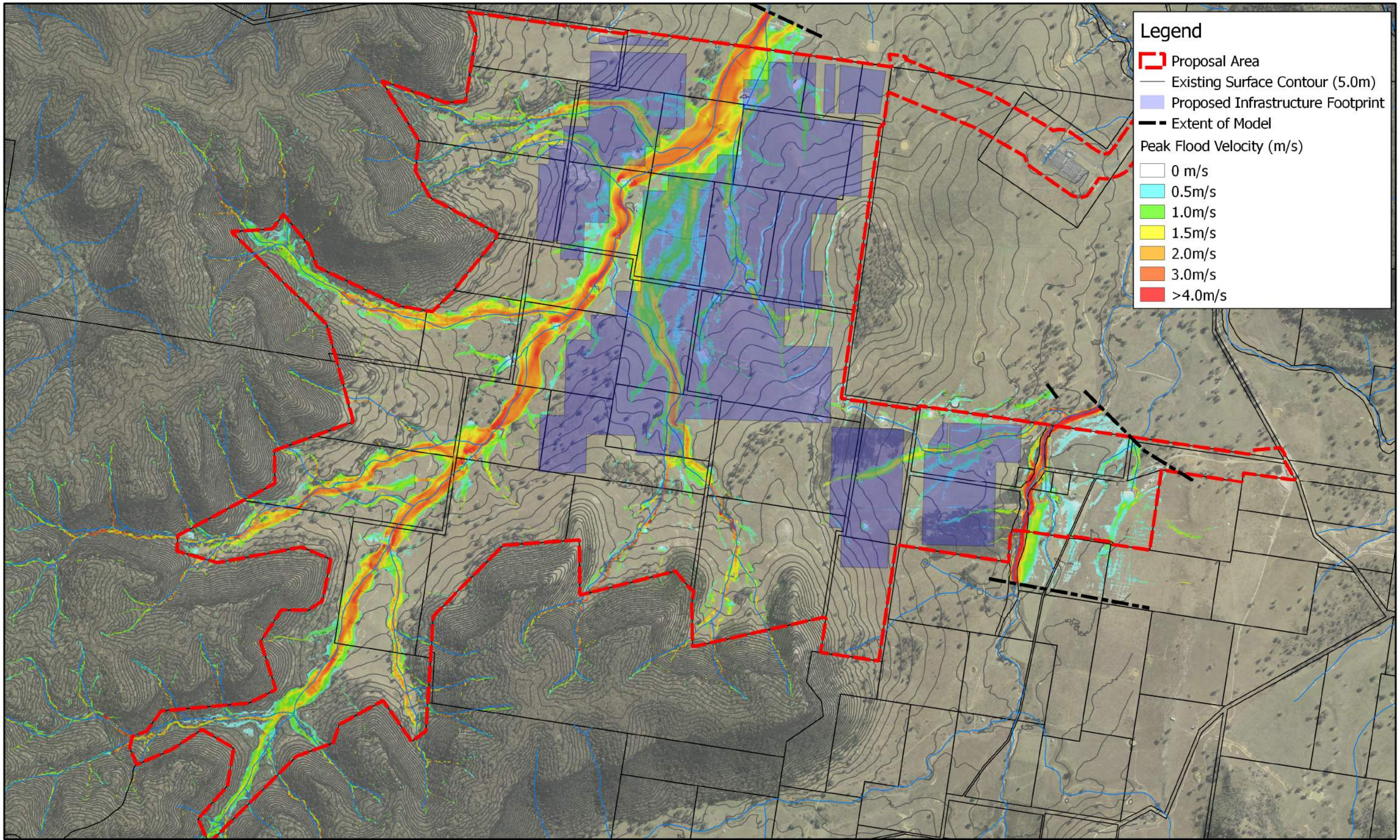

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WOLLAR SOLAR FARM
HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 6.2
Proposed 1% AEP Peak Flood Velocities

