APPENDIX I
FLOOD STUDY REPORT

Report

Stubbo Solar Farm Flood Study

UPC\AC Renewables Australia

14 November 2020

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Dear Cédric

Stubbo Solar Farm Flood Study

This report documents a flood risk assessment of the proposed Stubbo Solar Farm site. The report identifies the level of flood risk for the site and provides recommendations to aid the approval process. It also touches on other relevant surface water and groundwater EIS components.

If you have any queries regarding this report, please do not hesitate to contact me directly.

Yours sincerely

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WATER TECHNOLOGY PTY LTD

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1 SUMMARY OF SECRETARY'S ENVIRONMENTAL ASSESSMENT REQUIREMENTS

The items of concern identified in the project SEARs have been addressed in the report. The corresponding section for each SEAR is found in Table 1-1 below with a direct response to each SEAR detailed in Section 5 of this report.

TABLE 1-1 SEAR ITEMS AND RESPONSES

SEARs Items	Responses	
Items	**Water and soils**	
9	The EIS must map the following features relevant to water and soils including:	
a.	Acid sulfate soils (Class 1, 2, 3 or 4 on the Acid Sulfate Soil Planning Map).	Please refer to the soil section in the main EIS report.
b.	Rivers, streams, wetlands, estuaries (as described in s4.2 of the Biodiversity Assessment Method).	Sections 2.2.2, 5 and 6.
c.	Wetlands as described in 4.2 of the Biodiversity Assessment Method.	Sections 2.2.1 and 5.
d.	Groundwater.	Sections 2.2.2 and 5.
e.	Groundwater dependent ecosystems.	Not relevant to this project – refer to Biodiversity Development Assessment Report.
f.	Proposed intake and discharge locations.	Sections 2.3.2 and 5
10	The EIS must describe background conditions for any water resource likely to be affected by the development, including:	
a.	Existing surface and groundwater.	Sections 2.2.2, 5 and 6.
b.	Hydrology, including volume, frequency and quality of discharges at proposed intake and discharge locations.	Sections 2.3.2, 5 and 6.
c.	Water Quality Objectives (as endorsed by the NSW Government http://www.environment.nsw.gov.au/ieo/index.htm) including groundwater as appropriate that represent the community's uses and values for the receiving waters.	Sections 5 and 6.
d.	Indicators and trigger values/criteria for the environmental values identified at (c) in accordance with the ANZECC (2000) Guidelines for Fresh and Marine Water Quality and/or local objectives, criteria or targets endorsed by the NSW Government.	Sections 5 and 6.

e.	Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions	Sections 5 and 6.
11	The EIS must assess the impacts of the development on water quality, including:	
a.	The nature and degree of impact on receiving waters for both surface and groundwater, demonstrating how the development protects the Water Quality Objectives where they are currently being achieved, and contributes towards achievement of the Water proposed stormwater and wastewater management during and after construction. being achieved. This should include an assessment of the mitigating effects of proposed stormwater and wastewater management during and after construction.	Sections 5 and 6.
b.	Identification of proposed monitoring of water quality.	Sections 5 and 6.
12	The EIS must assess the impact of the development on hydrology, including:	Section 4, 5 and 6.
a.	Water balance including quantity, quality and source.	Assessment of flows from the site using a RORB and TUFLOW models, see Section 4, 5 and 6. Water balance modelling discussion is included in the main EIS report.
b.	Effects to downstream rivers, wetlands, estuaries, marine waters and floodplain areas.	Assessment flows from the site using RORB and TUFLOW models see Section 4, 5 and 6.
c.	Effects to downstream water-dependent fauna and flora including groundwater dependent ecosystems.	Please refer to Biodiversity Development Assessment Report.
d.	Impacts to natural processes and functions within rivers, wetlands, estuaries and floodplains that affect river system and landscape health such as nutrient flow, aquatic connectivity and access to habitat for spawning and refuge (e.g. river benches).	See Sections 5 and 6.
e.	Changes to environmental water availability, both regulated/licensed and unregulated/rules-based sources of such water.	Please refer to the EIS main report.
f.	Mitigating effects of proposed stormwater and wastewater management during and after construction on hydrological attributes such as volumes, flow rates, management methods and re-use options.	No major stormwater and wastewater infrastructure proposed for the site. See Sections 5 and 6 for surface water impacts and the EIS main report for wastewater.

g.	Identification of proposed monitoring of hydrological attributes.	See Sections 5 and 6.
	Flooding	
13	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.	Sections 4, 5 and 6.
b.	Flood planning area, the area below the flood planning level.	Sections 4, 5 and 6.
c.	Hydraulic categorization (floodways and flood storage areas).	Sections 4, 5 and 6.
d.	Flood hazard	Sections 4, 5 and 6.
14	The EIS must describe flood assessment and modelling undertaken in determining the design flood levels for events, including a minimum of the 5% Annual Exceedance Probability (AEP), 1% AEP, flood levels and the probable maximum flood, or an equivalent extreme event.	Sections 4, 5 and 6.
15	The EIS must model the effect of the proposed development (including fill) on the flood behaviour under the following scenarios:	Sections 5 and 6.
a.	Current flood behaviour for a range of design events as identified in 14 above. This includes the 0.5% and 0.2% AEP year flood events as proxies for assessing sensitivity to an increase in rainfall intensity of flood producing rainfall events due to climate change.	Section 4s and 5.
16	Modelling in the EIS must consider and document:	
17	Existing council flood studies in the area and examine consistency to the flood behaviour documented in these studies.	Sections 2.2.5 and 5.
18	The impact on existing flood behaviour for a full range of flood events including up to the probable maximum flood, or an equivalent extreme flood.	Sections 4 and 5.
19	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.	Sections 5 and 6.
20	Relevant provisions of the NSW Floodplain Development Manual 2005.	Sections 4, 5 and 6.

21	The EIS must assess the impacts on the proposed development on flood behaviour, including:	
a.	Whether there will be detrimental increases in the potential flood affectation of other properties, assets and infrastructure.	Sections 4, 5 and 6.
b.	Consistency with Council floodplain risk management plans.	Sections 4, 5 and 6.
c.	Consistency with any Rural Floodplain Management Plans.	Sections 4, 5 and 6.
d.	Compatibility with the flood hazard of the land.	Sections 4, 5 and 6.
e.	Compatibility with the hydraulic functions of flow conveyance in floodways and storage in flood storage areas of the land.	Sections 4, 5 and 6.
f.	Whether there will be adverse effect to beneficial inundation of the floodplain environment, on, adjacent to or downstream of the site.	Sections 4, 5 and 6.
g.	Whether there will be direct or indirect increase in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of riverbanks or watercourses.	Sections 4, 5 and 6.
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.	Sections 5 and 6.
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.	Sections 5 and 6.
j.	Emergency management evacuation and access, and contingency measures for the development considering the full range of flood risk (based upon the PMF or equivalent extreme flood event). These matters are to be discussed with and have the support of Council and the NSW SES.	Sections 5 and 6.
k.	Any impacts the development may have on the social and economic costs to the community as a consequence of flooding.	Sections 5 and 6.

2 INTRODUCTION

2.1 Overview

The proposed Stubbo Solar Farm (Stubbo, NSW) is a State Significant Development assessed under the EP&A Act 1979 and relevant State Environmental Protection Policy (SEPP). An Environmental Impact Statement (EIS) is required for this assessment, and this report forms part of the EIS. The Department of Planning, Industry and Environment (DPIE) issued a list of requirements outlined in the Secretary's Environmental Assessment Requirements (SEARs). Water, soil and flooding requirements are outlined in Items 9 to 21 of the SEARs and must be addressed in the EIS. Water Technology was commissioned by UPC\AC Renewables Australia to address Items 9 to 21 of the SEARs (Note: this report excludes groundwater components of the SEARs, refer to the main EIS report for groundwater assessment).

This report discusses the assessment conducted by Water Technology, including the hydrologic and hydraulic modelling used to assess the proposed developments level of flood risk under existing and estimated climate change conditions. Existing and climate change scenarios were assessed for the following flood events; 5%, 1%, 0.5%, 0.2% Annual Exceedance Probability (AEP) and the Probable Maximum Flood (PMF).

2.2 Regional hydrologic information

The Study Area is in Stubbo, approx. 10 km north of Gulgong in NSW, as shown in Figure 2-1. The site has a total area of approx. 1,750 Ha and is mostly used for agriculture (grazing and cropping). Some patches of native vegetation and scattered trees are also within the Study Area.

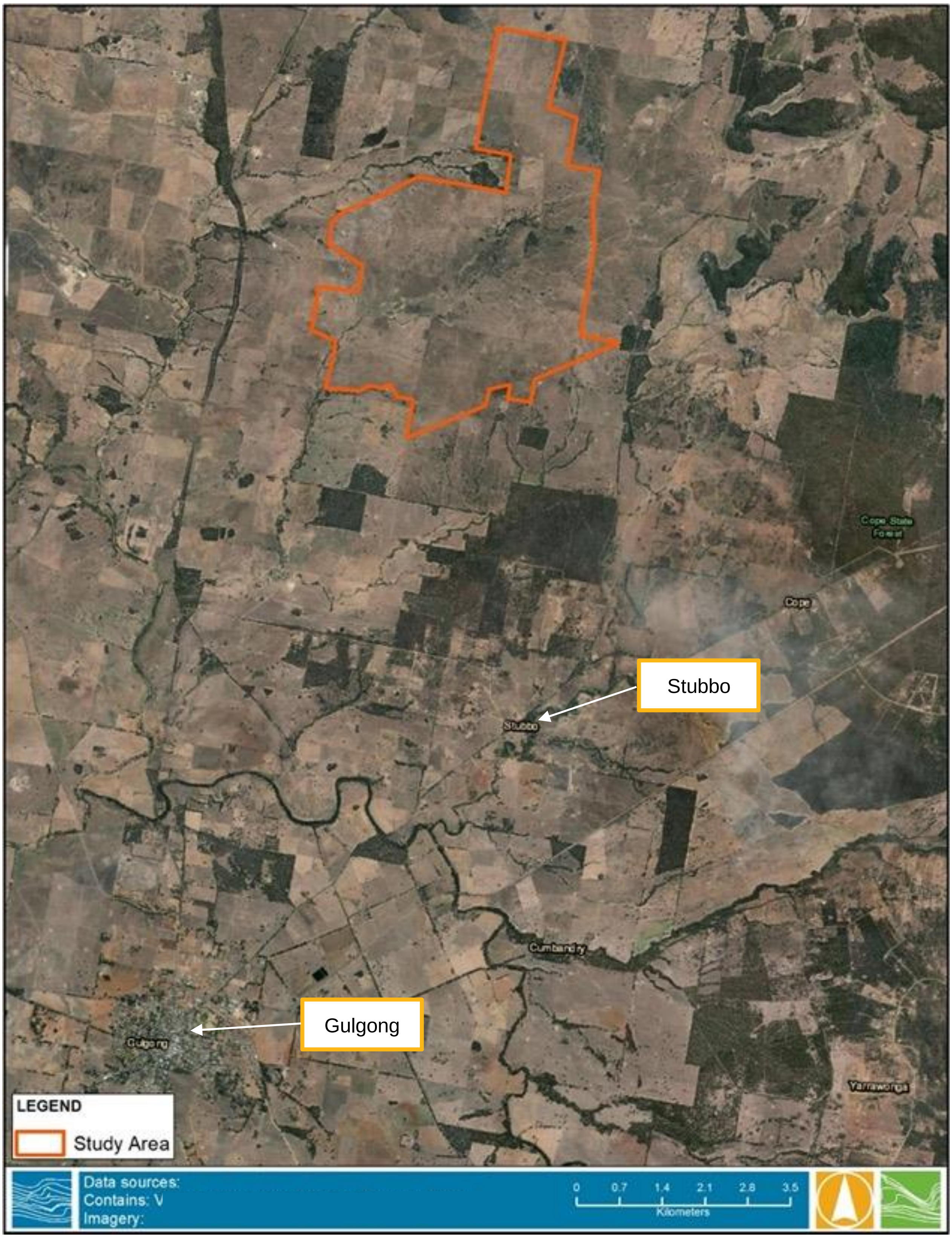

FIGURE 2-1 SUBJECT SITE WITH CONTEXT TO THE BROADER AREA

2.2.1 Landscape features

The Study Area topography (Figure 2-2) shows higher ground to the east, reaching to above 500 m AHD, and lower ground to the west (to around 460 m AHD). The Study Area is in the upper catchment of Stubbo Creek, with Pine Creek to the north and Gum Creek to the south.

Several patches of native vegetation are located within the Study Area and its vicinity, as shown in Figure 1-3 (refer to the Biodiversity Development Assessment Report for more information).

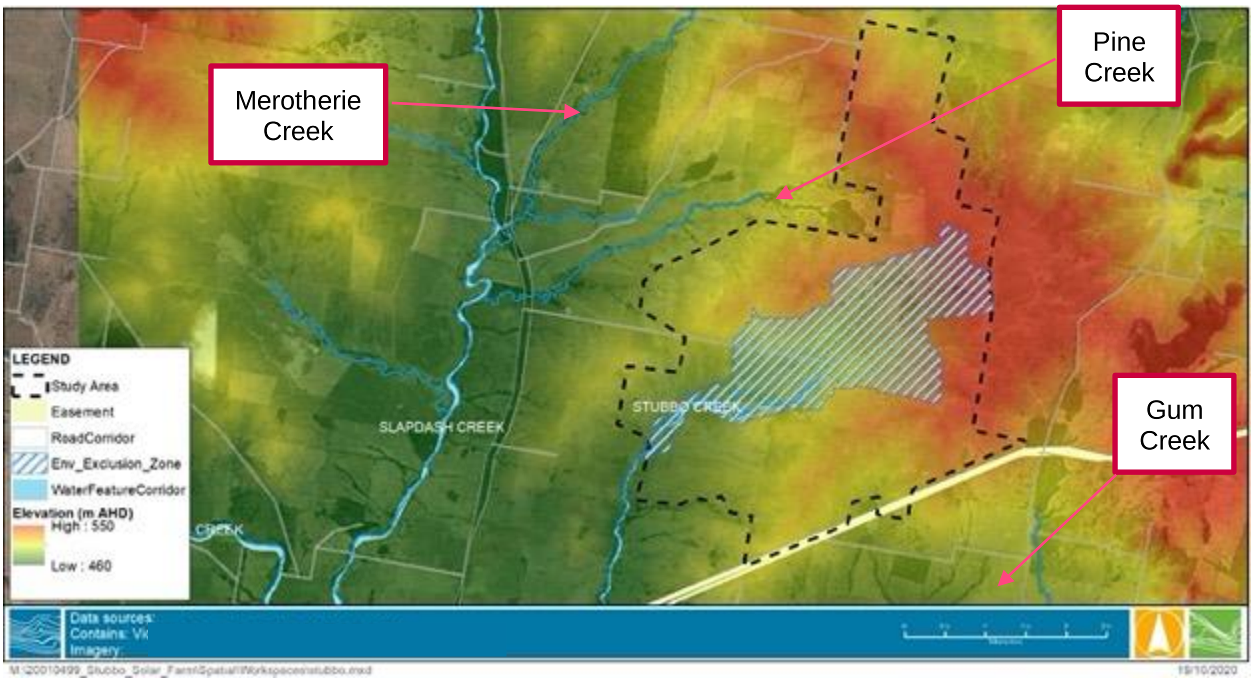

FIGURE 2-2 STUBBO SOLAR FARM

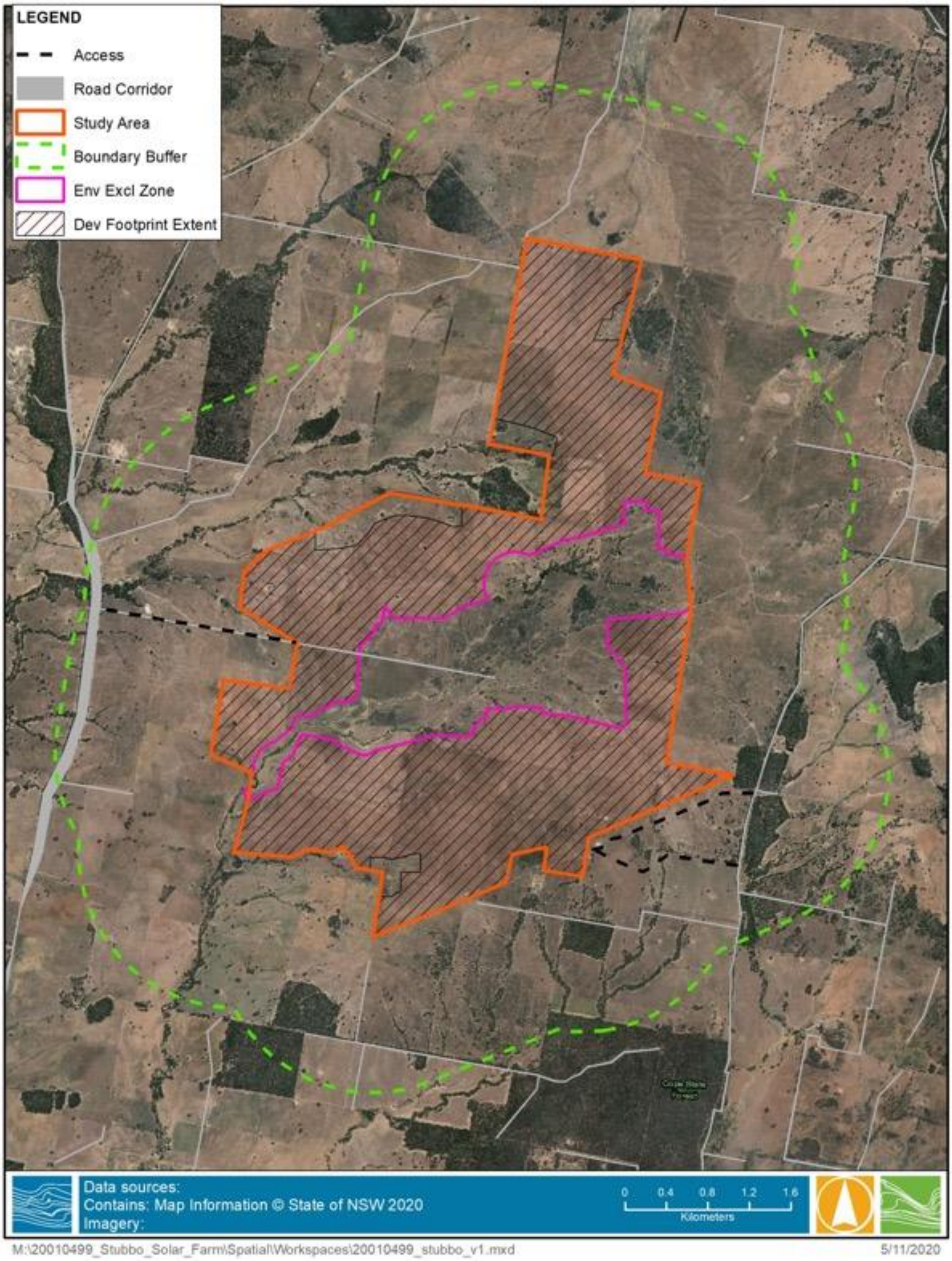

FIGURE 2-3 STUDY AREA BOUNDARY BUFFER

2.2.2 General hydrology and hydrogeology

The Study Area is located within the Macquarie-Bogan Rivers System. There is a depression in the middle of the Study Area which forms the upper reaches of Stubbo Creek. Pine Creek is located to the north and Merotherie Creek is further north. Both waterways discharge to Slapdash Creek, around 1.7 km west of the site at its closest point. Gum Creek is located to the south and is also connected to Slapdash Creek. Slapdash Creek flows south and discharges to Waldra Creek, which flows into Cudgegong River, connecting to Lake Burrendong, located south of Gulgong.

While the focus of this report is on surface water and the project is not anticipated to interact with groundwater in any way it is important to note there may be some groundwater presence within the Subject Site in the lower parts of the EEZ.

An example overland flow path is shown in Figure 2-4.

FIGURE 2-4 OVERLAND FLOW PATH WITHIN THE SUBJECT SITE

2.2.3 Rainfall

The closest Bureau of Meteorology (BoM) daily rainfall gauge to the Subject Site is Gulgong Post Office (gauge 062013), as shown in Figure 2-5, with an annual rainfall average of 649.1 mm. The monthly rainfall data from the Gulgong Post Office is presented in Figure 2-6. The mean and median rainfalls are highest during Spring/Summer, with the highest monthly mean reaching 70.3 mm in January and is lowest in April at 44.2 mm. The highest daily rainfall values indicate storm events are most likely to occur during February and March with peak daily totals exceeding 120mm.

