Gunnedah Solar Farm - Flood Impact Assessment

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Prepared for:	**Photon**
Client representative:	**Robert Ibrahim**
Date:	**22 March 2018** **Rev02**

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Prepared by: .... Martin Jacobs Date: 22 March 2018

Reviewed by: .... Haydn Betts Date: 22 March 2018

Authorised by: .... Haydn Betts Date: 22 March 2018

Revision History					
Rev No.	**Description**	**Prepared by**	**Reviewed by**	**Authorised by**	**Date**
00	First Draft	Martin Jacobs	Haydn Betts	Adam Bishop	02/03/2018
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Executive summary

A flood impact assessment has been carried out on the proposed Solar Farm located at 765 Orange Grove Road Gunnedah, NSW for inclusion in the Environmental Impact Statement (EIS), in accordance with the Secretary's Environmental Assessment Requirements (SEARs). Flood modelling was undertaken to estimate flood levels for a range of design events, and to estimate the impacts the Solar Farm would have on flood levels.

The modelling indicated that the greatest impacts on flood levels would arise from the security fencing and the blockage caused by the accumulation of vegetative debris mats as debris on the fencing. It was found that, in the worst case, a solid wall of debris matting on the fence would increase flood levels by about 550mm at the fence, but these impacts are reduced to about 100 to 300mm at the site boundary. The impacts can be mitigated by dividing the fenced areas into paddocks with laneways between the fencing that allow flood flows to pass through the site. By adding these laneways and reducing the amount of debris blockage (to a realistic scenario), the impacts are reduced to about 340mm directly adjacent to the fence, about 110mm at the upstream property boundary and up to about 18mm at the most affected sensitive receiver. These impacts decrease with increasing distance from the site and depend on undulations in the ground surface and the pattern of flow around the site.

Flood maps have been prepared that show the spatial distribution of the impacts, and tables show how the impacts affect various sensitive receivers (especially residences and farm buildings) and other features (e.g. roads) in the vicinity of the proposed Solar Farm.

1. Context and purpose

Photon Energy Australia Pty Ltd has engaged the services of **pitt&sherry** to undertake a preliminary flood impact assessment for the proposed Gunnedah Solar Farm. The intent of the flood assessment is to:

- Understand the nature of flooding at the site
- Estimate flood levels
- Estimate the impacts that the proposed Solar Farm has on flood levels.

2. Location

The site is located at 765 Orange Grove Road, Gunnedah, New South Wales, and is located on the floodplain of the Namoi River approximately 9km north-east of the town of Gunnedah, as shown in Figure 1. The Lot details of the subject property are summarised in Table 1.

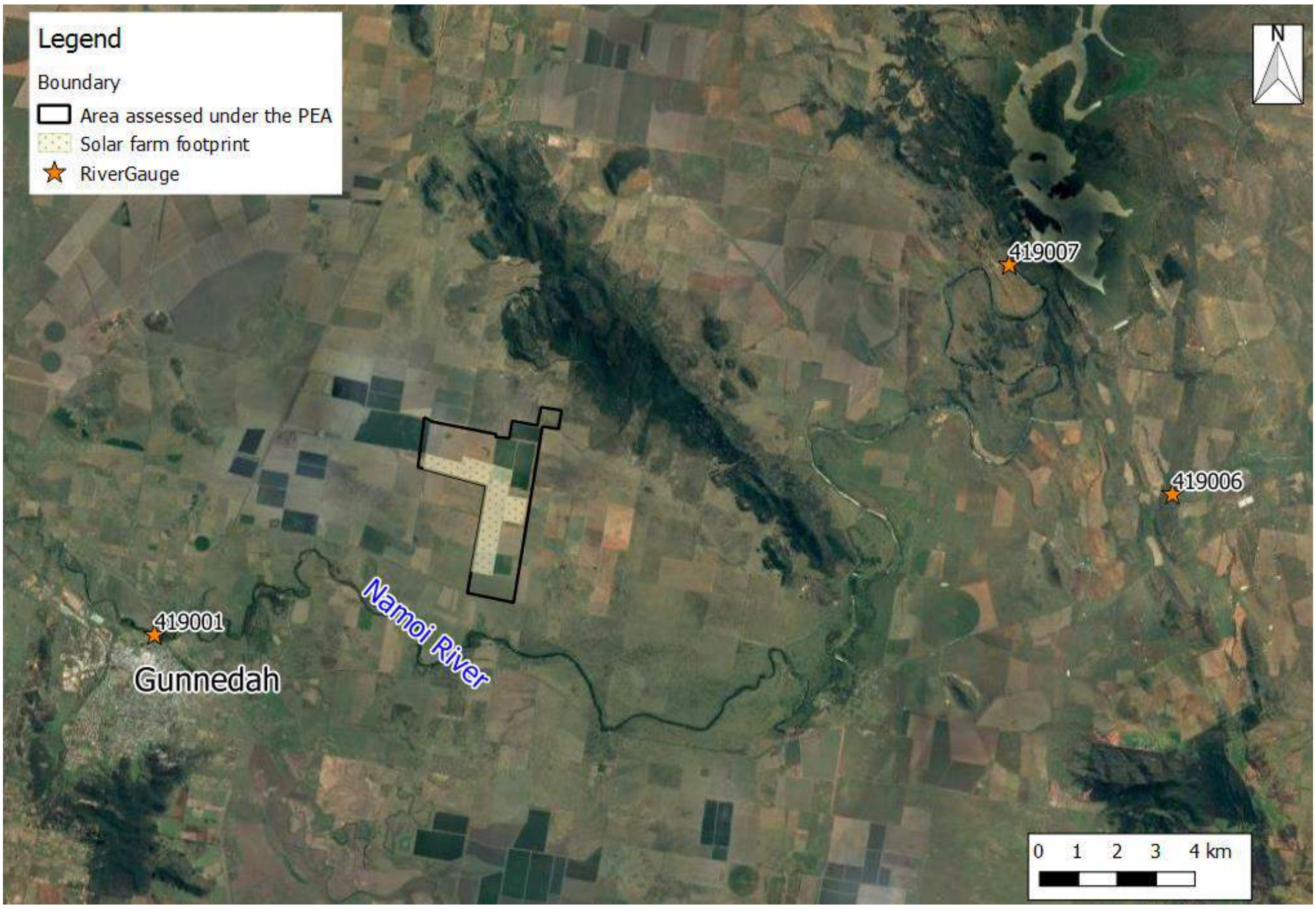


Figure 1 Gunnedah Solar Farm property boundary

Table 1 Property details

Location	Address	Lot and DP
Gunnedah	765 Orange Grove Road, Gunnedah, NSW, 2380	Lot 1 DP 186590 Lot 1 DP 1202625, Lot 153 DP 754954, Lot 264 DP 754954, Lot 2 DP 801762, Lot 151 DP 754954

3. Gunnedah SEARs - Flooding and Coastal Erosion

Secretary's Environmental Assessment Requirements (SEARs) for the proposed Gunnedah Solar Farm were issued on 25 August 2017 from the Office of Environment and Heritage. The SEARs addressed in this document are outlined in Table 2.

Table 2: Relevant SEARs items

Item Number	Sub-Item	Comments
10. The EIS must **map the following features** relevant to flooding as described in the Floodplain Development Manual 2005 (NSW Government 2005) including:	a. Flood prone land	The site is located within an area that is prone to flooding in events less than 5%AEP
	b. Flood planning area, the area below the flood planning level.	The site is located within the Flood Planning area under the Gunnedah Local Environment Plan (published 26-02-2012)
	c. Hydraulic categorisation (floodways and flood storage areas).	The site is located in the floodplain of the Namoi River and functions principally as flood storage.
11. The EIS must **describe flood assessment and modelling undertaken** in determining the design flood levels for events, including a minimum of the 1 in 10 year, 1 in 100 year flood levels and the probable maximum flood, or an equivalent extreme event.		See Sections 4, 5 and 6
12. The EIS must model the effect of the proposed development (including fill) on the flood behaviour under the following scenarios:	a. Current flood behaviour for a range of design events as identified in item 11 above. This includes the 1 in 200 and 1 in 500 year flood events as proxies for assessing sensitivity to an increase in rainfall intensity of flood producing rainfall events due to climate change.	See Section 6 The Probable Maximum Flood (PMF) has been included as a proxy for the 200 year ARI and 500 year ARI floods.
13. Modelling in the EIS must consider and document:	a. The impact on existing flood behaviour for a full range of flood events including up to the probable maximum flood.	See Sections 4, 5 and 6 The range of flood events comprises 10%AEP, 5%AEP, 1%AEP and PMF
	b. 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, hazards and hydraulic categories.	Changes to flood levels and velocities are shown in the flood maps in Appendix A, and the tables of changes at sensitive receivers in Section 5.8
	c. Relevant provisions of the NSW Floodplain Development Manual 2005.	The NSW Floodplain Development Manual has been addressed where practical in the model preparation for this assessment.
14. The EIS must assess the impacts of the proposed	a. Whether there will be detrimental increases in the potential flood affectation of	Changes to flood levels are shown in the flood maps in Appendix A,

Item Number	Sub-Item	Comments
development on flood behaviour, including:	other properties, assets and infrastructure.	and the tables of changes at sensitive receivers in Section 5.8
	b. Consistency with Council floodplain risk management plans.	Council's floodplain risk management plans have been consulted in the course of this Flood Impact Assessment
	c. Compatibility with the flood hazard of the land.	Council's floodplain risk management plans have been consulted in the course of this Flood Impact Assessment
	d. Compatibility with the hydraulic functions of flow conveyance in floodways and storage in flood storage areas of the land.	It is considered that the proposed development is compatible with the hydraulic functions of flow conveyance and flood storage in the vicinity.
	e. Whether there will be adverse effect to beneficial inundation of the floodplain environment, on, adjacent to or downstream of the site.	It is considered that the development will not appreciably change the beneficial effects of inundation in the vicinity.
	f. Whether there will be direct or indirect increase in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.	The site is not located close to the Namoi River, and will not affect the river's erosion, siltation, vegetation, and bank stability
	g. Any impacts the development may have upon existing community emergency management arrangements for flooding. These matters are to be discussed with the SES and Council.	It is considered that the development will not affect community emergency management arrangements.
	h. Whether the proposal incorporates specific measures to manage risk to life from flood. These matters are to be discussed with the SES and Council.	It is considered that the development will not change risks to life from flooding.
	i. Emergency management, evacuation and access, and contingency measures for the development considering the full range or flood risk (based upon the probable maximum flood or an equivalent extreme flood event). These matters are to be discussed with and have the support of Council and the SES.	It is considered that the development will not change emergency evacuation and access.

Item Number	Sub-Item	Comments
	j. Any impacts the development may have on the social and economic costs to the community as consequence of flooding.	It is considered that the development will not change social costs to the community. The economic costs relate to changes in flooding, which are mapped in Appendix A. There are economic benefits associated with the development of the proposed Solar Farm, but a comprehensive economic assessment is beyond the scope of the current study.