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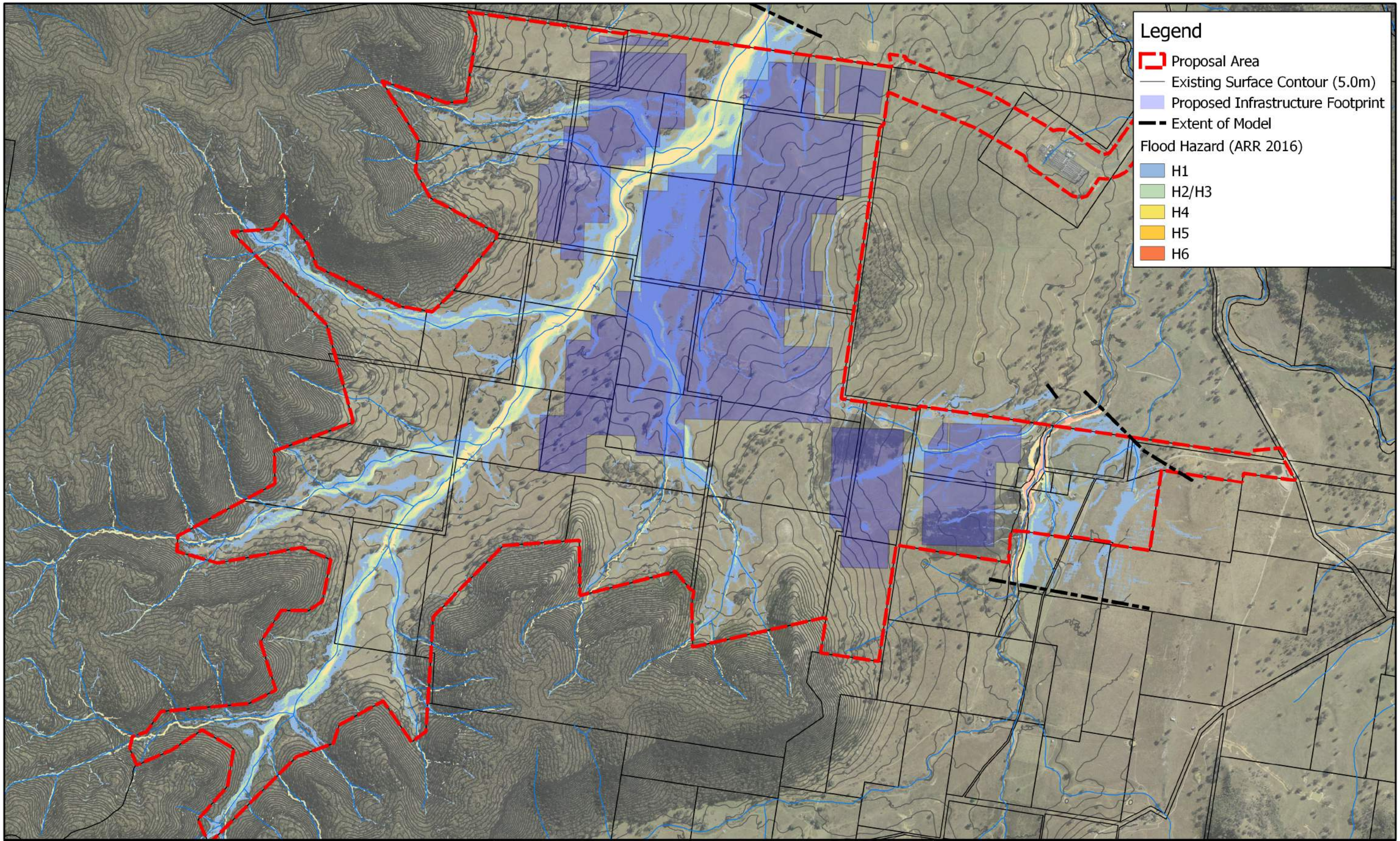

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HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 6.3
Proposed 1% AEP Flood Hazard

