Flood Impact Assessment:
Jemalong Solar Station

Report Prepared for:

NGH Environmental

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1.0 INTRODUCTION

This report provides an assessment of the impacts of the proposed Jemalong Solar Station on flood behaviour in this part of the Lachlan River Floodplain. In particular this report addresses the following Director Generals Requirements issued for the application:

- *An assessment of any proposed modification to surface water management including modelling of redistribution of waters and an assessment of the impact on neighbouring properties and the associated watercourse and floodplain including a review of the proposed levees in accordance with the requirements of the Lachlan River Jemalong Gap to Condoblin Floodplain Management Plan, 2012).*
- *An appropriate assessment of potential flooding impacts undertaken generally in accordance with the principles, processes and guidelines as outlined in the NSW Government Floodplain Development Manual, 2005. The study shall consider a full range of potential flood events up to and including the Probable Maximum Flood (PMF) and any local floodplain management processes.*

The report if to be read in conjunction with the broader Environmental Impact Statement (EIS), to that end, a detailed description of the proposal and proposal background is not included in this report as this is covered in detail in the EIS documents.

2.0 FLOOD BEHAVIOUR

2.1. Existing knowledge

The development site is located on the Lachlan River floodplain, immediately downstream of the Jemalong Gap (Figure 2.1), a significant hydraulic control. A number of studies have been completed over the area to assist with planning for flood controls which have been implemented primarily to manage floodwaters for agriculture.

In 1978 the *Guidelines for Floodplain Development; Lachlan River Jemalong Gap to Condobolin (WRC, 1978),* hereon referred to the 1978 Guidelines, determined a flood planning level based on the 25 year ARI flood. These guidelines determined levee locations and heights and outlined proposed modifications to hydraulic control structures to better manage floodwaters for economic and environmental benefit.

From 2003 through to 2012 the floodplain risk management process (NSW Government, 2005) was followed and a flood study, floodplain risk management study and floodplain management plan were developed for this stretch of the Lachlan River

The flood studies undertaken make use of existing gauging data and use flood frequency analysis to estimate flood recurrence. The more recent significant events of 1952, 1974 and 1990 have been modelled as these historical events have influenced floodplain management and are recent enough to be understood by landholders.

The adopted 'design flood' for the current Floodplain Management Plan (FMP) (OEH, 2012) is the 1990 historical event and is identified as the 25 year ARI event. This adopted 'design flood' is very similar to the flood planning levels developed in the 1978 guidelines.

2.2. Flood behavior

Floods in this area are common, and cover a vast area of the floodplain for prolonged periods (DECCW, 2009). As mentioned, the Jemalong Gap, is a significant control with almost all floodwaters passing through this point. Downstream of the Jemalong Gap large flows in the Lachlan River spill onto the northern and southern floodplains. Generally the Lachlan River can be expected to convey approximately 15% of flood flows with the remainder split between the north and southern systems.

The proposed development is located in the southern system (Figure 2.1). Flows to the southern system enter at the 17 and 21 mile breakouts, downstream of the Jemalong Gap. The 21 mile breakout delivers floodwaters to the proposed development site.

The flows from these breakouts traverse an approximate 11km long corridor and merge downstream of the proposed development site at the Wilbertroy State Forest then move toward Lake Cowal, and re-join the Lachlan River further downstream.