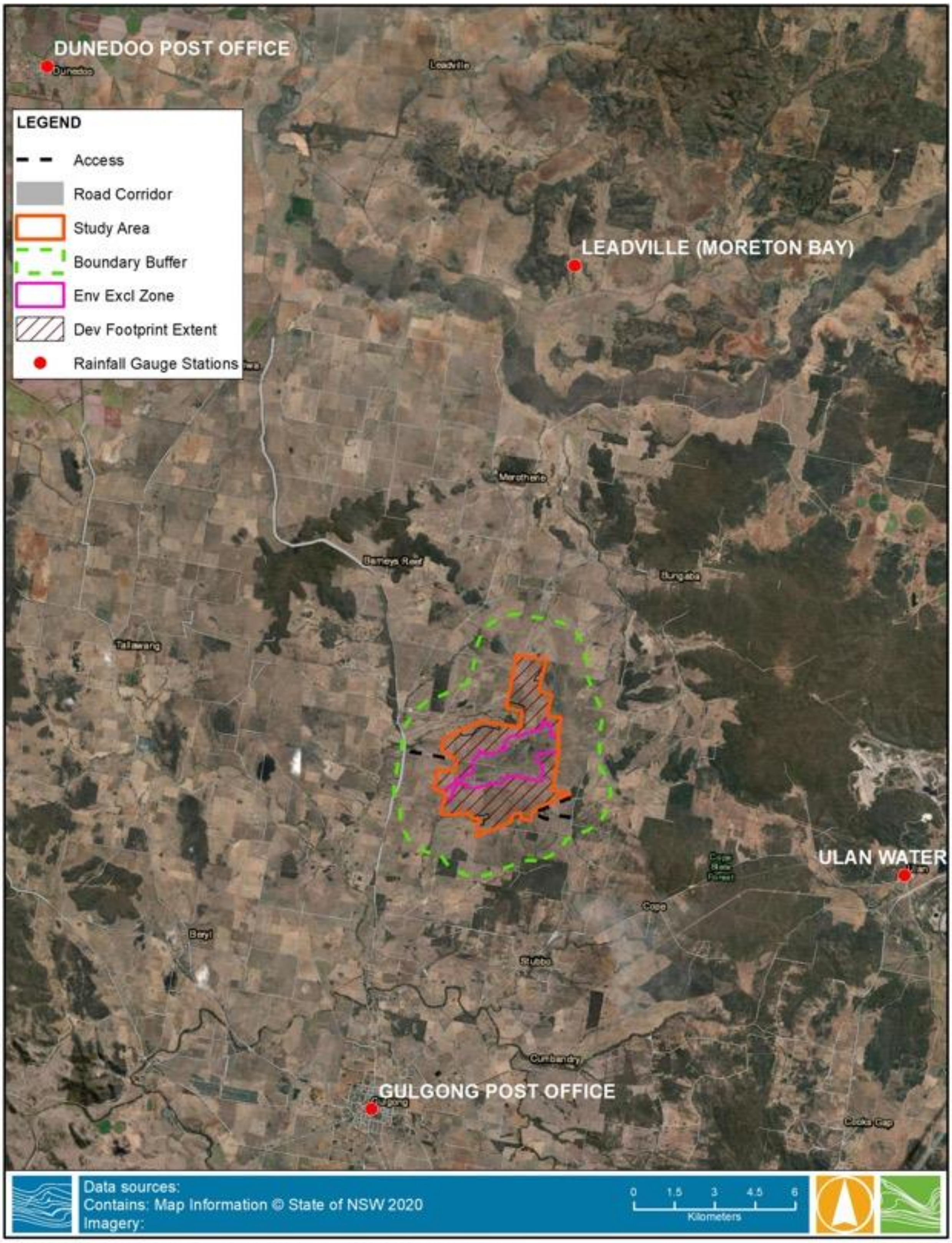

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FIGURE 2-5 BOM DAILY RAINFALL GAUGES

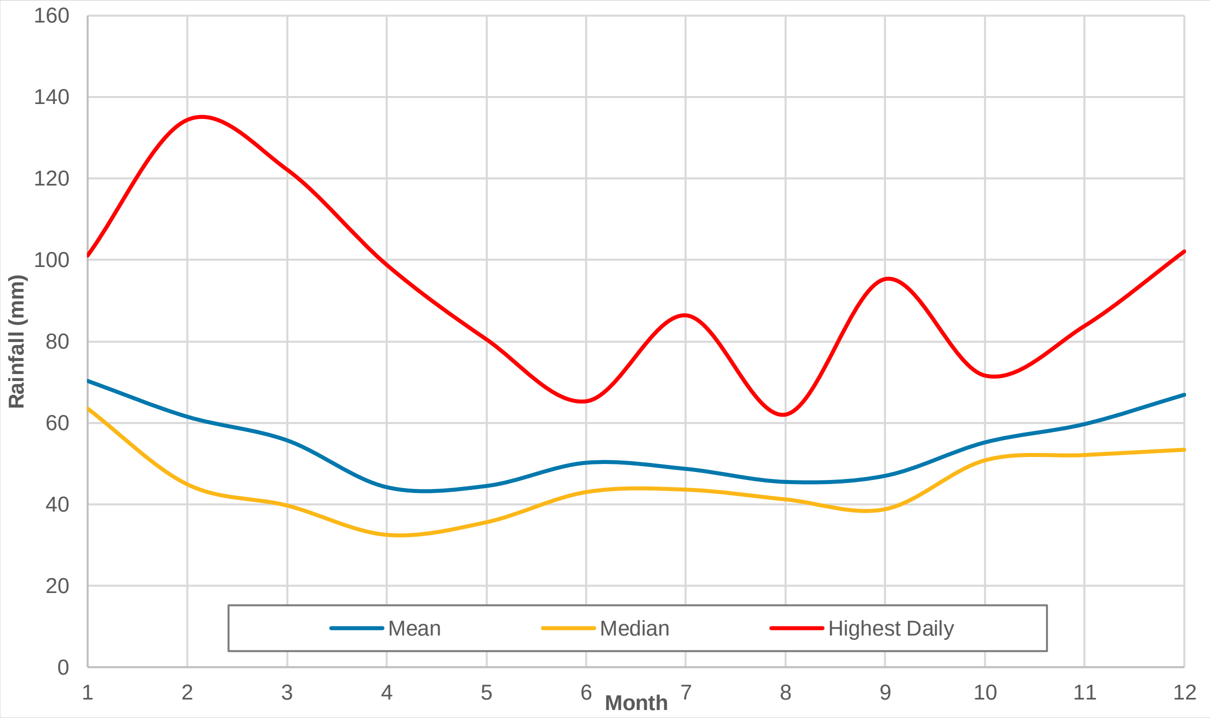

FIGURE 2-6 MONTHLY RAINFALL AT THE GULGONG POST OFFICE STATION (BOM GAUGE 062013[1])

2.2.4 Evaporation

The average annual evaporation across the Study Area is estimated to be between 1,600 and 1,800 mm/year, as shown Figure 2-7.

[1] http://www.bom.gov.au/climate/averages/tables/cw_062013.shtml

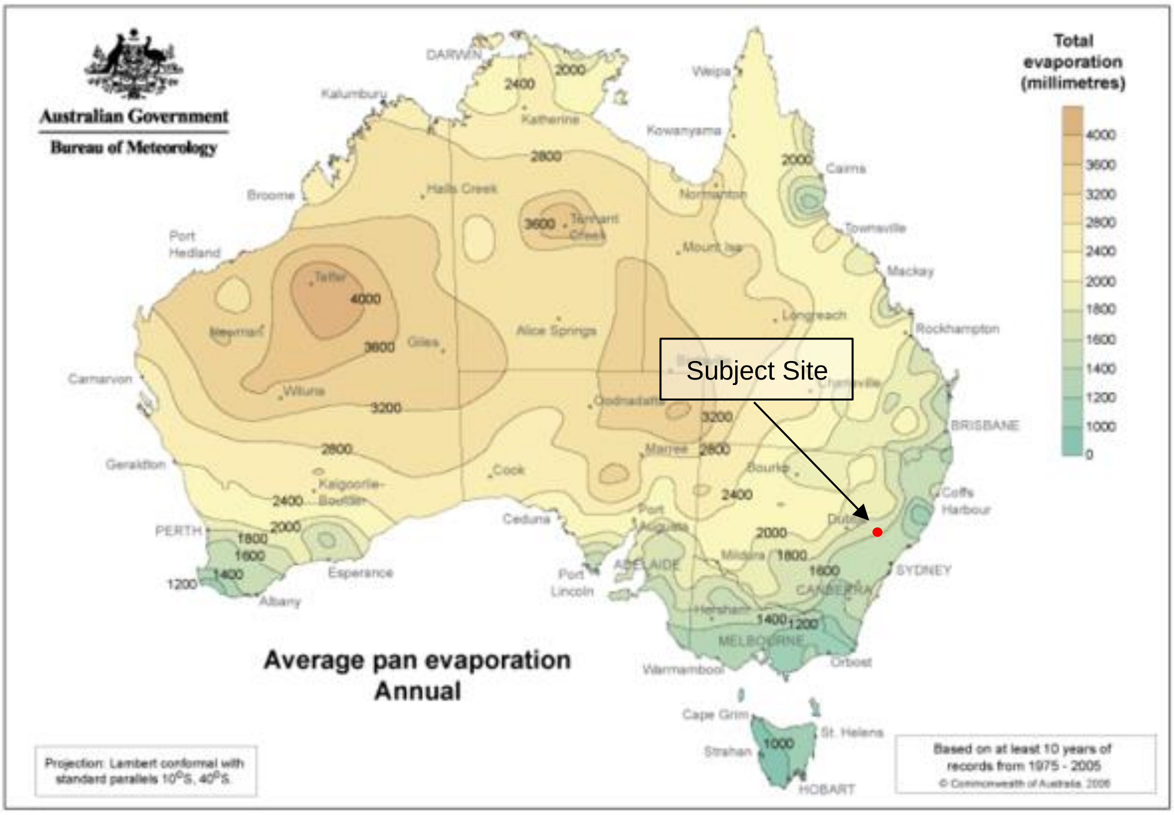

FIGURE 2-7 AVERAGE ANNUAL EVAPORATION

2.2.5 Existing flood related studies

The only flood study found in the nearby area, is the Gulgong Stormwater Drainage Study 2009: https://flooddata.ses.nsw.gov.au/flood-projects/gulgong-stormwater-drainage-study.

There is little information available on Gulgong study to make any realistic comparison with the flood estimation conducted in this study. In addition, the Gulgong study area was confined to the urban area of Gulgong and there was no overlapping between the flood study areas or similarities in study area.

2.3 Proposed Development

2.3.1 Overview

The extent of the proposed solar farm is shown in Figure 2-9. A series of solar Photovoltaic (PV) arrays (totalling up to 400MW, note: the number of arrays will depend on the technology chosen before construction), substation, potential battery storage (BESS) and ancillary infrastructure are proposed to be within the development footprint. The substation, BESS and ancillary infrastructure are proposed to be location in one of the two potential locations along the southern boundary of the Study Area. The project design also includes an Environmental Exclusion Zone (EEZ) broadly located in the centre of the Study Area. The EEZ contains most watercourses within the Subject Site, aside from the very upper reaches of several unnamed waterways located on the site fringe. The most major unnamed creek is located at the southern end of site and is a tributary of Stubbo Creek. The EEZ was created avoid and minimise the impact on biodiversity and aboriginal cultural heritage values. Within the EEZ, no development is proposed aside from up to two waterway crossings which consist of a track and cables. These locations have been chosen where the predicted impact on environmental and cultural heritage values are minimised.

Outside of the EEZ but within the Development Footprint, the only proposed development within a 20 metre buffer of a second order stream (Strahler's stream ordering) consists of internal tracks with appropriate crossings and fences.

2.3.2 Intake and Outlet

There is no specific ongoing surface water or groundwater use proposed for the project as the solar farm is not expected to extract water for operational purposes. Surface water stored in farm dams may be used during construction. This use would not exceed that currently used for agricultural purposes.

The existing dams and stock and domestic water use is unlikely to be licenced due to the following exemptions:

- The existing dams are like to capture water under a harvestable right.
  - Licences are not required for harvestable rights dams built on minor streams that capture 10 per cent of the average regional rainfall run-off on land in the Central and Eastern Divisions of New South Wales, and up to 100 per cent on land in the Western Division. The total capacity of all dams on a property allowed under the harvestable right is called the Maximum Harvestable Right Dam Capacity (MHRDC). The MHRDH for the site (1,750 Ha) is approximately 105 ML[2].
- The dams are likely to be built before 1999.
  - Licences are not required for dams built before 1 January 1999, provided these dams are only used for stock and domestic watering purposes and are located on a minor stream.

Given the existing dams are likely to be unlicenced no licencing change would be required; however, this should be investigated before construction. The natural surface water outlet for the site is at the intersection of the site boundary and Stubbo Creek. This is a natural waterway and no artificial structures planned to be installed in the creek with the exception of two waterway road and cable crossings.

2.3.3 Farm Dams – water pooling

There are farm dams and areas which pool water for extended periods within the site, as shown in Figure 2-9. If there is an intent to fill or level these areas for the construction of PV arrays and/or ancillary infrastructure individual or collective assessments would be required. These assessments would form part of a more detailed Management Plan as required by the Secretary prior to commencement of construction. Farm dams covering the Subject Site do not appear to hold significant volumes of water as per the 1% AEP flood depths (discussed further in Section 4), and filling them is unlikely to cause any significant adverse impacts to flood behaviour within receiving watercourses but may increase general day to day flows within receiving waterways due to a decrease in catchment storage. This would need to be considered further in a Management Plan to define the degree of potential impact.

An example farm dam on the site is shown in Figure 2-8.

[2] https://www.waternsw.com.au/customer-service/water-licensing/blr/harvestable-rights-dams/maximum-harvestable-right-calculator

FIGURE 2-8 EXAMPLE DAM WITHIN THE SUBJECT SITE

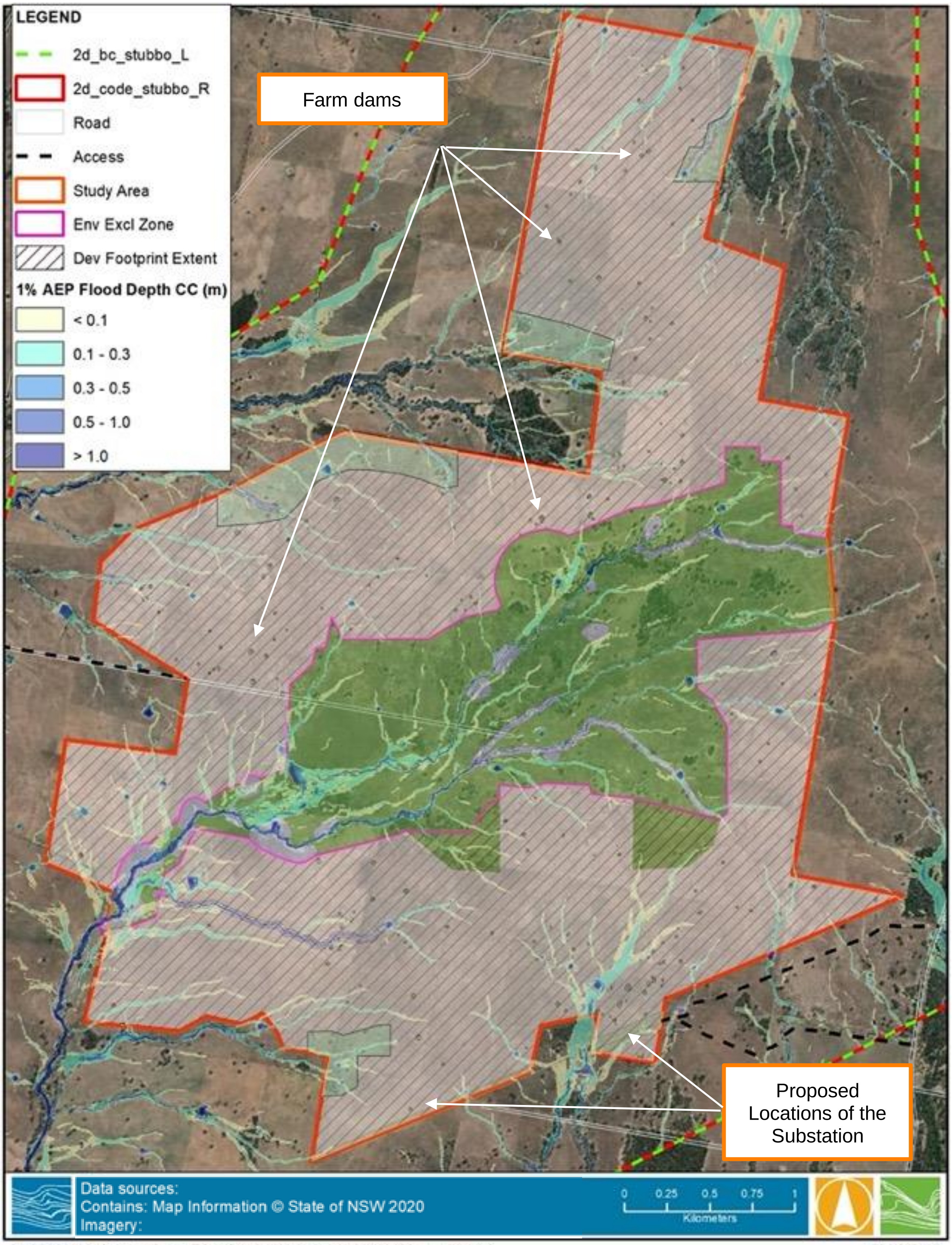

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FIGURE 2-9 EXTENT OF THE PROPOSED DEVELOPMENT

3 METHODOLOGY

3.1 Overview

The methodology used for this assessment was developed to address the surface water components of the SEARs Items 9 to 21. These tasks are discussed in following sub-sections.

A flood investigation was carried out for several Annual Exceedance Probability (AEP) and the Probable Maximum Flood (PMF) events. AEP is a measure of the likelihood a flood level or flow will be equalled or exceeded in any given year. The PMF is the largest flood that could be conceivably expected to occur at a particular location, usually estimated from Probable Maximum Precipitation (PMP). The flood investigation consisted of hydrologic (development of flows from converting rainfall to runoff) and hydraulic modelling (determining water levels, velocities and depths). The hydrologic model generated flows from the upstream catchment and determined the critical storm durations used in the hydraulic model, which in turn determined flood behaviour. Details of the hydrologic and hydraulic modelling are presented in the following sections.

Waterways immediately outside the site boundary were included in the flood risk assessment as runoff from the site contributes surface water to them. The eastern boundary of the site runs parallel to an easement for electrical transmission lines as shown in Figure 2-2.

3.2 Hydrologic Modelling

3.2.1 Overview

Hydrologic modelling was conducted using RORB, a widely used Australian runoff routing model. RORB was used to calculate flood hydrographs upstream and throughout the Subject Site. Hydrographs for the following events were estimated: 5%, 1%, 0.5%, 0.2% AEP and the PMF using the recommended methodology and parameters outlined in Australian Rainfall and Runoff 2019 (ARR2019)[3]. The purpose of the hydrologic modelling was to identify the critical duration and temporal patterns to be used for each AEP within the hydraulic model, and to develop a series of peak flows to compare those determined by the hydraulic model.

The methodology for determining the design flows is summarised below:

- Catchment delineation.
- Determination of Kc and m (RORB routing parameters).
- Design inputs (e.g. rainfall, losses).
- Verification of model results.
- Selection of temporal patterns.
- Determination of design hydrographs.

Details on each step is given in the following sections.

3.2.2 Catchment Delineation

Sub-catchments were delineated using the Stubbo 2m LiDAR and are shown in Figure 3-1. The selected sub-catchments (cyan colour) are those within the Subject Site boundary that contribute flow to Stubbo

[3] Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2019, Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia

Creek, the major watercourse within the Subject Site. The unselected sub-catchments within the Subject Site boundary contribute flows to other watercourses including:

- Pine Creek and an unnamed creek to the north-west.
- Unnamed creeks to the north-east.
- Gum Creek to the south.

There are no sub-catchments within the Subject Site that contribute flow to Merotherie Creek.

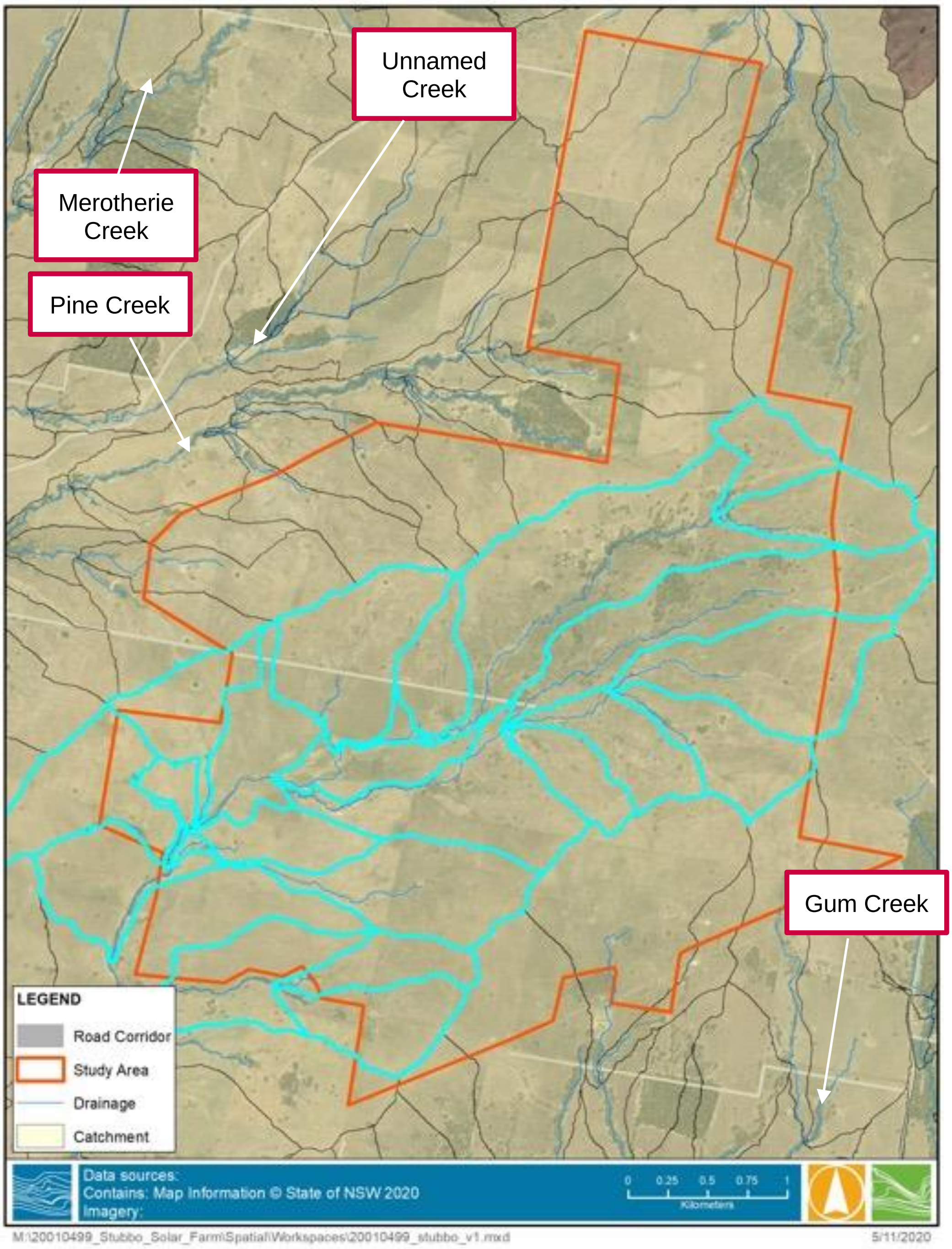

FIGURE 3-1 DELINEATED SUB-CATCHMENTS

Only the sub-catchments within the site that contribute flows to Stubbo Creek were used to develop the RORB model. The sub-catchments contributing flows to other nearby watercourses outside of the site were not included as their flow contributions were estimated in the hydraulic model (further explained in Section 3.3). The total catchment area of the site was calculated as 14 km^2. The overall catchment has a general slope varying between 1% to 2%.