4. Construction of flood model

4.1 General approach

The flood model has been constructed from available rainfall and terrain data and has been verified by comparing flood levels with historic records and other flood studies, especially river gauge records and the *Gunnedah and Carroll Floodplain Management Plan* 1999 (SMEC Study, updated 2014). Flows are described as flood hydrographs, which are based on historic data for the 1984 flood. The terrain data used were acquired from the Shuttle Radar Topography Mission (SRTM), which comprises a digital elevation model (DEM) with a grid size of about 30m. Though a finer grid size would be preferable, especially in describing small features such as minor irrigation channels and farm drains, these terrain data were considered the most appropriate because they cover the entire flood plain. The roughness of the flood plain was described as a single roughness value that covers the state of crops, vegetation and general farm fences. A low estimate of the roughness was used because it conservatively over-estimates impacts. The fences around the Solar Farm were described as discrete features that included representations of the nature and degree of blockage that would occur from flood debris.

4.2 Previous assessments, studies and sources of flood information

Previous assessments of flood levels around the site include the following:

- Stewart Surveys, which estimated a 1% AEP flood level at RL 269.95 at the site for Lot 2 DP 801762
- NSW SES FloodSafe brochure, which refers to estimated flood levels at the Gunnedah Gauge (Cohen's Bridge) for the 1998, 1955 and the 1% AEP flood level (available on-line)
- Gunnedah and Carroll Floodplain Management Plan 1999, SMEC Study, updated 2014, which approximates the 1955 flood to the 1% AEP flood event. (available on-line)
- Carroll to Boggabri Floodplain Management Plan 2006, Webb Mckeown & Associates on behalf of Department of Natural Resources (available on-line), which relies on earlier modelling by SMEC and infers conclusions for the purposes of planning.

4.3 Hydrology

4.3.1 Gauges

The nearest River Gauges to the site are as follows:

- Gauge 419001 – Catchment area = 17100 km², Namoi River at Gunnedah located about 10 km downstream of the proposed solar farm site

- Gauge 419006 – Catchment area = 4670 km², Peel River at Carroll Gap, located about 25 km upstream of the proposed solar farm site
- Gauge 419007 – Catchment area = 5700 km², Namoi River, Downstream Keepit Dam located about 28 km upstream of the proposed solar farm site .

The gauge catchment areas and flow records were obtained from the NSW Department of Primary Industries Office of Water Real Time Data – Rivers and Streams data portal, http://realtimedata.water.nsw.gov.au/water.stm. Flood frequency analyses were carried out on the gauge flow records, as described in Section 4.3.4.

The catchment of the Namoi River at the site is 9961km², which is about 58% of the total area of the catchment at Gauge 419001.

4.3.2 Terrain data

The catchment area at the Gunnedah Solar Farm site was estimated from the 1 second SRTM-H data, which are public domain and were acquired from elevation.fsdf.org.au. The data are described on the Geoscience Australia Website as follows;

> *The 1 second SRTM derived DEM-H Version 1.0 is a 1 arc second (~30 m) gridded digital elevation model (DEM) that has been hydrologically conditioned and drainage enforced. The DEM-H captures flow paths based on SRTM elevations and mapped stream lines, and supports delineation of catchments and related hydrological attributes. The dataset was derived from the 1 second smoothed Digital Elevation Model (DEM-S; ANZCW0703014016) by enforcing hydrological connectivity with the ANUDEM software, using selected AusHydro V1.6 (February 2010) 1:250,000 scale watercourse lines (ANZCW0503900101) and lines derived from DEM-S to define the watercourses. The drainage enforcement has produced a consistent representation of hydrological connectivity with some elevation artefacts resulting from the drainage enforcement. A full description of the methods is in preparation (Dowling et al., in prep). This product is the last of the Version 1.0 series derived from the 1 second SRTM (DSM, DEM, DEM-S and DEM-H) and provides a DEM suitable for use in hydrological analysis such as catchment definition and flow routing.*

The digital elevation model (DEM) has a vertical and horizontal accuracy of 9.8m against 90% of tested heights across Australia. It is considered that although absolute levels may not be precise in the flood plain around the site, they are consistent, which should allow a fair reflection of the extent and nature of flooding in the vicinity, and the potential impacts of the proposed Solar Farm.

The SRTM EDM terrain data used for the study are illustrated in Figure 2.

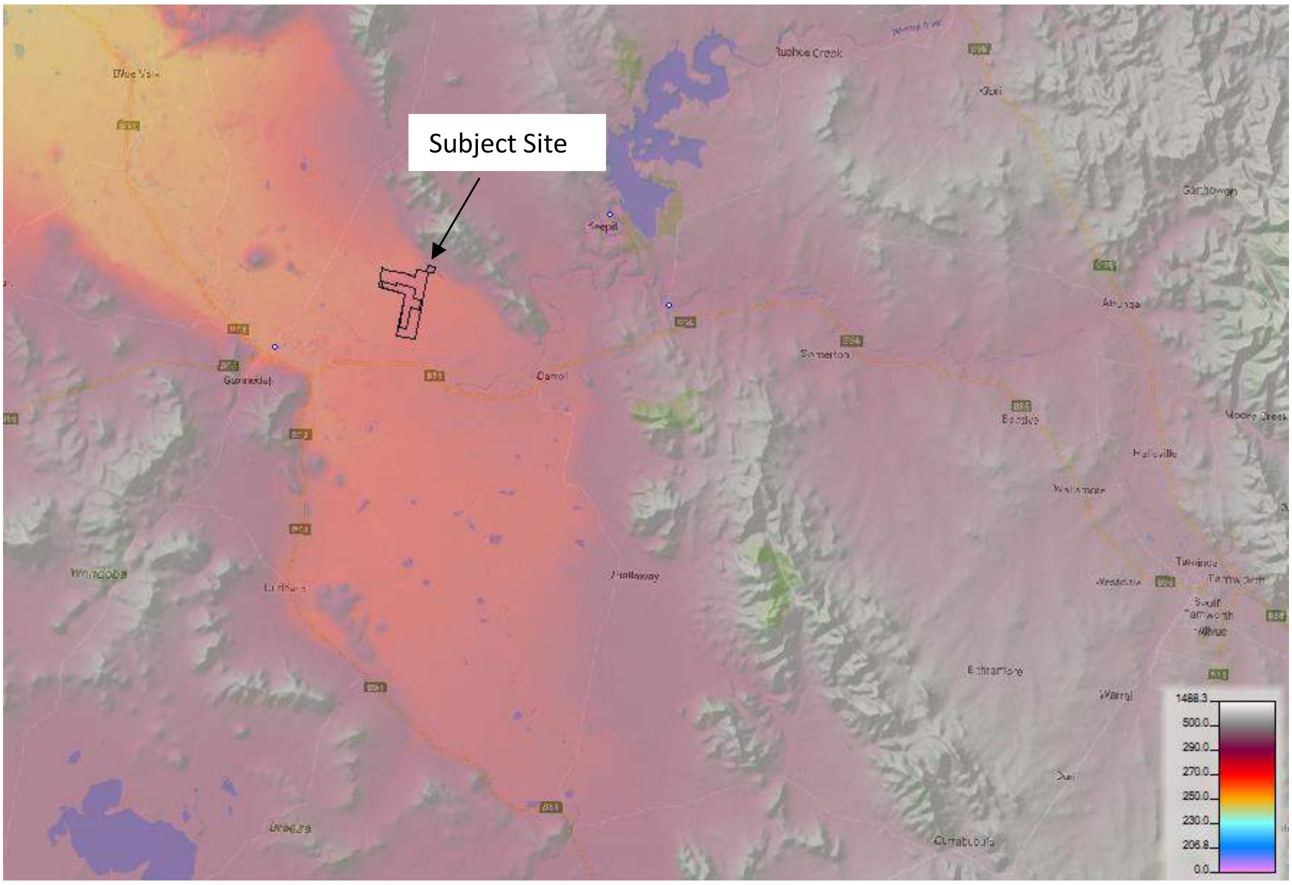


Figure 2 Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) data used in this study

4.3.3 Flood frequency analysis of gauge data

The annual maxima flood data were extracted from the Bureau of Meteorology (BoM) records for each gauge and each calendar year and subject to a Flood Frequency Analysis (FFA) using the program HEC-SSP and the Log Pearson III (LPIII) statistical distribution. The results are illustrated in Figure 3, Figure 4 and Figure 5, and Table 3, which show the computed flow distribution and the 95%ile and 5%ile confidence limits. Catchment yields (flow per km²) are summarised in Table 4.

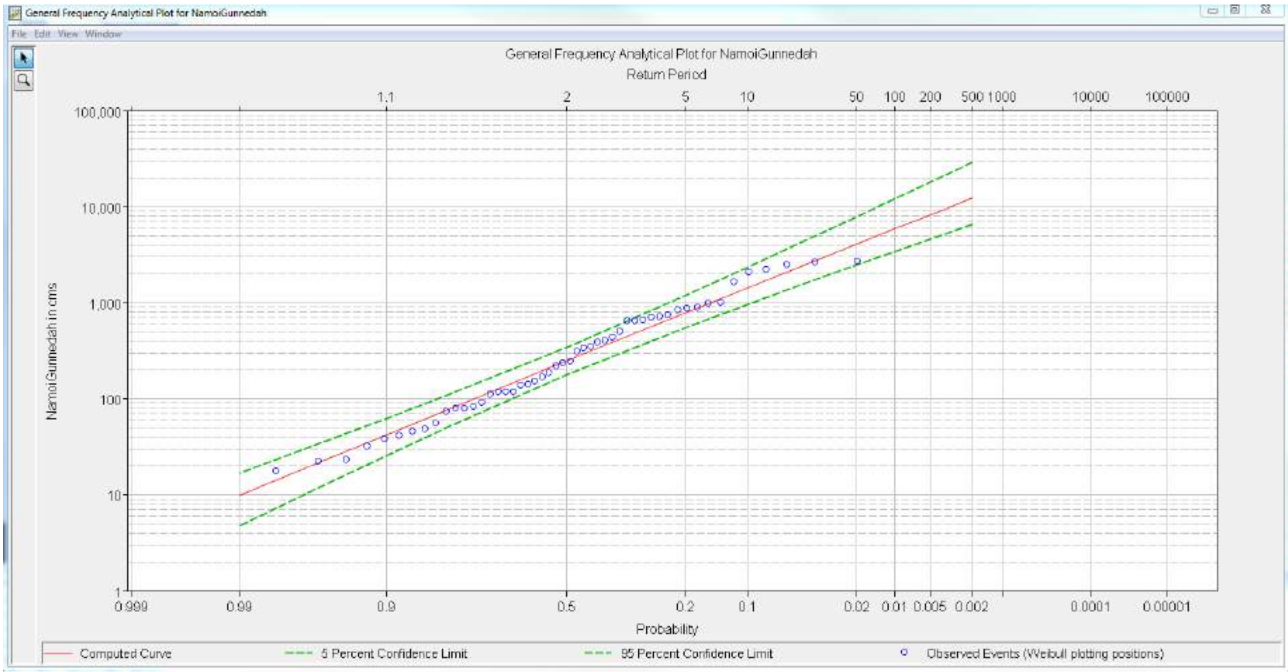


Figure 3 Results of LPIII flood frequency analysis of flow record at Gauge 419001 (units, cms = m³/s)