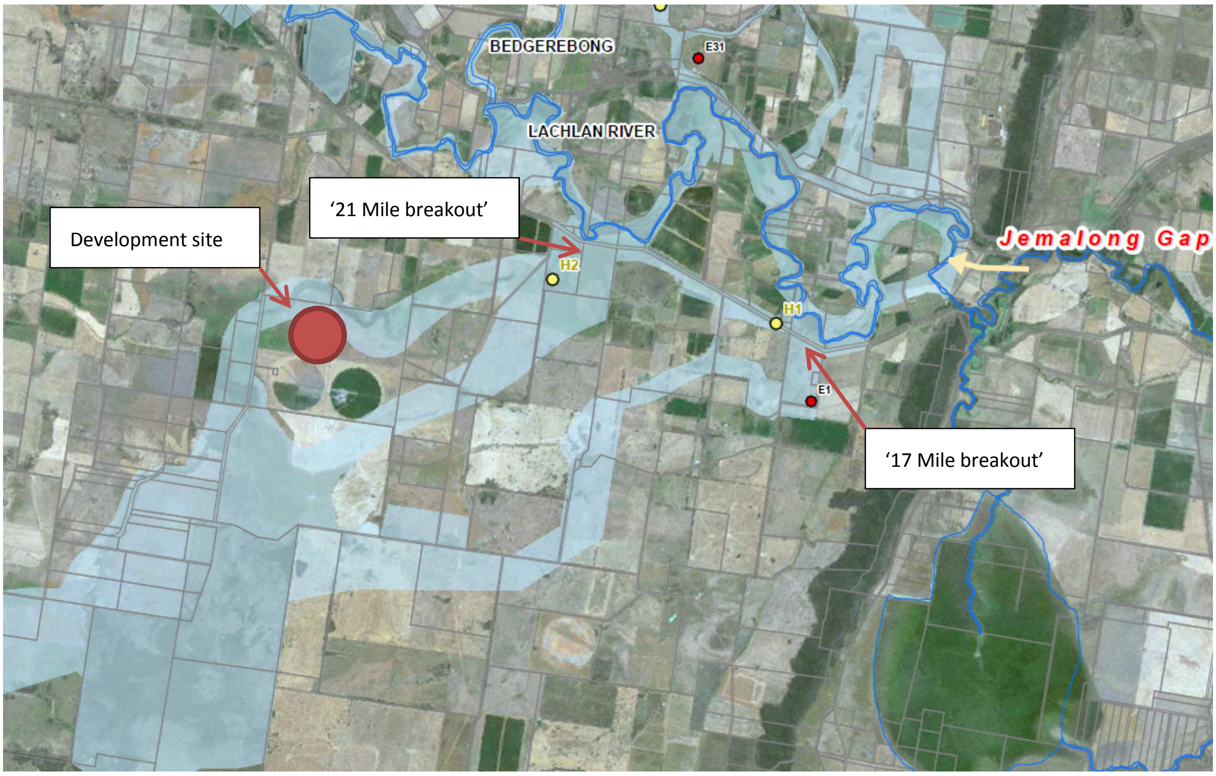


Figure 2.1 Development location in relation to design flood extents (approx.)

The area immediately downstream of the Jemalog Gap is particularly sensitive to hydraulic modifications. This part of the floodplain determines how flows are distributed to the northern floodplain, southern floodplain and the Lachlan River. This part of the floodplain (Zones A and B) have the highest level of control on in-stream works, discussed further below. The development site is located around the boundary between zone A and zone B. Refer Figure 2.2

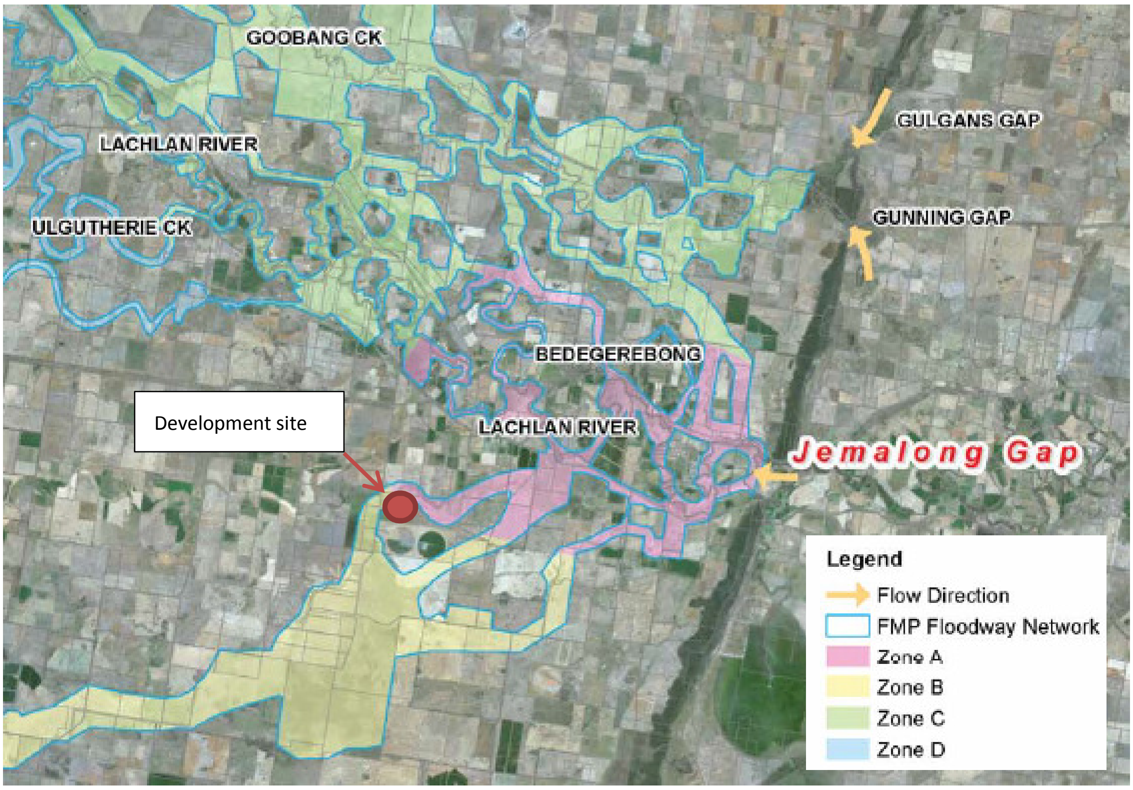


Figure 2.2 Floodway network and zones for management

2.3. Floodplain planning controls

The 1978 Guidelines established a feasible floodway network for this area of the floodplain. As mentioned, these guidelines included modifications to existing flood controls and the addition of new controls to improve floodway hydraulics for both economic and environmental objectives.

The more recent flood studies, floodplain risk management plans and flood management plans have further refined the 'floodway network' from the 1978 Guidelines. These studies have included further adjustments to maintain flow distribution and ensure the sustainable and equitable use of floodplain resources (OEH, 2012). Examples of modifications include removal of obstruction and reinstatement of natural flow regimes where feasible.

Modifications in and around floodways in the western rural areas of NSW is managed through Part 8 of the Water Act 1912. The Water Act 1912 requires that all flood control works within a designated floodplain need to be assessed for approval. The designated floodplain is defined by the green line and shaded area as shown in Figure 2.3. Works that are managed through the Water Act 1912 are known as 'controlled works', which are generally earthworks, embankments or levees or other works that are likely to affect the flow of water that are also declared to be a 'controlled work'. It is assumed that this project, given its location within the designated floodplain would be considered a 'controlled work'. More specifically; the following definition from the FMP (OEH, 2012) best describes the proposed works:

> *Any work that is situated, or proposed to be constructed on land that is, or forms part of, the bank of a river or lake, or, is within a designated floodplain, and is declared to be a 'controlled work'…*

Figure 2.3 Designated floodplain (development site shown in red)

Controlled works within the floodplain are either considered complying, or non-complying works under the Water Act 1912. The definition of 'complying' generally refers to where the NSW Office of Water (NOW) are satisfied that the work complies with the floodplain management plan for the area in which the work is situated or proposed to be constructed.

