APPENDIX E HYDROLOGICAL AND HYDRAULIC ASSESSMENT

Proposed Solar Farm, Wellington New South Wales

Hydrological and Hydraulic Analysis

Project No. 1724
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Prepared for: First Solar (Australia) P/L

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1.0 INTRODUCTION

Footprint (NSW) Pty. Ltd. (***Footprint***) has been engaged by First Solar (Australia) Pty. Ltd. (***First Solar***) to undertake a hydrological and hydraulic analysis in support of a proposed solar farm located north-east of Wellington, New South Wales.

The purpose of the analysis is to define the flood behaviour, including depth of inundation, over three ephemeral watercourses/overland flow paths that traverse the subject site, in order 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 site survey, topographic maps, proposed development plans.
2. Undertake hydrologic calculations to determine peak flows arriving at the site for each watercourse for the 20%, 10%, 5%, 2% and 1% AEP events.
3. Undertake hydraulic modelling (using HEC-RAS) to determine the depth and extent of flooding over the each of the three watercourses 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 SUBJECT SITE

The subject site is described as Lots 89, 90, 91, 92 , 99, 102, 103 and 104/DP2987; Lot1/DP34690; Lot 1/DP520396 and Lot 2/DP807187 and is located approximately 2 kilometers north-east of the township of Wellington. The site location in relation to Wellington is shown in Figure 1.

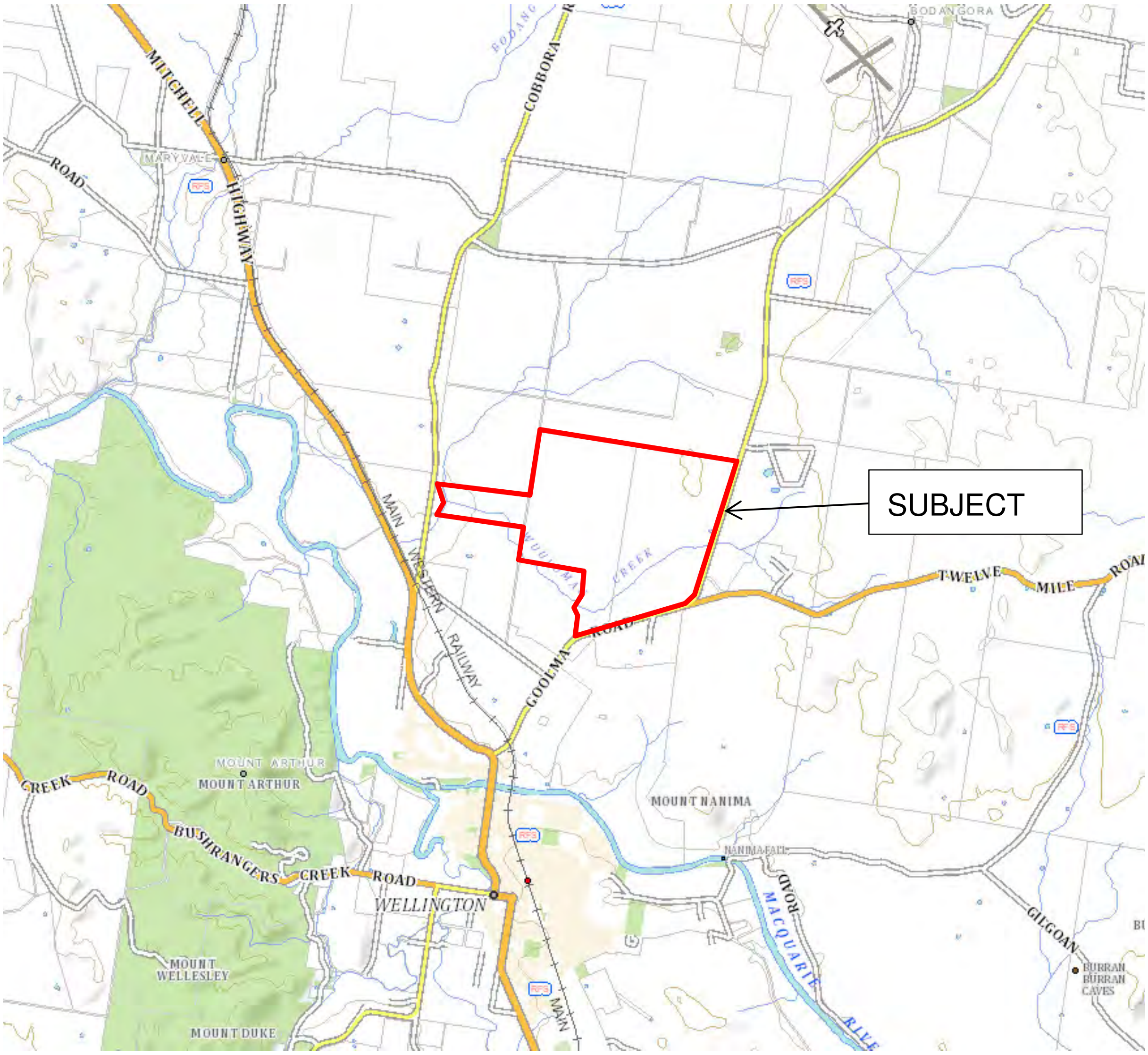

Figure 1: Location of Subject Site

The site consists of an area of approximately 490 hectares and is traversed be three watercourses including Wuuluman Creek and two tributaries. Wuuluman Creek traverses east to west along the southern portion of the site. One of the tributaries (Tributary 1), an overland flow path, traverses east to west in the northern and central areas of the site. The third tributary (Tributary 2), traverses north to south across the extreme western edge of the subject site.

All watercourses are described as ephemeral and only contain flowing water during rainfall.

Wuuluman Creek is a tributary of the Macquarie River, which is located approximately 1.3km west of the subject site.

The dominant land use on the subject site is agriculture with the steeper landforms mainly used for grazing activities whilst the flatter landforms are mostly cropped. Native vegetation remnants are present across some of the site, particularly on the knolls and along Wuuluman Creek.

An aerial view of the subject site showing the ephemeral watercourses described above is depicted in Figure 2.

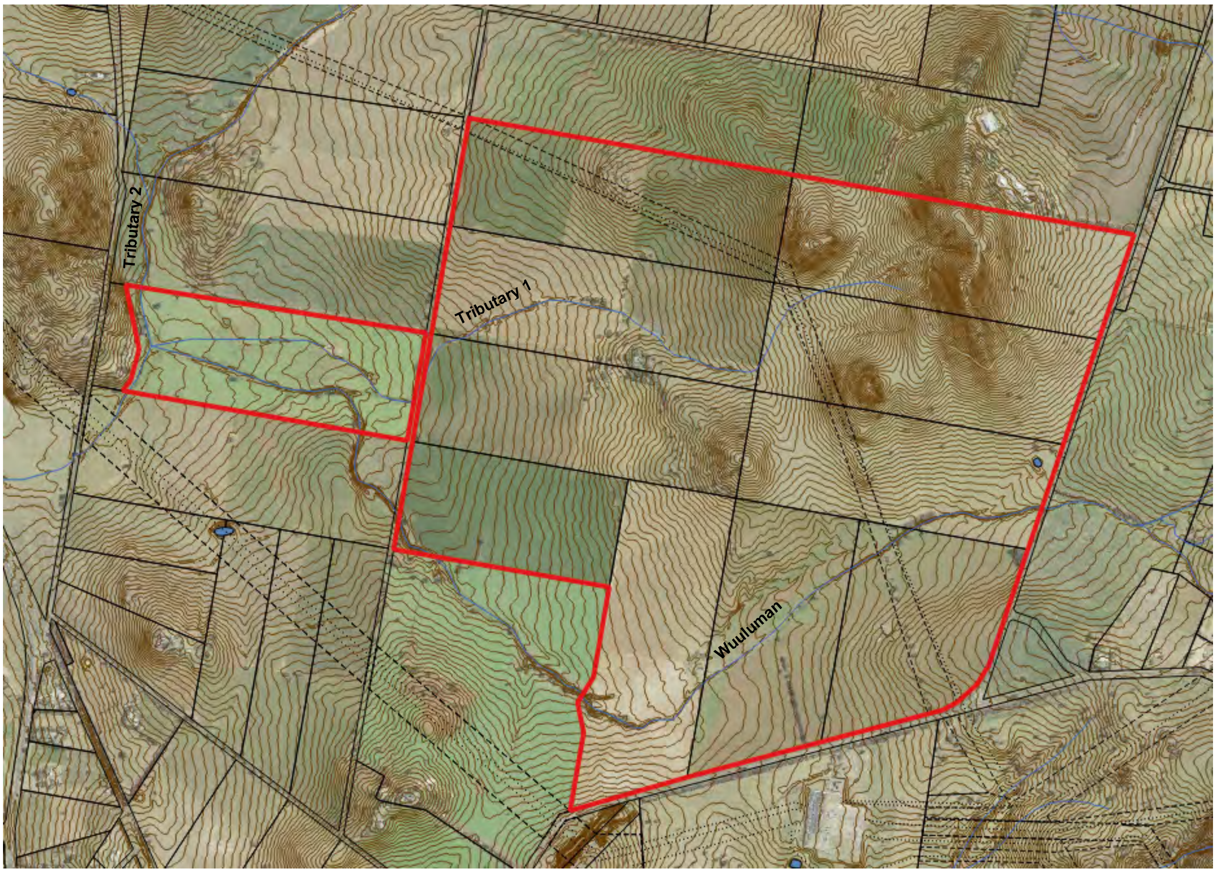

Figure 2: Aerial View of Subject Site

Elevations over the site range from RL299 m AHD to RL424m AHD as depicted in Figure 3.

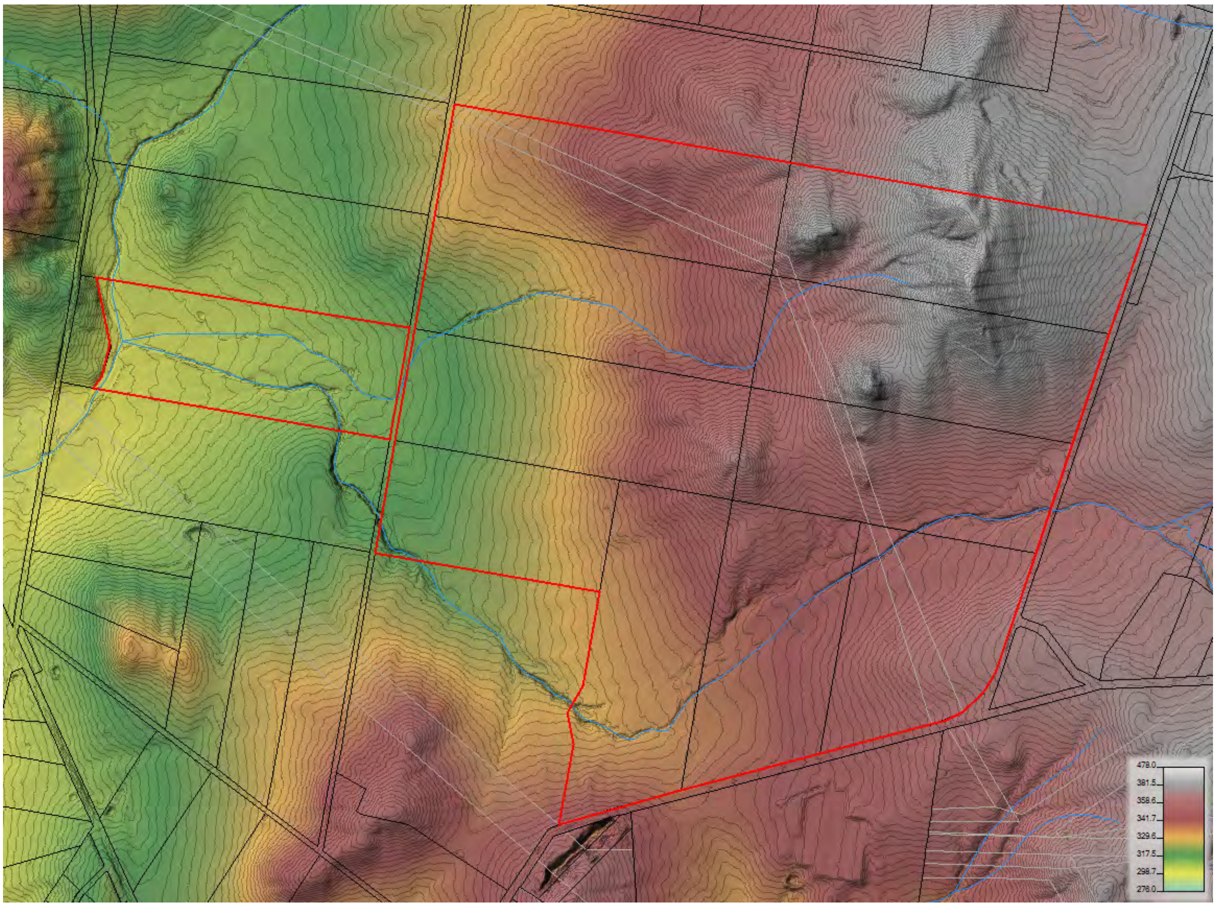

Figure 3: Terrain Analysis over Subject Site (1m contour interval)

3.0 HYDROLOGICAL MODELLING

3.1. Model Adoption

XP-RAFTS was chosen to develop the hydrological model for this study. XP-RAFTS is a non-linear runoff routing model used extensively throughout Australia and South East Asia. XP-RAFTS has been shown to work well on catchments ranging in size from a few square metres to 1000's of square kilometres of both urban and rural nature. XP-RAFTS can model up to 2000 different nodes and each node can have any size sub-catchment as well as a storage basin.

XP-RAFTS uses the Laurenson non-linear runoff routing procedure to develop a stormwater runoff hydrograph from either an actual event (recorded rainfall time series) or a design storm utilising Intensity-Frequency-Duration (IFD) data together with dimensionless storm temporal patterns as well as standard AR&R data.

3.2. Catchment Area

The catchment area contributing to Wuuluman Creek just downstream of the subject site and including the two tributaries was estimated to be 60.45km^2 and was determined using 10m contour data obtained through NSW Government Spatial Services.

The overall catchment was discretised into 19 sub-catchments ranging in size from 27 – 780 hectares as shown in Figure 4.

The approximate catchment area draining to each of the three watercourses is shown in ***Table 1***.

Table 1: Summary of Catchment Areas by Tributary

Watercourse	Sub-Catchments	Approx Catchment Area (ha)
Wuuluman Creek	1.01 – 1.08	1300
Tributary 1	2 – 2.02	235
Tributary 2	3.01 – 3.07 & 4	4510
Total		6045

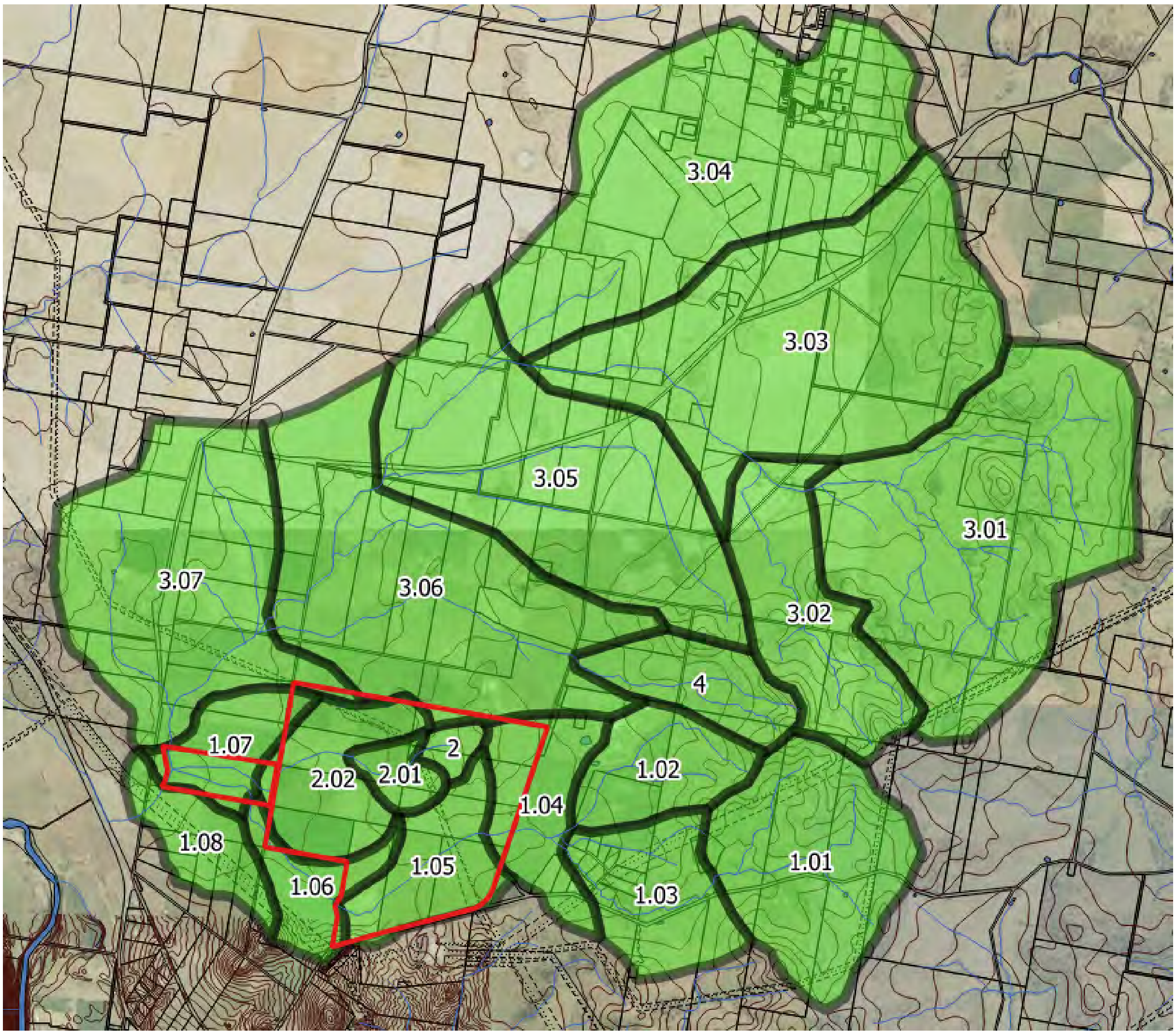

Figure 4: Sub-catchment Plan

3.3. Modelling Input Parameters

The parameters adopted for hydrological modelling are shown in ***Table 2***.