A series of nodes and reaches were defined in the RORB model to represent the routing characteristics of the catchment. The reaches were mainly defined as ‘natural’ (opposed to ‘excavated unlined’ and ‘lined’, the other reach types available within RORB). These definitions were derived from expected flow characteristics based on the aerial photography.

Impervious areas of the catchment (such as roads and buildings) were represented in the RORB model using appropriate Fraction Impervious (FI) values for each RORB subarea.

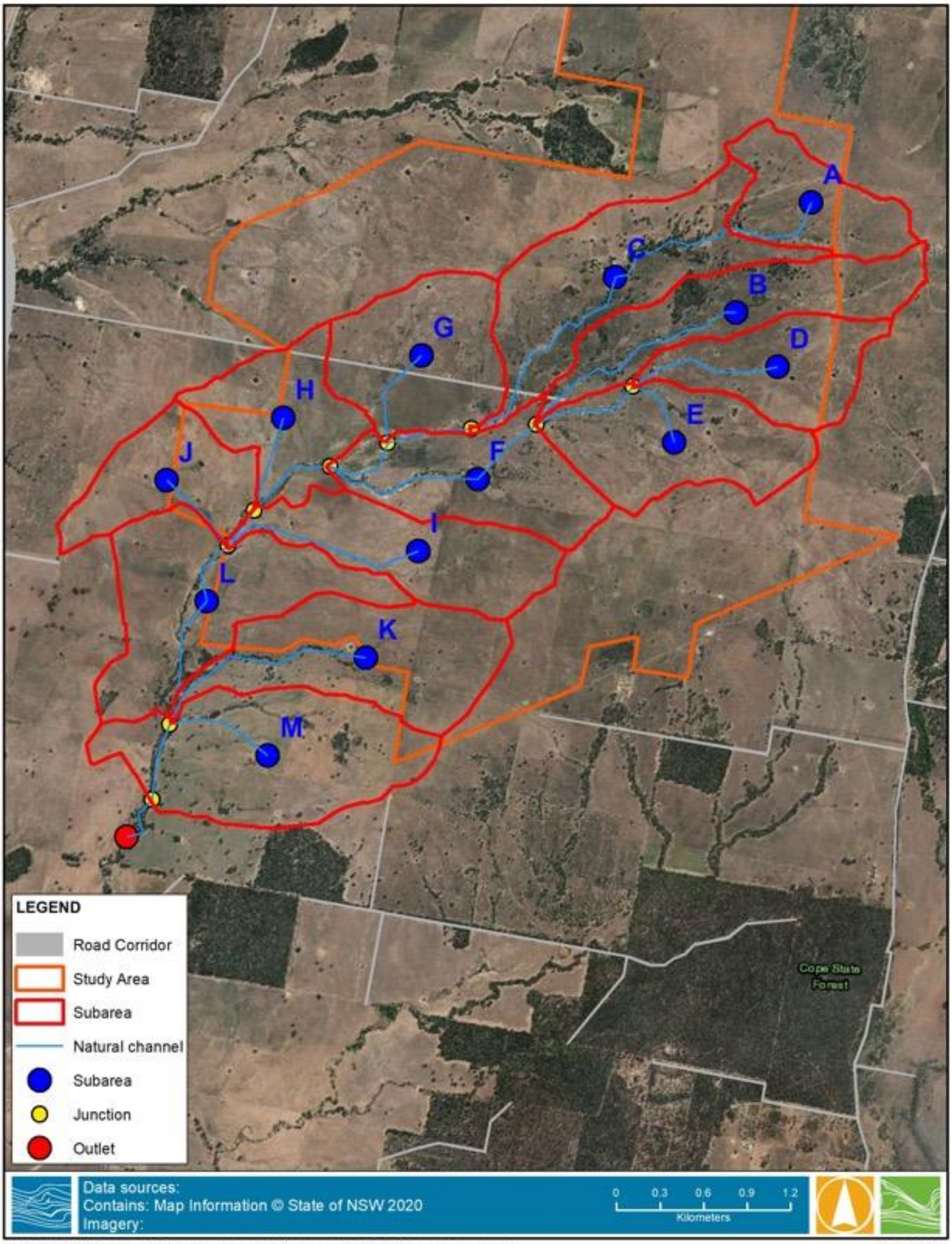

FIGURE 3-2 CONTRIBUTION SUB-CATCHMENTS AND RORB SUB-AREAS

3.2.3 Routing parameters – kc and m

There were no streamflow gauges within the Study Area catchment to calibrate the RORB model. Therefore, prediction equations for ungauged catchments were used to inform the selection of a 'reasonable' routing parameter, k_C.

McMahon and Muller (1983) showed that *kc* is directly proportional to the average flow distance (d_{av}). The recommended equation for catchments east and west of the Great Dividing Range for New South Wales is expressed as:

$k_C = 1.18A^{0.46}$

Where, *A* is the catchment area.

Sensitivity testing of k_C values was carried out using the RORB Monte Carlo analysis and verified against the ARR Regional Flood Frequency Estimation Model (RFFE), this process is discussed in more detail in Section 3.2.5.

The RORB model *m* was set at 0.8, this is the recommended value for ungauged catchments[4].

3.2.4 Design inputs

3.2.4.1 Event Duration

Design rainfall was derived for burst durations between 30 min and 12 hours, based on the expectation that the critical storm duration for the study area catchment would be relatively short, given its size.

3.2.4.2 Intensity-Frequency-Duration (IFD)

Rainfall burst depths for the modelled AEP events were estimated for the centroid of the catchment using the 2016 ARR IFD analysis available from the Bureau of Meteorology[5], as shown in Table 3-1.

TABLE 3-1 DESIGN RAINFALL DEPTHS (MM) FOR VARIOUS EVENT DURATIONS AND AEPS

AEP (1:Y)	30 min	1.5 hr	2.0 hr	3.0 hr	6.0 hr	12.0 hr
5	24.1	34.3	37.3	42.3	53.0	67.5
10	28.3	40.1	43.7	49.4	61.9	79.1
20	32.5	46.0	50.0	56.4	70.7	90.7
50	38.4	53.8	58.4	65.9	82.7	107.0
100	43.1	60.0	65.1	73.3	92.1	120.0
200	49.2	68.5	74.2	83.6	105.0	137.0
500	57.5	80.3	86.9	97.7	122.0	159.0

3.2.4.3 Areal Reduction Factors

The point rainfall estimates were converted to catchment average values using the areal reduction factors developed for Australia during the recent revision of ARR2019[6], Book 2 Chapter 4. Conceptually, this factor

4 E.M. Laurenson, R.G. Mein, and R.J. Nathan (2010), RORB User Manual
5 http://www.bom.gov.au/water/designRainfalls/ifd/
6 http://book.arr.org.au.s3-website-ap-southeast-2.amazonaws.com/

accounts for the fact that larger catchments are less likely to experience high intensity rainfall over the whole of the catchment.

3.2.4.4 Temporal Patterns

The 10 available temporal patterns were downloaded from ARR 2019 Data Hub[7], and used to simulate the temporal distribution of burst rainfall depths during each storm duration modelled.

3.2.4.5 Spatial Patterns

As the catchment was small, a uniform spatial pattern was adopted.

3.2.4.6 Design Losses

An initial/continuing loss model was applied for the RORB modelling. Losses were initially extracted from the ARR online datahub[5]. The suggested losses were a 19 mm initial loss (IL) and a 1.9 mm/hr continuing loss (CL). As the site is in NSW, the continuing loss was multiplied by a factor of 0.4, reducing it to a CL value of 0.76 mm/hr[8]. These losses were adopted as the starting values for the analysis.

3.2.5 Model Verification

3.2.5.1 Approach

The sensitivity of k_C and rainfall losses was determined by comparing the modelled peak flows with those produced by the ARR Regional Flood Frequency Estimation (RFEE) method[9]. The RFFE method is a replacement for the Probabilistic Rational Method described in the previous version of ARR. A full description of the method is provided in ARR project (http://arr.ga.gov.au/).

The RORB model (assuming natural catchment conditions and no urbanization) was run in a Monte Carlo framework, and the 20% to 1% AEP flood quantiles were compared with results from the RFFE method. Natural catchment conditions were modelled during this step because the RFFE method assumes natural catchment conditions. The discharge determined for each is presented in Table 3-2, with the RORB adopted parameters shown in Table 3-3.

For the 1% AEP event, the RORB model produced a peak flow of 62.0 m³/s compared to 134.0 m³/s produced by the RFFE model at the outlet position for 1% AEP. The RORB peak flow was still within the confidence limits although was much closer to the lower confidence limit. For the lower AEPs, the peak flows were a much closer match. For 50% AEP, RORB produced a peak flow of 13.6 m³/s, comparing to 11.8 m³/s for the RFFE tool. While for the 20% AEP, RORB produced 28.8 m³/s and the RFFE tool produced 27.9 m³/s.

The recommended *k* and loss values (shown in Table 3-3) were considered fit for purpose and were adopted in the RORB design modelling undertaken for this project.

[7] http://data.arr-software.org/
[8] WMA Water (2019) Review of ARR design inputs for NSW. Report for the NSW, Office of Environment and Heritage. Authors: Podger, S., Babister, M., Trim, A., Retallick, M. and Adam, M.
[9] https://rffe.arr-software.org/

TABLE 3-2 ARR REGIONAL FLOOD FREQUENCY MODEL RESULTS

AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%)	Upper Confidence Limit (95%)	RORB (m^3/s)
50	11.8	4.9	28.2	13.6
20	27.9	12.1	64.1	28.8
10	44.1	19.2	101.0	37.4
5	64.7	28.0	149.0	44.2
2	100.0	43.0	234.0	53.9
1	134.0	57.0	319.0	62.0

TABLE 3-3 ADOPTED RORB PARAMETER VALUES

Parameters	Adopted Values
m	0.8
k_C	4.0
Median Initial Loss (mm)	19.0
Continuing Loss (mm/hr)	0.76

3.2.6 RORB Outputs - Critical storm durations and Temporal Patterns

The RORB model was used to determine the critical storm duration for each of the investigated AEPs at different locations along Stubbo Creek. A single print point at the RORB model outlet was considered inadequate to account for the range of potential critical storm durations within the site and flow was assessed within RORB at three locations, F, L and the Outlet, as shown in Figure 3-2.

These three locations (F, L and Outlet) were assumed to represent the general critical storm durations in all watercourses, including those not discharging to Stubbo Creek. The peak values at the determined locations were used to determine the temporal pattern for each critical storm, based on the peak flow which most closely matched the Monte Carlo results. The results are presented in Table 3-4. These scenarios were modelled in the hydraulic model (discussed further in Section 3.3).

TABLE 3-4 CRITICAL STORM WITH SELECTED TEMPORAL PATTERNS

AEP	Critical Storm (min)	Temporal Pattern	Location
5%	120	6	F
	360	8	L
	360	8	Outlet
1%	90	2	F
	360	1	L
	360	1	Outlet
0.5%	90	2	F
	180	9	L
	360	1	Outlet
0.2%	90	4	F

AEP	Critical Storm (min)	Temporal Pattern	Location
	180	9	L
	360	1	Outlet
PMF	90	4	F
	180	9	L
	360	1	Outlet

3.3 Hydraulic Modelling

3.3.1 Overview

Hydraulic modelling of the Subject Site was completed using a two-dimensional (2D) TUFLOW flood model. TUFLOW software is one of the most widely used hydraulic modelling software packages in Australia. The software is considered an appropriate modelling tool for modelling riverine and local overland flooding. TUFLOW allows the simulation of runoff generated from local rainfall on a grid that is representative of the site topography, known as "Rain on Grid" modelling.

The domain of the 2D TUFLOW model extended beyond the Subject Site boundary to cover the complete local catchment area draining to the site, as shown in Figure 3-4. The model domain was also surrounded by a 2d_bc layer which allowed overland flow to leave the model.

The model determined flood levels, depths velocities and Flood Hazard for each of the modelled AEPs, critical storm durations and Temporal Patterns (as highlighted in Table 3-4). The hydraulic model was run for both existing and climate change conditions.

Climate change modelling used forecasting data for changes to rainfall predicted for the year 2090 and Representative Concentration Pathway (RCP) 8.5. The RCPs are used for making projections based on four different 21st century pathways of anthropogenic Greenhouse Gas (GHG) emissions and atmospheric concentrations, air pollutant emissions and land use[10]. The RCPs include a stringent mitigation scenario (RCP2.6), two intermediate scenarios (RCP4.5 and RCP6.0) and one scenario with very high GHG emissions (RCP8.5). RCPs consider the impact of atmospheric concentrations of greenhouse gases and aerosols, along with the uncertainty in possible future emissions. The use of RCP 8.5 would allow for the worst-case scenario.

3.3.2 Rainfall

The Rain on Grid approach adopted the critical storm durations and selected temporal patterns determined by RORB and discussed in Section 3.1.

3.3.3 Model topography

The Rain on Grid modelling methodology was adopted during this project. The model topography was developed from the Stubbo 2m LiDAR available for the site, as shown in Figure 3-3.

[10] https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf

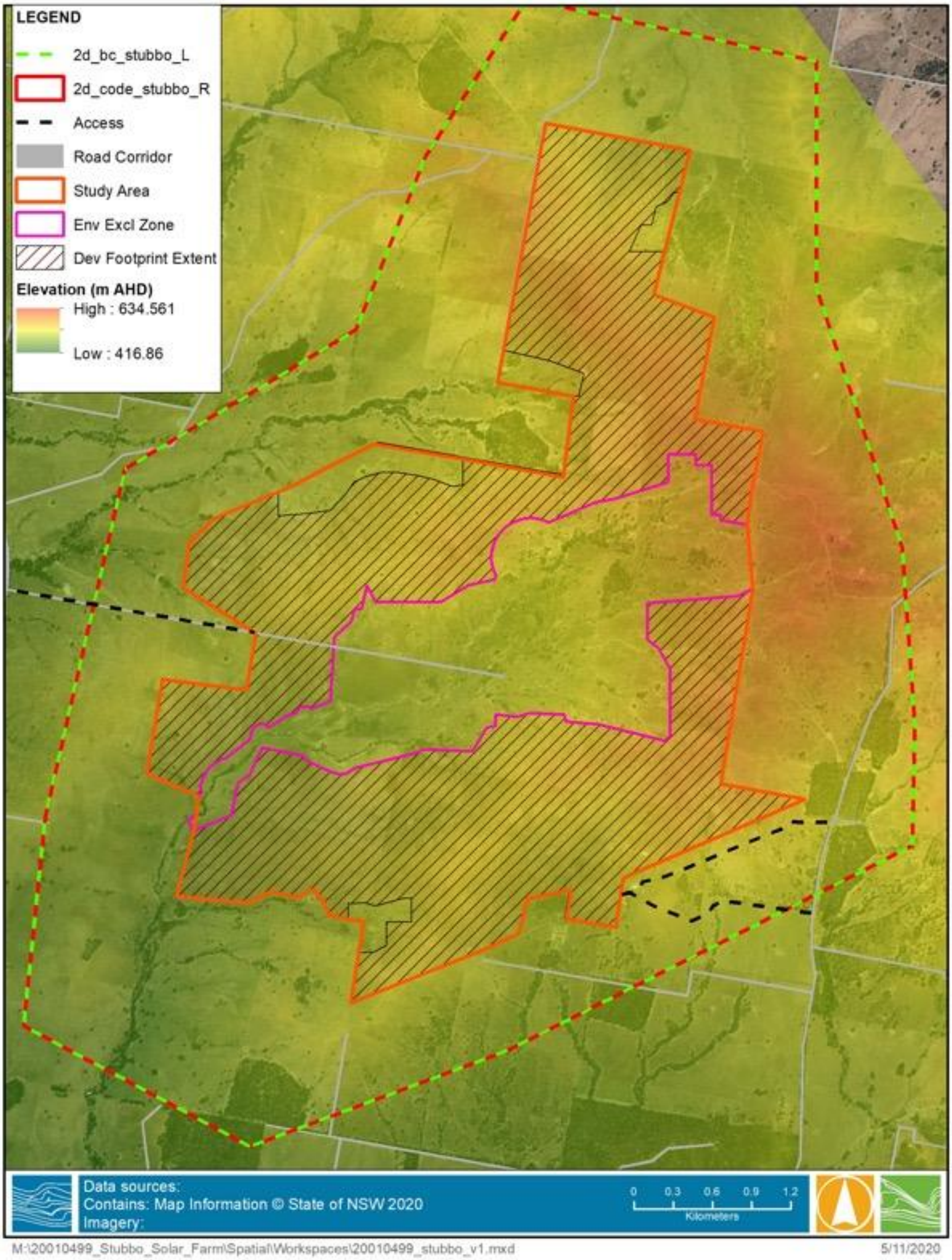

FIGURE 3-3 TUFLOW MODEL TOPOGRAPHY

3.3.4 Hydraulic Roughness

The hydraulic model used Manning's 'n' to represent the hydraulic roughness to determine the restriction caused by the range of land uses within the model area. Local council planning layers were used to assigned a specific Manning's 'n' roughness coefficient based on recommendations in ARR2019[11], as shown in Table 3-5. Most of the Subject Site was modelled with a roughness of 0.06. Similar to the RORB model, IL and CL values were applied within TUFLOW. These were also applied as per land use and the adopted values are shown in Table 3-5. The values used are typical and have been used in similar studies. The Manning's 'n' roughness values adopted are shown in Figure 3-4.