In this case no works are proposed within the floodway, although works are proposed on the broader designated floodplain. In this particular case the Floodplain Management Plan (OEH, 2012) notes:

> *Development outside of the limits of the FMP floodway network would not generally cause a significant redistribution of design flood flows or a significant increase in flood levels. However, while applications for flood control works in this area will generally be assessed as complying works, the assessment may need to take into account any potential increase in flood hazard or flood damage under flood conditions larger than the design flood. Adverse impacts could result, for example, if extensive works proposed near to the floodway network are substantially higher than the corresponding design level of the floodway network.*
>
> *Assessment of the flood hazard will be largely qualitative, taking into consideration existing works, the extent of proposed works, and the potential for localised impacts on neighbouring unprotected properties. Such an assessment would not need to go into the details required for works within the floodway, unless the impact on overall flood behaviour could be significant and therefore far-reaching.*

The key consideration for this development proposal is whether the possible; '*impact on overall flood behaviour could be significant and therefore far-reaching.'* As noted in the Floodplain Management Plan.

As outlined previously, the floodway network has been divided into four zones based on the hydraulic impact of works within the floodway (non-complying works). The proposed development is located adjacent to zone A and zone B. In general works within the floodway of these areas would not be approved. No works within these areas are proposed.

3.0 FLOOD IMPACT ASSESSMENT

3.1. Development in relation to floodway

Potential flood impacts are caused by modifications to the landscape within the floodplain. The proposed development consists of the following infrastructure located beyond the floodway, and within the designated floodplain; including:

- Approximately 90 solar array modules, each containing a field of 700 heliostats (tracking mirrors) and a 30m lattice-steel style tower with a small (1.8m x 2m) thermal receiver mounted at its top, facing downwards and southwards.
- A 'power island' located at the northern end of the site, comprising of (within a fenced compound):
    - two thermal storage tanks with associated pumps, valves and piping.
    - an air cooled condenser.
    - a steam generator and heat exchanger.
    - a noise hood, which is a light structure to limit noise from the electricity generator and steam turbine (but not a turbine shed structure).
    - a weatherproof kiosk containing control and communications equipment.
    - 1 weatherproof kiosk, housing 415V to 55V transformers and batteries, for each 3 solar arrays.
- A 66kV transformer station and switchgear in a separate, smaller fenced enclosure.
- Field piping, laid at approximately 500mm above ground level, connecting each of the 90 towers with the thermal storage tanks.
- One control kiosk for each 6 solar arrays, each housing 55kV electrical services, communications equipment and software systems (these kiosks being typical 40' storage containers).
- Internal gravel access tracks and parking to allow for site maintenance.
- Two 2400m^2 evaporation ponds (1.5m deep) located to the east of the solar field.
- Minimal flood levy earthworks comprising of a bund approximately 300mm in height, installed around the central 'power island' and transformer station. It is to be installed as a precaution against greater than 1:100 year flood events.
- Perimeter security fencing, approximately 2.3m high.

The 90 heliostat modules are spread out over the western portion of the property, taking up an area of about 52ha. The remaining power generation infrastructure, including generators, turbines, transformers, condenser and administration buildings are located close to the centre of the site.

Each module measures about 110 x 70m containing approximately 700 heliostats and a 30m tower with a thermal receiver at its top. Heliostats are set out in a fan arrangement focussed on the thermal receiver. Spacing between each heliostat ranges from about 2.6m at the front of the field, to 7m at the rear, an average of about 4.8m separation in each module

The heliostats consist of a steel support pole with the heliostat on top. The reflective surfaces are all set on the same horizontal plane with the base of the mirror at least 0.6m above the ground.

Figure 3.1 shows the layout of the proposed development in relation to the 1978 Guideline levees and the FMP approved levee locations. The proposed development is located beyond both the existing levee location which approximately follows the 1978 Guideline levee locations and the FMP approved levee location.

As mentioned 300mm high bund is proposed around the 'power island' to provide protection for infrastructure to the nominal 1% AEP event. The area of the power island is approximately 1ha.

No modifications within the floodway are proposed, and no modifications to existing levees are required for the proposal. If necessary, a new levee could be constructed following the alignment outlined in the FMP where it differs from the 1978 Guidelines to the north of the site.