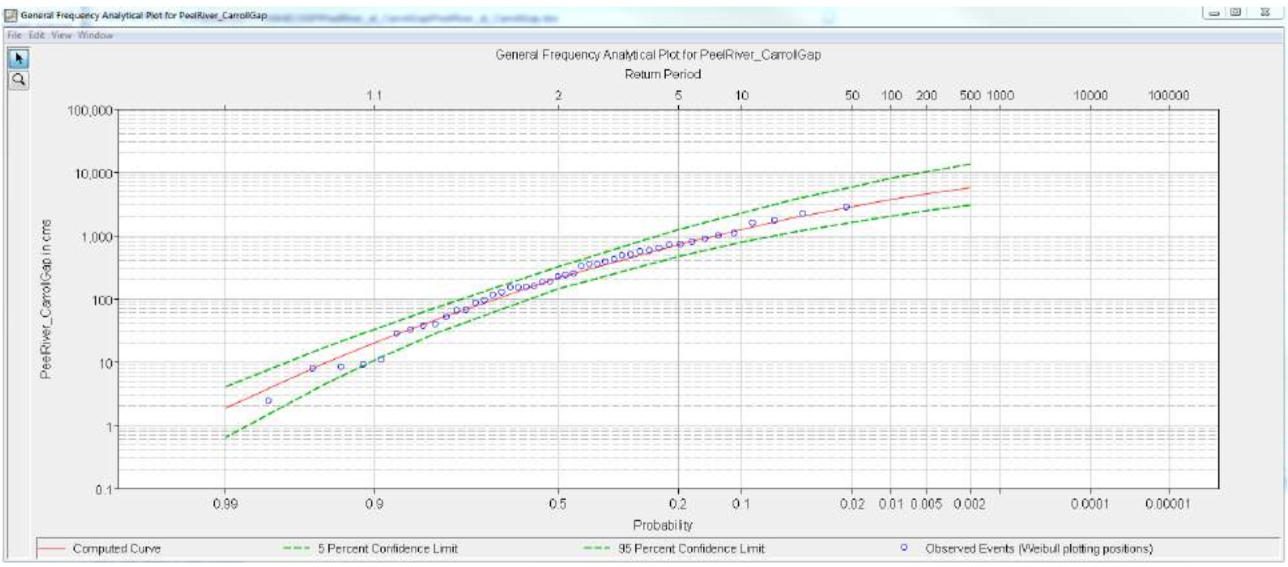


Figure 4 Results of LPIII flood frequency analysis of flow record at Gauge 419006 (units, cms = m³/s)

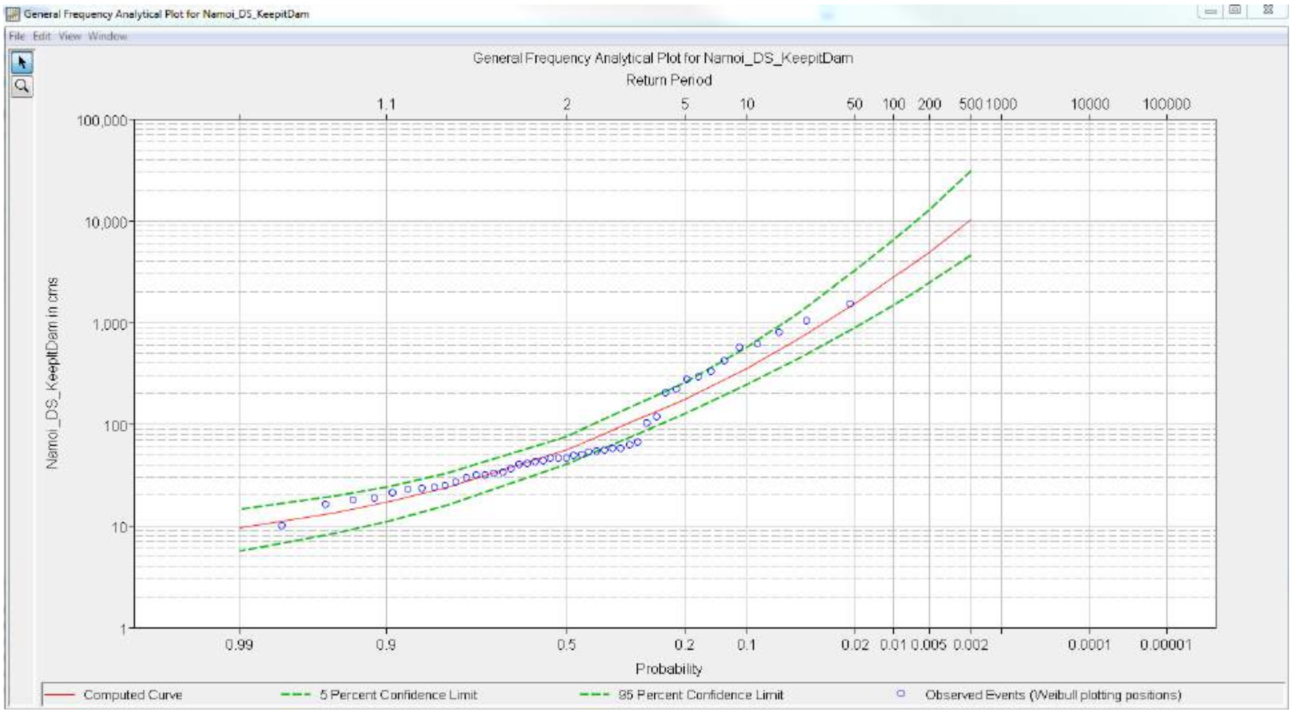


Figure 5 Results of LPIII flood frequency analysis of flow record at Gauge 419007 (units, cms = m³/s)

Table 3 Results of LPIII flood frequency analysis of flow record at river Gauges

AEP%	Gauge 419001 Namoi @ Gunnedah			Gauge 419006 Peel @ Carroll Gap			Gauge 419007 Namoi @ D/S Keepit Dam		
	95% (m^3/s)	Computed (m^3/s)	5% (m^3/s)	95% (m^3/s)	Computed (m^3/s)	5% (m^3/s)	95% (m^3/s)	Computed (m^3/s)	5% (m^3/s)
0.2%	6,555	12,332	28,967	3,009	5,695	13,427	4,606	10,229	31,213
0.5%	4,596	8,223	17,955	2,450	4,511	10,195	2,450	4,916	12,939
1%	3,422	5,881	12,102	2,034	3,656	7,959	1,496	2,779	6,534
2%	2,473	4,074	7,868	1,631	2,851	5,943	897	1,544	3,238
5%	1,511	2,344	4,134	1,127	1,888	3,672	438	684	1,234
10%	967	1,432	2,343	779	1,255	2,291	243	354	572
20%	556	787	1,189	469	725	1,226	126	173	253
50%	180	248	344	142	212	321	41	56	76
80%	51	78	110	29	48	74	16	24	33
90%	26	42	62	11	20	33	11	17	24

Table 4 1%AEP Catchment Yield

Gauge	1%AEP computed flow (m^3/s)	Catchment (km^2)	1%AEP Yield (m^3/s per km^2)
419001 Namoi @ Gunnedah	5,881	17,100	0.34
419006 Peel @ Carroll Gap	3,656	4,670	0.78
419007 Namoi @ D/S Keepit Dam	2,779	5,700	0.49

4.3.4 Flood frequency analysis at the site

The flood frequency analysis (FFA) at the site was estimated by combining daily flows from river Gauge 419006 and 419007 with data obtained from the NSW Department of Primary Industries – Office of Water. The FFA was generated using HEC-SSP as per Section 4.3.3 and the results are shown in Table 5 and Figure 6.

Table 5: Results of LPIII flood frequency analysis of flow record at site

AEP%	Flow: 5% Confidence Limit (m³/s)	Flow: Computed (m³/s)	Flow: 95% Confidence Limit (m³/s)
0.2%	6,810	13,400	34,300
0.5%	4,630	8,620	20,200
1%	3,370	5,990	13,100
2%	2,380	4,030	8,190
5%	1,420	2,250	4,110
10%	893	1,340	2,260
20%	506	725	1,120
50%	163	228	320
80%	47.9	73.8	106
90%	24.8	41.4	62.1
95%	14.3	25.9	40.6
99%	5.1	10.8	18.8

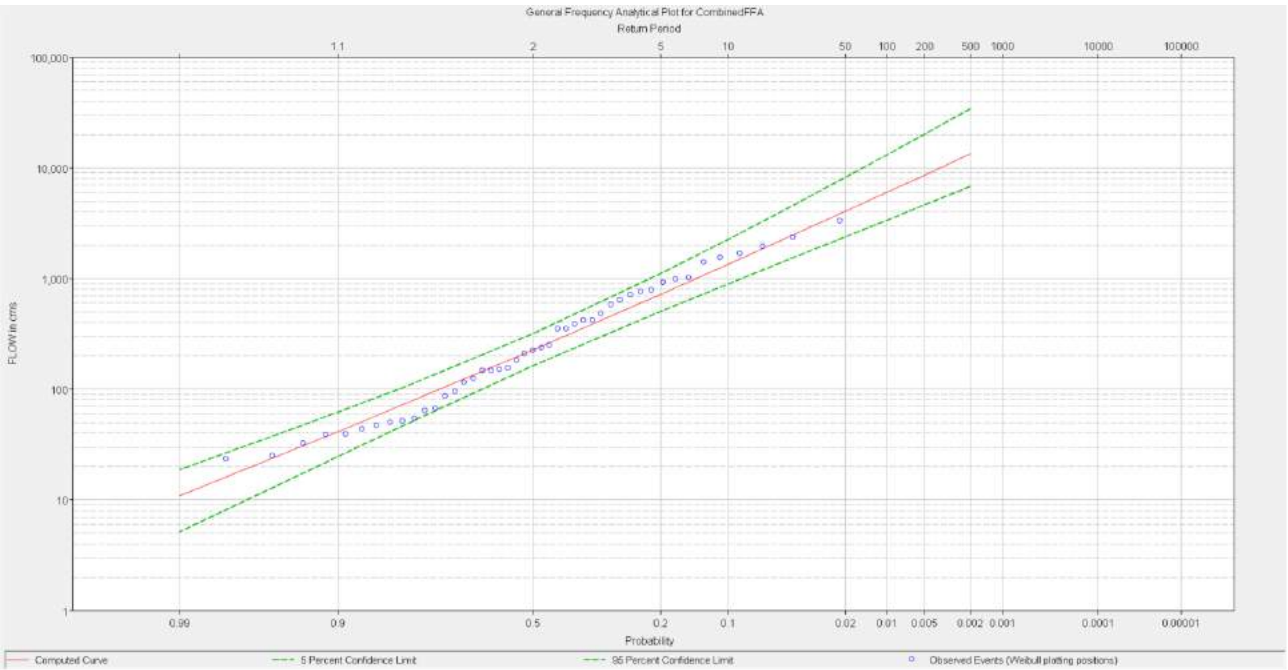


Figure 6: Results of LPIII flood frequency analysis of flow record at site (units, cms = m³/s)

The computed flow of 5,990m^3/s for the Namoi River at the proposed Solar Farm site represents a yield of 0.60m^3/s per square kilometre for the 1% AEP flood event, which agrees fairly with the observed yields at the nearby gauges as summarised in Table 4.