[11] http://book.arr.org.au.s3-website-ap-southeast-2.amazonaws.com/

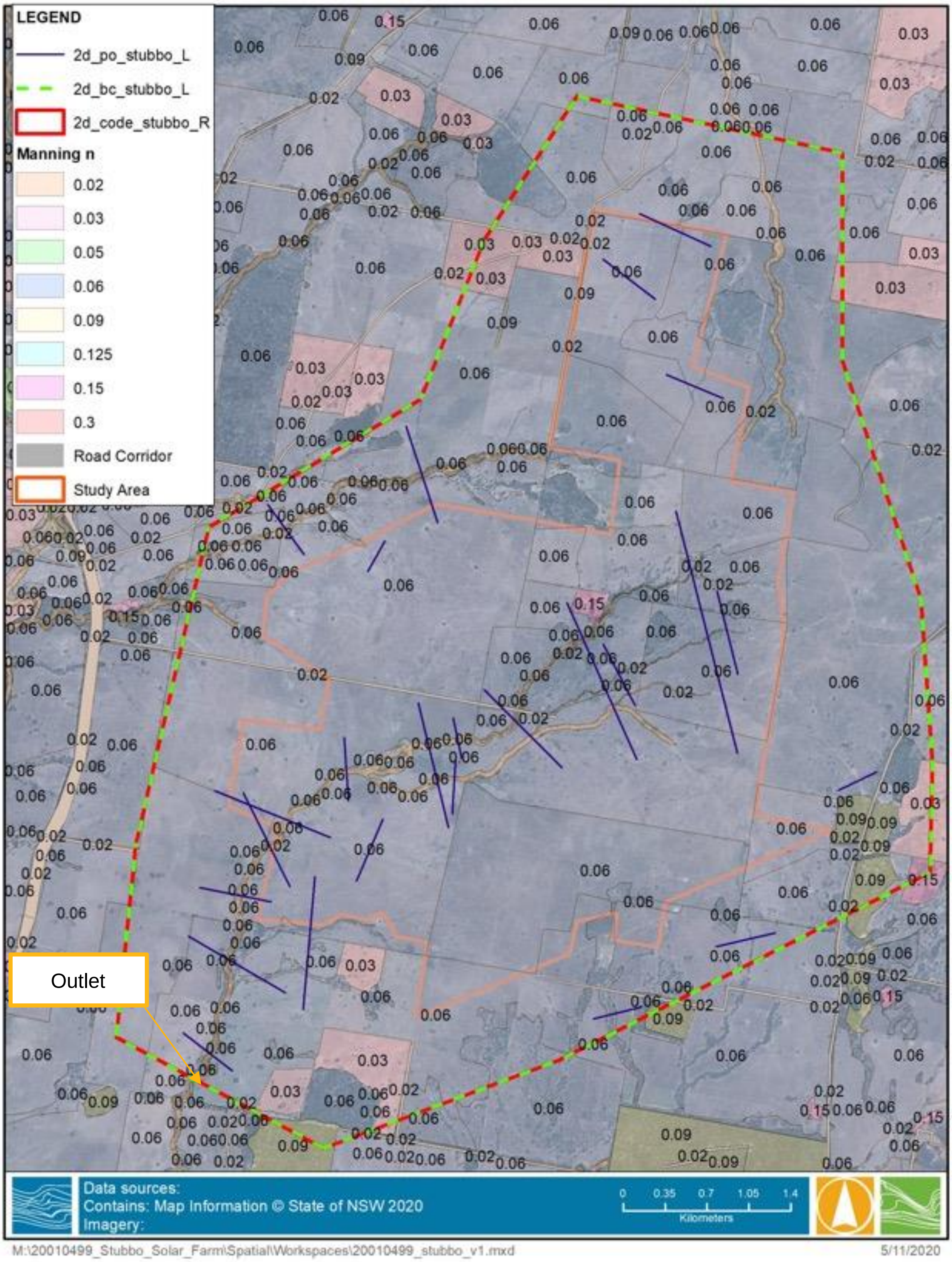

FIGURE 3-4 MODEL DOMAIN AND ADOPTED ROUGHNESS VALUES

TABLE 3-5 MANNING ROUGHNESS AND LOSSES USED IN THE DEVELOPED HYDRAULIC MODEL

Manning's 'n'	IL (mm)	CL (mm/hr)	Land Use
0.15	10.0	2.0	Residential - Rural (lower density) - when building footprints and remainder of parcel are modelled together (with one roughness value)
0.30	5.0	1.0	Industrial/Commercial or large buildings on site
0.05	15.0	2.0	Significant Drainage Easement (regardless of zone type)
0.03	15.0	1.0	Open Space or Waterway - minimal vegetation
0.06	15.0	1.0	Open Space or Waterway - moderate vegetation
0.09	15.0	1.0	Open Space or Waterway - heavy vegetation
0.06	0.0	0.0	Open water (with reedy vegetation)
0.02	0.0	0.0	Open water (with submerged vegetation)
0.02	2.5	0.5	Car park/pavement/wide driveways/roads

3.3.5 Model scenarios

Hydraulic modelling was undertaken for each AEP or PMF using three runs as per the critical storm durations and temporal patterns in Table 3-4.

The PMF rainfall depth was estimated from the Probable Maximum Precipitation (PMP) rainfall depth. A scale factor between the 1 in 2000-year rainfall depth and PMP was used to determine the PMF rainfall depth for each of the investigated storm durations.

4 RESULT AND DISCUSSION

4.1 Overview and Flood Hazard Classifications

The maximum flood level, depth, velocity and hazard for each modelled AEP was determined across the modelled event durations encompassing the maximum of each. Note that areas where the flood depths were less than 5 cm have been filtered from the results.

In this report only the 5% and 1% AEP and PMF events are discussed, with the remainder of the results provided in mapping and provided as GIS layers. Results for the 0.5% and 0.2% AEP were used for the discussion of flood levels with the incorporation of Climate Change.

Floods can be hazardous, producing harm to people, damage to infrastructure and potentially loss of life. In examining the potential hazard of flooding at the site, there are several factors to be considered, as outlined in ARR 2019 (Book 6 Chapter 7)[12]. An assessment of flood hazard should consider:

- Velocity of floodwaters.
- Depth of floodwaters.
- Combination of velocity and depth of floodwaters.
- Isolation during a flood.
- Effective warning time.
- Rate of rise of floodwater.

The flood hazard of the site was assessed in accordance with ARR2019, which defines six hazard categories. The combined flood hazard curves are presented in Figure 4-1 and vulnerability thresholds classifications are tabulated in Table 4-1.

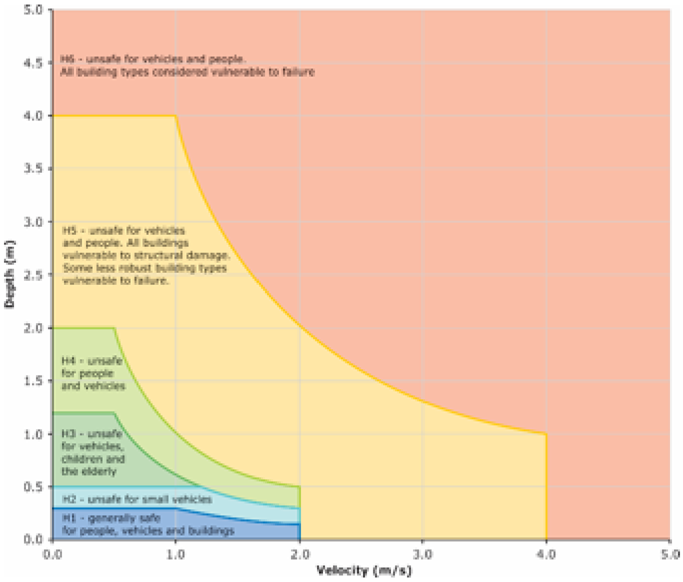

FIGURE 4-1 COMBINED FLOOD HAZARD CURVES

TABLE 4-1 HAZARD CLASSIFICATION (ARR, 2016)

Hazard Vulnerability Classification	Classification Limit (D and V in combination)	Limiting Still Water Depth (D)	Limiting Velocity (V)	Description
H1	D*V ≤ 0.3	0.3	2.0	Generally safe for vehicles, people and buildings.
H2	D*V ≤ 0.6	0.5	2.0	Unsafe for small vehicles.
H3	D*V ≤ 0.6	1.2	2.0	Unsafe for vehicles. children and the elderly.
H4	D*V ≤ 1.0	2.0	2.0	Unsafe for vehicles and people.
H5	D*V ≤ 4.0	4.0	4.0	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.

[12] http://book.arr.org.au.s3-website-ap-southeast-2.amazonaws.com/

Hazard Vulnerability Classification	Classification Limit (D and V in combination)	Limiting Still Water Depth (D)	Limiting Velocity (V)	Description
H6	D*V > 4.0	-	-	Unsafe for vehicles and people. All building types considered vulnerable to failure.

4.2 5% AEP Results

Modelled 5% AEP depths, velocities and Flood Hazard are presented in Figure 4-2, Figure 4-3 and Figure 4-4 respectively. There is generally no flooding within the proposed development area except for within the watercourses and local depressions. Flood depths are generally less than 0.1 m at the upstream reaches of each watercourse.

The major watercourses such as Stubbo Creek and others within the EEZ have flood depths between 0.5 m and 1.0 m. A similar flood depth range is observed for farm dams. Minor watercourses such as of those that flow northwest to Pine Creek have flood depths generally less than 0.3 m. The same flood depth range is observed for the watercourses at the northern part of the site.

Velocities within the proposed development area are very low and generally less than 0.3 m/s. Velocities only exceed 0.6 m/s within the waterways. Within Stubbo Creek, velocities reach between 1.0 and 2.0 m/s in the lower reaches.

The flood hazard within the site the site is mostly characterised as H1: ‘Generally safe for vehicles, people and buildings’ and only reaches above this in the waterways and defined drainage lines.

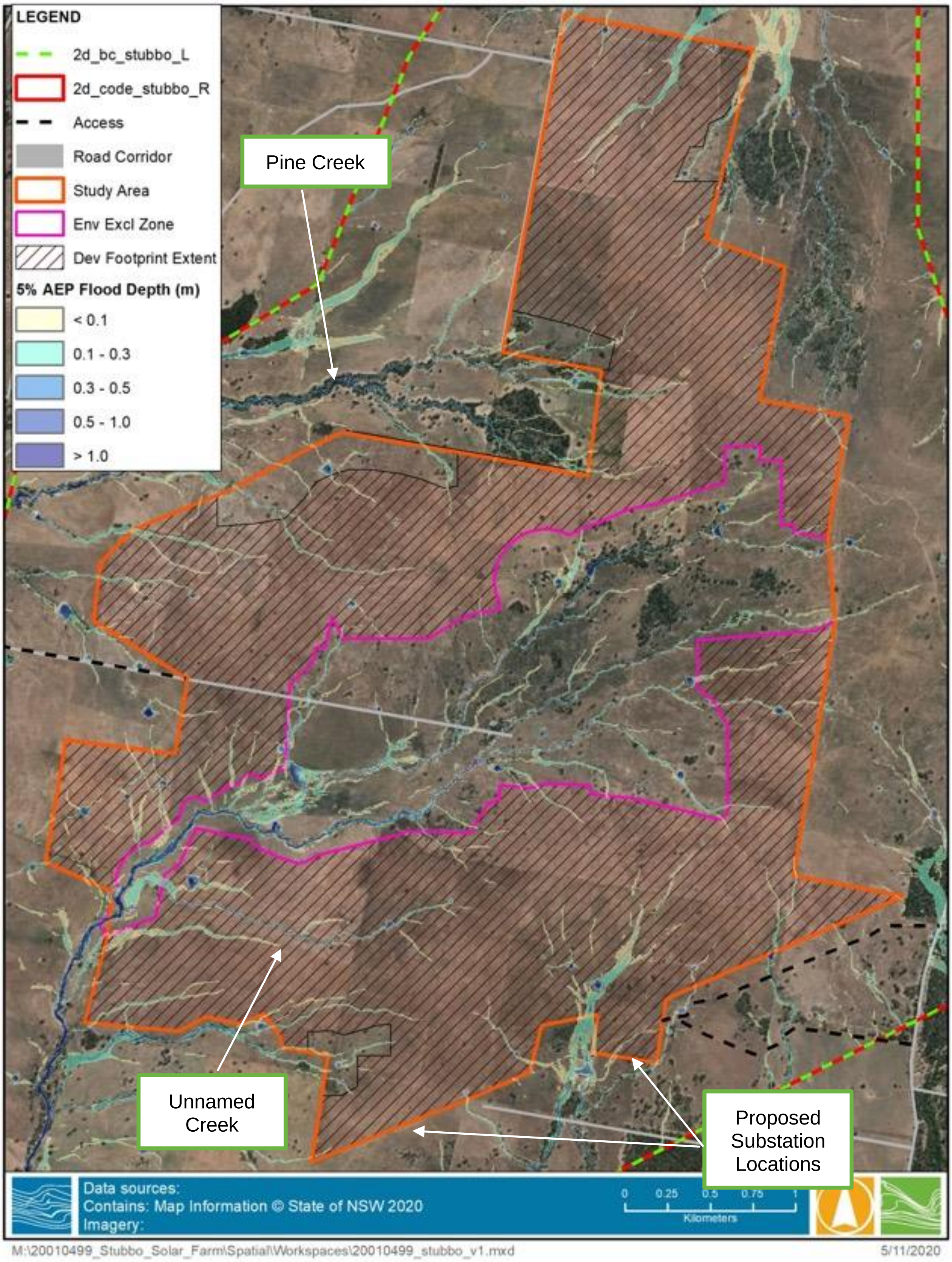

FIGURE 4-2 5% AEP FLOOD DEPTH FOR EXISTING CONDITION

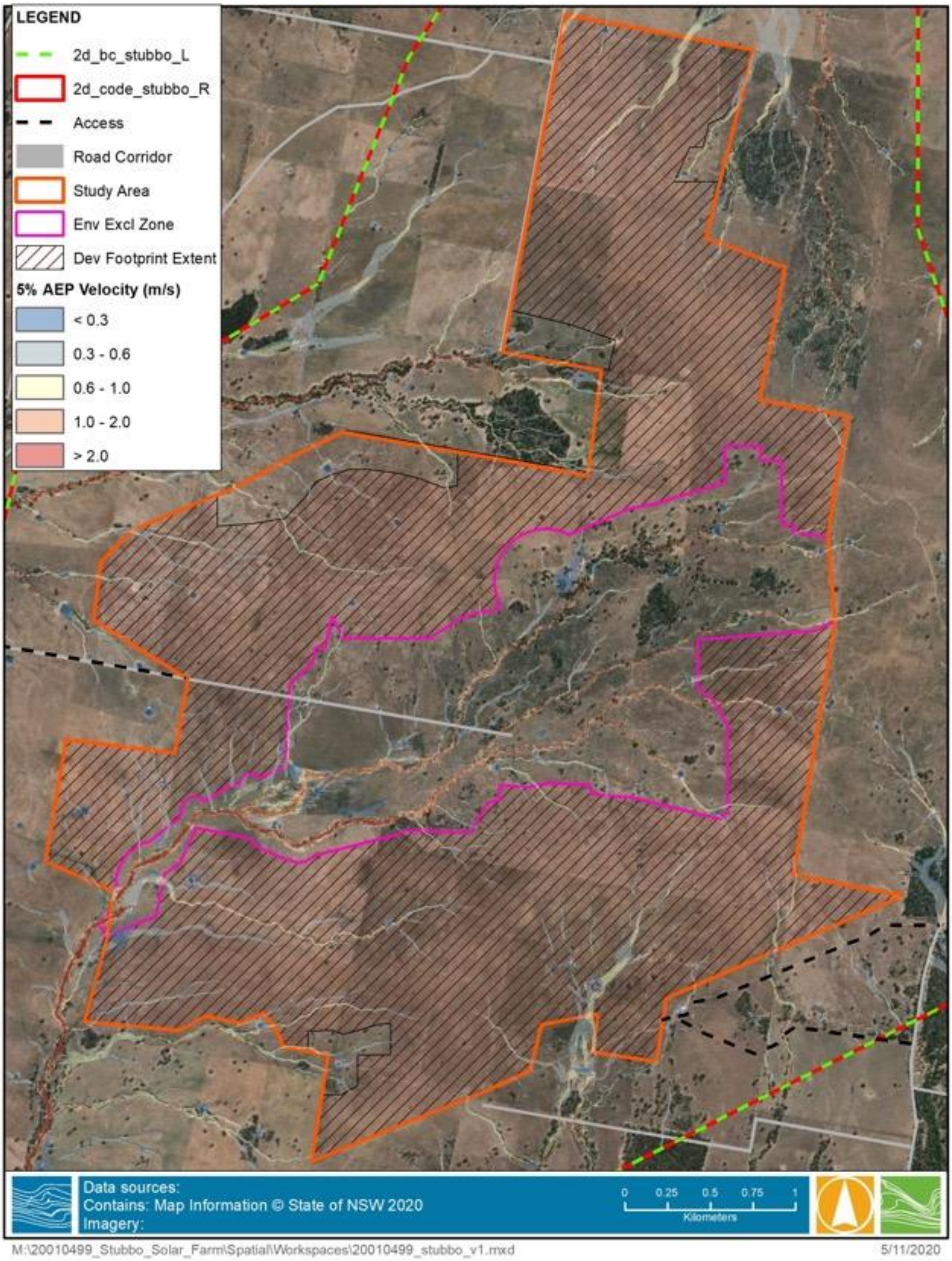

FIGURE 4-3 5% AEP FLOOD VELOCITY FOR EXISTING CONDITION

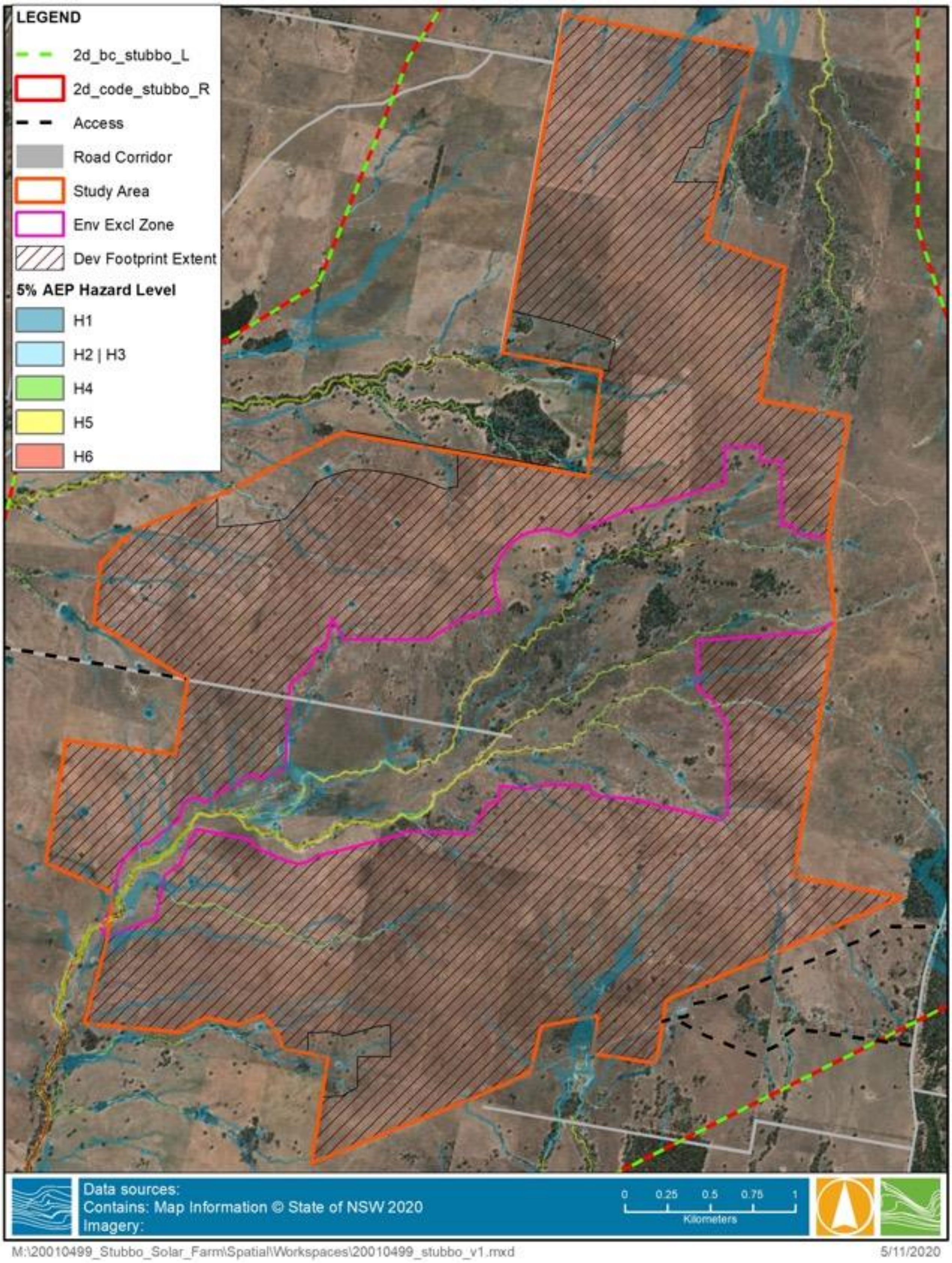

FIGURE 4-4 5% AEP FLOOD HAZARD FOR EXISTING CONDITION

4.3 1% AEP Results

The modelled 1% AEP flood depths, velocities and Flood Hazard categories within the Subject Site are shown in Figure 4-5, Figure 4-6 and Figure 4-7 respectively. Flood depth remains generally less than 0.1 m. Flood depths greater than 0.3 m are only observed within watercourses or defined overland flow paths. The major watercourses within the EEZ such as Stubbo Creek have flood depths between 0.5 m and 1.0 m. A similar flood depth range is observed within the Study Area's dams. Similar to the 5% AEP event, minor watercourses such as those that flow north western to Pine Creek, have flood depths generally less than 0.3 m. The same flood depth range is observed for the watercourses to the north of the Study Area. In the southern section of the Subject Site the main creek running parallel to Stubbo Creek has flood depths varying between 0.5 m and 1.0 m. Other unnamed watercourses that flow south a have flood depths less than 0.3 m, except for farm dams where the flood depths are much higher.

Velocities within the Subject Site are generally low, at around 0.3 m/s. Velocities higher than 0.6 m/s are only observed within watercourses. Within Stubbo Creek's downstream section, velocities reached the highest at between 1.0 and 2.0 m/s.

Similar to the 5% AEP event, Flood Hazard within the Subject Site is mostly characterised as H1: 'Generally safe for vehicles, people and buildings', identifying it as generally of low flood risk. This is largely because of the steep catchment grades and defined waterways allowing the Subject Site to drain without any significant areas of water reaching high depths, particularly outside the EEZ.