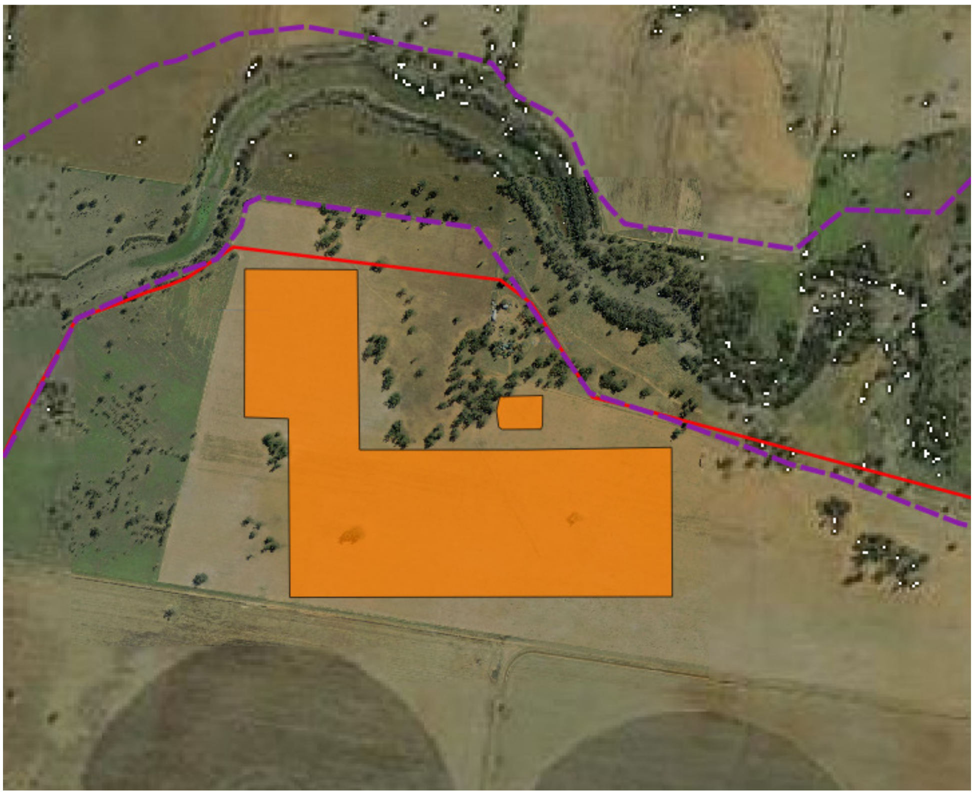


Figure 3.1 Development extents and 1978 Guideline Levees (purple) and FMP approved levee (red)

3.2. Flood conditions

Flood information in the area of the development is taken from the MIKE11 results in Appendix F of the Floodplain Management Study (DECWW, 2009). This area of the model is the flood path S21 MileB2, cross sections 2375 to 5549 (Appendix A).

As discussed, flood frequency analysis of gauged events was used to estimate flood depths, extents and predicted recurrence, and the 1952, 1974 and 1990 events were modelled as part of the Flood Management Study process. Both the 1974 and 1990 events have similar return intervals based on gauged data, of 30 years (3% AEP) and 25 years (4% AEP) respectively. The 1952 flood is estimated to be around a 200 year ARI event (0.5% AEP), although the available gauge data gives a large 90% confidence interval for this estimate from a 40 year to 1440 year recurrence.

3.3. Changes to the floodplain – surface roughness

As mentioned the development is located outside of the floodway network (Figure 3.1), however events greater than the 4% AEP (1990) event would overflow onto the floodplain and the proposed development may impact on these flood flows.

The addition of the solar arrays and their associated infrastructure, particularly the fields of heliostats will change the surface roughness over the site, from existing managed pasture to a large area of steel poles, at an average of 4.8m spacing over each of the 90 modules. In total the addition of approximately 62000 heliostats on steel support poles, over an area of about 52ha.

Flow behaviour (being a function of flow area, wetted perimeter and surface roughness) may change as a result of modification surface roughness and could subsequently impact flood levels and distribution over the broader landscape.

Existing pasture on the floodplain has a Manning's roughness of approximately 0.025-0.045 depending on the depth of flow. In this case value of 0.037 has been assumed for the floodplain areas based on a modified Cowan method for estimation of Manning's roughness (Table 3.1). The same method has been used to estimate the roughness associated with the heliostat field, producing a roughness of 0.102. As a comparison, of the Brisbane City Council guidelines for natural channel design (Table C.5) suggests a manning's roughness of 0.08 for *trees at 4 metre spacing, some low branches, few shrubs, few restrictions to walking*, which is not dissimilar to the field in terms of obstruction, suggesting that a roughness value of 0.102 may be conservative.

Table 3.1 Modified Cowan method for estimation of Manning's roughness (Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains, http://www.fhwa.dot.gov/BRIDGE/wsp2339.pdf, accessed 24/06/15)

Roughness component	**Floodplain pasture**	**Heliostat field**
Surface component (clay base soils)	0.020	0.020
Irregularity	0.000	0.000
Obstructions in floodplain	0.001	0.001
Vegetation height and type	0.015	0.080
Total	**0.037**	**0.102**

3.4. Changes to the floodplain – bund

A bund is proposed around the 'power island', an area of about 1ha. The bund height is proposed to be about 0.3m to provide flood protection for the infrastructure on site from approximately the 1% AEP event.

3.5. Impact assessment

The FMP states that "*Development outside of the limits of the FMP floodway network would not generally cause a significant redistribution of design flood flows or a significant increase in flood levels"* and that works beyond the floodway would *generally* be considered complying works. However in some cases impacts could be significant.

Given the extents of the works this issue of significance needs to be addressed. In this case adjustments to the existing hydraulic model are used to assess whether the impact is significant, or not, and therefore whether the works are considered 'complying' in relation to the current Floodplain Management Plan.

To investigate the impact of surface roughness changes over the area, a HECR RAS model was created using cross section information from the MIKE11 model. Cross sections from the S21Mile branch, from chainage CH849 to CH7617 were used as these are located adjacent to the proposed development area (refer to Appendix A).

In order to assess the impact of the development over the floodplain, surface roughness in the model was adjusted from pasture; a Manning's roughness of 0.037, to 0.102 to represent the heliostat field.

Two approaches were modelled to understand the likely flood impacts of the proposed development:

Approach 1.

Roughness was increased from the approved levee location into the floodplain to the edge of the current modelled extent, for CH 3275 to CH 5102 (chainages at or adjacent to the proposed development). This extends outside of the actual development footprint in some areas. For this approach the model extents (i.e. chainage cross sections) do not extend over the entire development site. Refer to Appendix A showing the overlay of these two areas.