4.3.5 Allowance for Climate Change

An allowance for Climate Change was estimated using procedures outlined in Australian Rainfall and Runoff 2016, Chapter 1 (ARR16). The proposed site is located in the Central Slopes Cluster. Table 1.6.2 of ARR16 advises that 38 models indicate a "Much hotter" outcome with a predicted increase in temperature of 4.4°C by 2090 in this region. By comparison, 4 models indicate a "Hotter" outcome with an increase in temperature of 1.5 to 3.0°C, and no models indicate lower outcomes.

ARR16 also translates the effects these changes in temperature have on rainfall intensity, in Chapter 1 Section 6.2 as follows;

> *Given the uncertainty in rainfall projections and their considerable regional variability, an increase in rainfall (intensity or depth) of 5% per °C of local warming is recommended.*

The increase is compounded in Equation 1.6.1 in ARR16, which is reproduced below.

$I_p = I_{ARR} \times 1.05^{Tm}$
Where
I_p = Adjusted rainfall intensity
I_{ARR} = Rainfall intensity recommended by ARR16
Tm = Rise in temperature (°C)

The transformation of rainfall to flood flows involves soil losses, and attenuation in river reaches, dams and lakes, which introduces further complexity into the modelling. A simplified approach has been used that equates the predicted rise in temperature (about 4°C) to an increase in flood flows (20%) by the end of the Century (2100).

4.3.6 Hydrological verification

Testing for changes to Keepit Dam releases and catchment

A double mass curve was created that compares the cumulative flows from river Gauge 419007 with cumulative flows from river Gauges 419001 and 419006 for the period 1973 to 2017, as shown in Figure 7. The double mass curve illustrates the consistency of flows in these gauges, and changes in the slope of the curve would indicate a change in the flow releases from Keepit Dam, or a change to the catchment characteristics. The double mass curve suggests that no significant changes have been made to the catchments upstream of Gauge 419001, 419006 and 419007 after construction of Keepit Dam.

Gauge 419007, downstream of Keepit Dam, was installed after construction of the dam. The Gauge records therefore include the effects of the dam on flows.

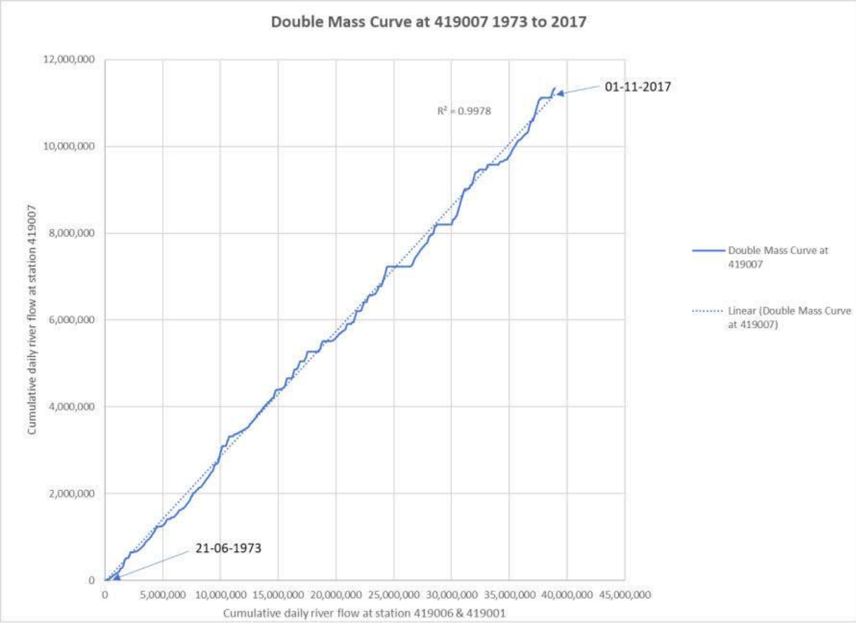


Figure 7: Double Mass Curve that compares cumulative flow at Gauge 419007 with cumulative flow from Gauges 419006 and 419001 for the period between 1973 and 2017

Previous assessments – NSW SES

NSW SES has estimated flood levels at the Gunnedah Gauge (Cohen's Bridge) for the 1998, 1955 and the 1% AEP flood level, as shown in Figure 8.

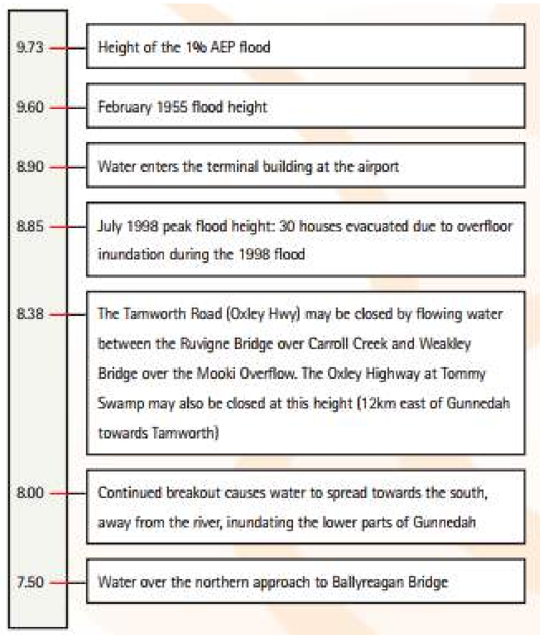


Figure 8: Key heights in metres at Gunnedah (Cohen's Bridge) Gauge. Source SES NSW FloodSage brochure

The Table in Figure 8 suggests that the 1%AEP is equivalent to the 1955 flood water level plus 0.13m, and that the 1955 flood was of a lesser magnitude than the 1%AEP flood.

Previous assessments – NSW DPI Gauge Rating

The NSW Department of Primary Industries rating curve for Gauge 419001 Namoi @ Gunndeah is shown in Figure 9, and it is based on the cross section shown in Figure 10.

By applying the height of the 1%AEP flood (9.73m) to the rating curve, the estimated peak discharge of the 1955 flood is estimated to be about 480,000ML/day, or an average discharge of about 5,560m³/s. By comparison, the peak 1%AEP flow estimated in the flood frequency analysis is 5,881 m³/s (see Table 3) and the peak flow reported in the *Gunnedah and Carroll Floodplain Management Plan* 1999 (SMEC Study) for the 1955 event is 9,160m³/s (see Table 6).

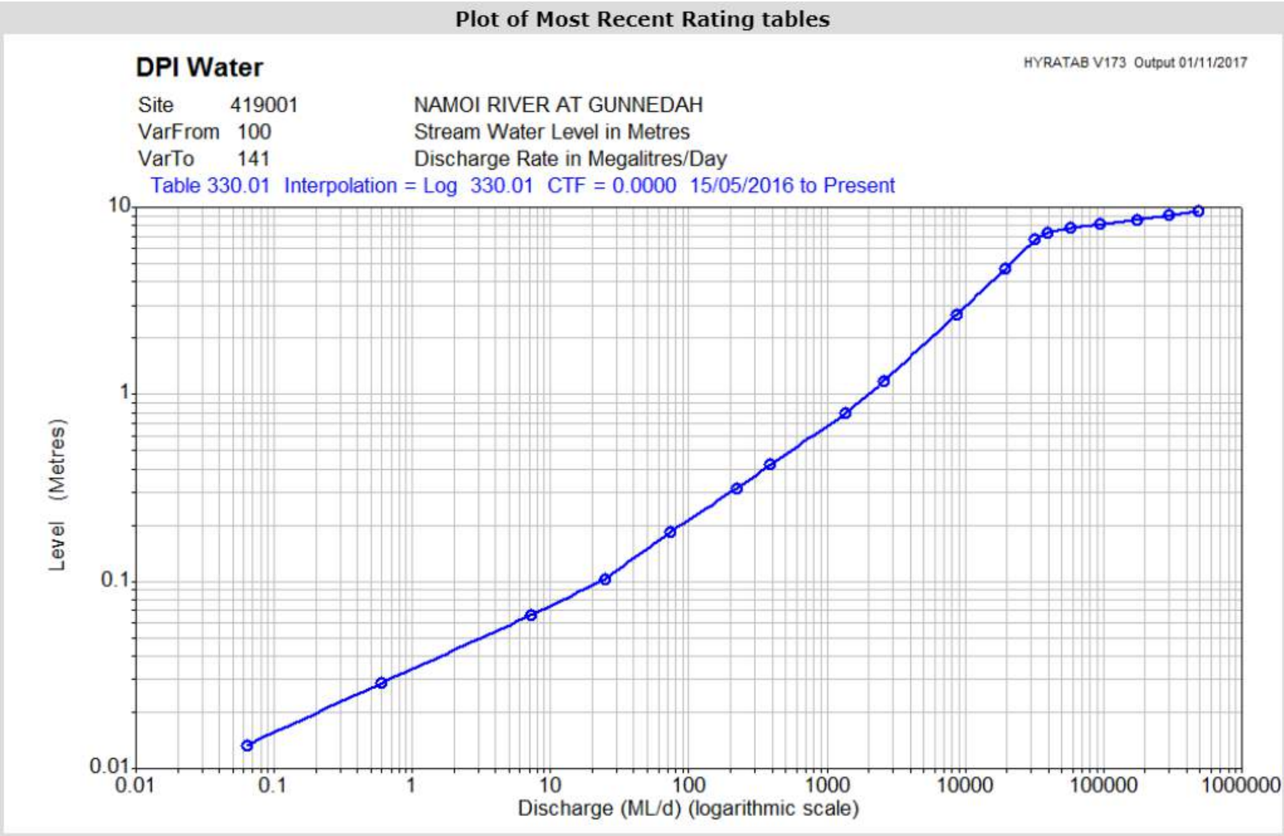


Figure 9: Rating Table of Gauge 419001, obtained from NSW Department of Primary Industries