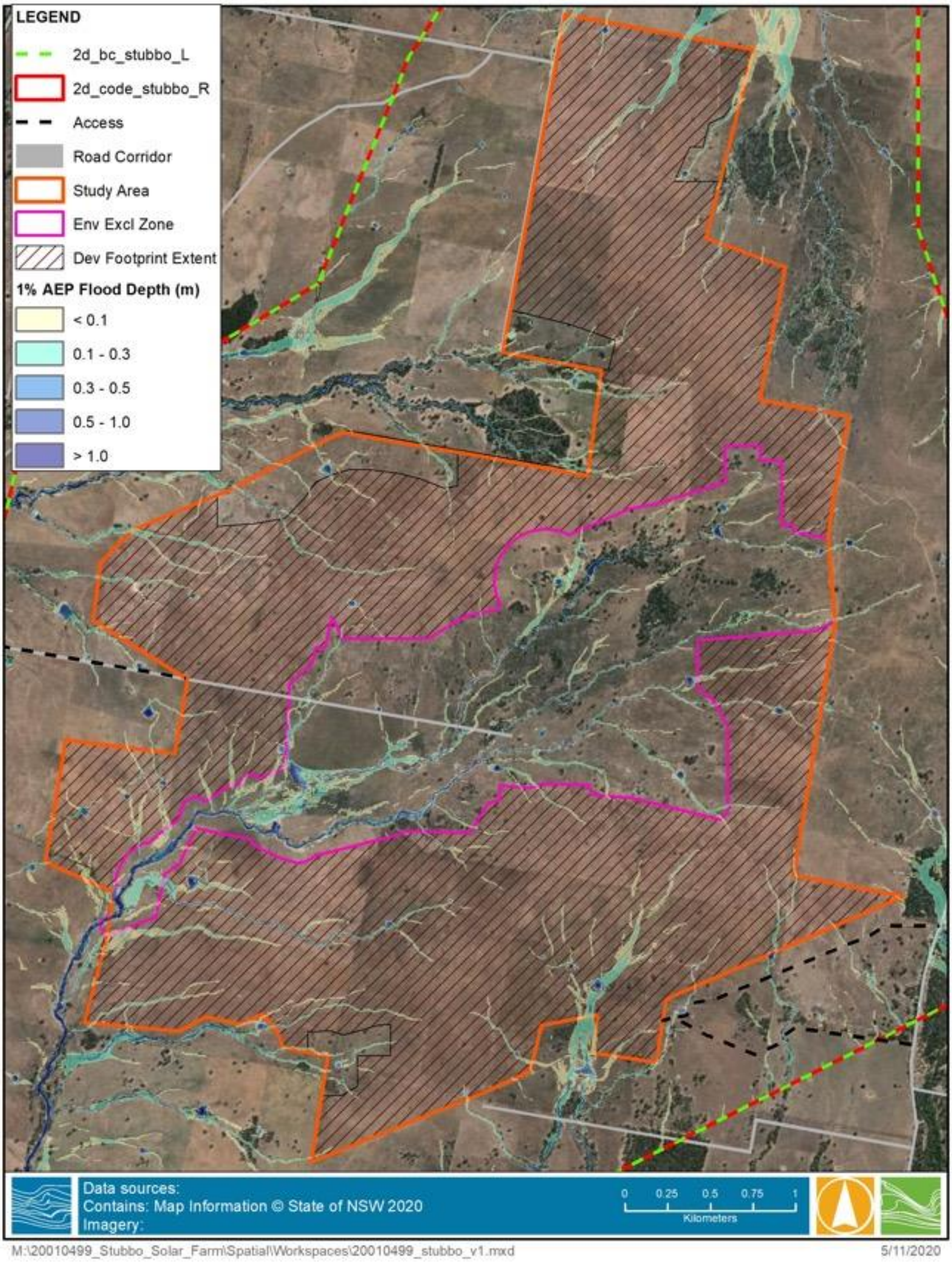

FIGURE 4-5 1% AEP FLOOD DEPTH FOR EXISTING CONDITION

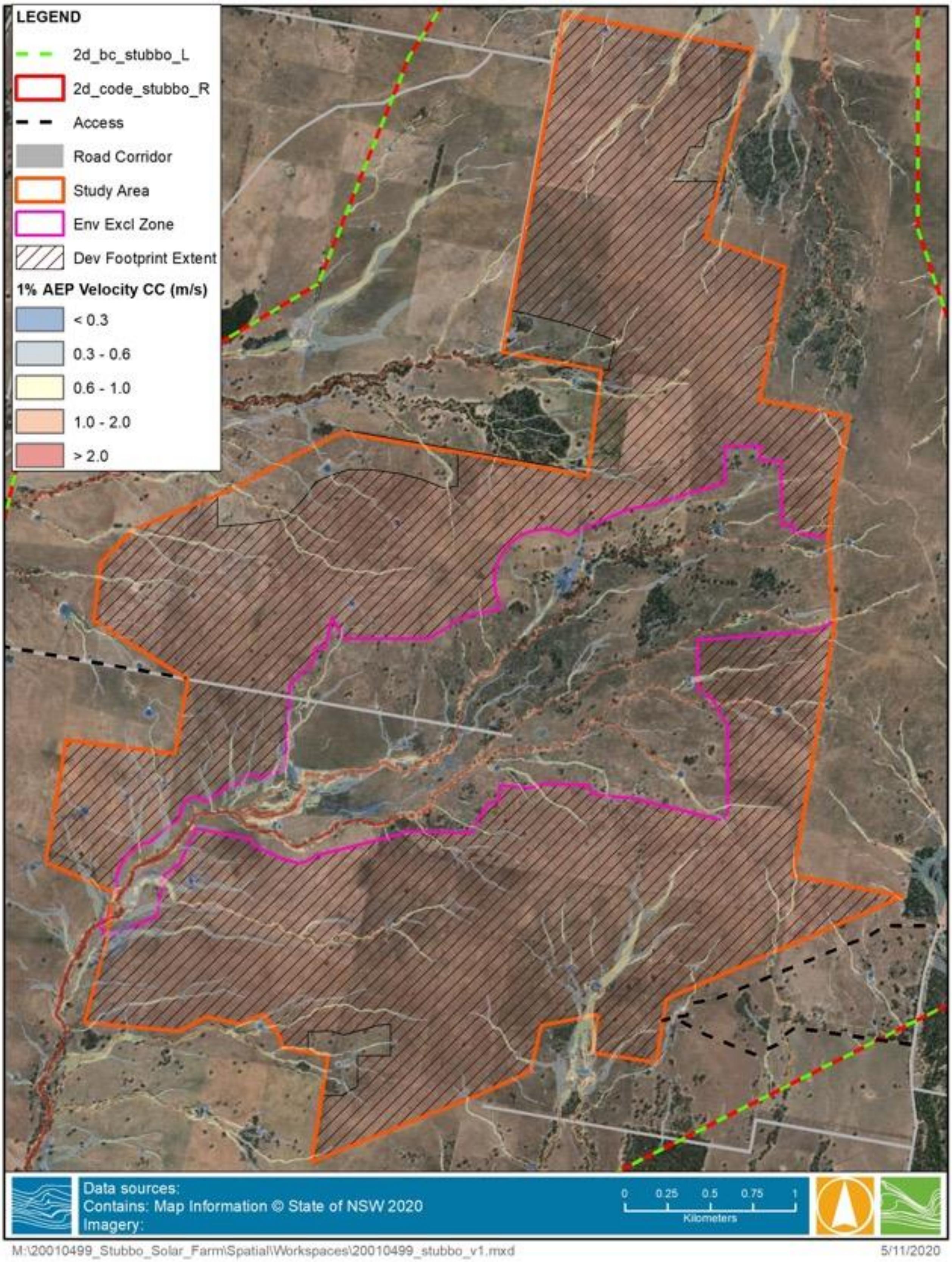

FIGURE 4-6 1% AEP FLOOD VELOCITY FOR EXISTING CONDITION

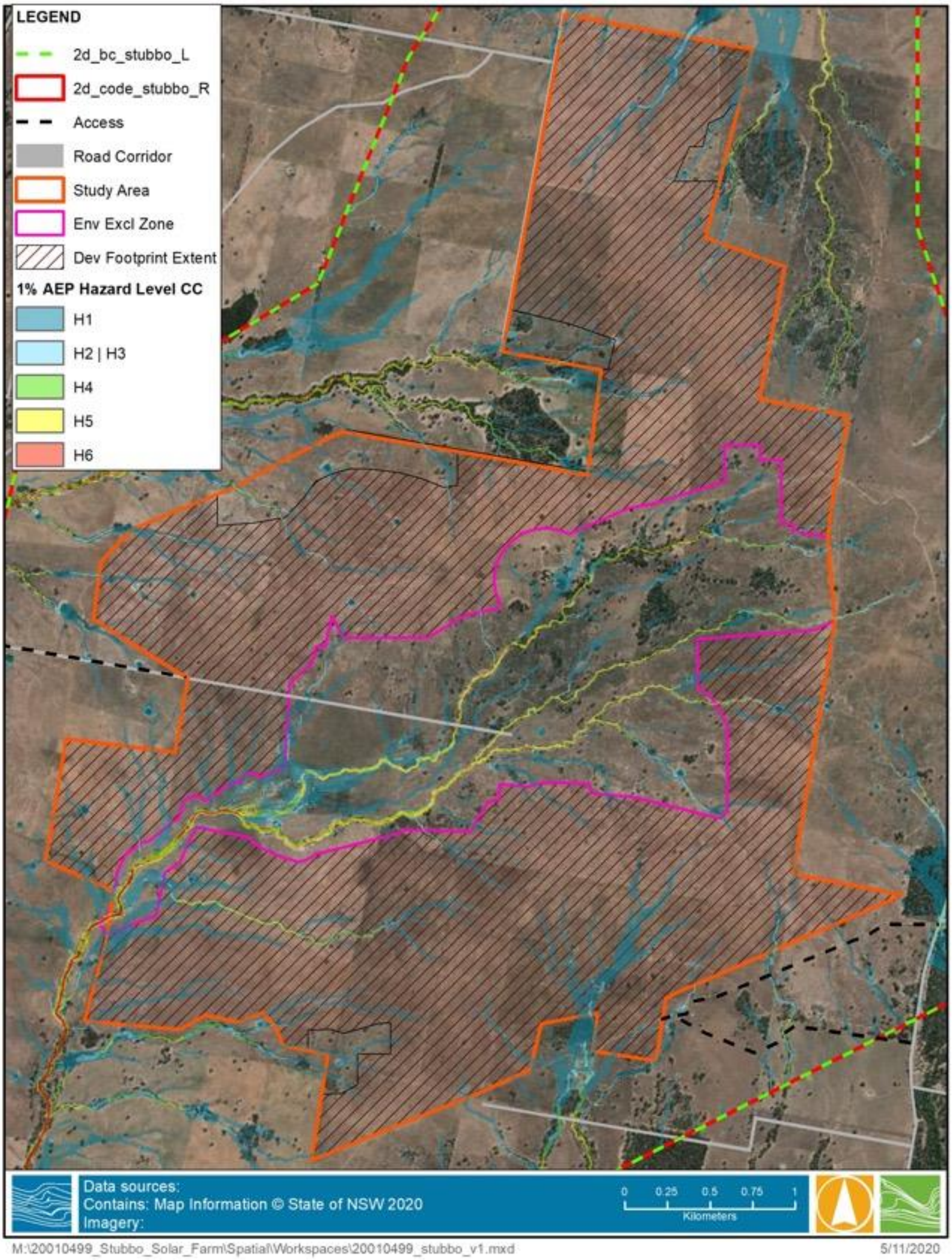

FIGURE 4-7 1% AEP FLOOD HAZARD FOR EXISTING CONDITION

4.4 Probable Maximum Flood

The PMF flood depths, velocities and Flood Hazard categories within the Subject Site are shown in Figure 4-8, Figure 4-9 and Figure 4-10 respectively. As expected, the inundation extent and depths are much larger than the previously discussed AEPs given it is significantly larger event (closer to a 1:100,000 year AEP). Depths reach up to 0.5 m in the defined overland flow paths and isolated instances where the velocities exceed 2 m/s.

Flood Hazard outside the EEZ generally remains as H1, but there are areas of up to H4 with isolated areas up to H6 within the centre of waterways or major drainage lines.

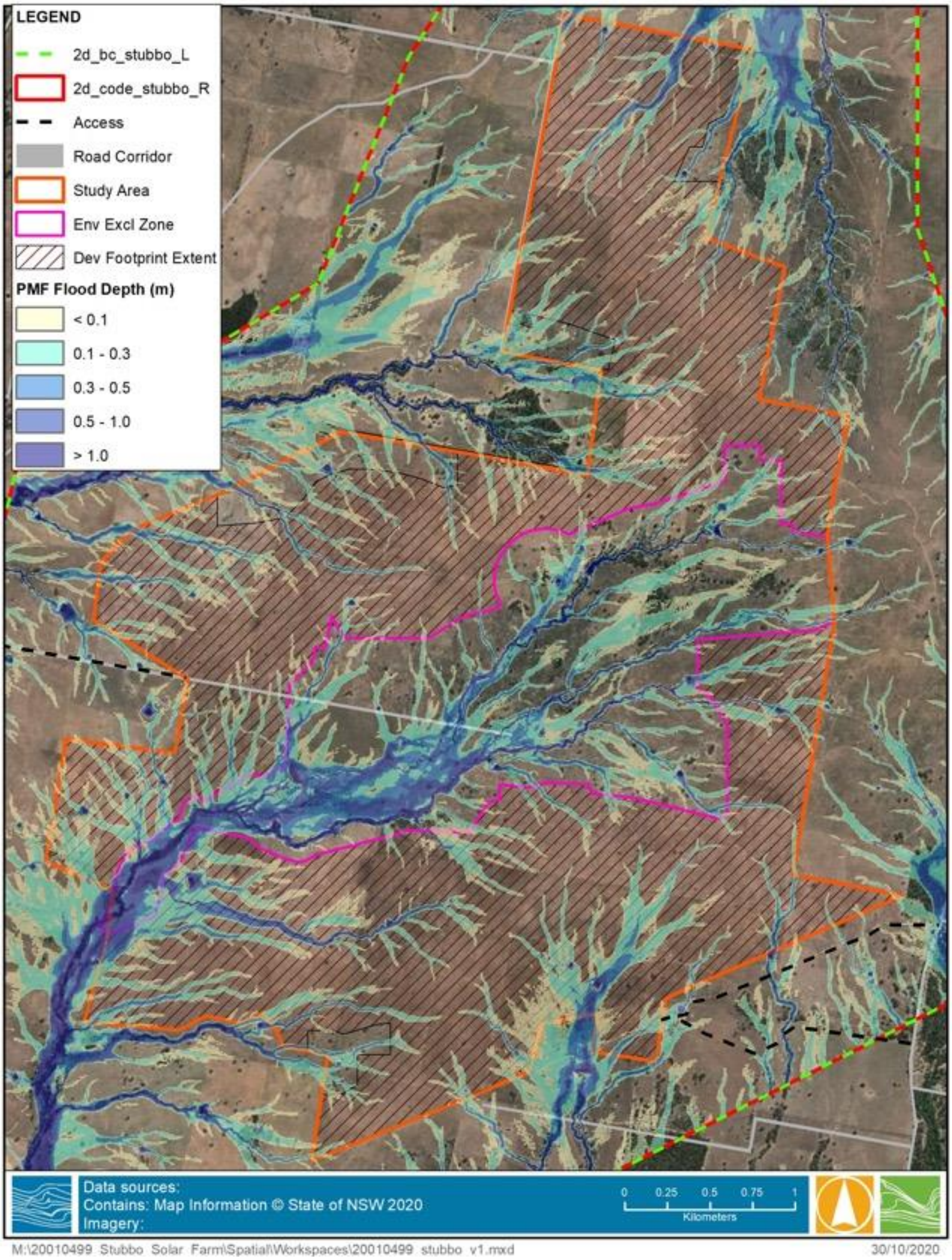

FIGURE 4-8 PMF FLOOD DEPTH FOR EXISTING CONDITION

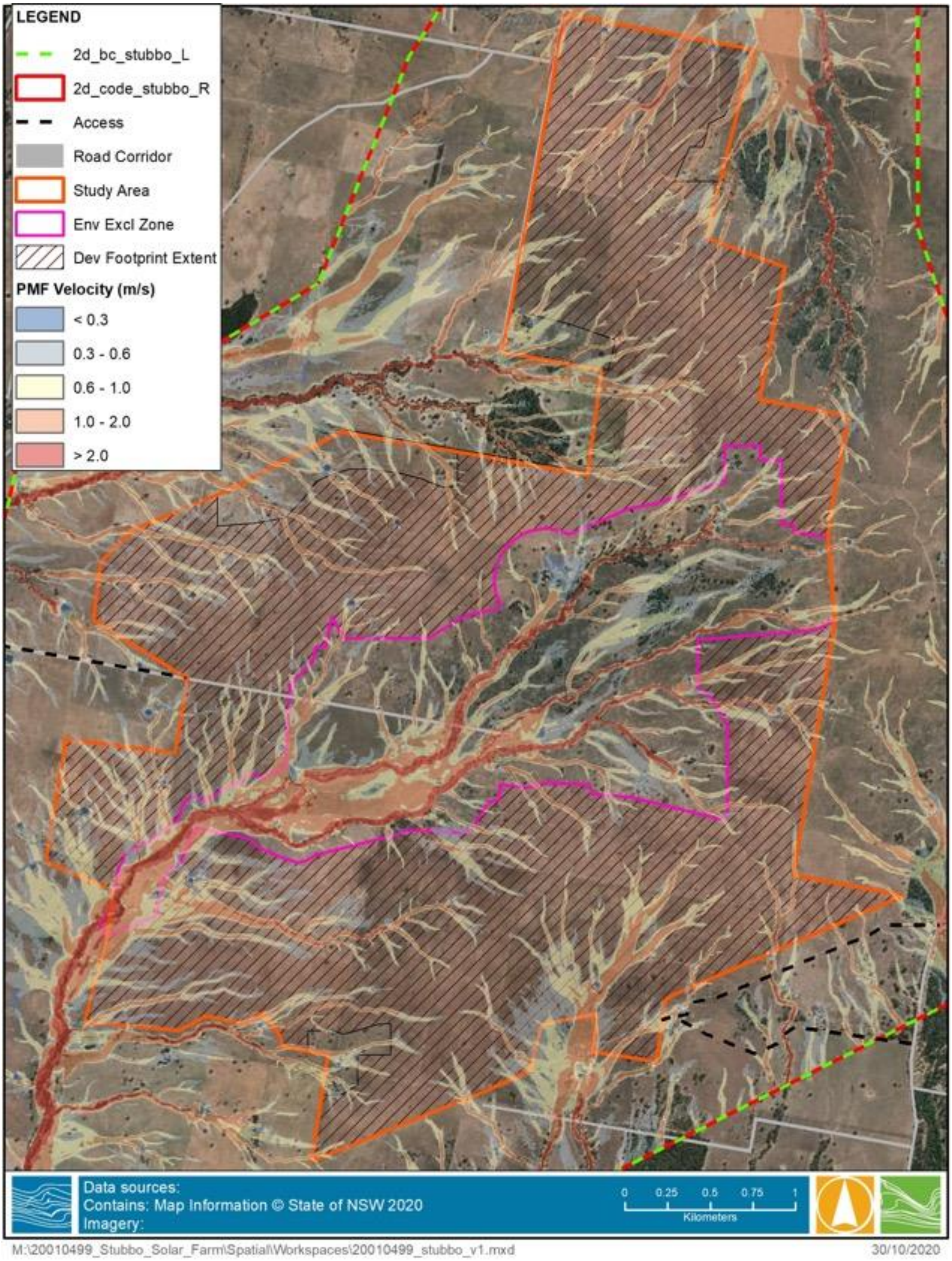

FIGURE 4-9 PMF FLOOD VELOCITY FOR EXISTING CONDITION

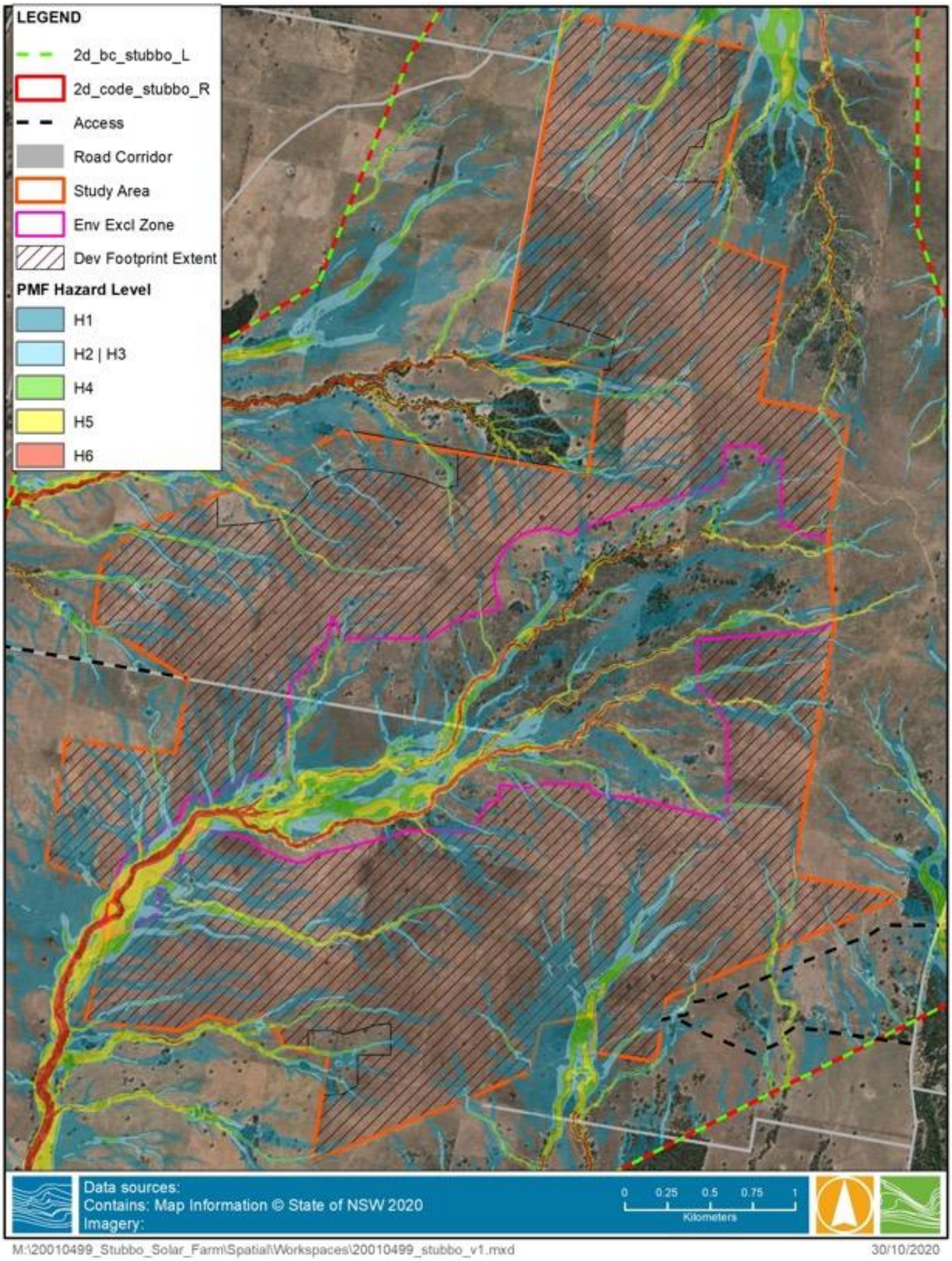

FIGURE 4-10 PMF FLOOD HAZARD FOR EXISTING CONDITION

4.5 Hydrologic and Hydraulic Model Comparison

The peak flows from both the hydrologic (RORB) and hydraulic (TUFLOW) models were compared at the natural Subject Site outlet location, as shown in Figure 3-2. For the 1% AEP, 6hr storm duration the peak flow within the hydrologic model (RORB) was 62.0 m^3/s, compared to that determined within hydraulic model (TUFLOW) of 55.6 m^3/s. The close match suggests that the hydraulic model is producing an accurate estimation of the flood behaviour and confirms the model results.