Approach 2

Select model cross sections were extended over the development area maintaining the existing level at the end of the section (no survey data is available), and roughness adjusted over the footprint of the development area for CH 3275 to CH 5102. Refer to Appendix A showing the overlay of these two areas.

3.6. Development impact - quantitative assessment

The HEC RAS model created for this assessment estimates flood levels at less than the Mike11 model for the 0.5% AEP (1952) event. This is the result of removing simulated walls in the Mike11 model that artificially confine the 0.5% AEP event to within the levee bounds. The walls were removed to ensure that flows for the 0.5% AEP event spread out over the floodplain, as would occur in reality. Refer to the comparison between HEC RAS model results for the MIKE11 approach and the lowered wall approach in Figure 3.2 below.

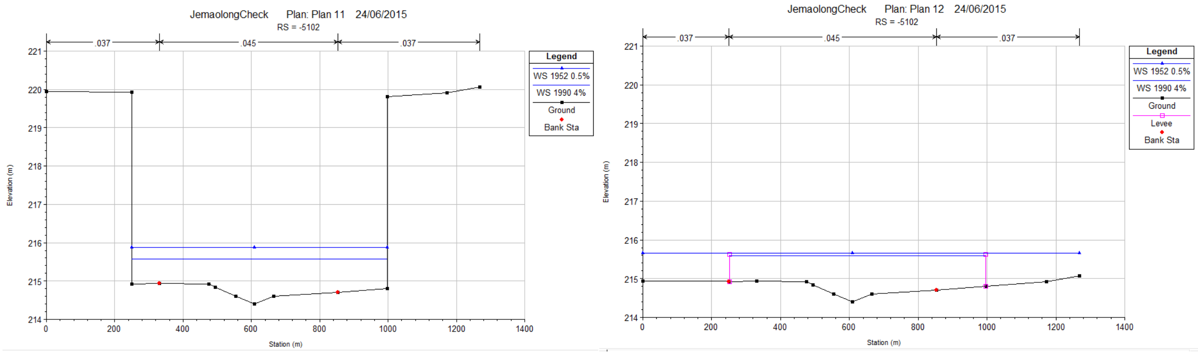


Figure 3.2 Modification to MIKE11 surface data - impact on flow depth at CH 5102

For Approach 1 which uses the existing model section widths from CH 3275 to CH 5102, the impact of roughness change to the area beyond the approved levees, was an increase to the 0.5% AEP flood level by a maximum of 2cm, with the impact extending upstream to CH 1689.

For Approach 2 which extended existing sections to cover the proposed development extent, the impact of roughness change to the area beyond the approved levees, from CH 3275 to CH 5102 was an increases flood levels by a maximum of 3cm with the impact extending upstream to CH 1689.

The small change in flood level reported from both Approach 1 and Approach 2 suggests that changes to roughness (as a result of the proposed development) is not sufficient to create a significant change in flood level to the overall flood extents.

Although the impact of the bund around the power island is not modelled as the bund does not intersect existing cross sections, the area of impact, in comparison to the area of impact associated with the heliostat field, and the impact of the heliostat field suggests that the bund around the 'power island' will not have a significant effect.

In addition there is no impact of the development on the 4% AEP event (1990) as this event is confined by the approved levee structures beyond the development area.

Approximate flood depths for the 0.5% AEP event over the site range between 0.45m to 0.88m at the upstream end and 0.09m to 1.14m at the downstream end (Table 3.2). Depths are based on recorded cross section surface levels closest to the development site.

Table 3.2 Flood depth estimates over the site

	Height difference between modelled 0.5% AEP flood and approximate ground surface in location of Solar Farm (m)		
	MIKE 11 model results from Flood Study (DECWW, 2009)*	**HEC RAS (Approach 1)**	**HEC RAS (Approach 2)**
3275 (upstream end of solar farm)	0.88	0.45	0.45
5102 (downstream end of solar farm)	1.14	0.67	0.09

* This result is highest due to the artificial walls used in the MIKE 11 model, see Figure 3.2 and associated discussion.

3.7. Events outside of those included in the FMP

The assessment criteria provided by the assessment agencies suggest a review of impacts for the full range of potential flood events up to and including the Probable Maximum Flood (PMF). The existing flood investigations cover the 1990 (4%), 1974 (3%) and 1952 (0.5%) events were estimated through a combination of flood frequency analysis, runoff routing Actual events were used as these are relevant to landowners' experiences in the area.

Estimation of flood flows outside of those considered in the Floodplain Management Study (DECCW, 2009) would require modelling of the entire system to determine flow distribution into the development area which would be considerable work, particularly when considered against the amount of disturbance in the floodplain.

An assessment of the available modelled events is considered sufficient to garner an understanding of the flood impacts associated with development at the site.

4.0 FLOOD MANAGEMENT RECOMMENDATIONS FOR THE DEVELOPMENT

4.1. Heliostat field

The area of heliostat fields is outside of the floodway. For events that extend out of the floodway, that is events nominally greater than the 4% AEP, the field will be inundated to some degree. For the largest event modelled, the 0.5% AEP event, flood depths over the heliostat area, using the highest estimates from the flood study (DECWW, 2009) range from 0.9m to 1.1m. The base of the heliostat panel, depending on surface levels is approximately 0.5m above the ground level, and can be tilted to bring the base more than 1.1m above the ground. In the event of a large flood making its way down the Lachlan River valley, the heliostat panels should be positioned to provide maximum clearance from the panel to the ground to keep the panels beyond flood waters. Panels can be tilted to avoid the 0.5% AEP estimated flood level.