Table 2: Hydrological Parameters Adopted

Parameter	Value Adopted	Justification/Source
Pervious Area Initial Loss (mm)	25	Recommended value for Central NSW obtained through ARR 2016 data hub (refer Appendix A)
Pervious Area Continuing Loss (mm/h)	2.0	Recommended value for Central NSW obtained through ARR 2016 data hub (refer Appendix A)
BX	1	RAFTS Default
Sub-catchment Area (ha)	Varies	As per Figure 4
Impervious Area (%)	5	Value considered representative of rural lands on the urban fringe
Sub-catchment Slope (%)	Varies	Varies based on site topography.
Manning's n	0.025	Typical value for rural pasture lands

3.4. Rainfall Data

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

A copy of the Rainfall depth for Durations, Exceedance per Year (EY) and Annual Exceedance Probabilities (AEP) table is included in Appendix B.

3.5. Results

The RAFTS Model was run for storm durations ranging from 30 minutes to 24 hours and hydrographs at the outlet for the median storm for the range of events modelled are shown in Figure 5.

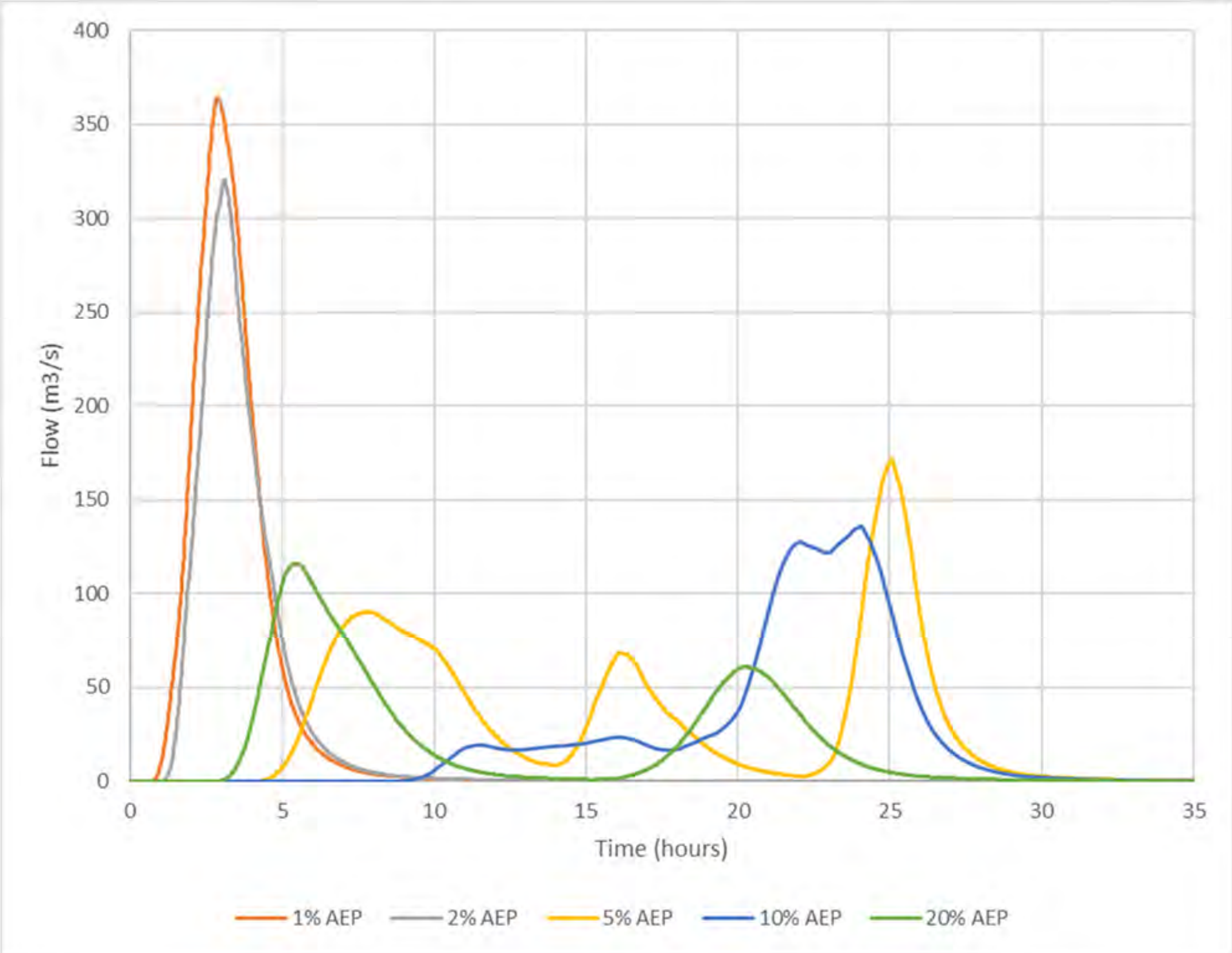

Figure 5: Median Flood Hydrographs Derived from Hydrological Model

The peak flows derived in RAFTS at the outlet 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 6.

Table 3: Comparison of Peak Flows to Regional Flood Frequency Estimation Model

AEP	Peak Flow Rate (cumecs)			
	RAFTS	Regional Flood Frequency Estimation Model		
		Discharge	Lower (5%)	Upper (95%)
20%	116	48.0	20.6	111
10%	136	75.0	32.5	173
5%	171	109	47.1	252
2%	321	167	71.2	391
1%	364	221	93.7	526

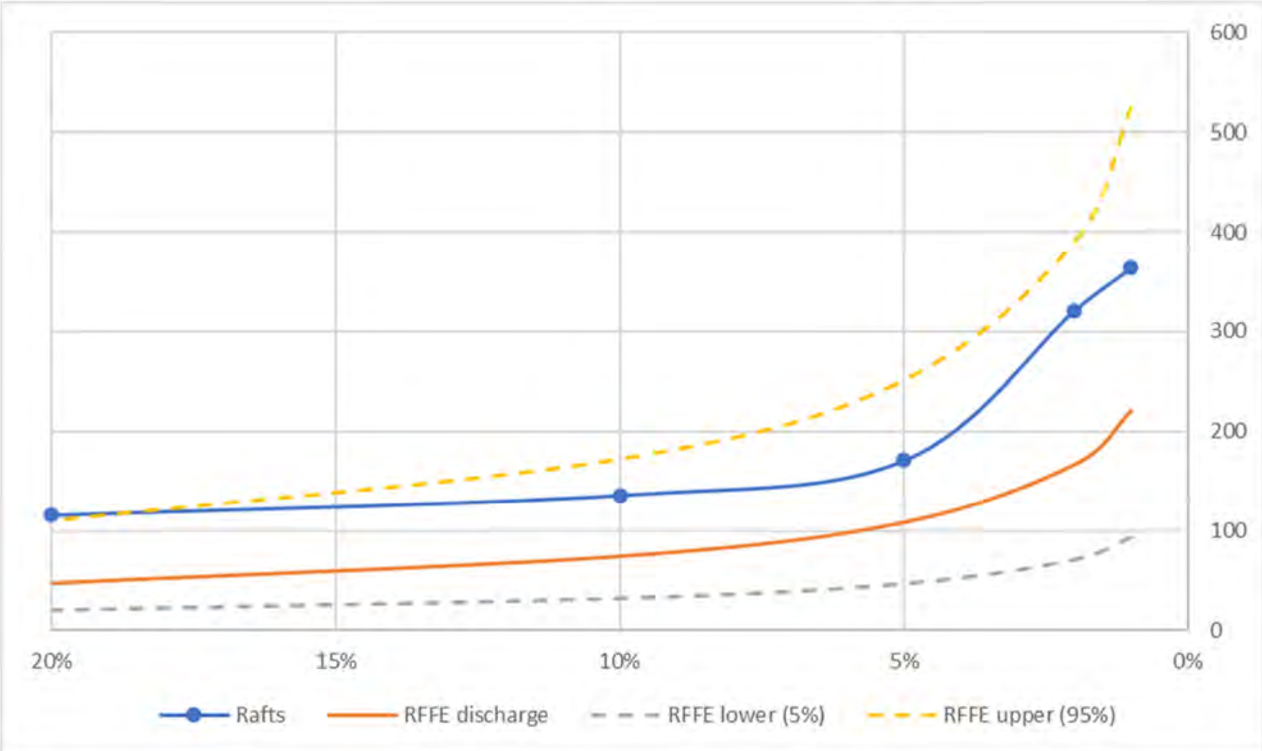

Figure 6: Comparison of Peak Flows to Regional Flood Frequency Estimation Model

The comparison of results shows that the runoff routing model results tend to estimate peak flows higher than the RFFE method. Without calibration reasons for this are not able to be determined. However possible causes could be due to routing effects and/or surface roughness which may result in increased peak flows from the RAFTS model. Results are well within the confidence limits for flow estimations based on gauged events from regional catchments, apart from the 20% AEP.

Outputs from the RFFE method are included in Appendix C.

4.0 HYDRAULIC MODELLING

Hydraulic modelling was conducted using an unsteady two-dimensional HEC-RAS model (Version 5.0.3) run in mixed flow regime to enable both subcritical and supercritical flow regimes to be assessed.

4.1. Model Inputs

4.1.1. Two Dimensional Domain

A digital elevation model (DEM) of the subject site was established using a 5m gridded digital elevation model (wellington1009.tif) sourced from www.elevation.fsdf.org.au.

A two dimensional flow area (i.e. active cells) was defined over the subject site over an extent considered large enough to accommodate the expected flows. The extent of the two-dimensional flow area is shown in Figure 7.

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 over each watercourse by applying breaklines with a maximum cell spacing of 5m. An example of the additional definition along each watercourse is shown in Figure 8.

The two-dimensional flow area was assigned a Manning's n value of 0.025 which is considered representative of the current condition of the land. The Manning's n value was increased to 0.06 in several isolated areas to represent some more densely vegetated areas along the creek corridors. The areas of increased Manning's n are shown in Figure 7.

4.1.2. Boundary Conditions

The hydrographs derived using RAFTS were used to define the upstream boundary condition within each watercourse for each of the modelled events. Hydrographs for each storm event at each of the inflow locations are provided in Appendix D and were derived using total hydrographs from subcatchments outlet as defined in Table 4.

Table 4: Adopted hydrographs for inflow boundaries

Inflow Boundary	Total Hydrograph from Subcatchment Outlet
Inflow_1	1.07
Inflow_2	2.02
Inflow_3	3.07

The upstream boundaries were extended along the upstream face of the two-dimensional domain at each watercourse over a sufficient length to enable the model to appropriately distribute the flow to the cells that are wet. At any given time step, 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.

Flows leaving the two-dimensional area were defined with a normal depth downstream boundary condition with a friction slope of 0.07% which is based on 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 and extent of the upstream and downstream boundary condition lines is shown in Figure 7.

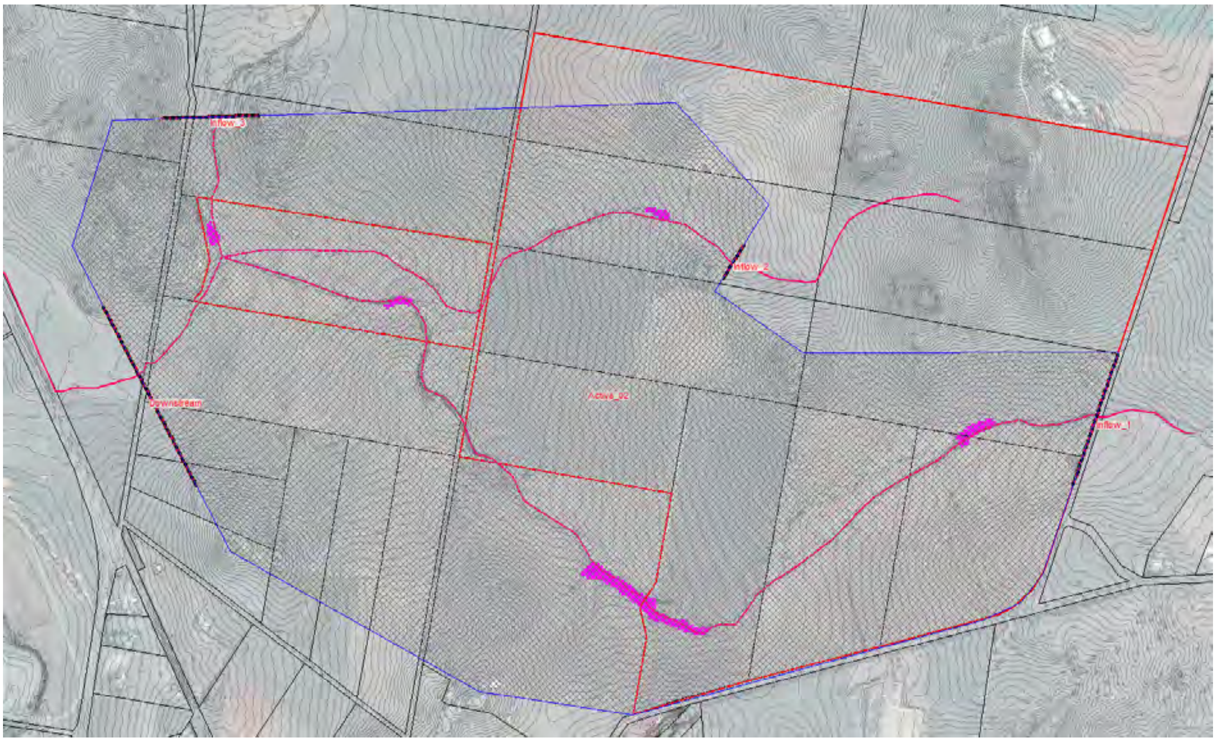

Figure 7: Two Dimensional Flow Area and Hydraulic Boundary Conditions (Mannings n = 0.06 areas shown in pink)