4.6 Climate Change Modelling

Climate Change modelling is discussed using the flood depth and Flood Hazard results for the 1%, 0.5% and 0.2% AEPs.

The 1% AEP Climate Change flood depths are only marginally larger than that of existing conditions, higher AEP events show similar results indicating the inundation impact of Climate Change may not be a significant issue for the development. The minor increases in depth reinforce the Subject Site is able to drain effectively without a significant floodplain area which could hold water at high depths for extended periods. Climate Change flood depths for the 1% AEP, 0.5% AEP and 0.2% AEP events are shown in Figure 4-11, Figure 4-12 and Figure 4-13 respectively, Climate Change velocities for the 1% AEP, 0.5% AEP and 0.2% AEP events are shown in Figure 4-14, Figure 4-15 and Figure 4-16 respectively and Climate Change Flood Hazard for the 1%AEP, 0.5% AEP and 0.2% AEP events is shown in Figure 4-17, Figure 4-18 and Figure 4-19 respectively.

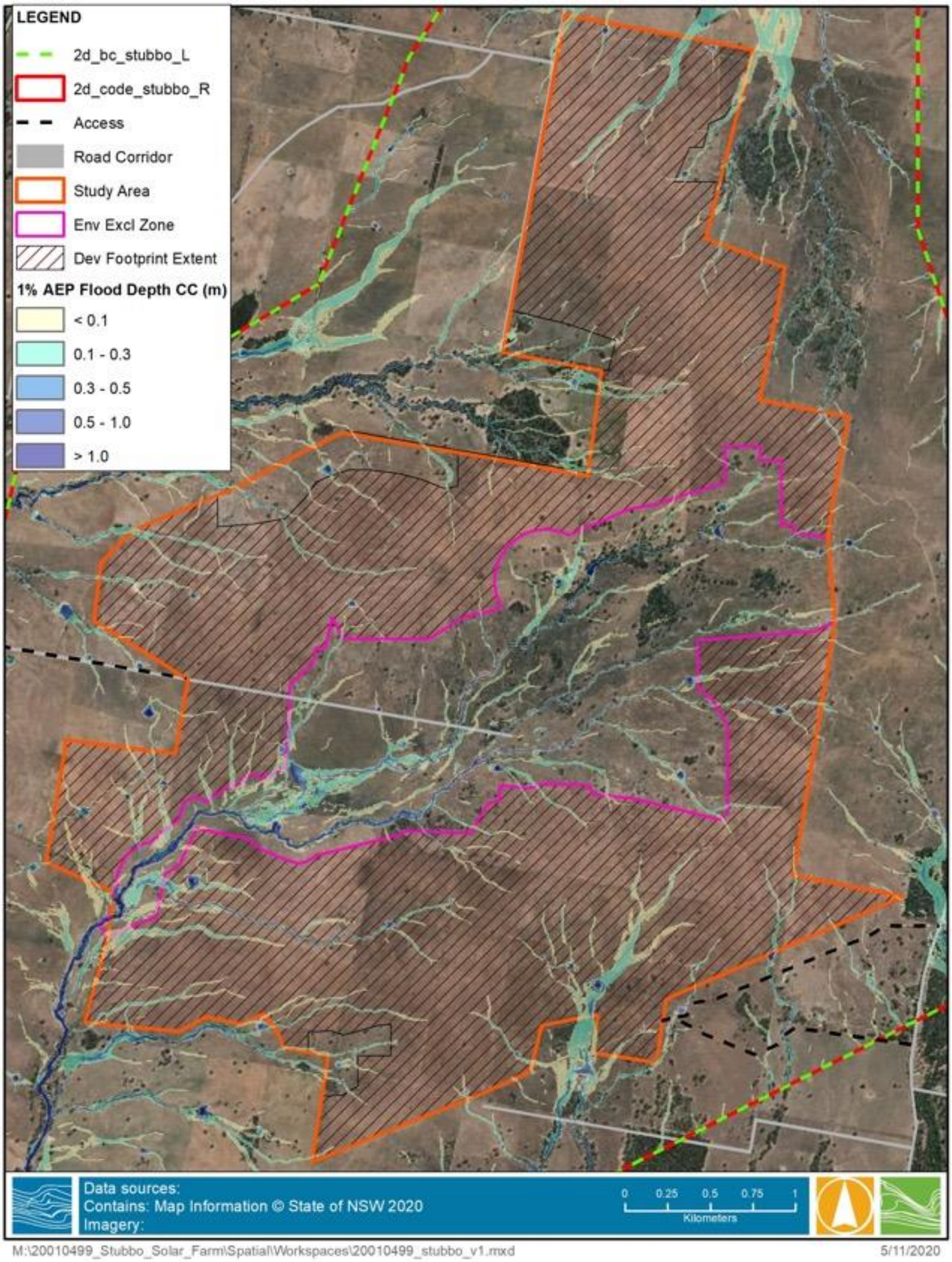

FIGURE 4-11 1% AEP FLOOD DEPTH - CLIMATE CHANGE

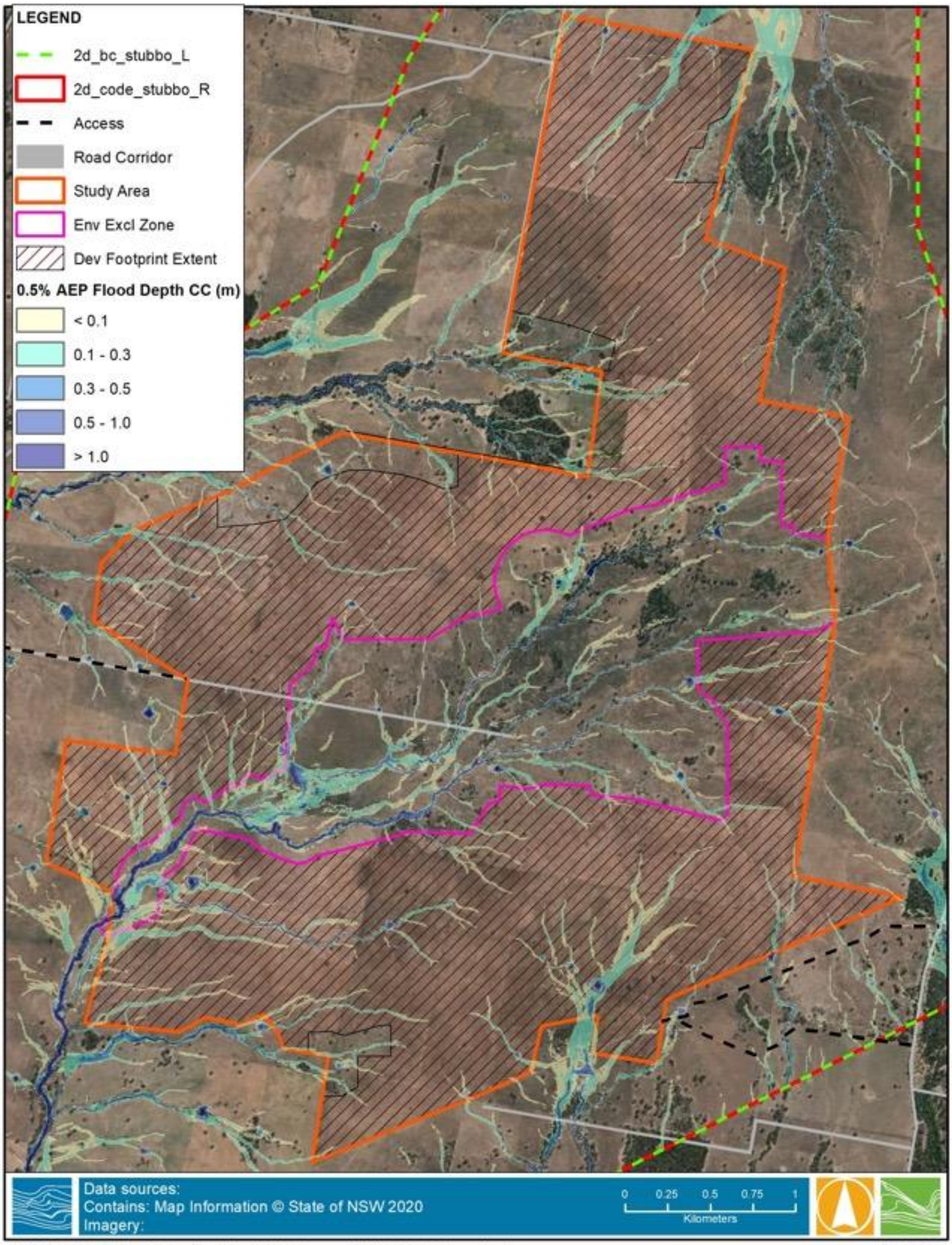

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FIGURE 4-12 0.5% AEP FLOOD DEPTH - CLIMATE CHANGE

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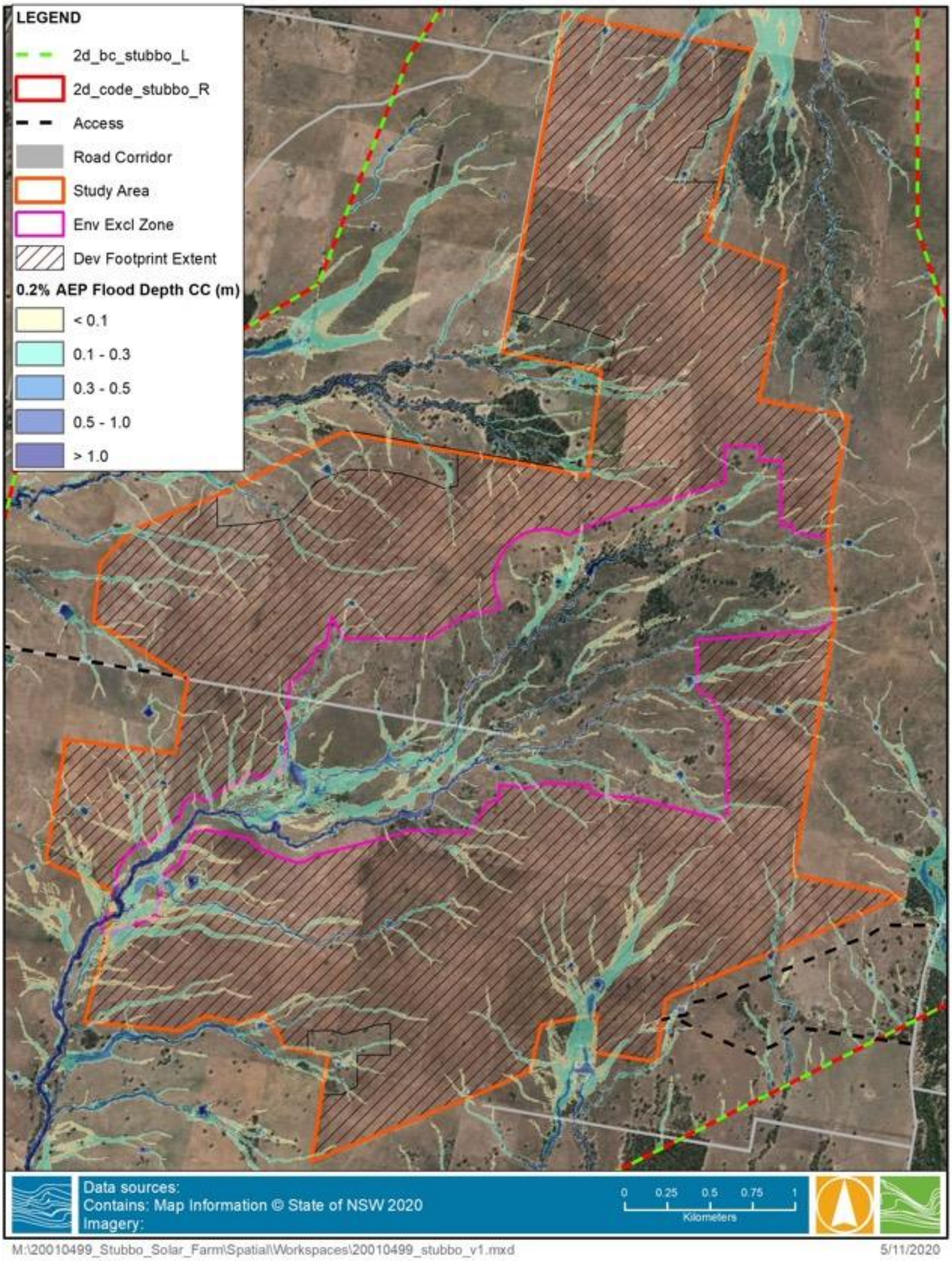