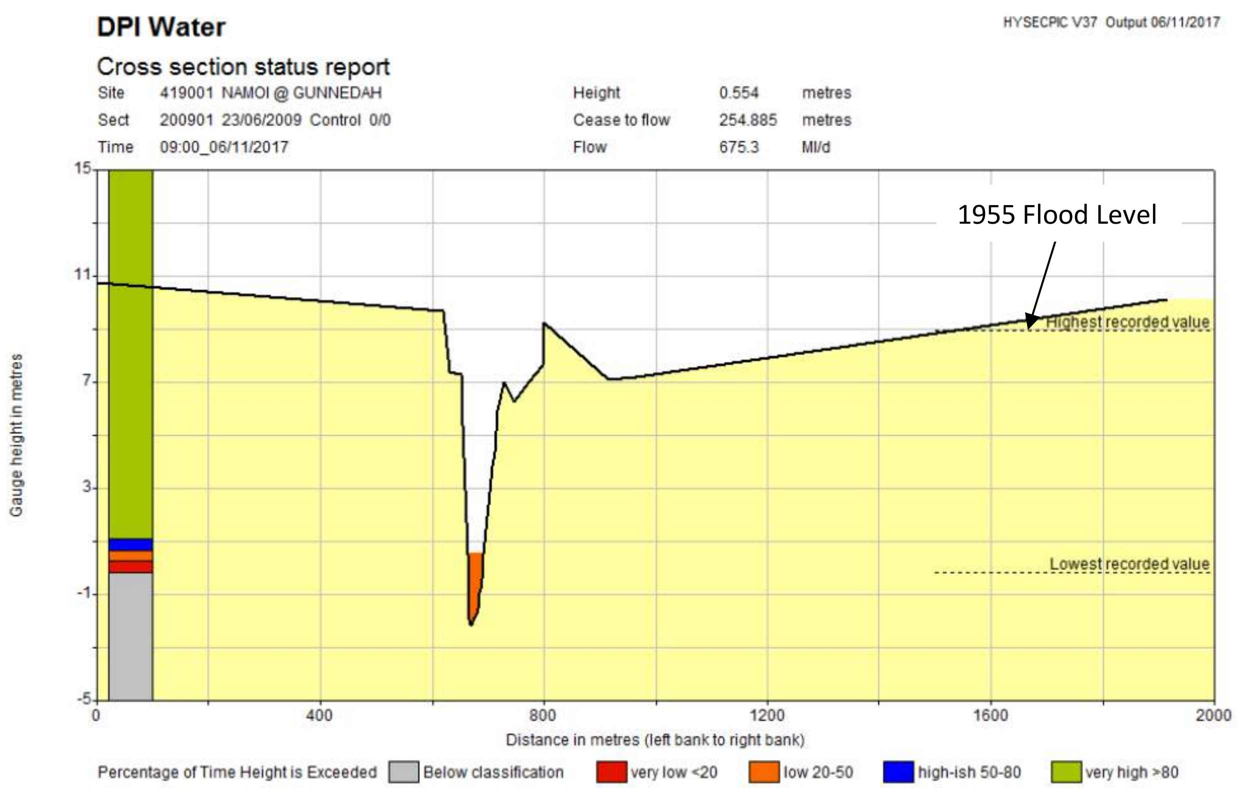


Figure 10: Cross Section at Gauge 419001, obtained from NSW Department of Primary Industries, dated 06-11-2017

Regional Flood Frequency Estimation (RFFE)

The website rffe.arr-software.org includes a function for Regional Flood Frequency Estimation (RFFE), which is commonly used to estimate flood flows under the following conditions and limitations:

- Catchments should be less than 1,000km²
- Catchments should not contain dams or weirs that could significantly the rainfall-runoff behaviour.

As the catchment for the site greatly exceeds 1,000km², and it contains the Keepit Dam, the RFFE was not used to verify or estimate flood flows at the site.

Previous flood studies – Gunnedah and Carroll Floodplain Management Plan

An existing flood study of Gunnedah and Carroll was undertaken by SMEC in 1999, the *Gunnedah and Carroll Floodplain Management Plan* 1999 (SMEC Study) and updated in 2014. Relevant findings from this study are reproduced in Table 6 and Table 7.

The SMEC study estimated the 1% AEP discharge at Gauge 419001 to be about 9160m³/s (February 1955 event), but this study estimates it to be 5,881m³/s (see Table 3), based on the overlapping period of the Gauge Records (1973 to present). A comprehensive analysis of the SMEC study is beyond the scope of the current study. However, it is considered that this study's estimation of the AEPs of flows is appropriate for the purposes of this study because it is primarily concerned with impacts (relative changes to flood levels) such that comparisons of 1%AEP flows are not expected to appreciably change the assessment of impacts.

Table 6 SMEC Study Peak Discharges and Volumes, Gunnedah (419001) (Source DLWC, 1996)

Event	Discharge (m³/s)	Volume (ML)
February 1955	9,160	2,000,000
February 1971	4,750	2,170,000
January 1994	3,960	835,000

Table 7 SMEC Study Flood Frequency Analysis Results

Gauge 419001 Namoi @ Gunnedah		Carroll (SES Gauge)	
Year	AEP (%)	Year	AEP (%)
1864	1.0 – 0.7	February 1955	1
February 1955	1.4 – 1.0	1964	2
February 1971	4	February 1971	4
Jan – Feb 1984	5	1984	10

4.4 Hydraulics

4.4.1 Flows used for hydraulic modelling

The major flood event of January 1984 was used to generate a hydrograph shape for the 1% AEP flood event. The 1984 event is the largest on record for Gauges 419006 and 419007, and it falls between the 5% AEP and 2% AEP probabilities. The 1984 event flows were scaled up to yield hydrographs for a range of AEP events, as shown in Figure 11.

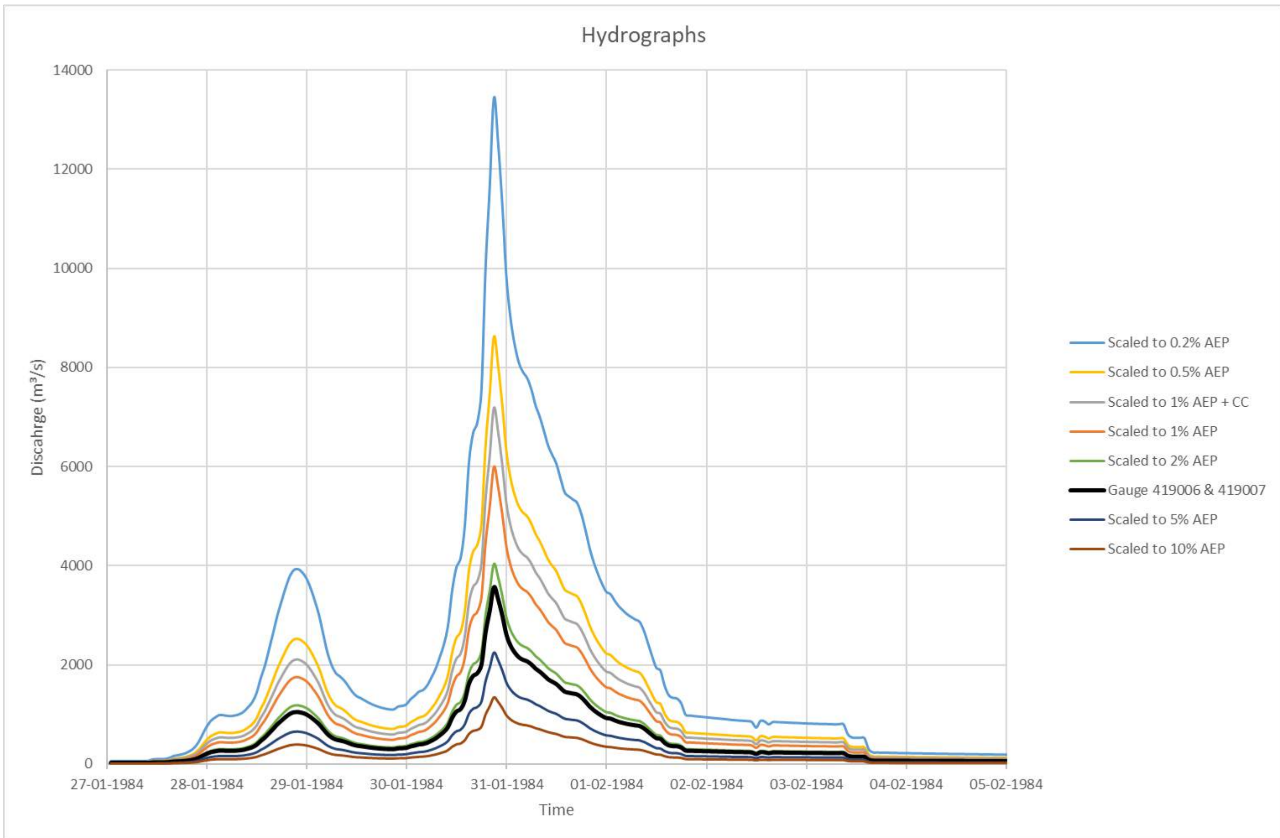


Figure 11: 1984 Flood Hydrograph at site and scaled hydrographs for different AEPs

4.4.2 Software

The hydraulic modelling software used for the peak flood level estimation was HEC-RAS Version 5.0.3 in 2D mode.

4.4.3 Input data

Topography

The HEC-RAS 2D model topography was sourced from the 30m SRTM-derived Hydrological digital elevation model (DEM) from Geoscience Australia, as described in Section 4.3.2, and as illustrated in Figure 2. The DEM was resampled to a 30m grid in HEC-RAS for the purposes of generating flood levels though flood modelling.

Flows

The flows used in the flood model were the AEP events described in Section 4.4.1. These flows were input as dynamic hydrographs as illustrated in Figure 11.

Boundaries

Two boundary conditions were applied:

- The tail water condition at the downstream boundary, which was set to a normal depth with a hydraulic gradient of 0.016 (m/m)
- Inflow at the upstream boundary for Namoi River, which was applied with a hydraulic gradient of 0.016 (m/m).

The upstream and downstream boundaries were set at about 18km upstream and 9km downstream of the site respectively. The distances between the boundaries and the site are sufficient to ensure that hydraulic conditions at the site are not significantly affected by assumptions of conditions at the boundaries.

Fences and floodplain roughness

Events modelled comprise of a uniform Manning's roughness coefficient which was applied to the 2D model domain. Manning's roughness is expected to vary with crop conditions, as follows

- Smooth crop roughness (after cropping) Manning's n = 0.03
- Normal crop roughness (during growing) Manning's n = 0.06
- Rough crop roughness (before cropping) Manning's n = 0.09.

Estimates of impacts are based on the smooth crop roughness (Manning's n = 0.03). This approach yields lower depths and higher velocities than an approach that uses a higher value of the roughness coefficient. However, it also yields higher impacts because the changes to flood levels are greater when a blockage is introduced to the flood plain. Therefore, it is considered that this approach yields conservatively high estimates of impacts, in terms of changes to flood levels.

General farm fences and stock fences are not represented in the model as individual fence lines but are included in the floodplain roughness. The resistance to flow by the stock fences is difficult to predict because it depends on the degree of blockage by flood debris. There are further uncertainties related to whether gates are open or closed, or whether fences are pushed over by flood water, or where fences have been added or removed. The approach taken is considered appropriate for the purposes of this study.

Security fences for the Solar Farm are represented in the model as lateral structures with vertical barriers and slots to represent the blocked and open sections of the fence, and open gates. A number of fence configurations were tested, which included different fence plans, degrees of blockage, and numbers of open gates.

Individual solar panels were not represented as discrete structures or as changes in the floodplain roughness value for the following reasons

- The solar panels stand on posts above the ground, and the ground will be grassed. This will have the same kinds of effects as, say, an apple orchard, which could be developed on the site without the approvals and flood study assessments needed for the Solar Farm. The effects on flooding would not be pronounced, because floodwaters would generally pass below the panels and around posts in the same way that they would pass below the branches and around trunks in an orchard
- The solar panels are corralled behind the security fences such that they would only influence flow within the area enclosed by the fences
- The final arrangement of solar panels within the security fences has not been determined accurately, and it is unlikely that the modelling will reflect the final arrangements of the panels in plan.

Bridges and structures

No bridges or structures were identified which could significantly affect flooding at the subject site. The Chandos Street bridge (Figure 14) is located at the downstream boundary of the model and does not significantly affected flooding at the subject site. No bridges or structures were included in the hydraulic model.

Previous flood studies

A flood study of Gunnedah and Carroll was undertaken by SMEC in 1999 and updated in 2014, *Gunnedah and Carroll Floodplain Management Plan* 1999 (SMEC Study).