4.2. Power Island

The 'Power Island' contains essential infrastructure associated with the conversion of collected heat to electricity. A bund, approximately 300mm high is proposed to provide protection for this infrastructure. A 300mm high bund will provide protection for this infrastructure for an event between and 4% AEP and 0.5% AEP. Refer to the range of flood depths for the 0.5% AEP listed in Table 3.2 for an indication of flood depths through the site.

4.3. Other infrastructure

Electrical systems below the 0.5% AEP level should be made flood-proof, or enclosed in water proof enclosures to ensure that in the event of a large flood infrastructure is protected.

Heat transfer piping of its nature will be waterproof, however electrical components associated with management and monitoring should also have associated protection from floodwaters.

5.0 EIS ASSESSMENT CRITERIA AND COMMENT

Assessment criteria	Comment
An assessment of any proposed modification to surface water management including modelling of redistribution of waters and an assessment of the impact on neighbouring properties and the associated watercourse and floodplain including a review of the proposed levees in accordance with the requirements of the *Lachlan River Jemalong Gap to Condoblin Floodplain Management Plan, 2012).*	The development is located outside of the approved floodway, therefore has no impact on floodway flows, which are flows up to approximately the 4% AEP event. For the 0.5% AEP event, which extends beyond the floodway into the floodplain, the assumed surface roughness change associated with the development has a minor impact on flood heights of up to 3cm in the vicinity of the site. This is not considered significant and therefore the works would be considered 'complying' as defined in the Floodplain Management Plan. A bund is proposed around the 'power island'. The area confined by the bund is small in relation to the heliostat field as such impacts are not significant. If requested the proponent may relocate the existing floodway levee location to the north of the site to align with the Floodplain Management Plan (OEH, 2012). If this occurs the available floodway will be increased, improving flood conveyance.

Assessment criteria	Comment
An appropriate assessment of potential flooding impacts undertaken generally in accordance with the principles, processes and guidelines as outlined in the NSW Government *Floodplain Development Manual, 2005.* The study shall consider a full range of potential flood events up to and including the Probable Maximum Flood (PMF) and any local floodplain management processes.	No modelling or assessments of events outside of those provided in the Floodplain Management Study (DECWW, 2009) and Floodplain Management Plan (OEH, 2012) have been undertaken. The range of events used in the FMP (4%, 3% and 0.5% AEP) is used to assess flood impacts over a range of recurrence intervals. There are no impacts from the development up to the 4% AEP design event which is confined to the floodway. For events up to the 0.5% AEP event there is a minor impact on flood levels of up to 3cm, this is not considered significant.

REFERENCES

Brisbane City Council 2009, *Natural Channel Design Guidelines*

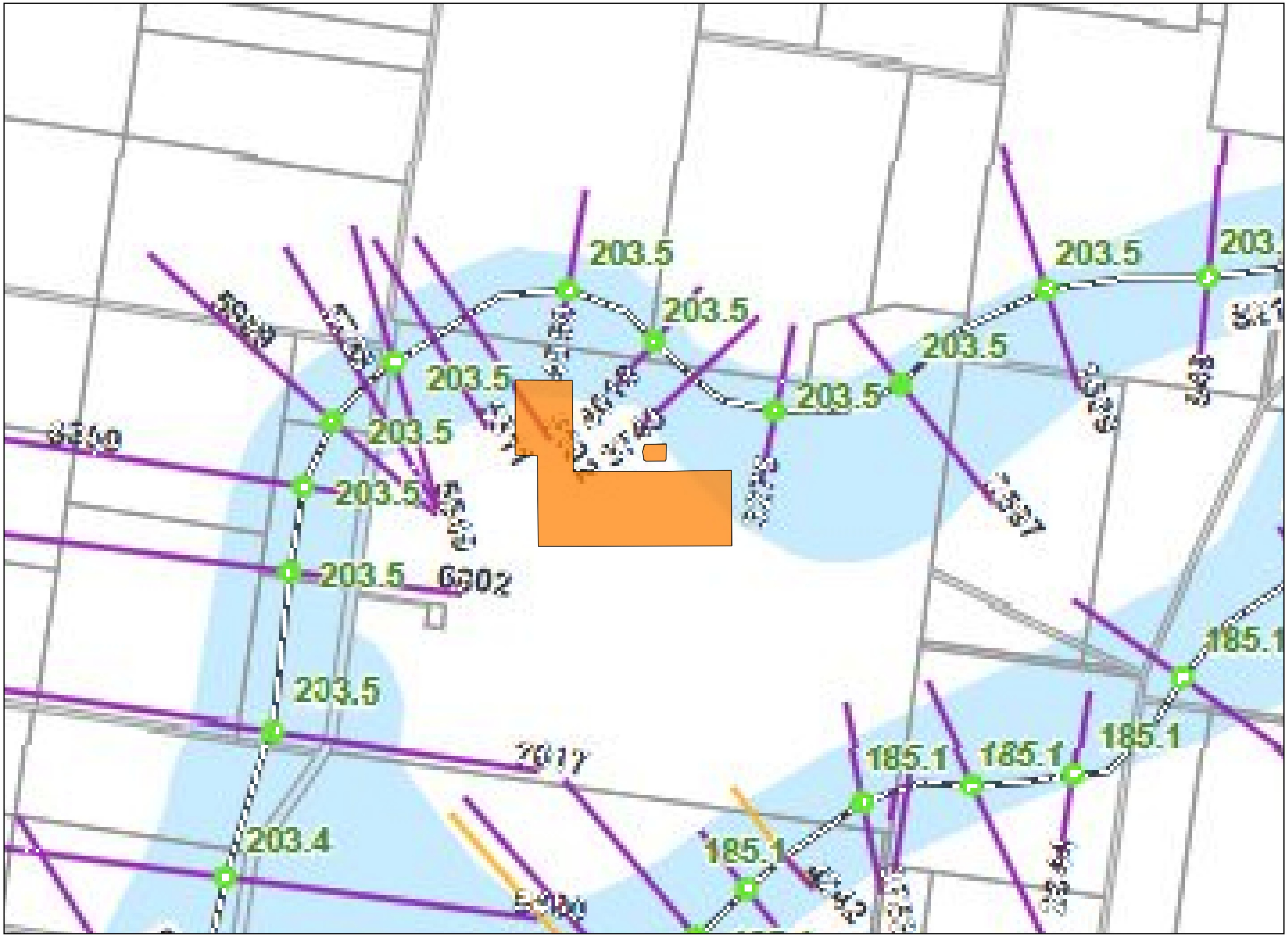
Department of Environment and Climate Change 2009, *Lachlan River Jemalong Gap to Condobolin Floodplain Risk Management Study*