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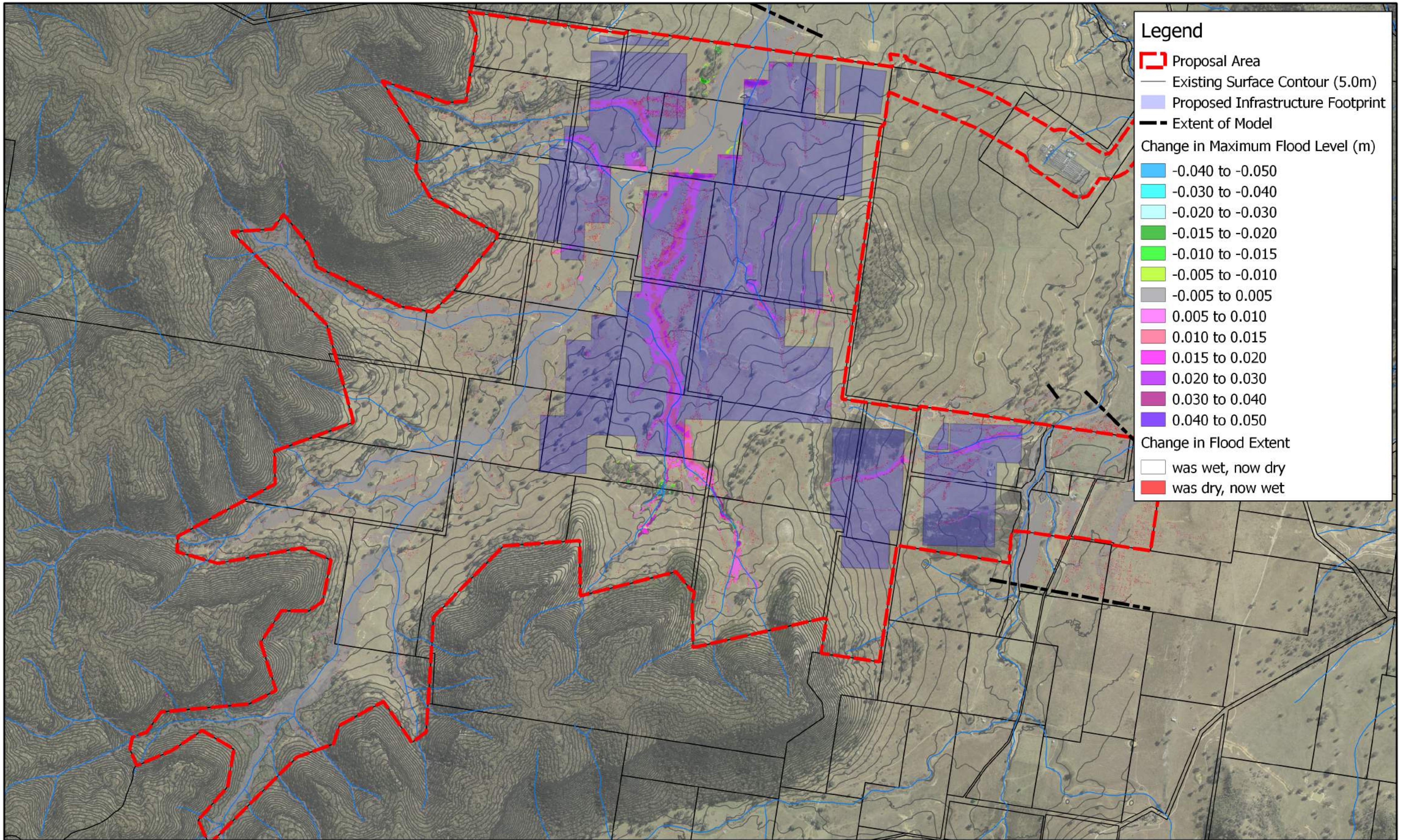

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HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 7.1