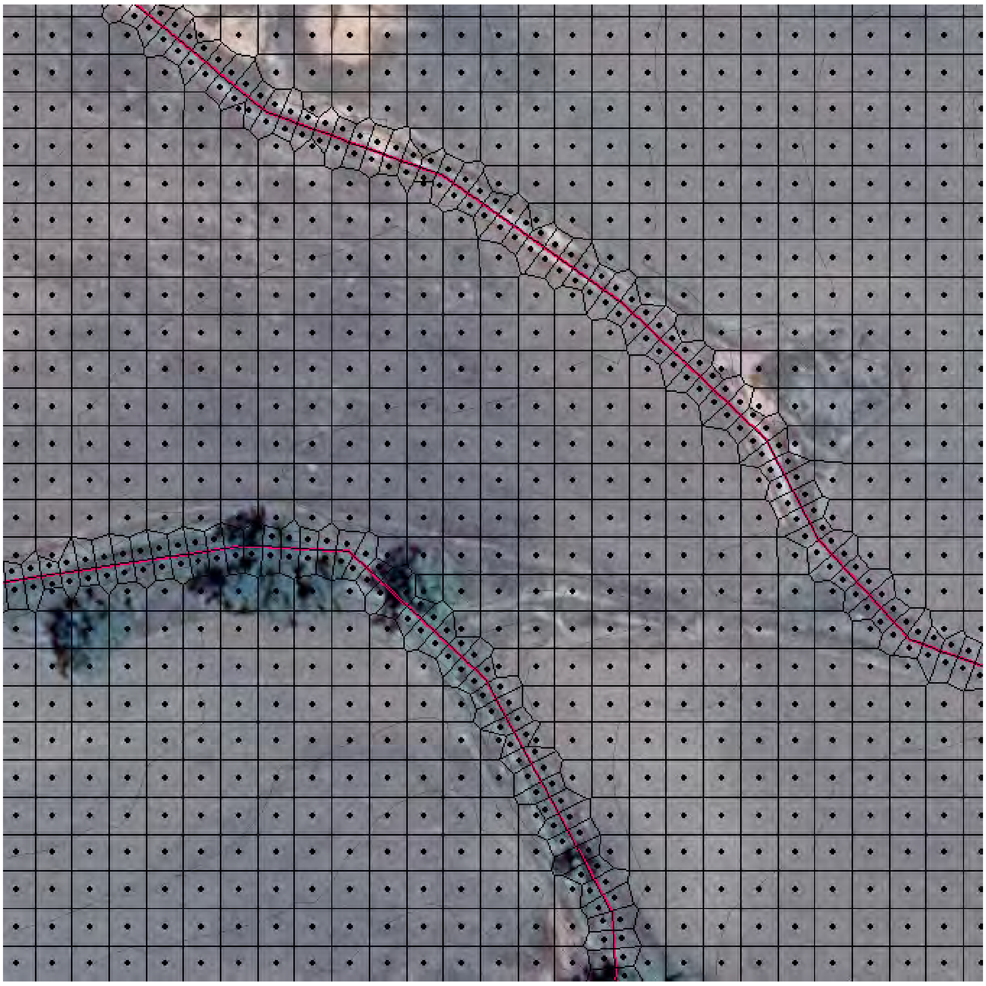

Figure 8: Example of additional definition along each watercourse

4.2. Results

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

Figure 1.1 – 1% AEP Flood Levels and Depths

Figure 1.2 – 1% AEP Flood Velocities

Figure 2.1 – 2% AEP Flood Levels and Depths

Figure 2.2 – 2% AEP Flood Velocities

Figure 3.1 – 5% AEP Flood Levels and Depths

Figure 3.2 – 5% AEP Flood Velocities

Figure 4.1 – 10% AEP Flood Levels and Depths

Figure 4.2 – 10% AEP Flood Velocities

Figure 5.1 – 20% AEP Flood Levels and Depths

Figure 5.2 – 20% AEP Flood Velocities

The results show that in the 1% AEP event significant overbank flows are predicted to occur within the upper reaches of Wuuluman Creek. Flow depths in excess of 1m are predicted on the right overbank, where an overflow channel exists. This overflow channel is clearly visible when analysing the terrain as shown in Figure 9.

Elsewhere, with the exception of within Lot 2 DP807187 where the watercourses merge, flows are largely confined to the watercourses, with overbank flows limited to several hundred millimetres in depth.

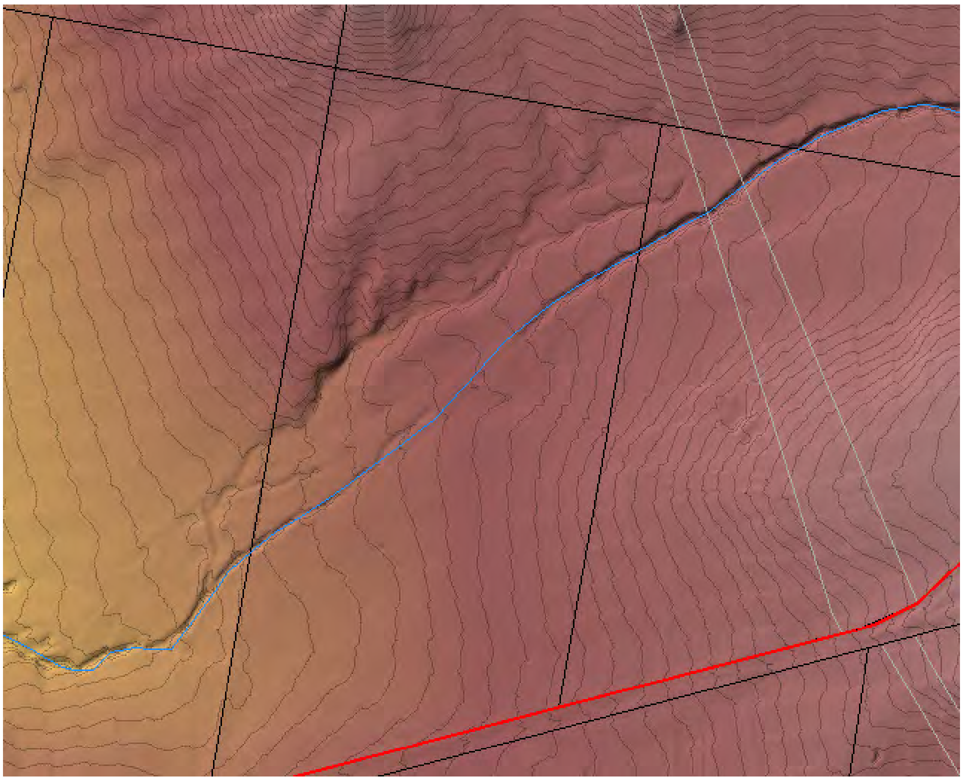

Figure 9: Wuuluman Creek Overflow Channel

It should be noted that due to the coarse nature of the 5m DEM grid used in the analysis that the watercourse profile does not provide accurate representation of the actual channel profile. This is depicted in Figure 10 where a longitudinal section along the channel invert is shown to contain a series 'humps' and 'hollows'. The variable channel profile would likely result in an underestimation of the channel flows and a corresponding overestimation of overbank flows. Nonetheless the results are considered to provide a good estimation of the extent and depth of inundation over the site.

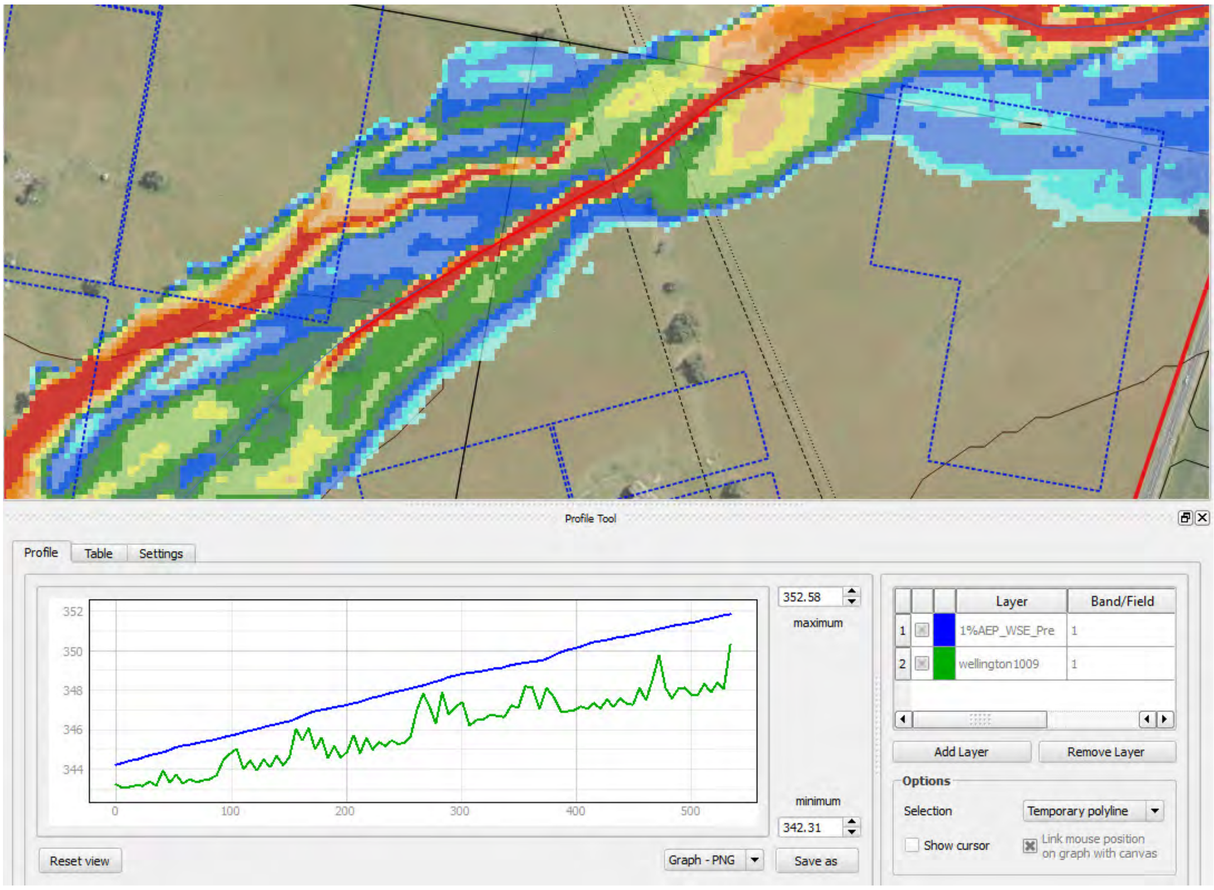

Figure 10: Analysis of Terrain within Watercourse Channel

5.0 IMPACT OF PROPOSED WORKS

The proposal would comprise an array of solar panels covering an area of approximately 360 hectares, a 132kV substation, and related infrastructure as follows:

- PV modules mounted on a horizontal tracking structure.
- Site office and maintenance building.
- A site access road off Goolma Road.
- Overhead transmission lines for grid connection to the adjacent substation (132kV).
- Overhead or underground electrical conduits and cabling to connect the arrays on the array site.
- Internal inverter stations to allow conversion of DC module output to AC electricity.
- Internal access tracks to allow for site maintenance.
- Perimeter security fencing.
- Native vegetation screening, where required to break up views of infrastructure to specific nearby receivers.

It is understood the solar modules will be erected on a frame supported on piers at an approximate grid spacing of 6 x 6 metres.

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 development was assessed using the Modified Cowan Method for Floodplain Roughness and is shown in Table 5. It demonstrates that the roughness is anticipated to slightly increase as a result of the development.

Table 5: 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 6m intervals)

It should be noted that the proposed network of access roads is to be constructed from dirt (gravel) and within the floodplain itself are to 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 E.

The results in Figures 6.1 and 6.2 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 and velocities remaining relatively unchanged. Furthermore, the proposed works within and over Tributary 1 are not predicted to result in an adverse impact on the hydraulic function of that watercourse.

The results in Figure 6.3 show that the increase in floodplain roughness over the area of the proposed solar module arrays is anticipated to result in localised increases in flood levels near the arrays with an associated minor decrease in flood levels downstream of the arrays. They also show that there is predicted to be a very marginal increase in the extent of flooding in the 1% AEP event.

The maximum increase in flood level resulting from the increase in surface roughness is predicted to be in the order of 70mm within the overflow channel along Wuuluman Creek within Lot 99, DP2987.

Importantly the modelling demonstrates that the changes in flood levels are principally isolated to the subject site, with the exception of some minor (in the order of 40mm) increases with the adjacent Lot 2, DP588075.

In addition, the proposed works are not anticipated to adversely increase the velocity in any of the watercourses or their associated overbanks therefore ensuring the stability of their bed and banks and minimising erosion potential.

6.0 FLOOD MANAGEMENT RECOMMENDATIONS

6.1. Solar Array Field

The Wuuluman Creek overflow channel within Lot 99 DP 2987 and Lot 1 DP520396 represents an area of high flood risk. In order to both minimise the impact of the development on flood behaviour and minimise the impact of flooding on the proposed development it is recommended that, within this area;

- the solar array mounting piers are 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;
- the layout of the solar array mounting piers are designed to minimise encroachment within the areas of highest velocity and depth. This may necessitate solar module frame spans in excess of those proposed.

Where the solar array fields encroach on Tributary 1 the layout of the mounting piers are to be designed to minimise encroachment within areas of the watercourse subject to high velocity and depth flows. Again, this may necessitate solar module frame spans more than those proposed.

Within the area of inundation, the mounting height of the solar module frames should be designed such that the lower edge of the module is clear of the predicted 1% AEP flood level so as not to impact on existing flood behaviour and to prevent the infrastructure from being damaged as a result of flooding.

In the event of a significant flood event the modules should be rotated to provide maximum clearance from the panels to the ground to keep them positioned well above the predicted flood level.

6.2. Electrical Infrastructure

All electrical infrastructure, including inverters, should be located above the 1% AEP flood level.

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

The proposed perimeter security fencing should be constructed in a manner which does not adversely affect the flow of floodwater and should designed to withstand the forces of floodwater, or collapse in a controlled manner to prevent impediment to floodwater.

6.4. Watercourse Crossings

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

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

APPENDIX A

BOM ARR 2016 Hub Data

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	148.982
Latitude	-32.508
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Temporal Patterns	show
Areal Temporal Patterns	show
Interim Climate Change Factors	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	Macquarie-Bogan Rivers
ARF Parameters	Central NSW
Temporal Patterns	Central Slopes

Data

River Region

division	Murray-Darling Basin
rivregnum	22
River Region	Macquarie-Bogan Rivers

Layer Info

Time Accessed	21 September 2017 05:43PM
Version	2016_v1

ARF Parameters

Long Duration ARF

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

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	21 September 2017 05:43PM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

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

Storm Initial Losses (mm)	25.0
Storm Continuing Losses (mm/h)	2.0

Layer Info

Time Accessed	21 September 2017 05:43PM
Version	2016_v1

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

code	CS
Label	Central Slopes

Layer Info

Time Accessed	21 September 2017 05:43PM
Version	2016_v2

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

code	CS
arealabel	Central Slopes

Layer Info

Time Accessed	21 September 2017 05:43PM
Version	2016_v2

BOM IFD Depths

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-32.50781&longitude=148.981899&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

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Version	2016_v2

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)	1.3 (0.058)	0.9 (0.029)	0.6 (0.017)	0.3 (0.008)	0.5 (0.009)	0.6 (0.01)
90 (1.5)	0.9 (0.037)	0.9 (0.027)	0.9 (0.022)	0.9 (0.019)	0.5 (0.009)	0.2 (0.002)
120 (2.0)	1.2 (0.044)	0.9 (0.025)	0.7 (0.016)	0.5 (0.01)	0.7 (0.012)	0.8 (0.012)
180 (3.0)	0.5 (0.015)	0.8 (0.019)	1.0 (0.021)	1.3 (0.022)	1.4 (0.021)	1.5 (0.02)
360 (6.0)	0.7 (0.017)	2.0 (0.038)	2.9 (0.047)	3.8 (0.053)	6.0 (0.073)	7.7 (0.083)
720 (12.0)	0.0 (0.001)	3.2 (0.05)	5.4 (0.071)	7.4 (0.085)	9.4 (0.091)	10.9 (0.094)
1080 (18.0)	0.0 (0.0)	0.9 (0.012)	1.5 (0.017)	2.0 (0.021)	5.7 (0.048)	8.4 (0.063)
1440 (24.0)	0.0 (0.0)	0.1 (0.001)	0.2 (0.002)	0.2 (0.002)	3.5 (0.027)	6.0 (0.041)
2160 (36.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.4 (0.003)	0.7 (0.004)
2880 (48.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
4320 (72.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

Layer Info

Time Accessed	21 September 2017 05:43PM
Version	2016_v2

10% Preburst Depths

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

Layer Info

Time Accessed	21 September 2017 05:43PM
Version	2016_v2

25% Preburst Depths

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.002)	0.0 (0.001)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
90 (1.5)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
120 (2.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
180 (3.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
360 (6.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
720 (12.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.001)	0.1 (0.001)
1080 (18.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
1440 (24.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
2160 (36.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
2880 (48.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
4320 (72.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)