Parsons Brinkerhoff 2004, *Lachlan River (Jemalong Gap to Condobolin), Lachlan, NSW, Rural Flood Study.*

Water Resoutces Commission 1978, *Guidelines for Floodplain Development; Lachlan River Jemalong Gap to Condobolin*

Office of Environment and Heritage 2012, *Laxchlan River, Jemalong Gap to Condoboli, Floodplain Management Plan.*

APPENDIX A – DEVELOPMENT FOOTPRINT AND MODEL SECTIONS



Legend

Development footprint

250 0 250 500 750 1000 m

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Flood impact assessment. Proposed Jemalong Solar Farm

Figure 1 - Development footprint in relation to MIKE11 model.

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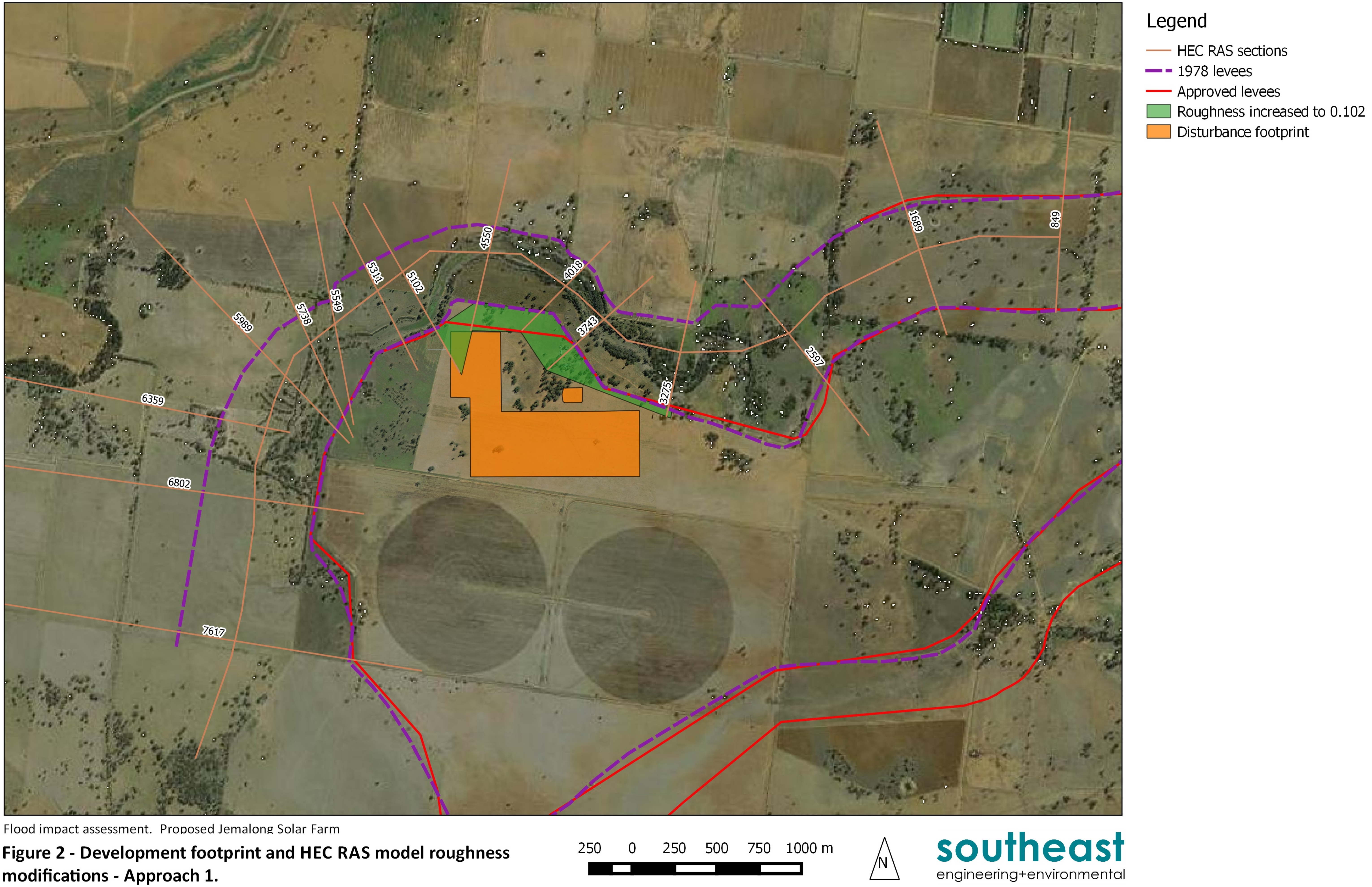

Flood impact assessment. Proposed Jemalong Solar Farm

Figure 2 - Development footprint and HEC RAS model roughness modifications - Approach 1.