The SMEC Study includes an inundation map at Gunnedah, which is reproduced in Figure 12. The inundation map was produced from a MIKe11 1D model constructed from cross sections, rather than an digital elevation model of the flood plain. This approach assumes a coarse approximation for the distribution of flows across the flood plain. SMEC's inundation plan is based on the discharges that are summarised in Table 6 and Table 7. The inundation areas from the 1999 study and the current study are superimposed in Figure 13 and they show fair agreement where they overlap.

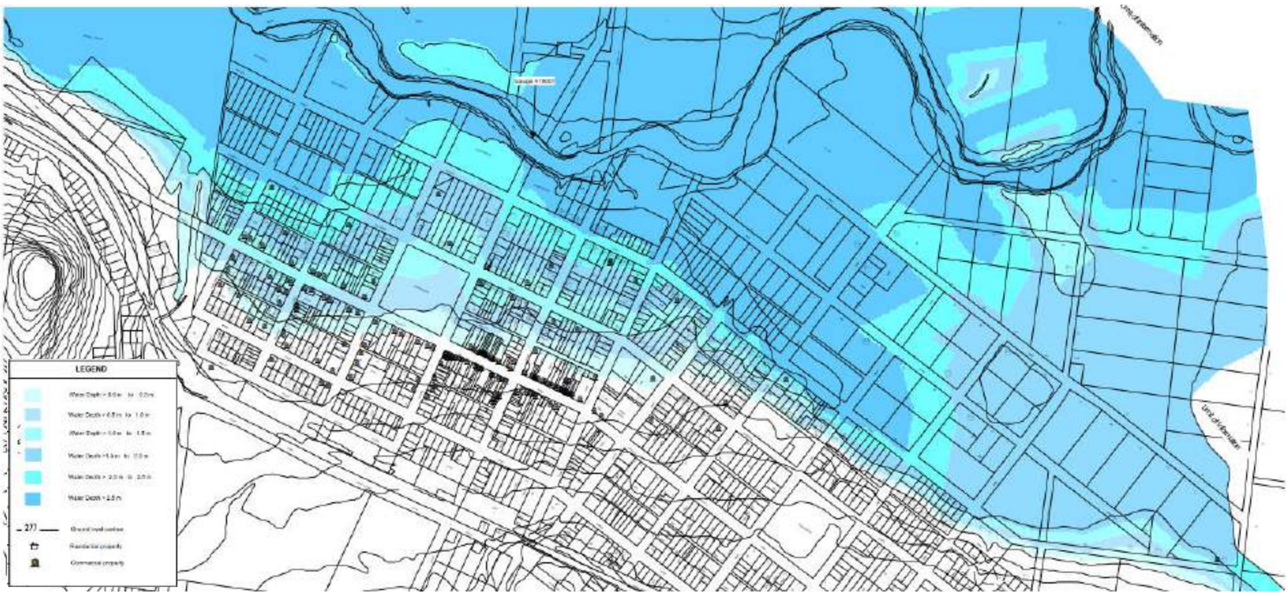


Figure 12: Gunnedah Floodplain Management Plan Inundation Map – Gunnedah 1% AEP (Drawing 31923-003)

Figure 13 Superimposed 1%AEP inundation areas from SMEC study and current study

4.4.4 River behaviour

On-line imagery of the site shows a varying width, low flow channel about 20 to 25m wide, as shown in Figure 14. Figure 14 shows the view upstream from the Chandos Street crossing over the Namoi River, which is located at the downstream boundary of the model. There is an extensive flood plain that extends beyond the river that is inundated in flood events.


Figure 14 Google street view of Chandos Street crossing over Namoi River at Gunnedah

5. Flood model results

5.1 Existing (baseline) scenario

The model results for flood levels in the existing (base line) situation, are shown in the flood maps in Appendix A.

5.2 Modelling configurations and objectives

The most significant influence on the flood levels associated with the Solar Farm is the fencing, and the degree of blockage caused by flood debris. A number of configurations were modelled to identify a suitable fencing configuration that would meet both the public safety and security requirements whilst minimising flood impacts upon sensitive receivers and the environment. These security fences are located within the property boundary of the site, as shown in the flood maps in Appendix A. The different configurations, and their flood impacts, are described below.

5.3 Fence Configuration 1 – 100% blocked

This configuration was modelled to estimate the worst possible scenario, and provides an upper limit on potential impacts, such that the impacts are unlikely to be exceeded regardless of the assumed degree of blockage. It comprises the following:

- Fences around Solar Farm paddocks
- Fence 100% blocked
- No laneways
- No gates.

The 100% blockage is analogous to a solid wall, and represents vegetation being compressed into a debris mat on the upstream face of a chain-link security fence. Some water will seep through the debris mat, but it will act like a solid wall on bulk flows in the flood plain.

The model results for flood levels in Configuration 1 are shown in the flood maps in Appendix A.

The model results indicate that Configuration 1 (100% blocked fence) produces a change in 1%AEP flood level of up to about 0.55m (550mm) immediately adjacent to the fence on the eastern side and about 0.1 to 0.3m (100 to 300mm) at the site boundary. Flood levels are reduced to the north and west of the fence, and increased to the east, southeast and southwest. The changes result from the hindrances caused by the fence to the flow as it travels north and west. This hindrance is particularly pronounced at the north-east corner of the fenced area, where water previously followed low ground to the flood plain to the north and west.

Flood levels and changes to flood levels at sensitive receivers are tabulated in Table 9, Table 10, Table 11 and Table 12.

5.4 Fence Configuration 2 – partially blocked fence with gates and laneways

This configuration comprises the following:

- Fences around Solar Farm paddocks
- Fence 100% blocked up to 0.5m above ground
- Fence 50% blocked above 0.5m above ground
- Laneways between solar panel paddocks
- 6m Gates at 100m intervals.

The blockages have been estimated to represent a less severe scenario than Fence Configuration 1. It is unlikely that the fences will be 100% blocked by debris mats to their full height, so this scenario represents blockage as 100% to 0.5m above ground and 50% thereafter. This blockage pattern reflects the kind of fence blockage expected in the vicinity, which is difficult to predict and is likely to be distributed unevenly in the horizontal and vertical dimensions. It is assumed that the vegetation that causes debris matting is more likely to affect lower sections of the fence than upper sections, being collected by flood waters and deposited against the fence during the rising stage of the flood.

The Carroll to Boggabri Floodplain Management Plan (FMP) includes criteria for complying works in Table 5, which sets the maximum average height of structural works (levees, ditches etc.) as 0.5m above ground. This provides an approximative comparison of the height of levees and fences that are expected to affect floodplain flows and indicates that the assumed height of 100% blockage should not be reduced below 0.5m for the purposes of providing conservative estimates of impacts.

This scenario also includes laneways. The laneways divide the Solar Farm into four paddocks. Each paddock is encircled with a separate fence, between which run the laneways. The purpose of including the laneways in the model configuration is to assess the benefit of allowing flood waters to move through the Solar Farm east to west. The fences were included in the model as lateral structures, as illustrated in the example in Figure 15.

The gates are distributed at regular intervals along the line of the fence and are shown as vertical slots down to ground level. The purpose of including the gates in the model configuration is to assess the benefit of opening gates to allow flood waters to move more easily through the boundary fence. The total length of fence in this configuration is about 16000m (16km). The placement of gates at intervals of 100m yields about 160 gates in total.

It is acknowledged that there are practical difficulties in manually opening 160 gates in advance of a predicted flood event, and that there are possible Workplace Safety issues related to workers driving around the site in poor conditions with rising floodwaters, to open gates. These considerations place a practical limit on the number of gates in operation. An alternative could be to automate the opening of gates by using remote controls and battery-operated solenoid motors with solar panels providing the power at each gate.

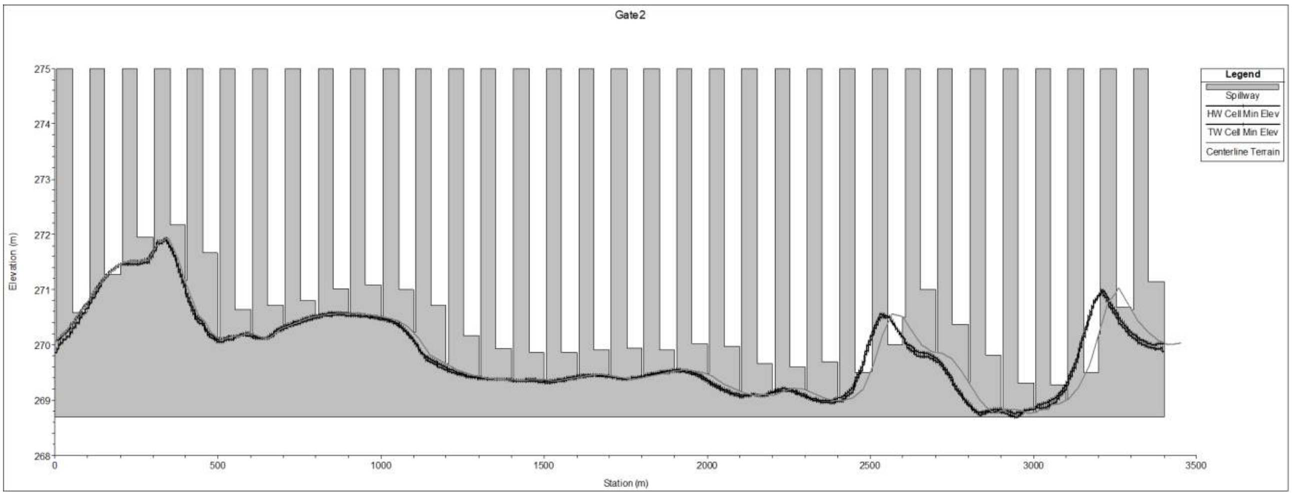


Figure 15 Example of representation of fence in model for Fence Configuration 2

The model results for flood levels in Configuration 2 are shown in the flood maps in Appendix A and in the tables of flood levels at the sensitive receivers in Table 9, Table 10, Table 11 and Table 12.

The model results indicate that Configuration 2 produces a change in 1%AEP flood level of up to about 0.1m (100mm) immediately adjacent to the fence on the eastern side. The change in flood level is reduced to about 0.05m (50mm) at the site boundary. Flood levels are reduced (compared to baseline) to the north and west of the fence and increase to the east, southeast and southwest. Configuration 2 produces a reduction in the increases in flood levels compared with Configuration 1, due to the increased number of pathways for water through the site and indicates how effective the pathways are in reducing potential flood impacts.

5.5 Fence Configuration 3 – partially blocked fence with laneways

This configuration comprises the following:

- Fence 100% blocked up to 0.5m above ground
- Fence 50% blocked above 0.5m above ground
- Laneways between solar panel paddocks
- No gates.

The blockages have been estimated to represent a less severe scenario than Fence Configuration 1. It is unlikely that the fences will be 100% blocked by debris mats to their full height, so this scenario represents blockage as 100% to 0.5m above ground and 50% thereafter. This blockage pattern reflects the kind of fence blockage expected in the vicinity, which is difficult to predict and is likely to be distributed unevenly in the horizontal and vertical dimensions. It is assumed that the vegetation that causes debris matting is more likely to affect lower sections of the fence than upper sections, being collected by flood waters and deposited against the fence during the rising stage of the flood.