Layer Info

Time Accessed	21 September 2017 05:43PM
Version	2016_v2

75% Preburst Depths

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	16.2 (0.707)	12.0 (0.386)	9.2 (0.251)	6.5 (0.154)	7.8 (0.158)	8.8 (0.16)
90 (1.5)	11.1 (0.43)	11.7 (0.335)	12.1 (0.294)	12.5 (0.263)	10.4 (0.186)	8.8 (0.142)
120 (2.0)	15.4 (0.545)	14.8 (0.389)	14.5 (0.322)	14.1 (0.274)	14.6 (0.241)	14.9 (0.222)
180 (3.0)	11.3 (0.356)	15.3 (0.357)	17.9 (0.356)	20.5 (0.354)	22.8 (0.336)	24.5 (0.325)
360 (6.0)	12.0 (0.307)	19.6 (0.373)	24.6 (0.399)	29.4 (0.416)	39.9 (0.48)	47.7 (0.514)
720 (12.0)	7.3 (0.152)	18.0 (0.28)	25.2 (0.331)	32.0 (0.366)	40.7 (0.394)	47.2 (0.407)
1080 (18.0)	3.3 (0.061)	10.6 (0.146)	15.5 (0.18)	20.1 (0.203)	27.2 (0.231)	32.4 (0.244)
1440 (24.0)	0.5 (0.009)	6.4 (0.081)	10.3 (0.11)	14.0 (0.129)	20.0 (0.155)	24.5 (0.168)
2160 (36.0)	0.0 (0.0)	2.7 (0.031)	4.5 (0.043)	6.2 (0.051)	8.2 (0.056)	9.8 (0.059)
2880 (48.0)	0.0 (0.0)	1.4 (0.015)	2.3 (0.021)	3.2 (0.025)	5.6 (0.035)	7.4 (0.041)
4320 (72.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1.4 (0.008)	2.4 (0.012)

Layer Info

Time Accessed	21 September 2017 05:43PM
Version	2016_v2

90% Preburst Depths

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	32.8 (1.43)	26.1 (0.842)	21.7 (0.593)	17.5 (0.414)	27.7 (0.558)	35.4 (0.638)
90 (1.5)	29.8 (1.148)	41.6 (1.188)	49.4 (1.197)	56.9 (1.198)	48.0 (0.86)	41.3 (0.664)
120 (2.0)	31.1 (1.102)	36.5 (0.958)	40.0 (0.892)	43.4 (0.842)	54.0 (0.893)	61.9 (0.92)
180 (3.0)	33.2 (1.044)	40.1 (0.935)	44.6 (0.885)	49.0 (0.847)	60.9 (0.899)	69.9 (0.927)
360 (6.0)	25.7 (0.658)	40.9 (0.78)	51.0 (0.827)	60.7 (0.858)	71.6 (0.861)	79.7 (0.86)
720 (12.0)	22.7 (0.473)	44.7 (0.692)	59.2 (0.779)	73.1 (0.836)	85.1 (0.824)	94.2 (0.812)
1080 (18.0)	15.8 (0.292)	32.3 (0.445)	43.2 (0.504)	53.6 (0.542)	67.3 (0.572)	77.5 (0.584)
1440 (24.0)	8.9 (0.152)	17.4 (0.221)	23.0 (0.247)	28.4 (0.263)	43.5 (0.338)	54.9 (0.376)
2160 (36.0)	4.1 (0.063)	12.5 (0.143)	18.1 (0.174)	23.4 (0.193)	35.5 (0.244)	44.6 (0.269)
2880 (48.0)	5.6 (0.081)	10.1 (0.108)	13.1 (0.117)	15.9 (0.122)	21.9 (0.139)	26.4 (0.147)
4320 (72.0)	0.5 (0.007)	3.8 (0.037)	5.9 (0.048)	8.0 (0.055)	12.3 (0.07)	15.5 (0.078)

Layer Info

Time Accessed	21 September 2017 05:43PM
Version	2016_v2

APPENDIX B

ARR 2016 IFD Data

Australian Government
Bureau of Meteorology

Location

Label: Not provided

Latitude: -32.50781 [Nearest grid cell: 32.5125 (S)]

Longitude: 148.981899 [Nearest grid cell: 148.9875 (E)]

IFD Design Rainfall Depth (mm)

Issued: 21 September 2017

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	1.83	2.06	2.78	3.28	3.79	4.47	5.01
2 min	3.09	3.48	4.71	5.55	6.39	7.45	8.27
3 min	4.27	4.80	6.50	7.67	8.82	10.3	11.5
4 min	5.33	5.99	8.10	9.55	11.0	12.9	14.4
5 min	6.27	7.04	9.51	11.2	12.9	15.2	17.0
10 min	9.75	10.9	14.8	17.4	20.1	23.8	26.7
15 min	12.0	13.5	18.2	21.6	24.9	29.5	33.2
20 min	13.7	15.4	20.8	24.6	28.4	33.7	37.8
30 min	16.1	18.1	24.5	29.0	33.4	39.5	44.3
45 min	18.6	20.9	28.2	33.4	38.5	45.4	50.8
1 hour	20.4	22.9	31.0	36.6	42.2	49.6	55.4
1.5 hour	23.1	25.9	35.0	41.3	47.5	55.8	62.2
2 hour	25.1	28.2	38.1	44.9	51.6	60.5	67.3
3 hour	28.3	31.8	42.8	50.4	57.9	67.8	75.4
6 hour	34.8	39.1	52.5	61.7	70.8	83.1	92.7
12 hour	43.0	48.1	64.5	76.0	87.4	103	116
24 hour	52.4	58.6	78.7	93.1	108	129	146
48 hour	62.0	69.2	93.7	112	131	158	180
72 hour	67.0	75.0	102	123	145	175	200
96 hour	70.3	78.8	108	130	154	186	213
120 hour	72.7	81.7	113	136	161	195	223
144 hour	74.6	84.1	116	140	166	201	230
168 hour	76.4	86.2	120	144	170	207	236

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.

Location

Label: Not provided

Latitude: -32.50781 [Nearest grid cell: 32.5125 (S)]

Longitude: 148.981899 [Nearest grid cell: 148.9875 (E)]

Rare Design Rainfall Depth (mm)

Issued: 21 September 2017

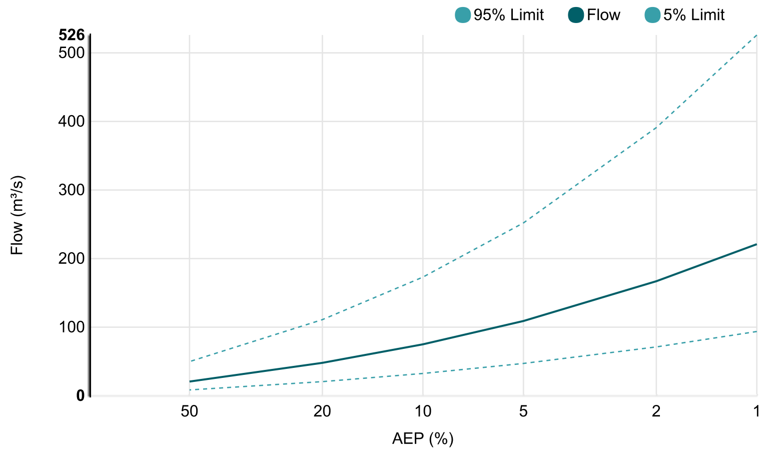
Rainfall depth for Durations, Exceedance per Year (EY), and Annual Exceedance Probabilities (AEP).
FAQ for New ARR probability terminology

	Annual Exceedance Probability (1 in x)				
Duration	**1 in 100**	**1 in 200**	**1 in 500**	**1 in 1000**	**1 in 2000**
24 hour	146	166	193	216	240
48 hour	180	205	241	270	303
72 hour	200	227	266	299	334
96 hour	213	241	283	318	355
120 hour	223	252	296	332	371
144 hour	230	261	306	344	384
168 hour	236	269	315	354	395

This page was created at **17:46 on Thursday 21 September 2017 (AEST)**

APPENDIX C
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	20.7	8.50	49.8
20	48.0	20.6	111
10	75.0	32.5	173
5	109	47.1	252
2	167	71.2	391
1	221	93.7	526

Statistics

Variable	Value	Standard Dev
Mean	3.034	0.526
Standard Dev	0.984	0.111
Skew	0.071	0.026

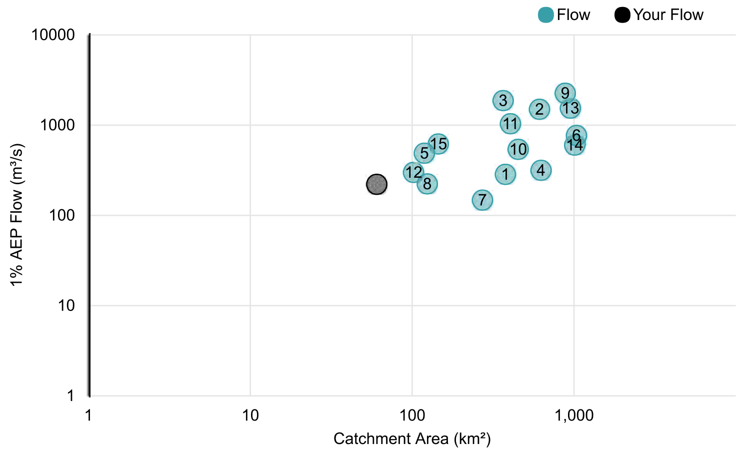
Note: These statistics come from the nearest gauged catchment. Details.

Correlation

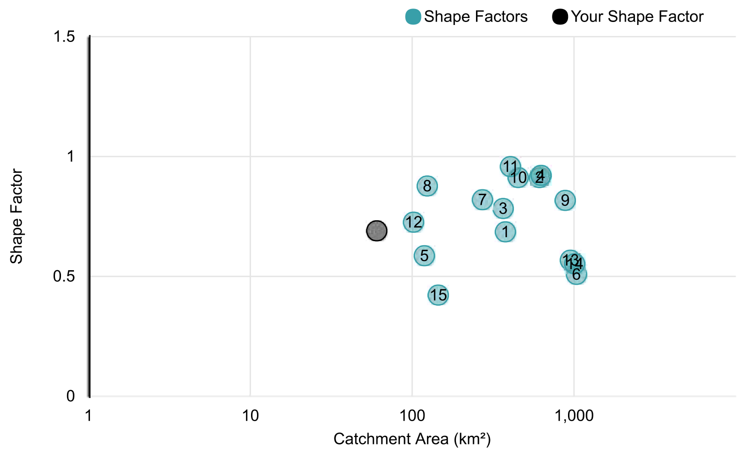
1.000		
-0.330	1.000	
0.170	-0.280	1.000

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

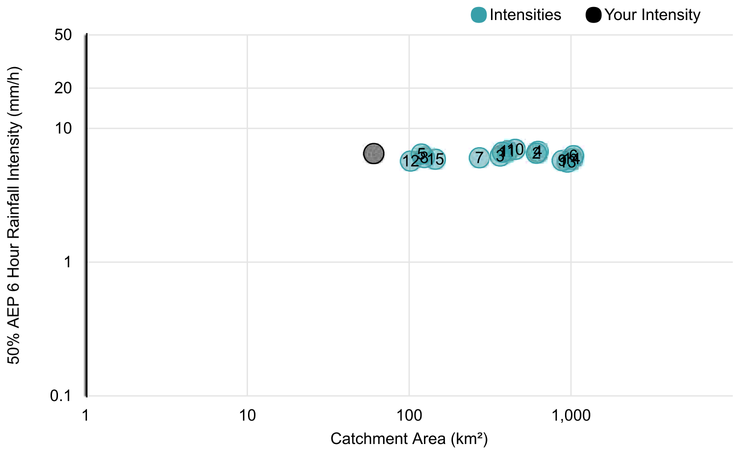
1% AEP Flow vs Catchment Area



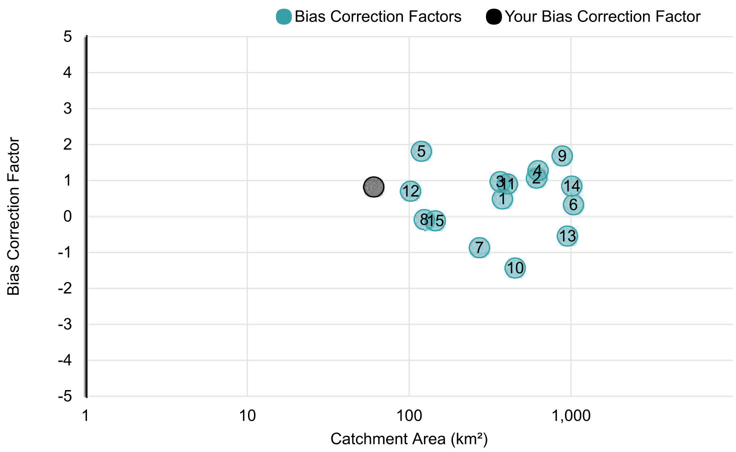
Shape Factor vs Catchment Area



Intensity vs Catchment Area



Bias Correction Factor vs Catchment Area



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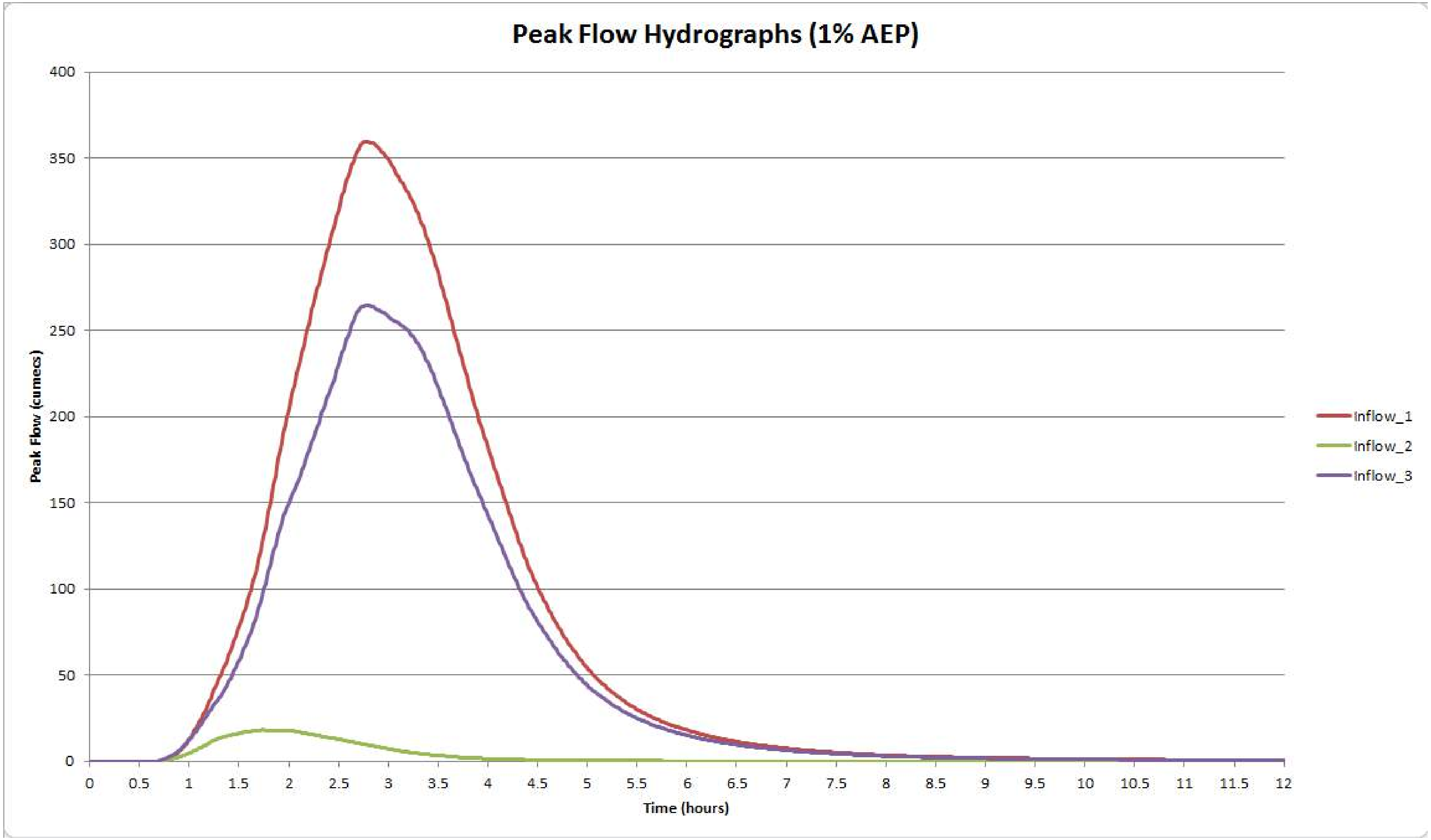
Input Data