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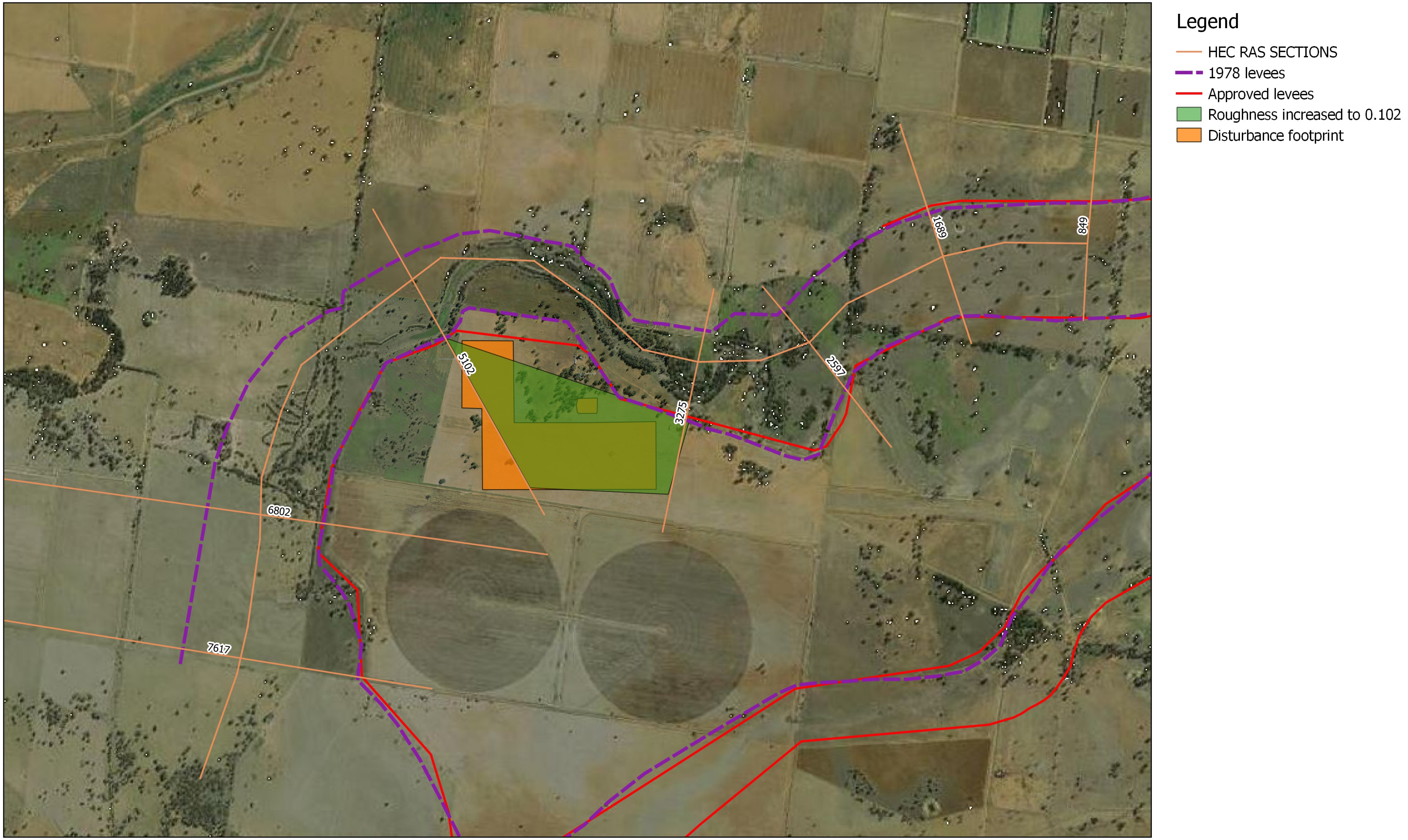

Flood impact assessment. Proposed Jemalong Solar Farm

Figure 3 - Development footprint and HEC RAS model roughness modifications - Approach 2

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APPENDIX B

Approach 1

River Sta	Flood levels for 1952 event (0.5% AEP) (mAHD)		
	Existing roughness	Modified roughness	Difference (m)
-849	216.55	216.55	0
-1689	216.43	216.44	0.01
-2597	216.42	216.43	0.01
-3275	216.26	216.28	0.02
-3743	216.16	216.17	0.01
-4018	216.1	216.11	0.01
-4550	215.87	215.87	0
-5102	215.61	215.61	0
-5311	215.49	215.49	0
-5549	215.41	215.41	0
-5738	215.27	215.27	0
-5989	215	215	0
-6359	214.96	214.96	0
-6802	214.95	214.95	0
-7617	214.94	214.94	0

Approach 2

	Flood levels for 1952 event (0.5% AEP) (mAHD)		
River Sta	Existing roughness	Modified roughness	Difference (m)
-849	216.55	216.55	0
-1689	216.39	216.41	0.02
-2597	216.38	216.4	0.02
-3275	216.25	216.28	0.03
-5102	215.03	215.03	0
-6802	214.95	214.95	0
-7617	214.94	214.94	0