FIGURE 4-13 0.2% AEP FLOOD DEPTH - CLIMATE CHANGE

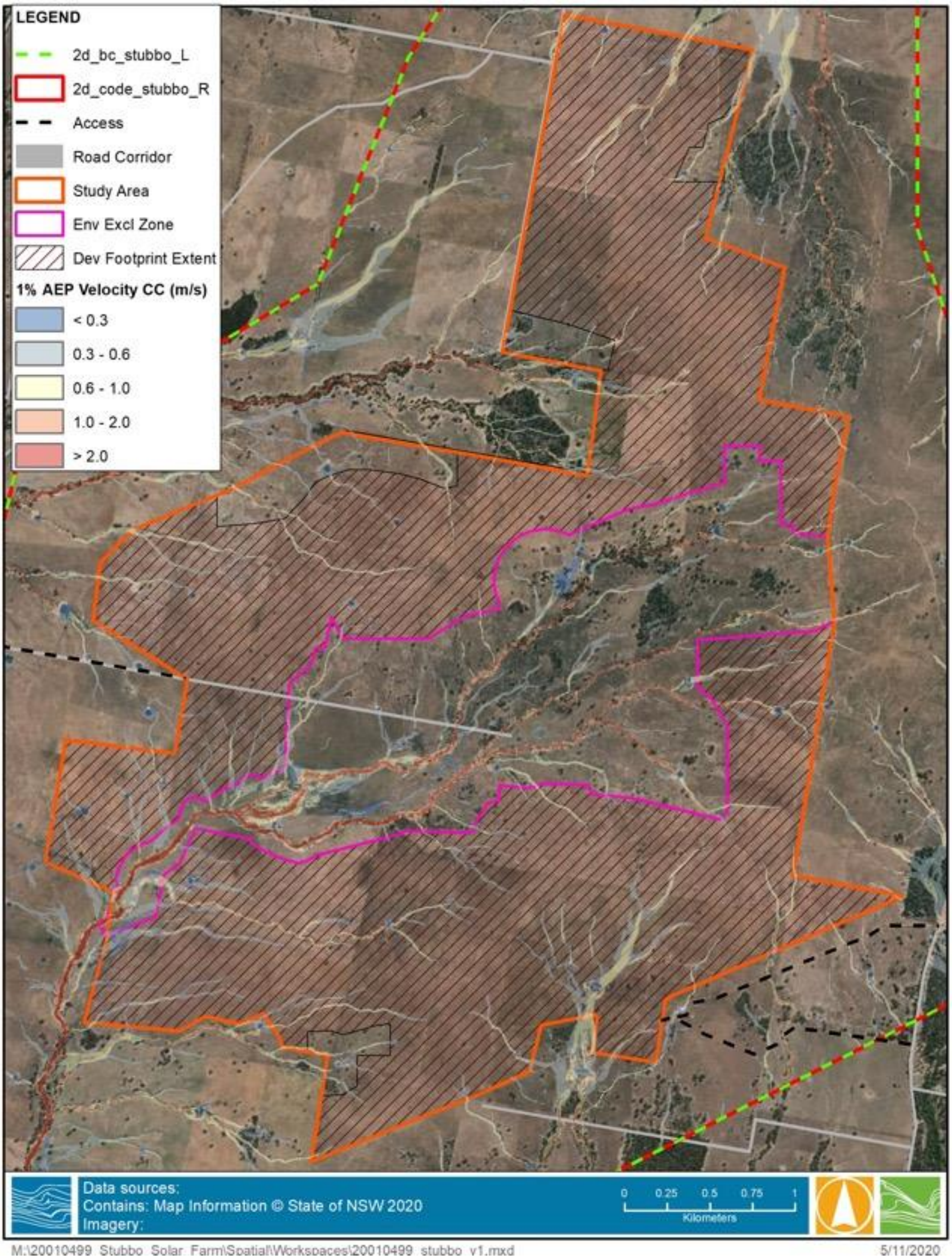

FIGURE 4-14 1% AEP FLOOD VELOCITY - CLIMATE CHANGE

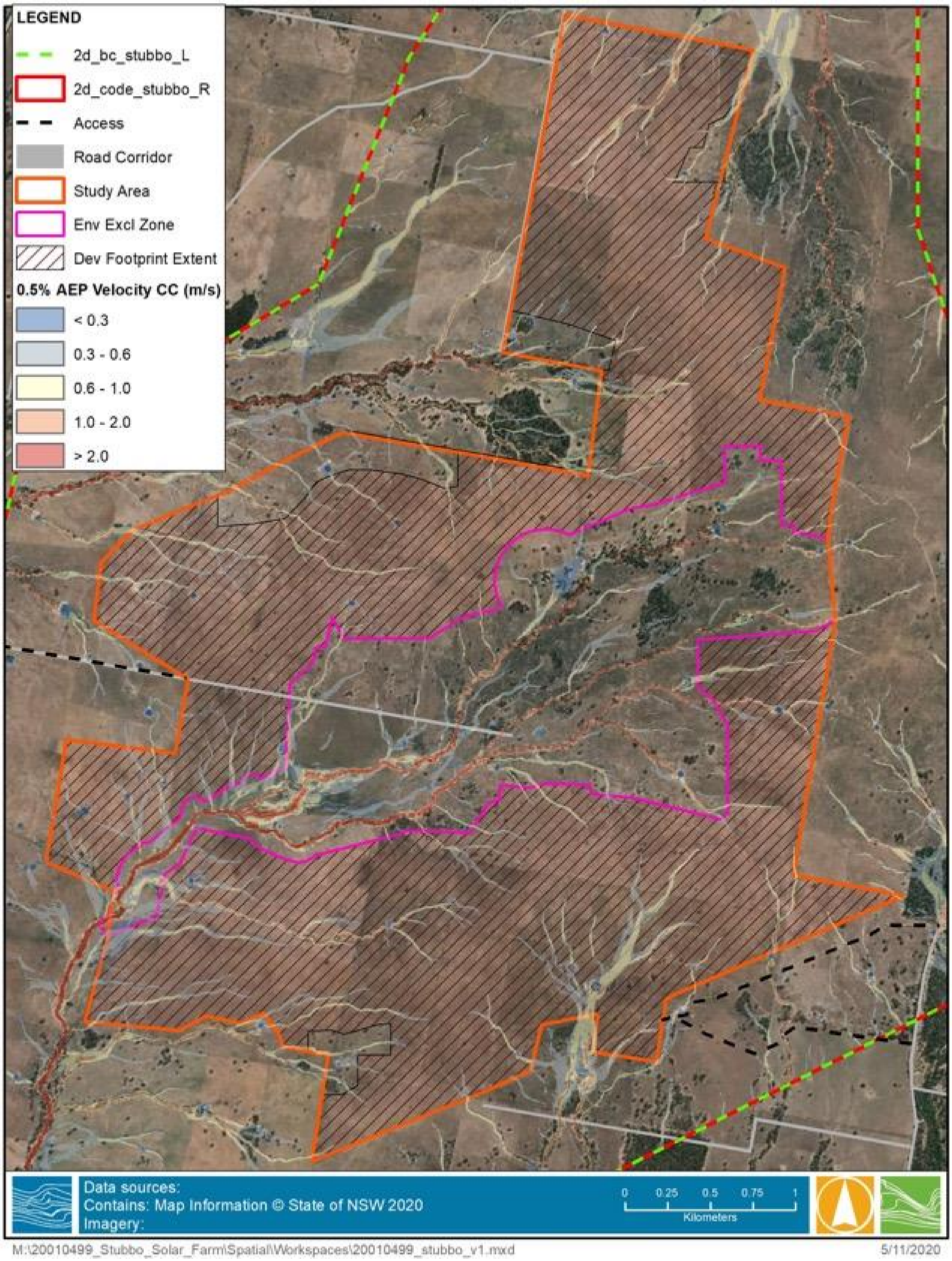

FIGURE 4-15 0.5% AEP FLOOD VELOCITY - CLIMATE CHANGE

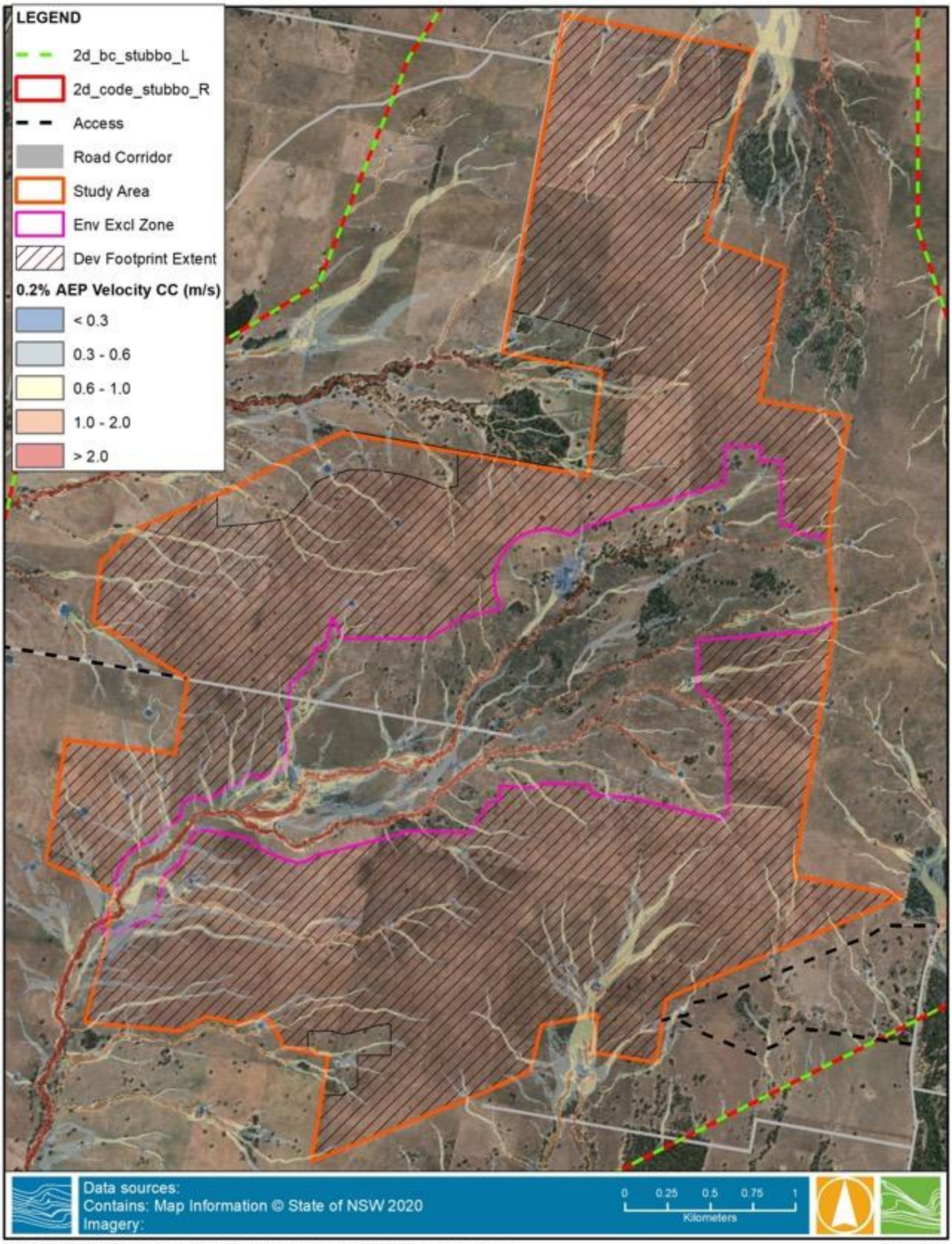

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FIGURE 4-16 0.2% AEP FLOOD VELOCITY - CLIMATE CHANGE

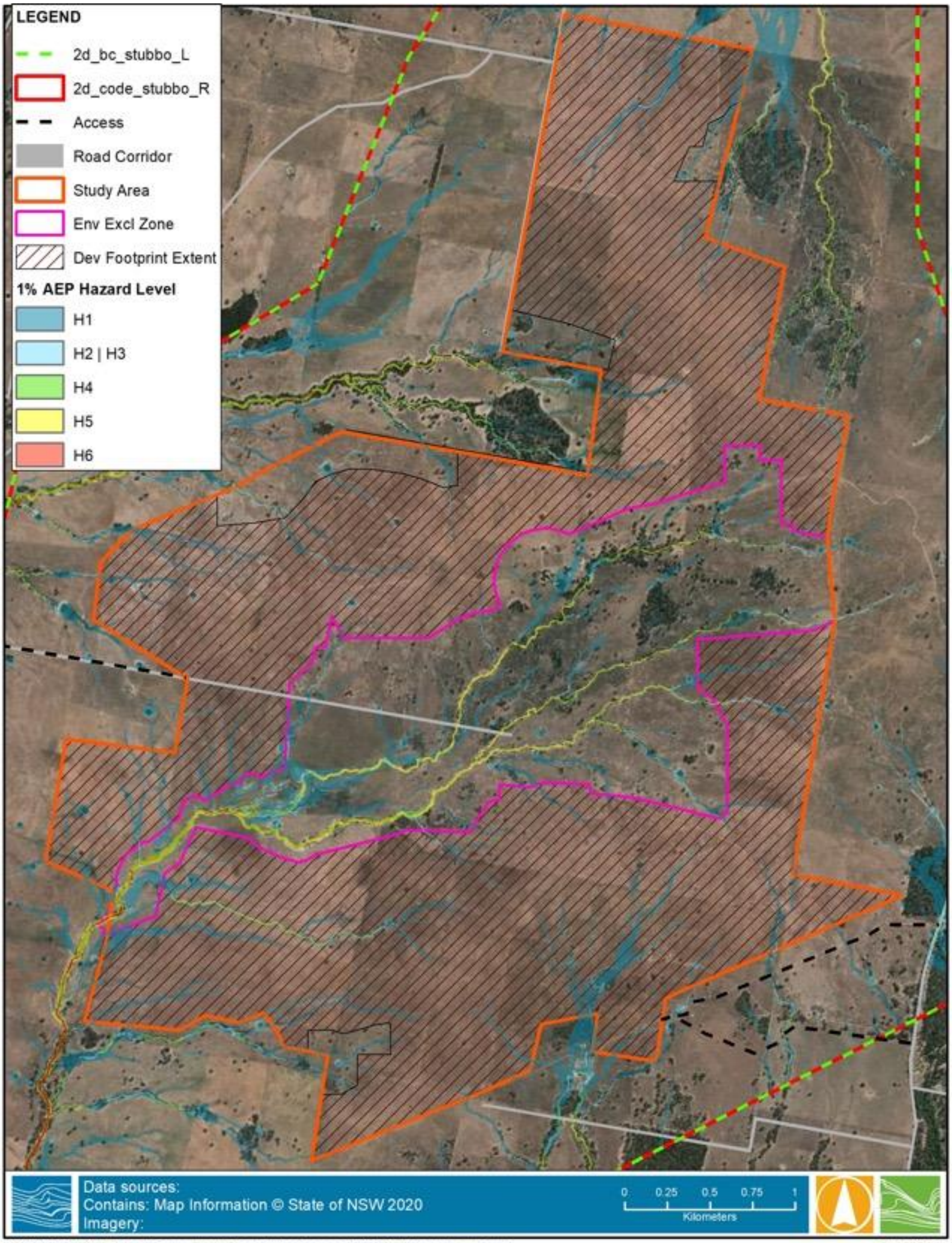

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FIGURE 4-17 1% AEP FLOOD HAZARD - CLIMATE CHANGE

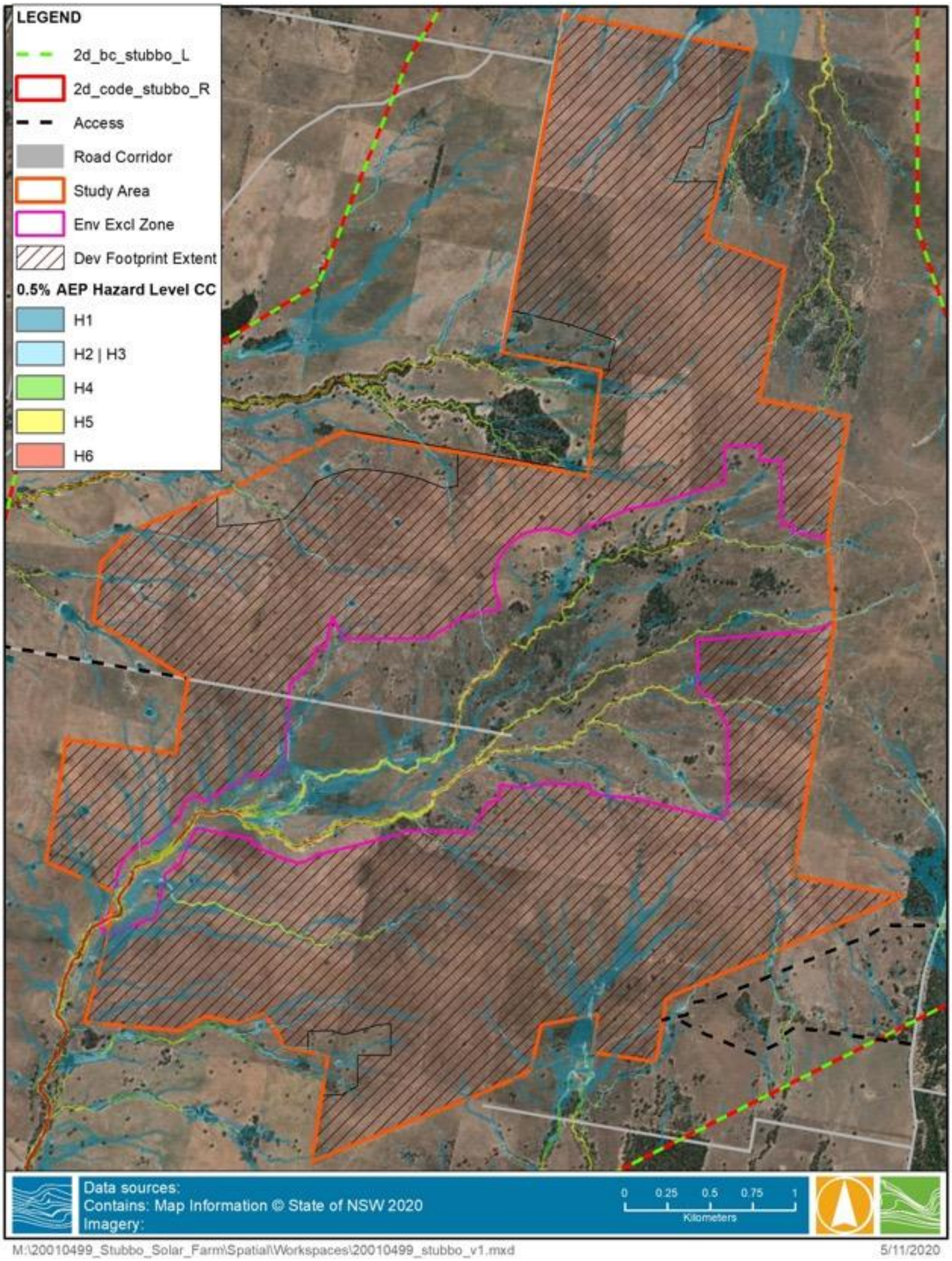

FIGURE 4-18 0.5% FLOOD HAZARD - CLIMATE CHANGE

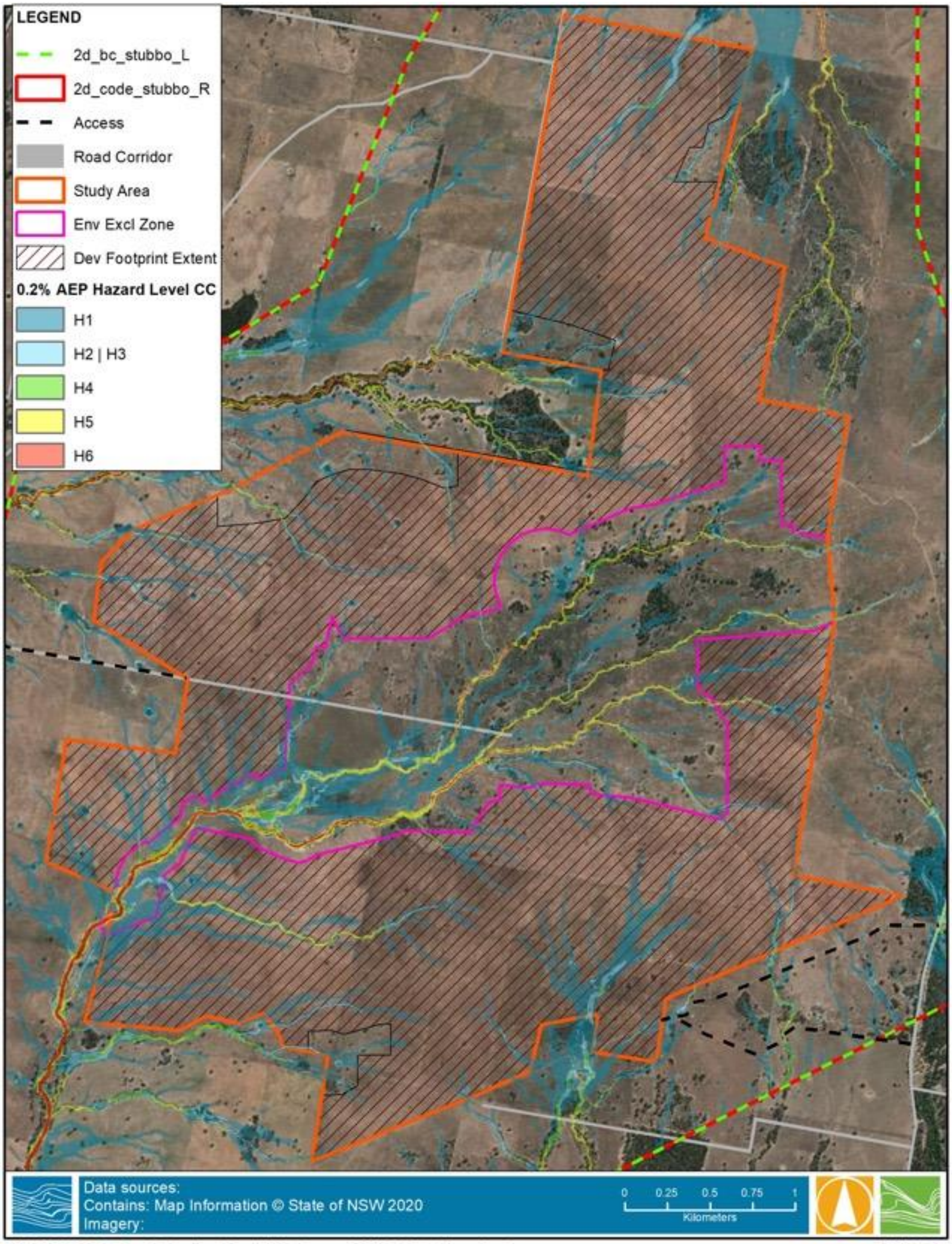

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FIGURE 4-19 0.2% AEP FLOOD HAZARD - CLIMATE CHANGE

4.7 Site Access

The site has two possible access locations as shown in Figure 4-20. The preferred option is to access the site from the south eastern side of the site. The flood depth in this area for the 1% AEP event is below 0.1 m. The alternate option accesses the site from the western side through an existing unsealed road. This area not inundated up to a 1% AEP event.

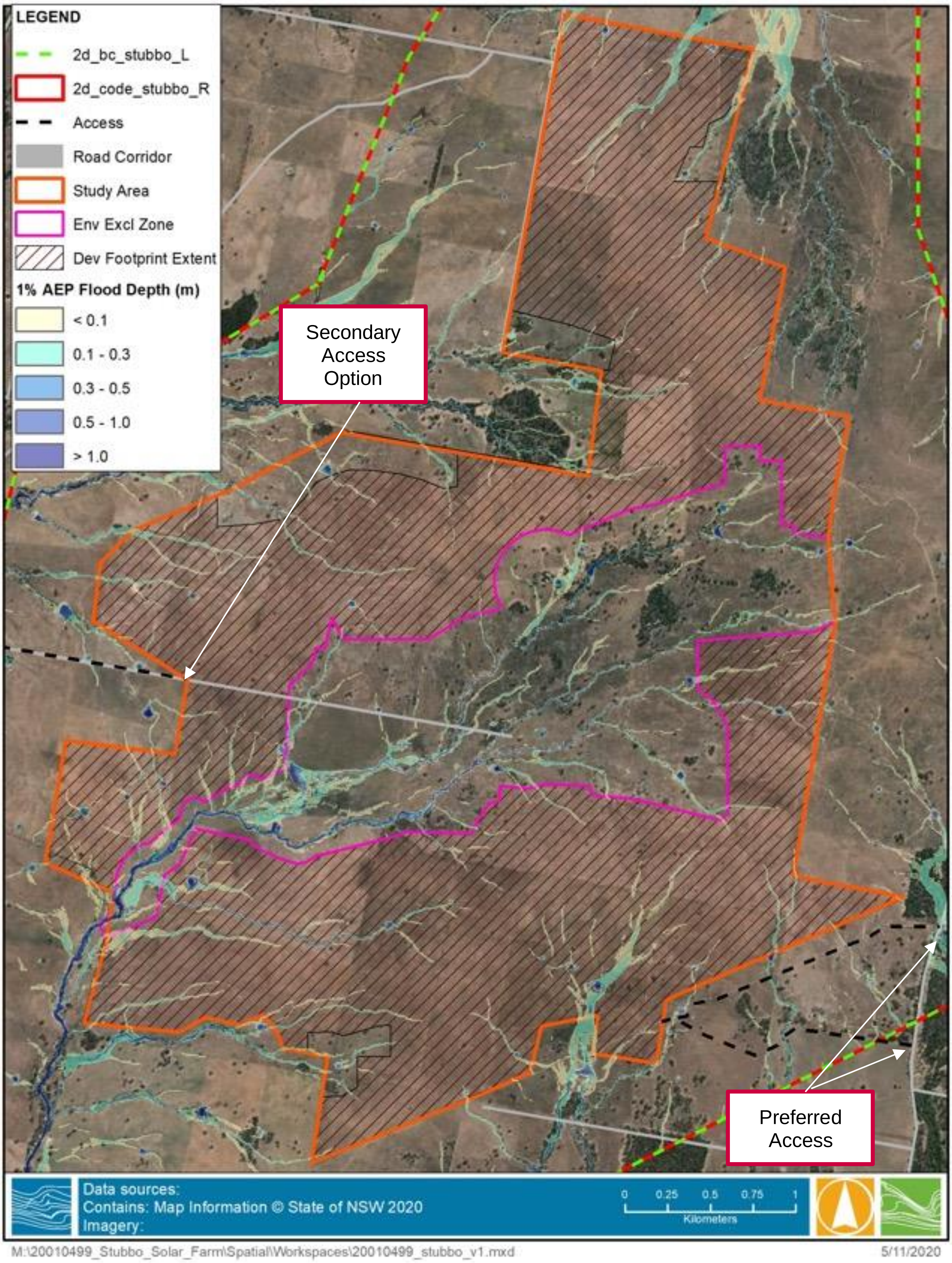

FIGURE 4-20 SITE ACCESS

5 PROPOSED DEVELOPMENT IMPACTS

5.1 Overview

The likely impact of the proposed development has been separated into the SEARs EIS requirements, including:

- Item 9 - Mapping of water and soils.
- Item 10 - Description of background conditions for any water resource likely to be affected by the development.
- Item 11 – Impacts on water quality.
- Item 12 - Impacts on hydrology.
- Item 13 - 21 - Impacts on flood behaviour.

Runoff management is an important consideration on solar farm sites as the addition of panels across large areas has the potential to increase erosion and runoff. There will be a shadow under each of the panels where rainfall will not fall directly on the ground, however runoff from the uphill panel will be able to flow across the ground and under the downhill panel, meaning that the PV array will not effectively increase the fraction impervious in the same way a paved road or a building does. As the PV panels are not fixed and change direction to track the sun, the drip line of runoff from the panels will vary depending on the time of the day. There has been a lot of discussion and some research[13] into the impact of solar farms on runoff in the USA and the UK. Some of the research has included theoretical modelling and some has been focused on applied field-based work. The general consensus is that a solar farm will not have a significant impact on the hydrology of the site under the following conditions:

- The soil profile has not been overly compacted due to heavy machinery during construction.
- Vegetation cover has been established.
- The site is established to encourage distributed flow across the surface rather than concentrated flows along narrow flow paths.
- The gap between each row of solar panels is greater than or equal to the width of the solar panel rows to allow the runoff from the upslope panel a buffer strip to spread across the surface and allow vegetation growth.
- Revegetation occurs along any concentrated drainage paths.
- Construction and operation of access tracks and crossings is completed ensuring appropriate sediment control and drainage is designed and implemented (slit fencing and sedimentation basins are used and swale are vegetated etc.).