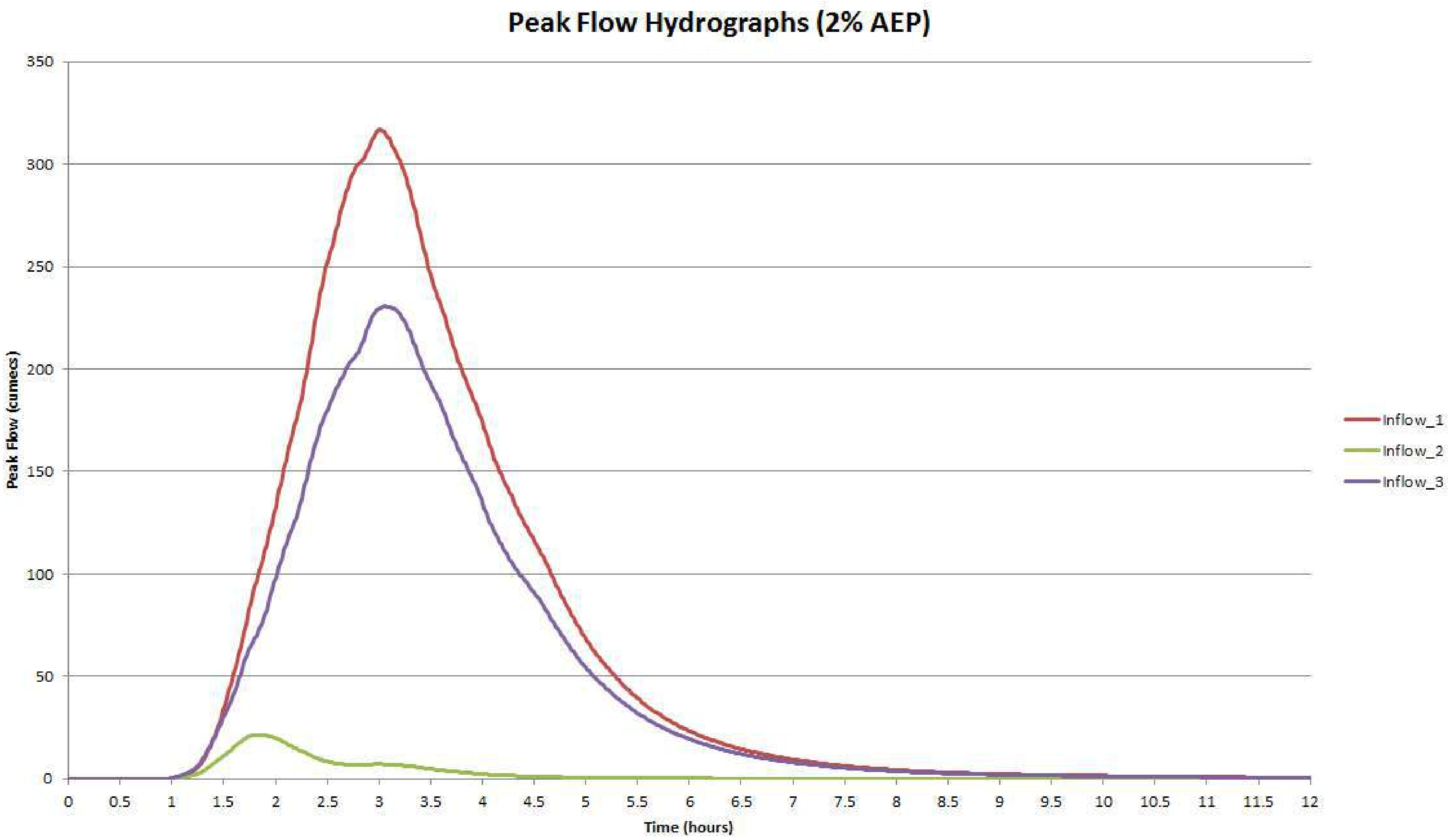
Date/Time	2017-10-24 12:46

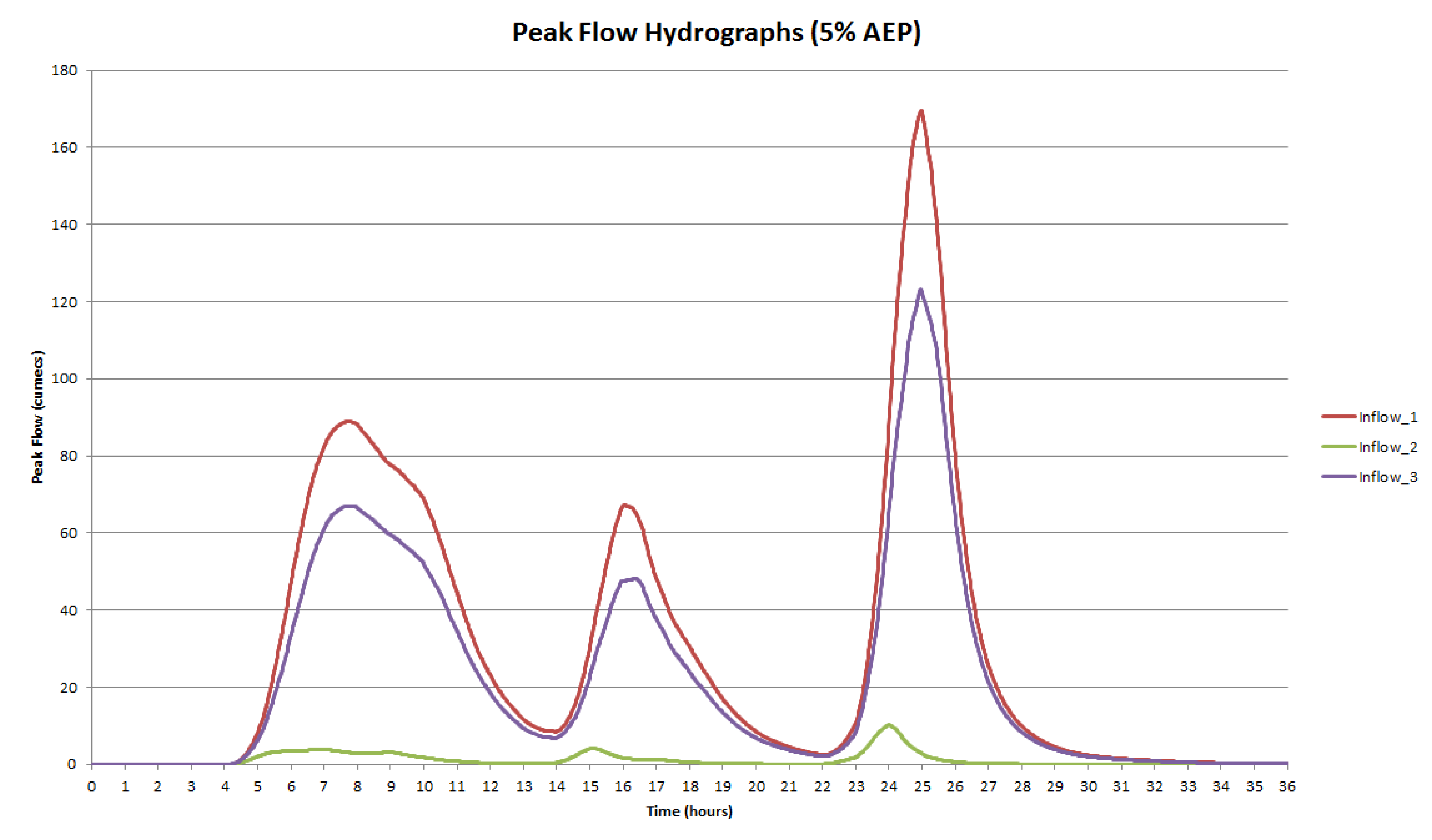
APPENDIX D

Inflow Hydrographs

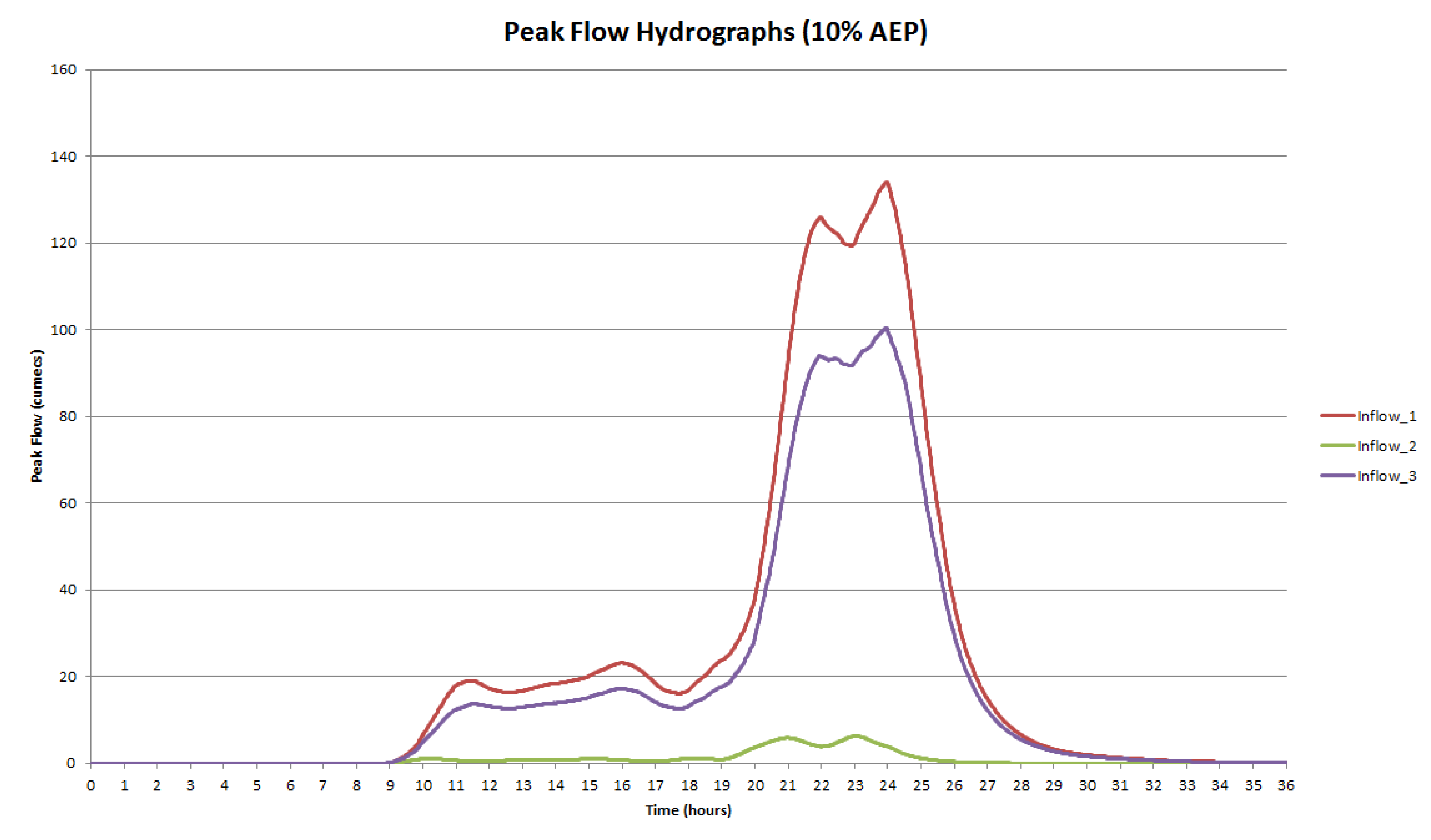


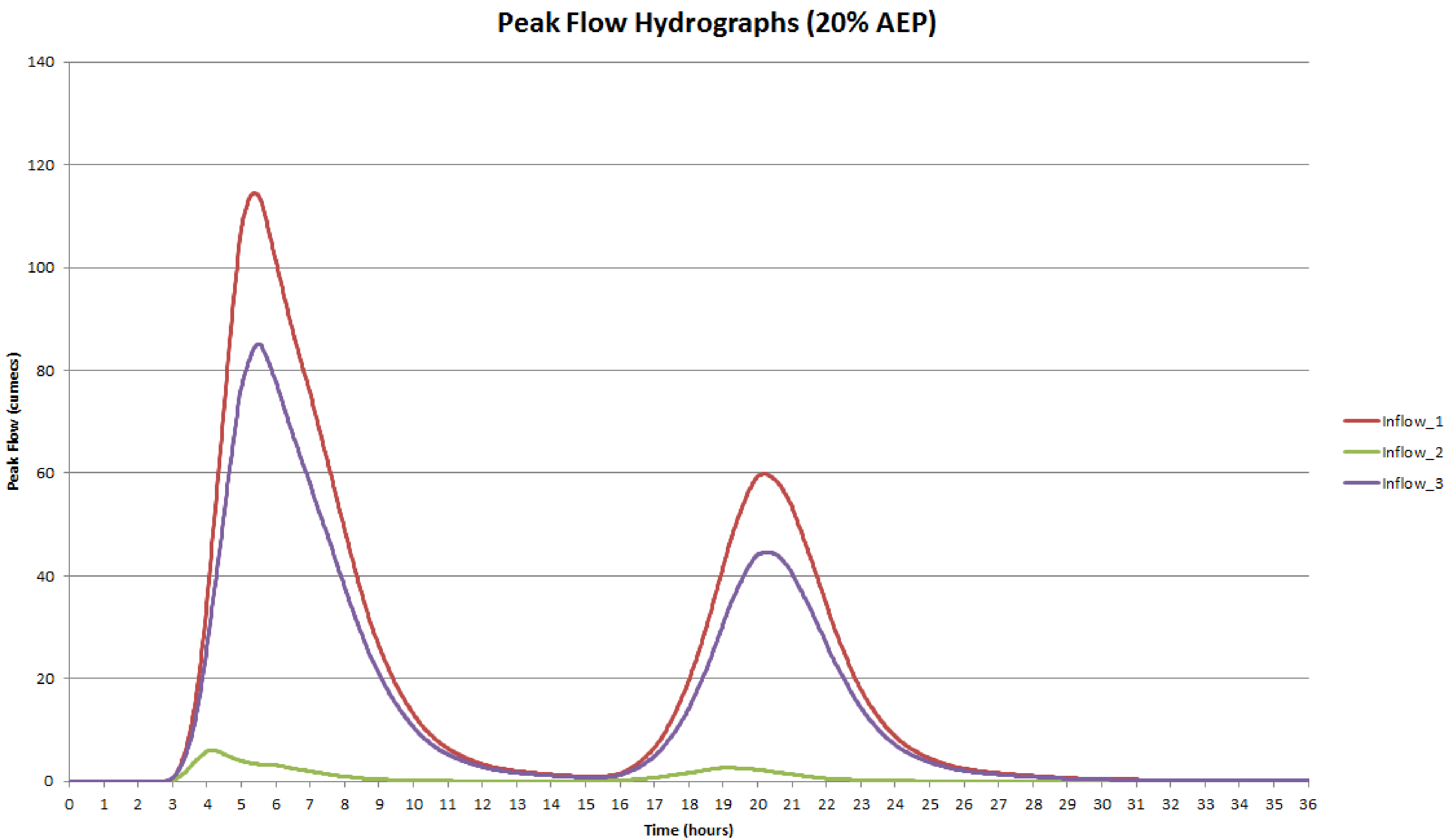
Peak Flow Hydrographs (1% AEP)
Peak Flow (cumecs)
400
350
300
250
200
150
100
50
0
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12
Time (hours)
Inflow_1
Inflow_2
Inflow_3


Peak Flow Hydrographs (2% AEP)
350
300
250
200
150
100
50
0
Peak Flow (cumecs)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8
8.5
9
9.5
10
10.5
11
11.5
12
Time (hours)
Inflow_1
Inflow_2
Inflow_3