The Carroll to Boggabri Floodplain Management Plan (FMP) includes criteria for complying works in Table 5, which sets the maximum average height of structural works (levees, ditches etc.) as 0.5m above ground. This provides an approximative comparison of the height of levees and fences that are expected to affect floodplain flows and indicates that the assumed height of 100% blockage should not be reduced below 0.5m for the purposes of providing conservative estimates of impacts.

This scenario also includes laneways. The laneways divide the Solar Farm into four paddocks. Each paddock is encircled with a separate fence, between which run the laneways. The purpose of including the laneways in the model configuration is to assess the benefit of allowing flood waters to move through the Solar Farm east to west. The fences were included in the model as lateral structures, as illustrated in the example in Figure 16.

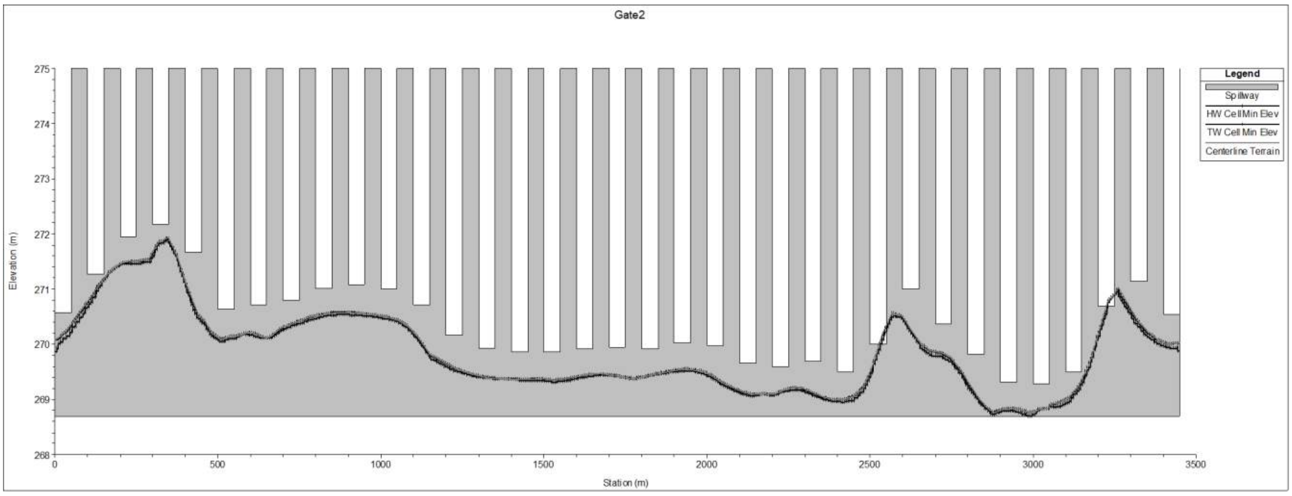


Figure 16 Example of representation of fence in model for Fence Configuration 3

The model results for flood levels in Configuration 3 are shown in the flood maps in Appendix A and in the tables of flood levels at the sensitive receivers in Table 9, Table 10, Table 11 and Table 12.

The model results indicate that Configuration 3 produces a change in 1%AEP flood level of up to about 340mm directly adjacent to the fence, about 110mm at the upstream property boundary and up to about 0.018m (18mm) at the most affected sensitive receiver. Compared to the baseline, flood levels are reduced to the north and west of the fence and increase to the east, southeast and southwest.

The increase in the changes to flood levels compared with Configuration 2 is due to the decreased number of pathways for water through the site in Configuration 3, which does not include the gates.

5.6 Velocities

The modelling provides indications of the velocities in the existing scenario and for the various Fence Configurations.

Velocity maps for 1%AEP and PMF flows for the existing situation are shown in Appendix A Figure SY17199-F006 and SY17199-F008 respectively. These show that the maximum velocities in the flood plain are about 1.4 m/s for the 1%AEP and about 2.1 m/s for the PMF.

The Carroll-Boggabri Floodplain Management Plan (FMP) September 2006 includes maximum permissible velocities for different ground conditions for crop, bare soil and native grass (FMP Table 4). These recommended maximum permissible velocities are 0.6, 0.4 and 0.8 m/s respectively. The FMP also notes, however, that "… in the majority of the floodplain, the velocity of flood flow is already greater than that which will cause significant erosion" (FMP Section 8.4.4).

Velocity maps for 1%AEP and PMF flows for Fence Configuration 3 are shown in Appendix A Figure SY17199-F306 and SY17199-F308 respectively. These show that the maximum velocities in the flood plain are about 1.4 m/s for the 1%AEP and about 2.1 m/s for the PMF, and that they occur in the same location as the existing case. Higher velocities are shown where floodwaters flow over the gaps in the partially blocked fence.

A close-up showing velocity vector arrows is shown in Figure 17 and a cross section showing PMF water speeds along a laneway is shown in Figure 18. These show that the velocities in the laneway are about 1.0 to 1.5 m/s in the centre of the laneway, and they increase to about 3.3m/s where they overtop and cross over the fence. The laneways do little to focus the flow into 'jets' along the laneways.

The following are inferred from these results:

- Flood plain velocities are generally low, and do not exceed 1.4 m/s and 2.1 m/s for the 1%AEP and PMF events respectively. This is typical of flood plain behaviour, in which flow travels relatively slowly across the flood plain and pools in local depressions and flow paths
- The introduction of a partial obstruction in the flood plain diverts some of this flow. The main effects are changes to the direction of flow and increased depths, rather than changes to velocity
- Maximum velocities correspond to maximum depths. In this case, the maximum depths are located at the north-east corner of the site, and the terrain is not changed by the development, hence the location of the maximum velocities is unchanged
- In Fence Configuration 3, the fence is fully blocked to 0.5m, and then 50% blocked thereafter. So, when the water depth exceeds 0.5m, water begins to flow through the partially blocked section of the fence above 0.5m. This is apparent in the alternating light and dark red areas along the fence lines in Figure 17 where flow is alternatively blocked and allowed to flow through the fence. The velocity pattern follows the idealised representation of the partial blockage in the model, but it illustrates how the model works, and is a credible indication of how flow might pass through a fence that is partially blocked by debris. Importantly, the pattern is less visible in areas where there are maximum depths and velocities, and this is because the 0.5m blockage has proportionally less effect in these areas than in areas where the depth is closer to 0.5m
- Maximum velocities around the fences occur where flood water passes over or through the fences, rather than where it passes between the fences along the laneways
- The laneways, therefore, do little to focus flows into 'jets' along the laneway. Velocities along the laneways are in the order of about 1.0 to 1.5 m/s. The maximum velocities at the boundaries of the site will correspond to the gaps in the debris blockage at the fences, which is a comparable situation to the blockage of ordinary stock fences in neighbouring paddocks
- Soil erosion is expected where flood velocities exceed 0.4 to 0.8 m/s, depending on the state of the covering vegetation, whether it be crop, bare soil or natural grass. However, these velocities are already exceeded in the existing situation for the 1%AEP and PMF flood events.

It is concluded, therefore, that soil erosion will already occur for major floods under existing conditions. The fences for the proposed solar farm are expected to change the direction of flow locally but will not greatly change the magnitude of the velocities over the flood plain. Higher velocities will occur at the gaps in the debris accumulated on the fence, which may exacerbate erosion in the immediate vicinity of the gap, but this is a comparable situation to the blockage of ordinary stock fences in neighbouring paddocks.

Furthermore, the erosion hazard would be reduced from the current situation as a result of the solar farm by the improved groundcover. Currently the farm is cropped and soils are often bare and exposed. The solar farm footprint would instead maintain a permanent pasture, a condition which would effectively improve groundcover and reduce the potential for erosion during flood.

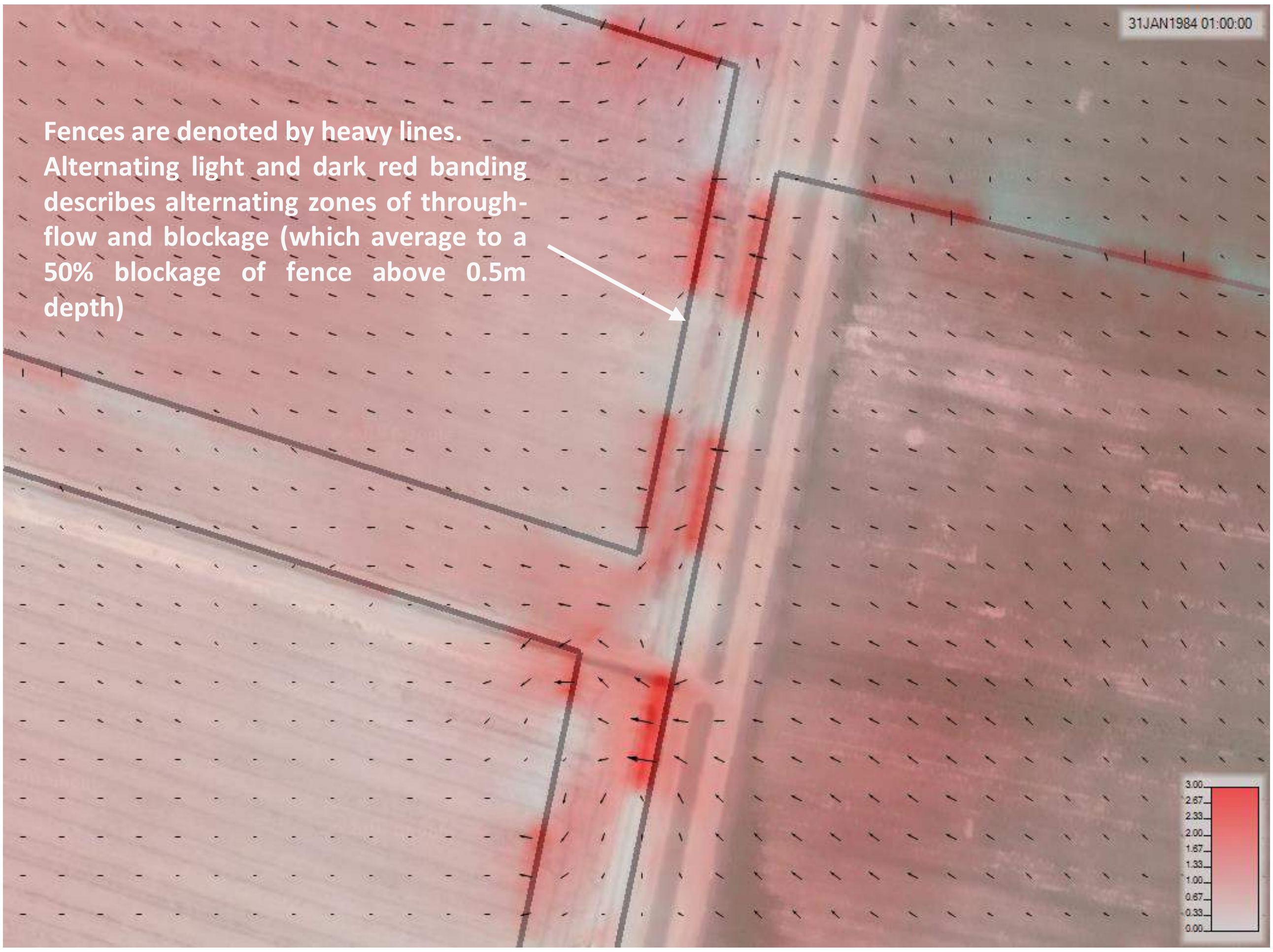


Figure 17 Example of velocity vectors at laneway in Fence Configuration 3 for PMF