While there may be some increase to the impervious fraction of the Subject site through the creation of roads and some small operational buildings this increase is considered to be very minor when compared to the site context as a whole.

5.2 Item 9 – Mapping of water and soils

Each of the EIS mapping of water and soils requirements (Item 9) are listed in Table 5-1 along with a response to each assessment requirement.

[13] Lauren M. Cook, S.M.ASCE; and Richard H. McCuen, M.ASCE (2013), Hydrologic Response of Solar Farms

TABLE 5-1 ITEM 9 - EIS ASSESSMENT REQUIREMENTS AND RESPONSES.

Item	EIS assessment requirement	Response
a.	Acid sulfate soils (Class 1, 2, 3 or 4 on the Acid Sulfate Soil Planning Map).	No analysis of acid sulphate soils has been undertaken within this report. Please refer to the soil section in the main EIS report.
b.	Rivers, streams, wetlands, estuaries (as described in s4.2 of the Biodiversity Assessment Method).	Mapping of the rivers streams and wetlands has been undertaken using a combination for hydrologic and hydraulic modelling. This is described in Section 3 and mapping shown in Section 4. Please see the Biodiversity Development Assessment Report for flora and fauna related analysis.
c.	Wetlands as described in 4.2 of the Biodiversity Assessment Method.	Mapping of the rivers streams and wetlands has been undertaken using a combination for hydrologic and hydraulic modelling. This is described in Section 3 and mapping shown in Section 4. Please see the Biodiversity Development Assessment Report for flora and fauna related analysis.
d.	Groundwater.	While groundwater analysis has not been undertaken in this project, the project is not anticipated to have any groundwater interaction with no changes to groundwater infiltration or extraction proposed. This is described in Section 2.2.2.
e.	Groundwater dependent ecosystems.	Not relevant to this project – refer to Biodiversity Development Assessment Report.
f.	Proposed intake and discharge locations.	There are no proposed intake or discharges proposed for the project, as described in Section 2.3.2.

5.3 Item 10 - Description of background conditions for any water resource likely to be affected by the development.

Each of the EIS water resource background conditions descriptions (Item 10) are listed in Table 5-2 along with a response to each assessment requirement.

TABLE 5-2 ITEM 10 - EIS ASSESSMENT REQUIREMENTS AND RESPONSES.

Item	EIS assessment requirement	Response
a.	Existing surface and groundwater.	The existing surface water background conditions have been mapped through the combination of hydrologic and hydraulic modelling. The methodology is covered in Section 3 with mapping shown in Section 4. While groundwater has not been covered in detail in this report there is no anticipated impact to groundwater given no extraction or change to infiltration is anticipated to occur.

Item	EIS assessment requirement	Response
b.	Hydrology, including volume, frequency and quality of discharges at proposed intake and discharge locations.	The hydrology of the site has been mapped through the combination of hydrologic and hydraulic modelling. The methodology is covered in Section 3 with mapping shown in Section 4. As discussed in Section 2.3.2 not intake or discharge is proposed to occur.
c.	Water Quality Objectives (as endorsed by the NSW Government http://www.environment.nsw.gov.au/ieo/index.htm) including groundwater as appropriate that represent the community's uses and values for the receiving waters.	The proposed development is not anticipated to have any negative water quality impacts provided the recommendations set out in Section 6 are met and construction and operation activities meet best practice guidelines for stormwater management and quality.
d.	Indicators and trigger values/criteria for the environmental values identified at (c) in accordance with the ANZECC (2000) Guidelines for Fresh and Marine Water Quality and/or local objectives, criteria or targets endorsed by the NSW Government.	The proposed development is not anticipated to have any negative water quality impacts provided the recommendations set out in Section 6 are met and construction and operation activities meet best practice guidelines for stormwater management and quality.
e.	Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions	The Subject Site has been shown to be of low flood risk (shown in Section 4) with minimal risk to changes in internal or external waterway flows (discussed in Section 5.1).

5.4 Item 11 – Impacts on water quality

Each of the EIS water quality impact requirements (Item 11) are listed in Table 5-3 along with a response to each assessment requirement.

TABLE 5-3 ITEM 11 - EIS ASSESSMENT REQUIREMENTS AND RESPONSES.

Item	EIS assessment requirement	Response
a.	The nature and degree of impact on receiving waters for both surface and groundwater, demonstrating how the development protects the Water Quality Objectives where they are currently being achieved, and contributes towards achievement of the Water proposed stormwater and wastewater management during and after construction being achieved. This should include an assessment of the mitigating effects of proposed stormwater and wastewater management during and after construction.	The proposed development is not anticipated to impact receiving waterways or groundwater, as described in Section 5.1, as long as the recommendations outlined in Section 6 are met. Similarly, no impact to water quality objectives should be achieved provided the recommendations set out in Section 6 are met and construction and operation activities meet best practice guidelines for stormwater management and quality.
b.	Identification of proposed monitoring of water quality.	Water quality monitoring is proposed in Section 6, recommending baseline water quality testing prior to construction and ongoing monitoring through construction and operation. Water quality testing should meet best practice guidelines and ANZECC (2000) Guidelines for Fresh and Marine Water Quality and/or local objectives.

5.5 Item 12 - Impacts on hydrology

Each of the EIS hydrologic assessment requirements (Item 12) are listed in Table 5-4 along with a response to each assessment requirement.

TABLE 5-4 ITEM 12 - EIS ASSESSMENT REQUIREMENTS AND RESPONSES.

	EIS assessment requirement	Response
a.	Water balance including quantity, quality and source.	Given there is no significant increase to the Subject Site fraction impervious no increase to runoff volumes are anticipated, see Section 5.1. Runoff water quality changes are most likely to be impacted during construction with limited operational impact. This will be managed with as part of the site Stormwater Management Plan developed as part of the Site Operation Plan. Recommendations for the Stormwater Management Plans are included in Section 6.

	EIS assessment requirement	Response
b.	Effects to downstream rivers, wetlands, estuaries marine waters and floodplain areas.	Given there is no significant increase to the Subject Site fraction impervious, no increase to runoff volumes are anticipated, see Section 5.1. Changes to runoff water quality are most likely during construction with limited impact during general operation. The potential for runoff water quality from the subject site to be impacted during construction will be managed through a Construction Stormwater Management Plan, with ongoing management of runoff water quality managed through an Operational Stormwater Management Plan (as well as any other relevant Management Plan as requested by the Secretary). General recommendations on the management of stormwater are included in Section 6.
c.	Effects to downstream water-dependent fauna and flora including groundwater dependent ecosystems.	Effects to downstream water dependent fauna and flora are addressed in the Biodiversity Development Assessment Report (BDAR).
d.	Impacts to natural processes and functions within rivers, wetlands, estuaries and floodplains that affect river system and landscape health such as nutrient flow, aquatic connectivity and access to habitat for sprawling and refuge (i.e. river benches).	Given there is no significant increase to the Subject Site fraction impervious, no increase to runoff volumes are anticipated, see Section 5.1. Changes to runoff water quality are most likely during construction with limited impact during general operation. The potential for runoff water quality from the subject site to be impacted during construction will be managed through a Construction Stormwater Management Plan (as well as any other relevant Management Plan as requested by the Secretary), with ongoing management of runoff water quality managed through an Operational Stormwater Management Plan. General recommendations on the management of stormwater are included in Section 6.
e.	Changes to environmental water availability, both regulated and unregulated/rules-based sources of such water.	Given there is no significant increase to the Subject Site fraction impervious, no increase to runoff volumes are anticipated, see Section 5.1. Changes to environmental water availability will be addressed in main EIS report.

	EIS assessment requirement	Response
f.	Mitigating effects of proposed stormwater and wastewater management during and after construction on hydrological attributes such as volumes, flow rates, management methods and re-use options.	Given there is no significant increase to the Subject Site fraction impervious, no increase to runoff volumes are anticipated. Changes to runoff water quality are most likely during construction with limited impact during general operation. The potential for runoff water quality from the subject site to be impacted during construction will be managed through a Construction Stormwater Management Plan (as well as any other relevant Management Plan as requested by the Secretary), with ongoing management of runoff water quality managed though an Operational Stormwater Management Plan. General recommendations on the management of stormwater are included in Section 6.
g.	Identification of proposed monitoring of hydrological attributes.	Monitoring of water quality during construction is recommended, primarily to ensure no increases in turbidity due to the earthworks occur. Prior to construction commencement it is recommended baseline water quality results be captured and periodic water quality sampling be undertaken during the construction period. This is discussed in Section 6.

5.6 Items 13 to 21 - Impacts on flooding

Each of the EIS flood assessment requirements (Items 13 - 21) are listed in Table 5-5 along with a response to each assessment requirement.

TABLE 5-5 ITEMS 13-21 - EIS ASSESSMENT REQUIREMENTS AND RESPONSES.

Item	EIS assessment requirement	Response
13 a.	Mapping of flood prone land.	Mapping of flood prone land has been completed through the combination of hydrologic and hydraulic modelling. The methodology is covered in Section 3 with mapping shown in Section 4.
13 b.	Mapping of the flood planning area, the area below the flood planning level.	Mapping of flood planning areas and levels has been completed through the combination of hydrologic and hydraulic modelling. The methodology is covered in Section 3 with mapping shown in Section 4.
13 c.	Mapping of Hydraulic categorization (floodways and flood storage areas)	Mapping of flood ways and storage areas has been completed through the combination of hydrologic and hydraulic modelling. The methodology is covered in Section 3 with mapping shown in Section 4.
13 d.	Mapping of Flood Hazard	Mapping of flood hazard has been completed through the combination of hydrologic and hydraulic modelling. The methodology is covered in Section 3 with mapping shown in Section 4.

Item	EIS assessment requirement	Response
14	The EIS must describe flood assessment and modelling undertaken in determining the design flood levels for events, including a minimum of the 5% Annual Exceedance Probability (AEP), 1% AEP, flood levels and the probable maximum flood, or an equivalent extreme event.	Flood modelling and mapping has been undertaken determining flood levels a range of events including the 5% AEP, 1% AEP and PMF. The methodology is covered in Section 3 with mapping shown in Section 4.
15a	Current flood behaviour for a range of design events as identified in 14 above. This includes the 0.5% and 0.2% AEP year flood events as proxies for assessing sensitivity to an increase in rainfall intensity of flood producing rainfall events due to climate change.	Flood behaviour has been determined for a range of events including the 5% AEP, 1% AEP and PMF. The methodology is covered in Section 3 with mapping shown in Section 4. Climate Change sensitivity has been assessed and is included in Section 4.6.
16	Modelling in the EIS must consider and document:	
17	Existing council flood studies in the area and examine consistency to the flood behaviour documented in these studies.	The only flood study found in the nearby area, is the Gulgong Stormwater Drainage Study. There is little information available on Gulgong study to make any realistic comparison with the flood estimation conducted in this study. In addition, the Gulgong study area was confined to the urban area of Gulgong and there was no overlapping between the flood study areas or similarities in study area. This is documented in Section 2.2.5.
18	The impact on existing flood behaviour for a full range of flood events including up to the probable maximum flood, or an equivalent extreme flood.	The development is no anticipated to increase the impervious fraction or alter the topography within the Subject Site and therefore no resulting in detrimental changes in potential flood affection of other developments or land is expected to occur if the recommendations set out in Section 6 are followed.
19	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.	The development is no anticipated to increase the impervious fraction within the Subject Site and therefore no resulting in detrimental changes in potential flood affection of other developments or land is expected to occur if the recommendations set out in Section 6 are followed.

Item	EIS assessment requirement	Response
20	Relevant provisions of the NSW Floodplain Development Manual 2005.	Mapping and assessment of Flood Hazard has been undertaken using recommendations set out in the updated 2019 Australian Rainfall and Runoff. The methodology is covered in Section 3 with mapping shown in Section 4. The mapping is inline with the NSW Floodplain Development Manual but provides additional detail and updated recommendations on hazard category thresholds.
21 a.	Whether there will be detrimental increases in the potential flood affectation of other properties, assets and infrastructure.	Given there is no significant increase to the Subject Site fraction impervious, no increase to runoff volumes or flow rates are anticipated, and therefore no increase in flow or flood levels within downstream waterways or adverse impacts to properties, assets and infrastructure. This is discussed in Section 5.1.
21 b.	Consistency with Council floodplain risk management plans	The Subject Site is within the Mid Western Regional Council. There are no specific floodplain risk management plans which cover the Subject Site. The most recent Council floodplain risk management plan prepared within Mid Western Regional Council is understood to have been the *Floodplain Risk Management Study and Floodplain Risk Management Plan for Kandos & Rylstone (2017).* This document uses the *NSW Government's Floodplain Development Manual (2005)* to characterise and map Flood Hazard. This report has used updated guidance from Australian Rainfall and Runoff (2019) to characterise and map Flood Hazard which Mid Western Regional Council are expected to be used in their future floodplain risk management plans. This mapping and discussion is shown in Section 4.
21 c.	Consistency with Rural Floodplain Management Plans	There are no Rural Floodplain Management Plans covering the Subject Site, but the analysis and reporting carried out in this report is in line guidance from Australian Rainfall and Runoff (2019) is consistent with the expectations of a Rural Floodplain Management Plan. This mapping and discussion is shown in Section 4.
21 d.	Compatibility with the flood hazard of the land.	The general Flood Hazard within the Subject Site is considered low, with the exception of waterways and confined drainage lines. Access to the Subject is also relatively flood free making the development compatible with the Flood Hazard of the land. Most of the high flood hazard areas are within the EEZ. This mapping and discussion is shown in Section 4.
21 e.	Compatibility with the hydraulic functions of flow conveyance in floodways and storage in flood storage areas of the land.	The site is covered by numerous overland flow paths which convey overland flood flows. There are no proposed PV arrays in these areas and most of areas considered floodways or to hold flood storage are within the EEZ and no works (aside from crossings area) proposed in these areas. This mapping and discussion is shown in Section 4.

Item	EIS assessment requirement	Response
21 f.	Whether there will be adverse effect to beneficial inundation of the floodplain environment, on, adjacent to or downstream of the site.	Given there is no significant increase to the Subject Site fraction impervious, no increase to runoff volumes or flow rates are anticipated, and therefore no adverse effect to beneficial inundation of the floodplain environment, on, adjacent to or downstream of the site is anticipated provided recommendations set out in Section 6 are followed.
21 g.	Whether there will be a direct or indirect increase in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.	Given there is no significant increase to the Subject Site fraction impervious, no increase to runoff volumes or flow rates are anticipated, and therefore no increases in erosion, siltation, destruction of riparian vegetation or reduction in the stability of the river banks or watercourses is anticipated. All constructed drainage will be designed through a Stormwater Management Plan with recommendations set out in Section 6.
21 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.	The site is covered by the Mid-Western Regional Local Flood Plan. There is no specific mention of Stubbo within the plan, but the Subject Site is likely to fit within the "intervening rural areas". The development will be discussed with NSW SES and Mid-Western Regional Council and an Emergency Response Plan will be prepared with the consultation prior to construction commencement.
21 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.	The Subject Site has been defined as having a generally low flood risk (see Section 4). However, an Emergency Response Plan will be prepared covering the management and response to flooding. This document will be discussed with NSW SES and Mid-Western Regional Council prior to construction commencement.
21 j.	Emergency management evacuation and access, and contingency measures for the development considering the full range of flood risk (based upon the PMF or equivalent extreme flood event). These matters are to be discussed with and have the support of Council and the NSW SES.	The Subject Site access points have been defined as having a generally low flood risk (see Section 4.7). However, an Emergency Response Plan will be prepared covering the management and response to flooding. This document will be discussed with NSW SES and Mid-Western Regional Council prior to construction commencement.
21 k.	Any impacts the development may have on the social and economic costs to the community as a consequence of flooding.	Given there is no significant increase to the Subject Site fraction impervious, no increase to runoff volumes or flow rates are anticipated. Therefore, no social and economic costs to the community as a consequence of flooding are anticipated.

6 RECOMMENDATIONS

The flood modelling detailed in this report has shown the site and its potential access and egress routes to be generally categorised as having low flood risk with a minimal risk of causing adverse surface water related impacts. If the following recommendations and general stormwater management principles proposed are met the solar farm should not cause any adverse impacts on the hydrology of the catchment or the sediment loading of the runoff from the catchment:

- Infrastructure with the potential to cause pollution to waterways in the event of flooding, such as inverters and battery storage will be located with a minimum 300 mm freeboard above the maximum 1% AEP flood level. It is common for this type of infrastructure to be housed within shipping containers or small sheds with relatively small footprints. Given the shallow depths across the site, raising these small fill pads is highly unlikely to result in any adverse impacts offsite.
- Solar panels will be designed to provide a minimum of 300 mm freeboard for the lowest edge above the maximum 1% AEP flood level.This need not be a permanent setting, but it is suggested that the panels could be operated to tilt so the lowest edge can lift in times of flood.
- The panel post and footings should be designed to withstand the flood velocities described in this report, which are mostly low in the areas proposed for solar panels.
- The layout provided shows that no works are proposed within the immediate vicinity of Stubbo Creek or the unnamed creeks within the Environment Exclusion Zone (aside from the two necessary waterway track and cable crossings), so setbacks are not a concern. For the unnamed creek located to the south of Stubbo Creek, a setback of 20 m from each bank has been adopted in the site design layout. It is recommended these design attributes and setbacks be maintained.
- The two necessary waterway track and cable crossings and all internal tracks crossing the smaller watercourses within the proposed development footprint should be designed and constructed in compliance with the Department of Primary Industries, Office of Water, Guidelines for riparian corridors on waterfront land[14] and Guidelines for watercourse crossings on waterfront land[15].
- The south eastern access track waterway crossing will be an important structure for the development to occur safely while minimising waterway impact. Site specific designs for this structure are recommended with the designed and constructed in compliance with the Department of Primary Industries, Office of Water, Guidelines for riparian corridors on waterfront land[16] and Guidelines for watercourse crossings on waterfront land[17].
- A vegetation buffer is recommended within the watercourse and 20 metre setback areas (for second order streams within the development footprint).
- It is recommended that the best practice principles for stormwater and sediment control be incorporated into the design, construction and operation phases of the solar farm site as part of a Stormwater

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14 https://www.industry.nsw.gov.au/__data/assets/pdf_file/0003/160464/licensing_approvals_controlled_activities_riparian_corridors.pdf

15 https://www.industry.nsw.gov.au/__data/assets/pdf_file/0019/160471/licensing_approvals_controlled_activities_watercourse_crossings.pdf

16 https://www.industry.nsw.gov.au/__data/assets/pdf_file/0003/160464/licensing_approvals_controlled_activities_riparian_corridors.pdf

17 https://www.industry.nsw.gov.au/__data/assets/pdf_file/0019/160471/licensing_approvals_controlled_activities_watercourse_crossings.pdf

Management Plan for both construction and ongoing operation, along with other relevant EPA guidelines such as the Guidelines for Erosion & Sediment Control on Building Sites[18], which relates to stormwater and erosion management. Sediment control is important at all stages of design, construction, and operation.

- As discussed in Section 5.1, solar farms will not have a significant impact on the hydrology of the site as long as the following conditions are met:
  - The soil profile has not been overly compacted due to heavy machinery during construction, and if it has, mitigate the soil to increase infiltration rates.
  - Vegetation cover is encouraged to become established. Native grasses would be the preference, but when dealing with cleared farmland, improved pasture is likely to exist in the soils seed bank already.
  - The site is established to encourage uniformity distributed flow across the site topography rather than concentrated flows along narrow flow paths. This can be achieved through minor earthworks.
  - The gap between each row of solar panels is greater than or equal to the width of the solar panel rows to allow the runoff from the upslope panel a buffer strip to spread across the surface and allow vegetation growth. It should be noted the Stubbo Solar Farm is proposing to use trackers, so the area located under the panel will change throughout the day
  - Revegetation along any concentrated drainage paths (drains) is encouraged. Native vegetation such as grasses and sedges that tolerate frequent inundation would be preferred. These vegetated drainage paths should not be designed to trap and concentrate large flows, but to provide a filter for sediment control. They therefore do not require a large channel capacity; they are really to ensure water does not exit the property carrying elevated sediment loads.
- As discussed in Section 2.2.2, there is no anticipated impact to groundwater due the lack of change in impervious surface and no intended interaction with groundwater. However, there is potential for groundwater interaction to occur if deep excavation was required for construction of structure foundations. It is recommended an understanding of depth to groundwater is developed if excavation of any reasonable depth is required.
- As discussed in Section 2.3.2, The use of any farms dams during construction will be agreed with the landholder and the estimated maximum harvestable right dam capacity will not be exceeded..

[18] https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Land-and-soil/guidelines-erosion-sediment-control-building-sites.pdf

7 SUMMARY

The flood risk assessment conducted in this study assessed the flood behaviour for both the existing and Climate Change conditions. The 5%, 1%, 0.5% and 0.2% Annual Exceedance Probability, and Probable Maximum Flood were assessed using flood depth, velocity, and hazard levels. The site is found to be a low risk of flooding for both the existing and Climate Change conditions. Minimum changes to the land topography, impervious fraction and therefore runoff and groundwater infiltration are expected due to the nature of solar

If the above recommendations outlined in Section 6 are met and a relevant set of construction and operation Management Plans (to be approved prior to construction/operation commencement) are developed the development is not likely to have any major residual impacts on surface or ground water.

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