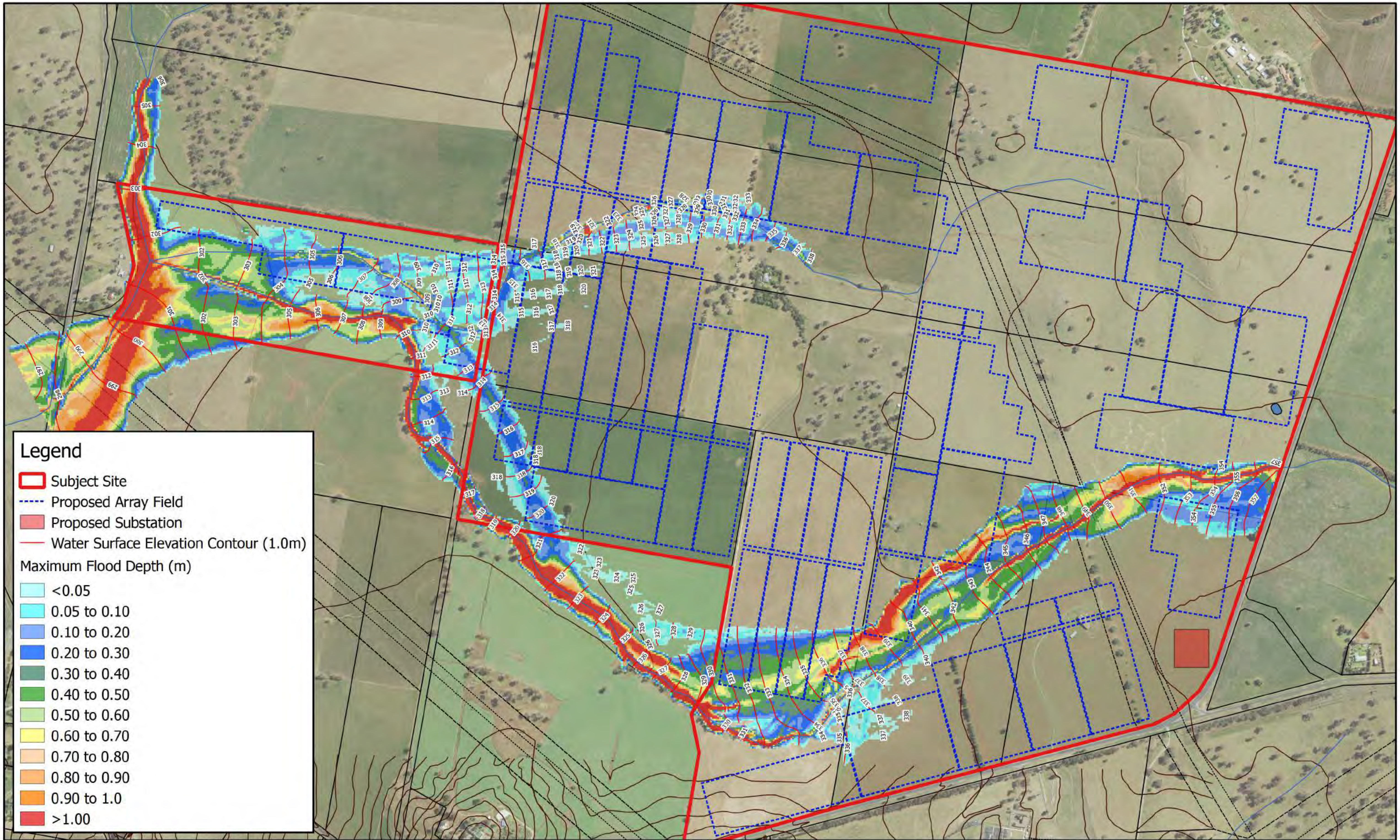


Peak Flow Hydrographs (5% AEP)
Peak Flow (cumecs)
180
160
140
120
100
80
60
40
20
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
Time (hours)
Inflow_1
Inflow_2
Inflow_3


Peak Flow Hydrographs (10% AEP)
Peak Flow (cumecs)
160
140
120
100
80
60
40
20
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
Time (hours)
Inflow_1
Inflow_2
Inflow_3


Peak Flow Hydrographs (20% AEP)
Peak Flow (cumecs)
0
20
40
60
80
100
120
140
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
Time (hours)
Inflow_1
Inflow_2
Inflow_3

APPENDIX E
Flood Mapping



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

First Solar.

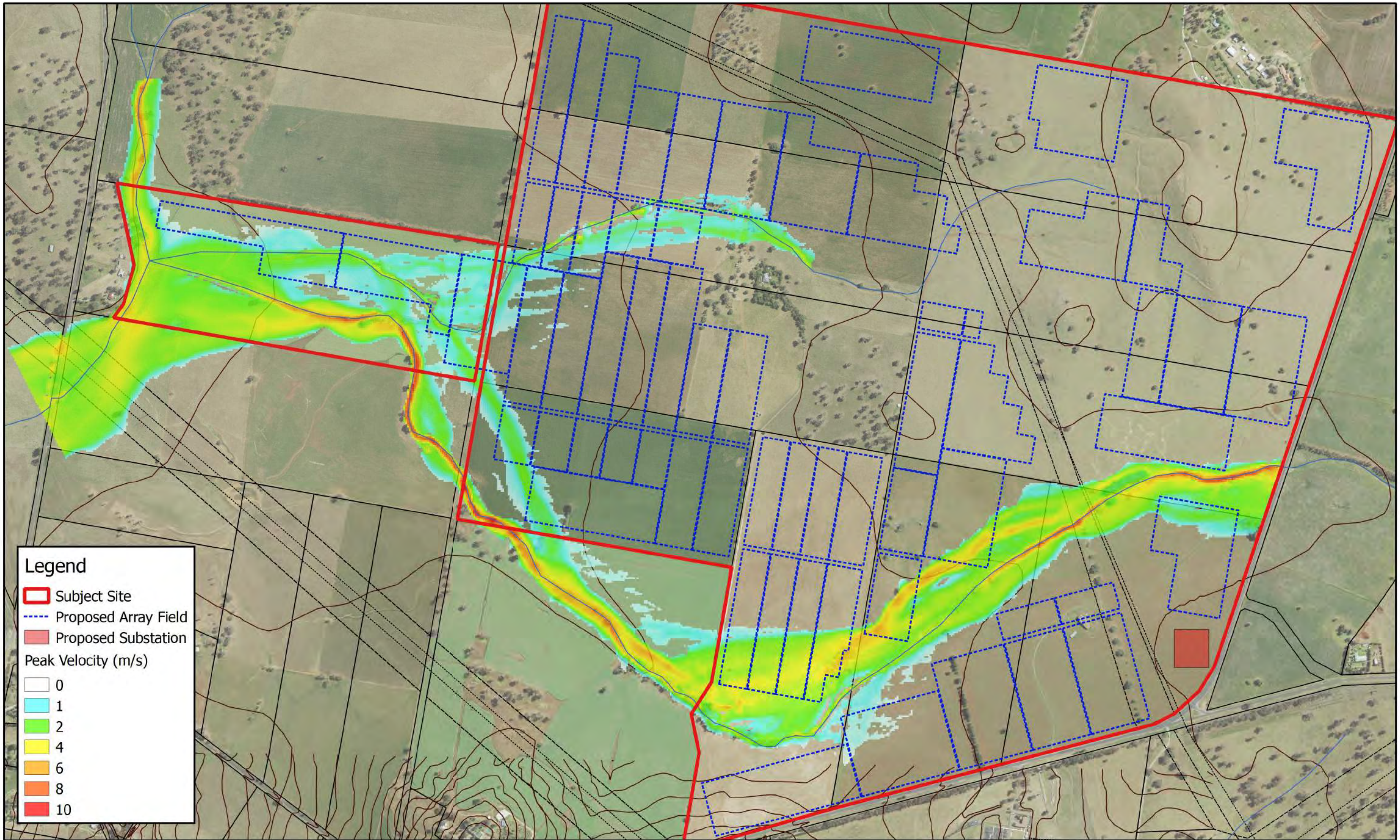
100 0 100 200 300 m

Scale 1:10,000 at A3

PROPOSED WELLINGTON SOLAR FARM
HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 1.1
1% AEP Flood Levels and Depths

Rev 1 -31 October 2017



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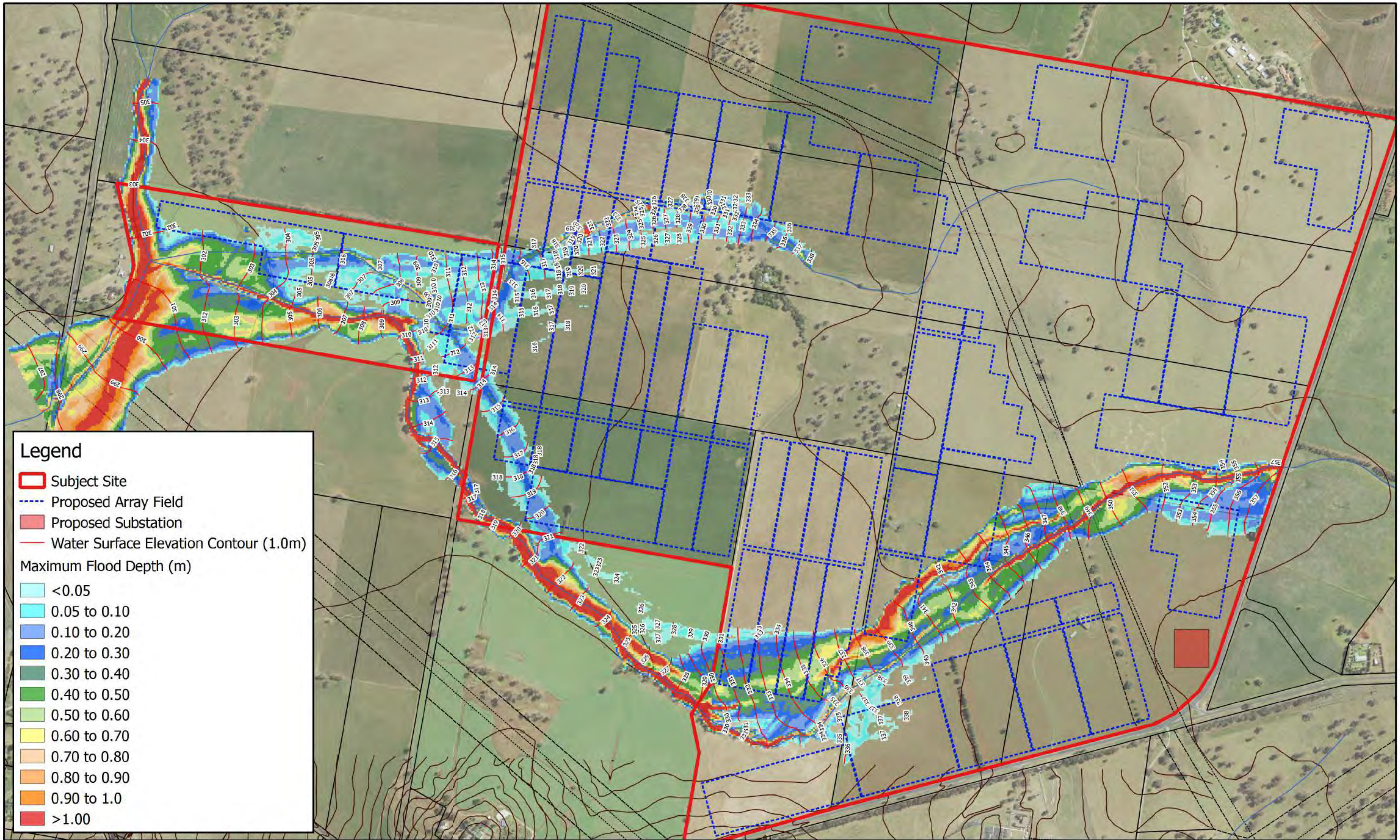
PROPOSED WELLINGTON SOLAR FARM
HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 1.2
1% AEP Peak Velocity

Rev 1 -31 October 2017



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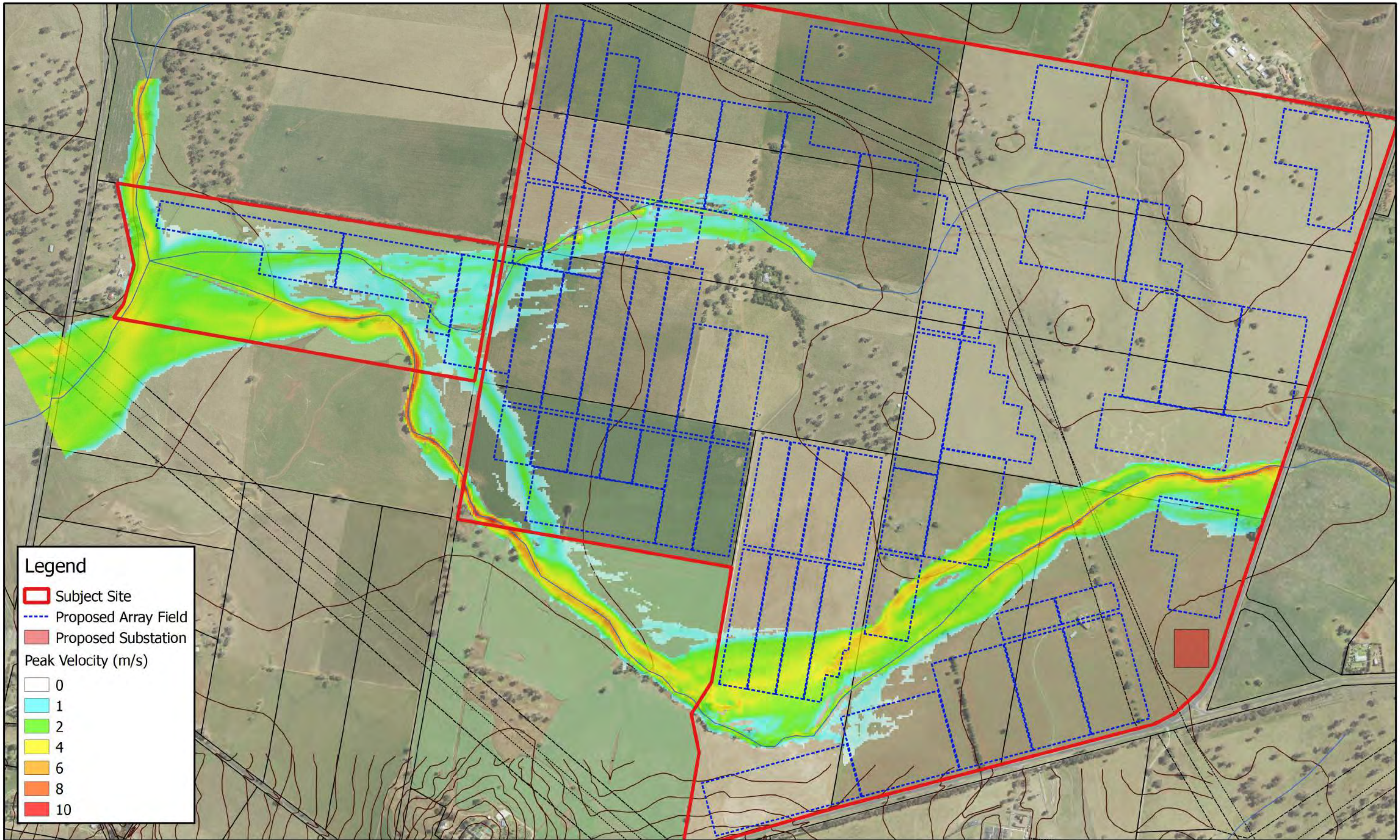
PROPOSED WELLINGTON SOLAR FARM
HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 2.1
2% AEP Flood Levels and Depths

Rev 1 -31 October 2017



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100 0 100 200 300 m
Scale 1:10,000 at A3

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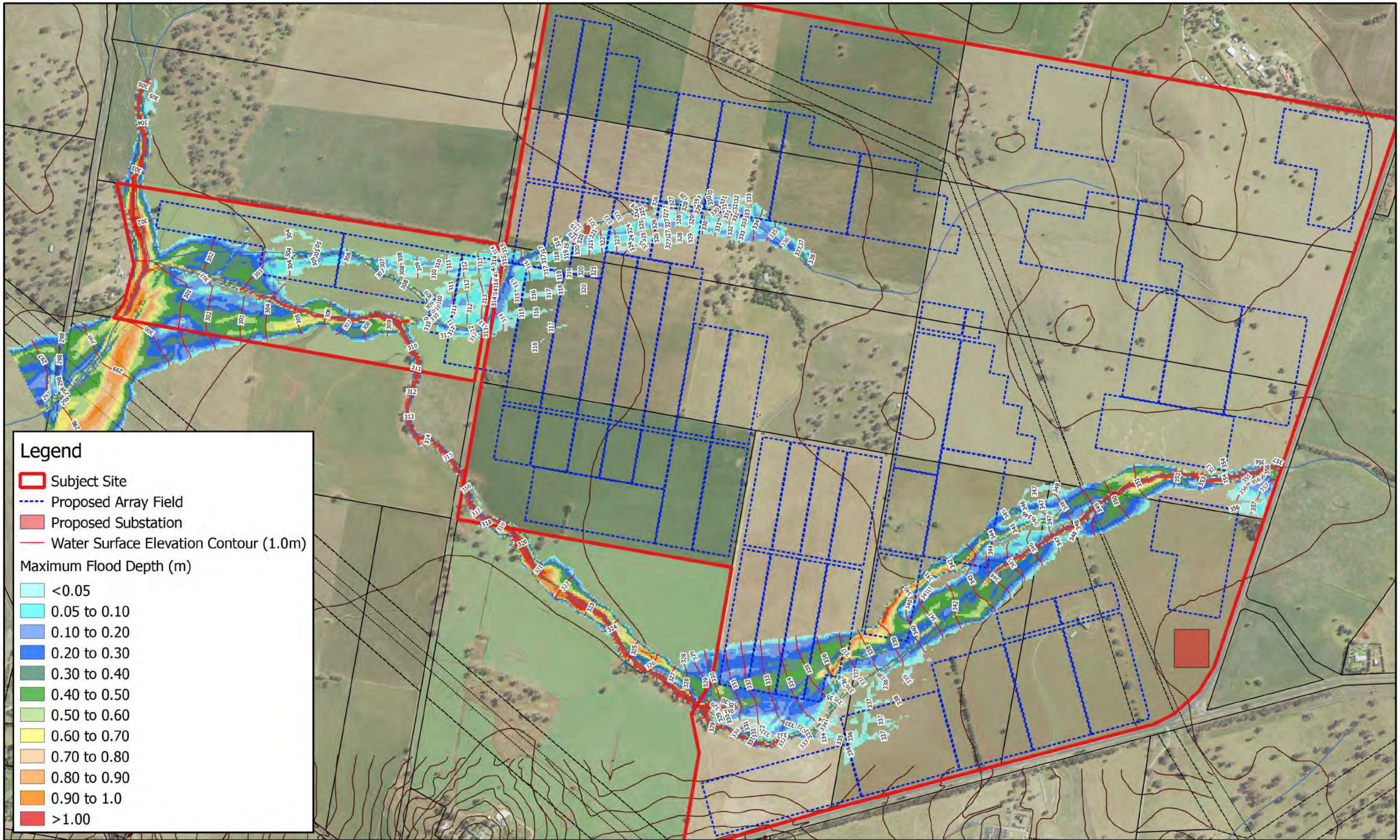
PROPOSED WELLINGTON SOLAR FARM
HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 2.2
2% AEP Peak Velocity