1% AEP Change in Maximum Flood Level

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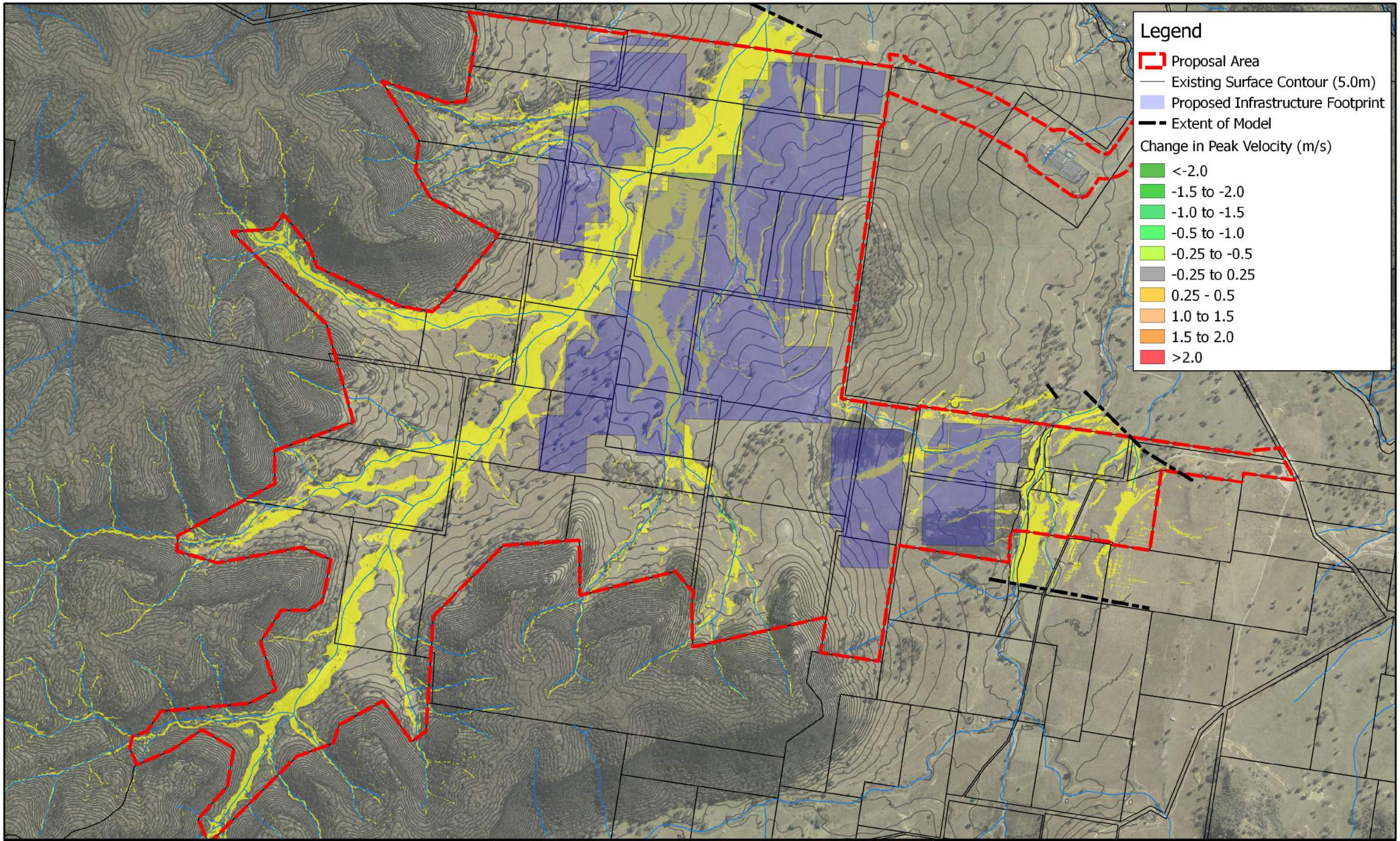

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WOLLAR SOLAR FARM
HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 7.2
1% AEP Change in Peak Flood Velocity

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