Rev 1 -31 October 2017



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PROPOSED WELLINGTON SOLAR FARM
HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 3.1
5% AEP Flood Levels and Depths

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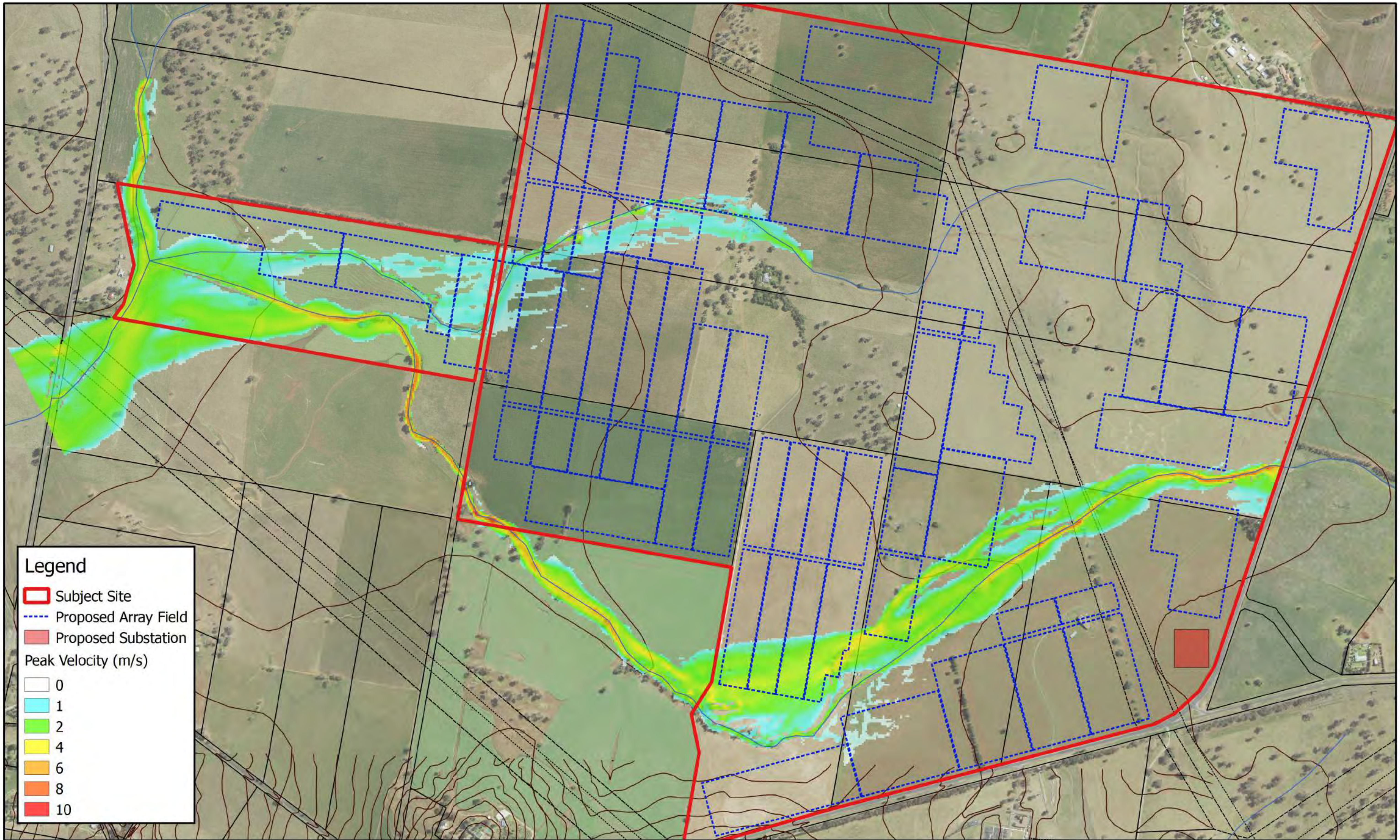

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sustainable engineering.

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First Solar.

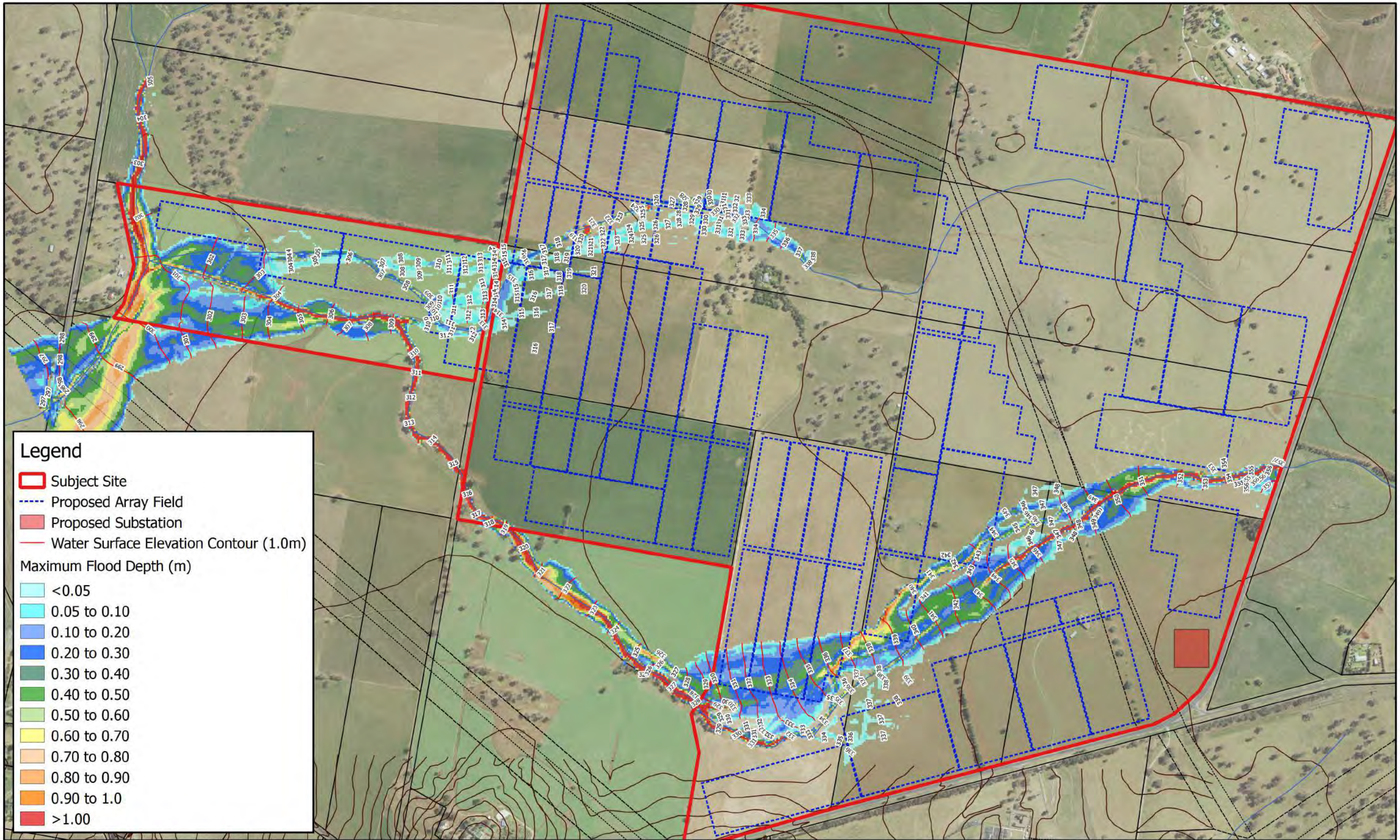
100 0 100 200 300 m

Scale 1:10,000 at A3

PROPOSED WELLINGTON SOLAR FARM
HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 3.2
5% AEP Peak Velocity

Rev 1 -31 October 2017



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sustainable engineering.
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nsw 2533 p: (02) 4237 6770

First Solar.

100 0 100 200 300 m

Scale 1:10,000 at A3

PROPOSED WELLINGTON SOLAR FARM
HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 4.1
10% AEP Flood Levels and Depths

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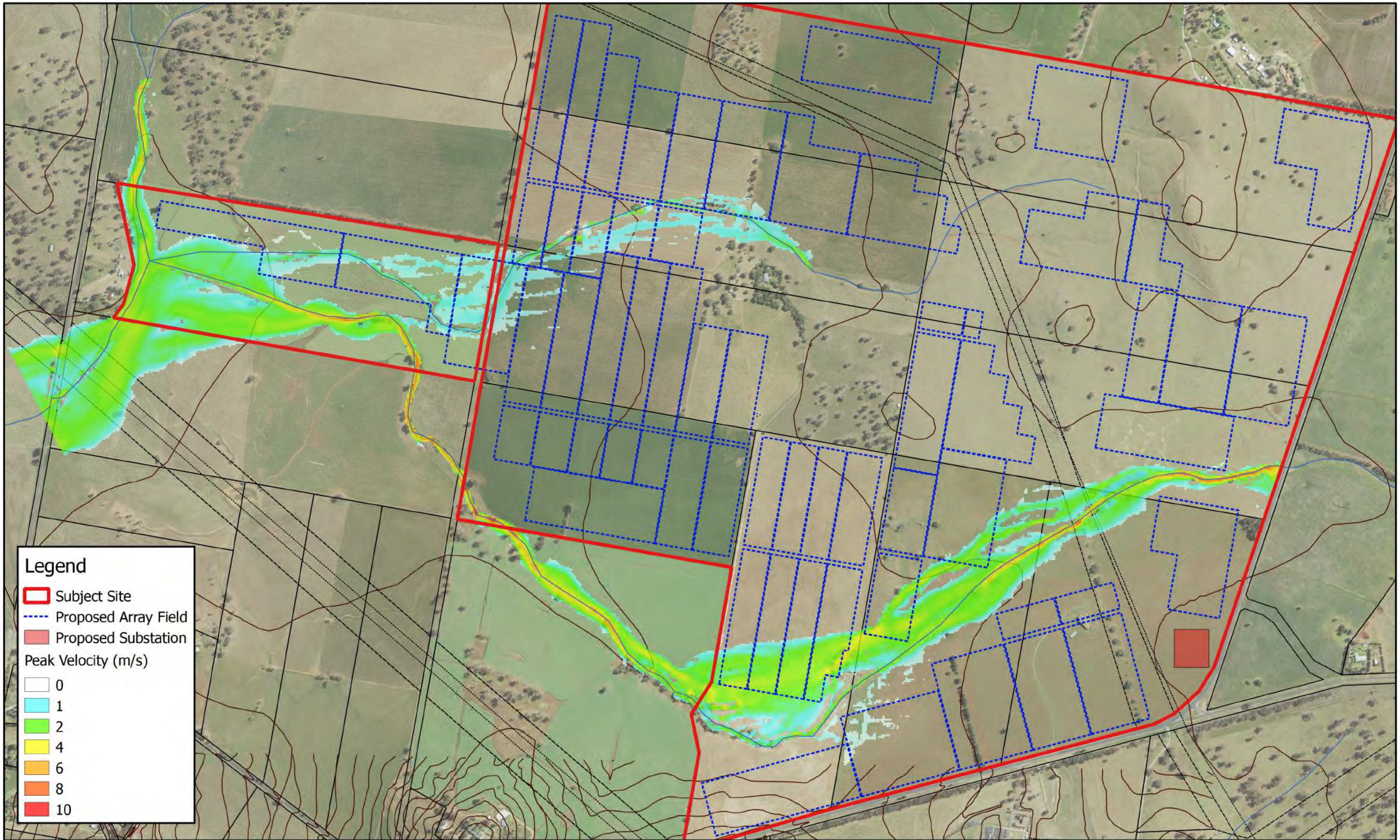

footprint.
sustainable engineering.
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nsw 2533 p: (02) 4237 6770

First Solar.

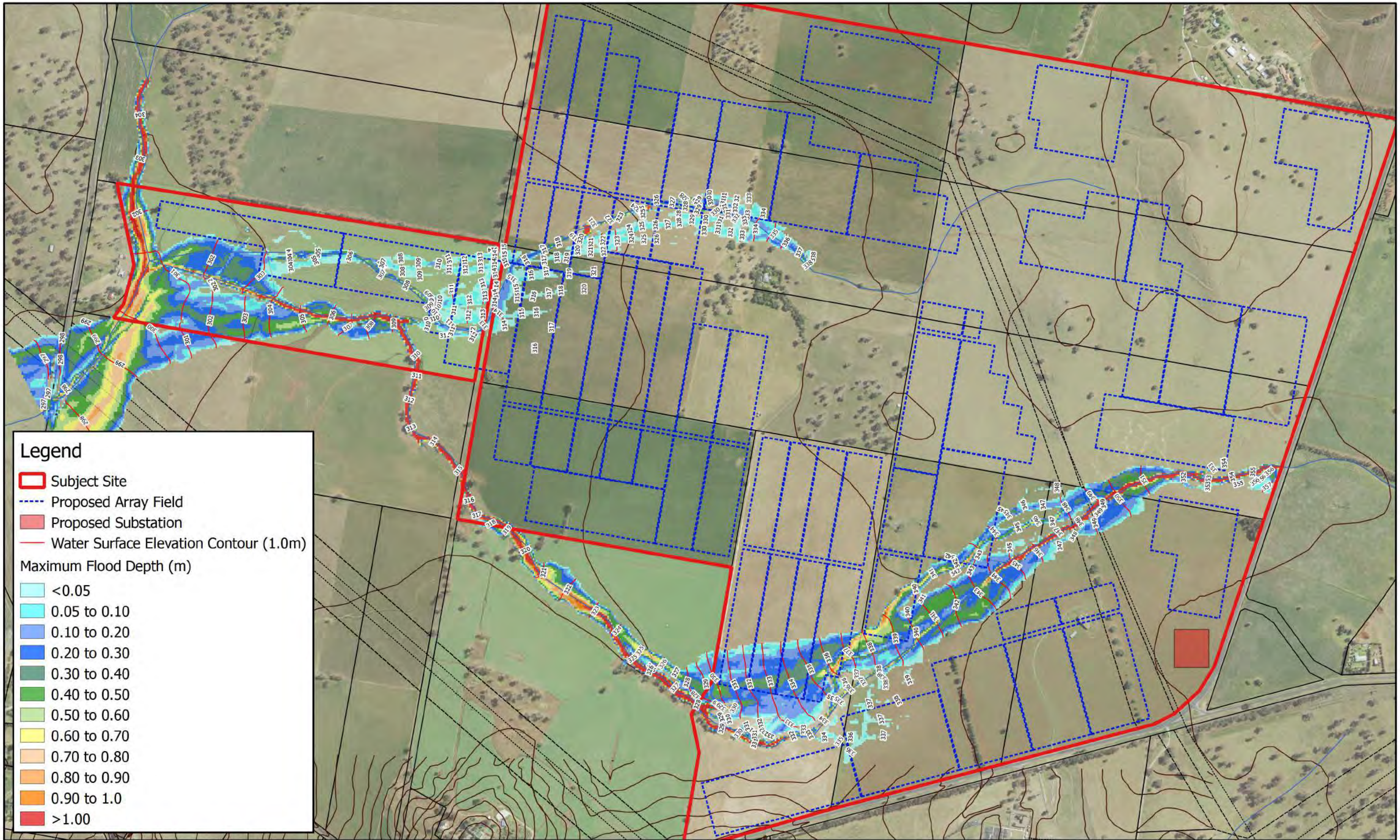
100 0 100 200 300 m

Scale 1:10,000 at A3

PROPOSED WELLINGTON SOLAR FARM
HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 4.2
10% AEP Peak Velocity

Rev 1 -31 October 2017



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sustainable engineering.
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First Solar.

100 0 100 200 300 m

Scale 1:10,000 at A3

PROPOSED WELLINGTON SOLAR FARM
HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 5.1
20% AEP Flood Levels and Depths

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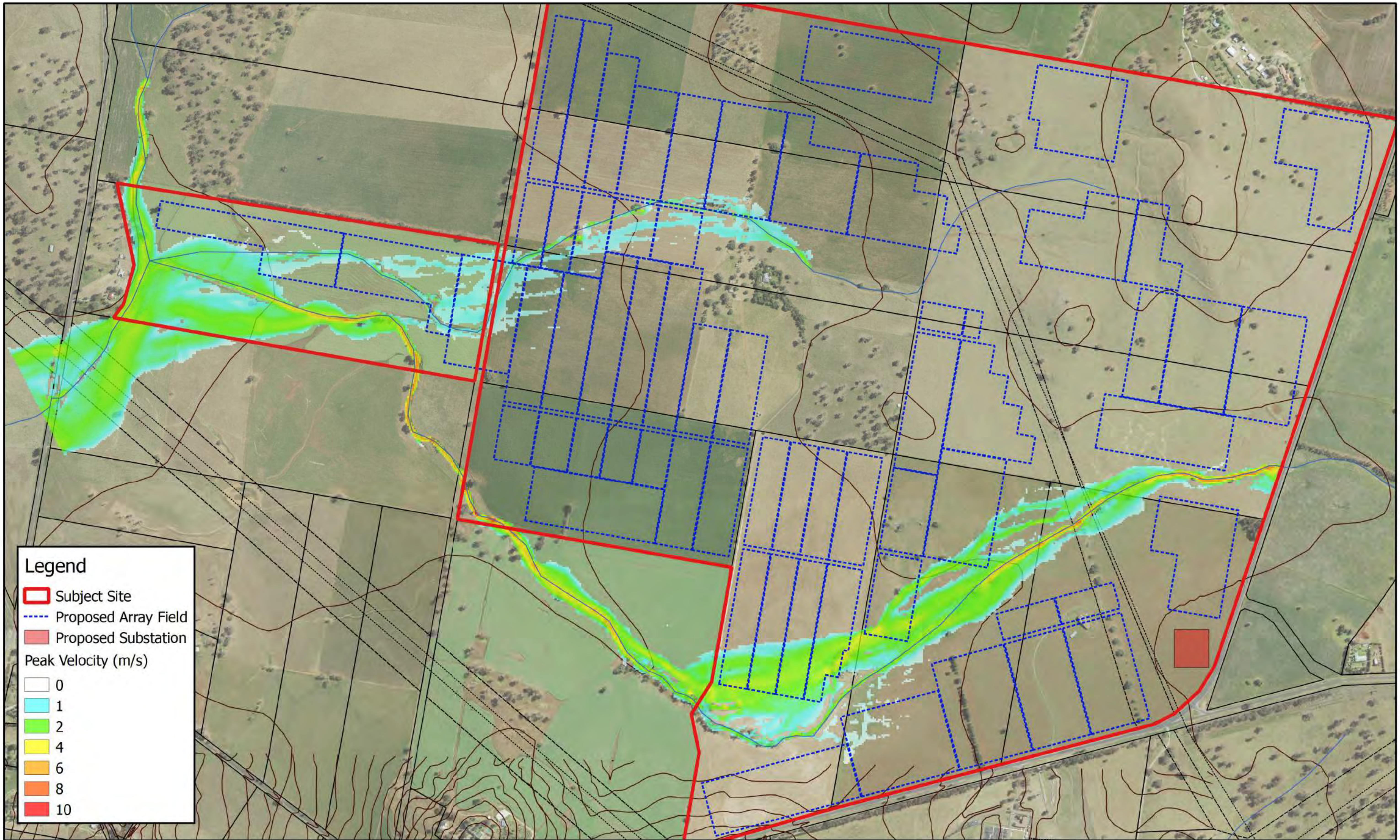


footprint.
sustainable engineering.

15 meehan drive, kiama downs,
nsw 2533 p: (02) 4237 6770

First Solar.

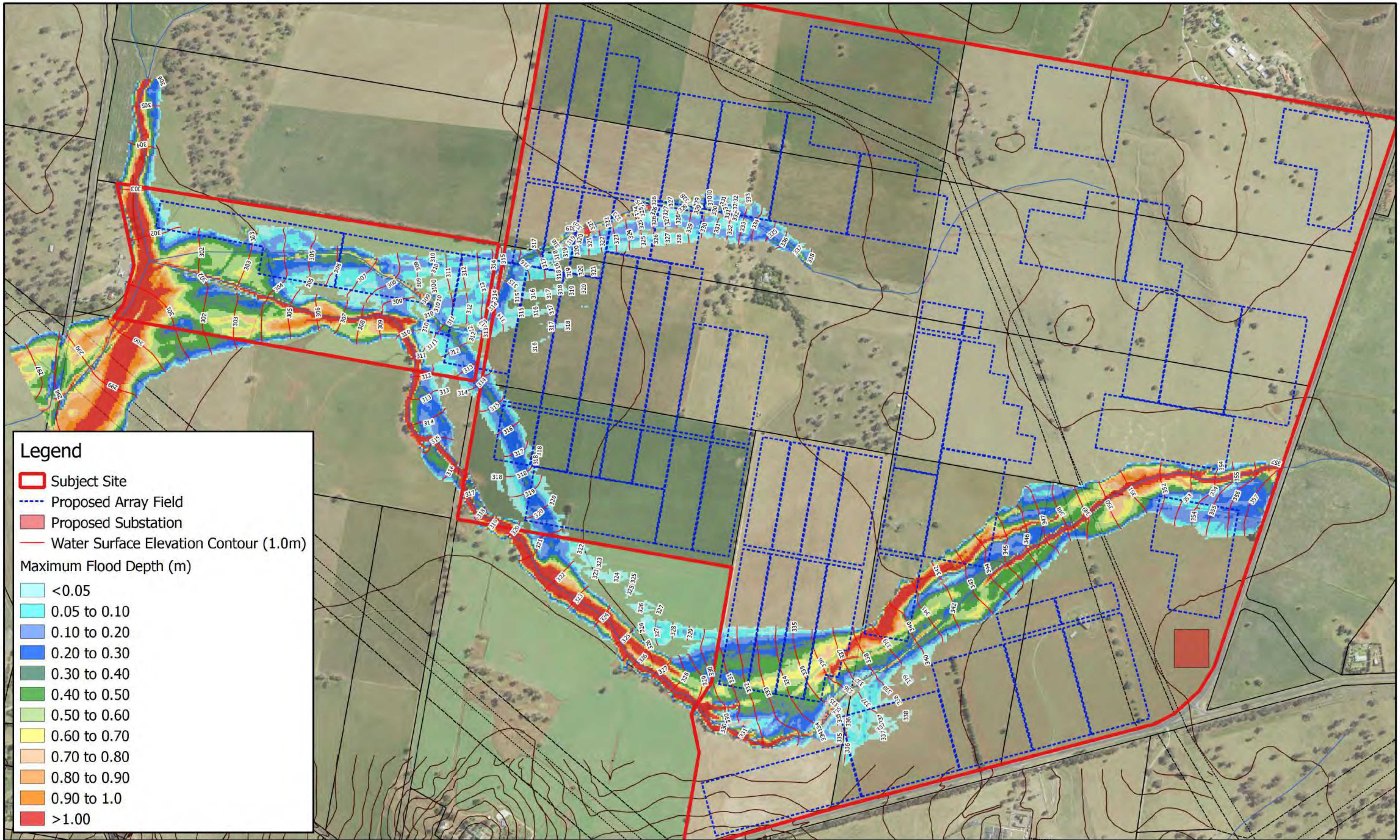
100 0 100 200 300 m

Scale 1:10,000 at A3

PROPOSED WELLINGTON SOLAR FARM
HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 5.2
20% AEP Peak Velocity

Rev 1 -31 October 2017



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

First Solar.

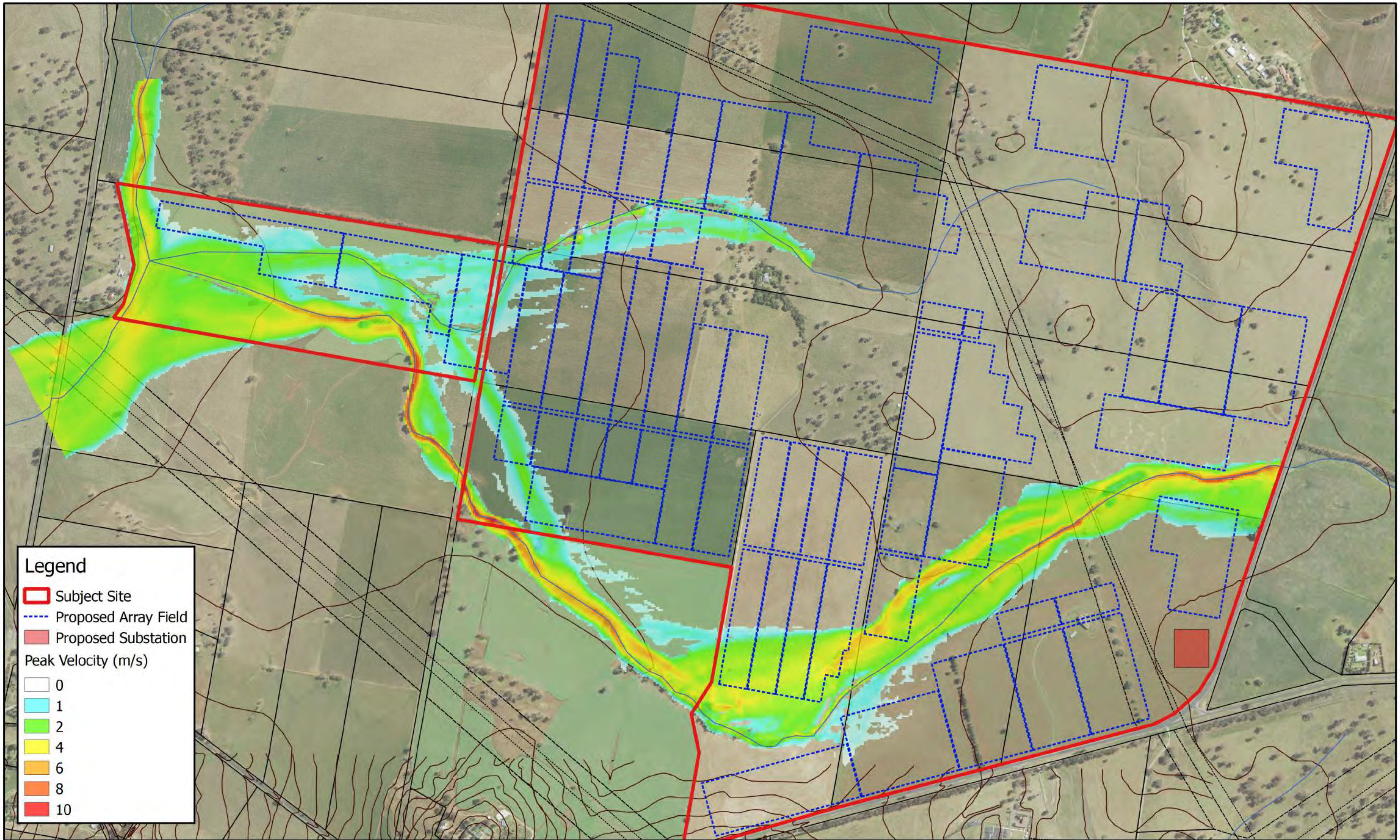
100 0 100 200 300 m

Scale 1:10,000 at A3

PROPOSED WELLINGTON SOLAR FARM
HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 6.1
Post Development 1% AEP Flood Levels and Depths

Rev 1 - 27 February 2018



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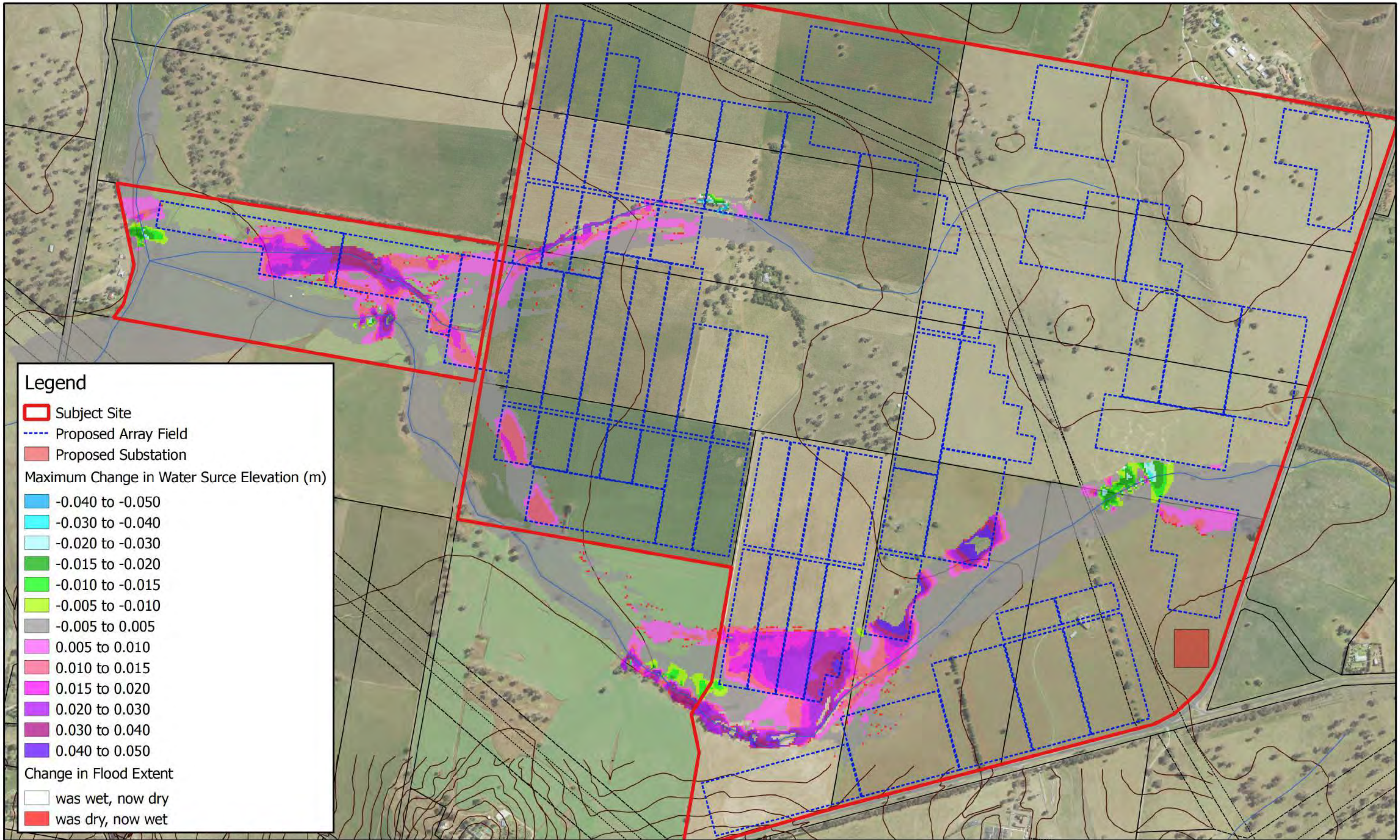
First Solar.

PROPOSED WELLINGTON SOLAR FARM
HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 6.2
Post Development 1% AEP Peak Velocity

Rev 1 - 27 February 2018



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First Solar.

Scale 1:10,000 at A3

PROPOSED WELLINGTON SOLAR FARM
HYDROLOGICAL AND HYDRAULIC ANALYSIS

FIGURE 6.3

Impact of Increase in Surface Roughness in 1% AEP

Rev 2 - 27 February 2018