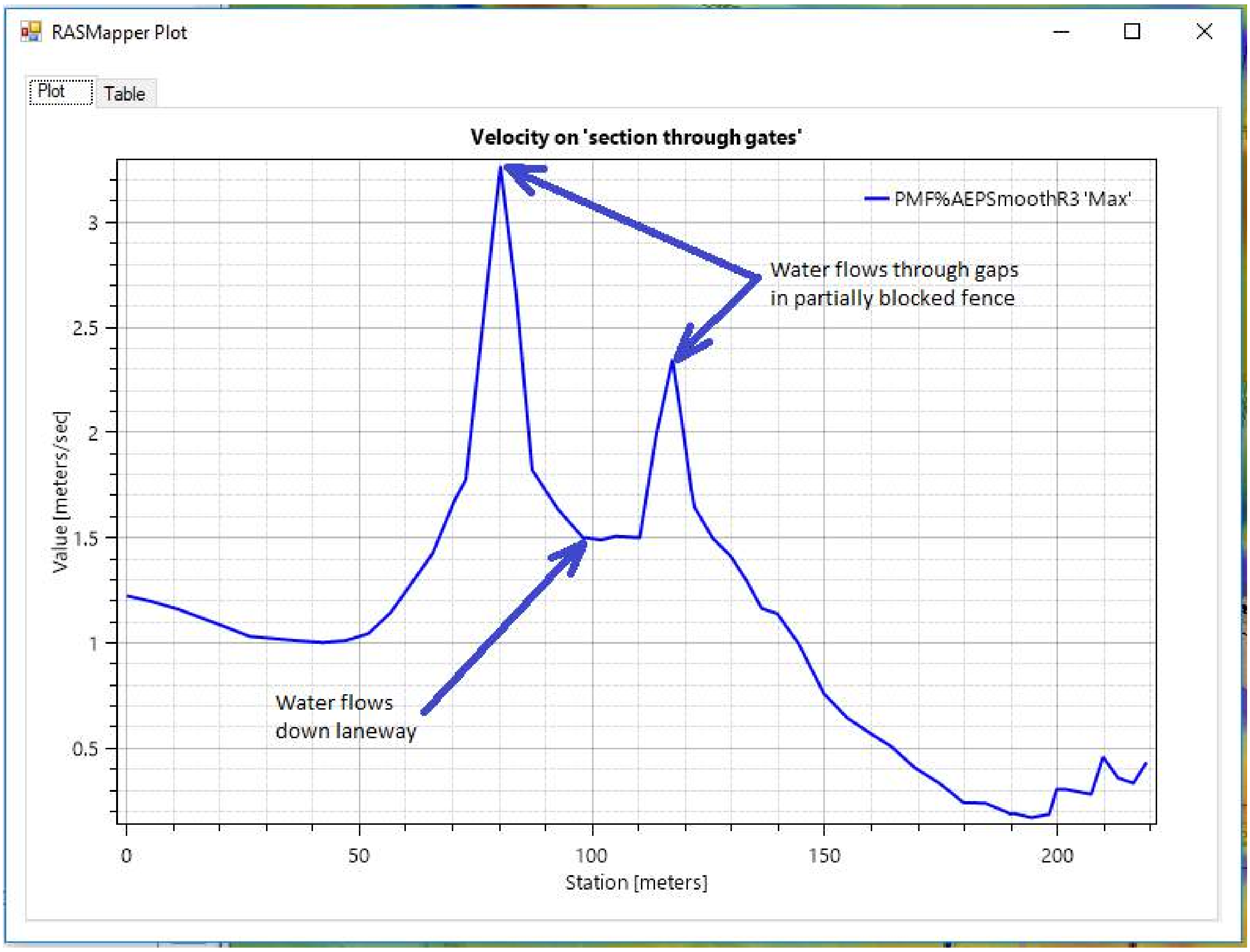


Figure 18 Example of flow speeds at cross section across laneway

5.7 Electrical substation

An electrical substation is proposed at the south-west corner of the site on fill above the flood levels, as illustrated in Figure 19. This fill has not been included in the Configurations modelled. Table 8 summarises the flood depths from Configuration 3 and adds a freeboard of 0.3m to recommend a height of the fill platform above ground level, depending on the degree of flood immunity desired. The fill and substation are not expected to appreciably change flood levels because it has a relatively small footprint in the context of flooding over the flood plain.

Table 8 Flood depths at electrical substation – Configuration 3

AEP	Flood depth (m)	Recommended height of fill platform above ground (m)
10%	0.28	0.58
5%	0.41	0.71
1%	0.75	1.05
PMF	1.32	1.62

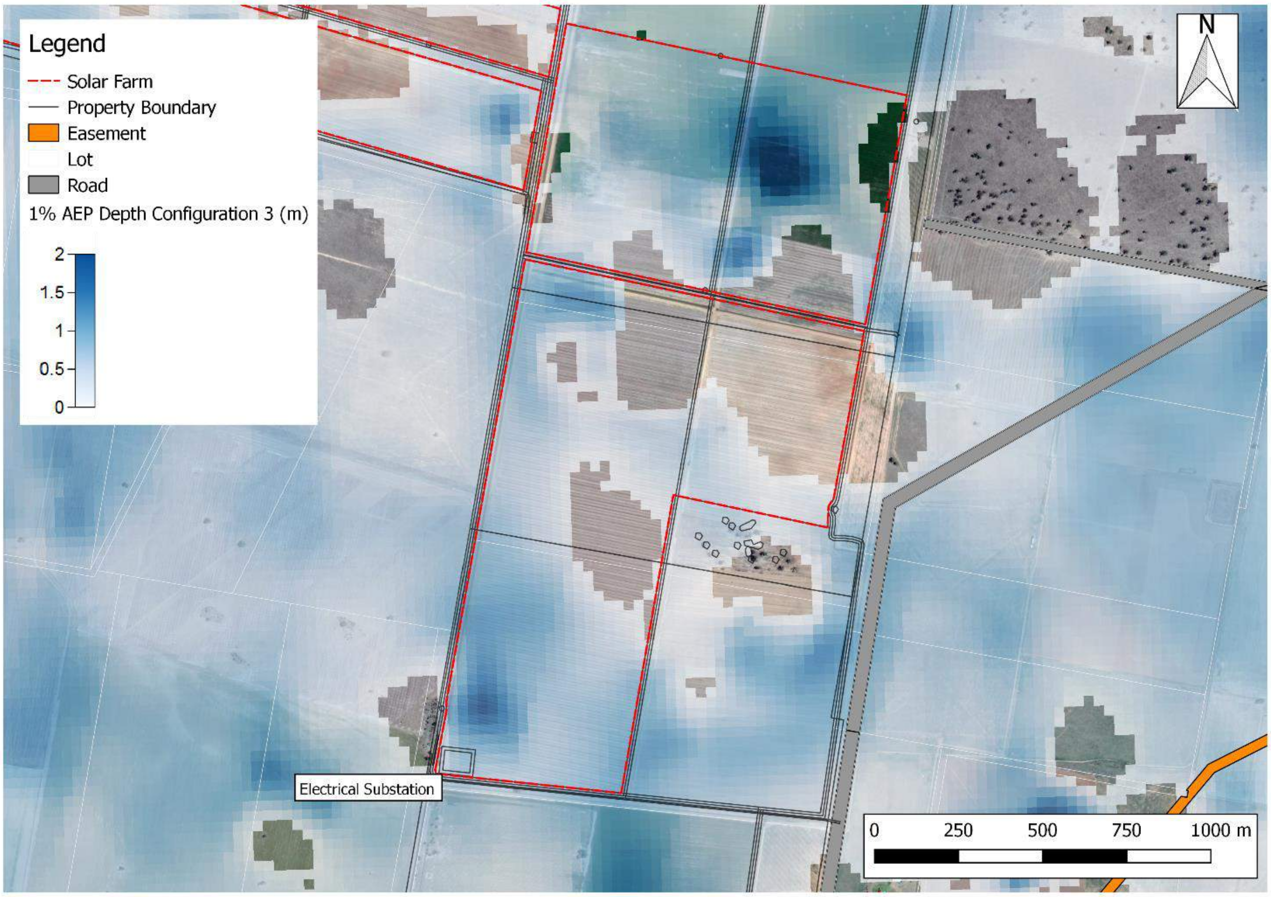


Figure 19 Location of electrical substation and flood depths for 1%AEP Configuration 3

5.8 Impacts at sensitive receivers

Flood behaviour was considered at the sensitive receivers surrounding the Solar Farm by comparing predicted flood levels under the baseline (existing) situation with flood levels under Fence Configuration 3. The locations of sensitive receivers are indicated in the flood maps in Appendix A. Further details of the sensitive receivers, such as the names and addresses of individual landowners, are withheld from this flood study for reasons of privacy.

Flood levels and changes to flood levels at sensitive receivers are tabulated in Table 9, Table 10, Table 11 and Table 12. The scenarios reported in these tables are:

- Existing case, as described in Section 5.1
- Configuration 3, as described in Section 5.5.

Flow depths are categorised as follows

- Shallow flow depths: depths less than 0.1m (100mm), which is typically less than the depth of flow needed to rise above the floor levels of slab-on-ground houses and sheds
- Moderate flow depths; depths between 0.1m (100mm) and 0.45m (450mm), which is typically knee-deep
- Deep flow depths; depths above 0.45m. Water this deep is difficult to keep out of houses by sand-bagging.

Results shown as '-', indicate that the sensitive receiver is not affected by flooding.

Table 9 Flood model results at sensitive receivers - 10%AEP event

Receiver	Peak flood level (m AHD)		Change (m)	Comments
	Existing	Conf. 3		
01.	-	-	-	
02.	0.413	0.413	0.000	
03.	0.079	0.083	0.004	Small change to shallow flow depths
04.	0.449	0.449	0.000	
05.	-	-	-	
06.	-	-	-	
07.	-	-	-	
08.	-	-	-	
09.	-	-	-	
10.	-	-	-	
13.	-	-	-	
14.	-	-	-	
16.	-	-	-	
17.	-	-	-	
18.	-	-	-	
19.	-	-	-	
21.	0.631	0.631	0.000	
22.	-	-	-	
23.	-	-	-	
24.	-	-	-	
26.	-	-	-	
27.	-	-	-	
28.	0.371	0.384	0.013	Small change to moderate flow depths
29.	-	-	-	
30.	-	-	-	
31.	-	-	-	

Table 10 Flood model results at sensitive receivers - 5%AEP event

Receiver	Peak flood level (m AHD)		Change (m)	Comments
	Existing	Conf. 3		
01.	-	-	-	
02.	0.463	0.463	0.000	
03.	0.108	0.116	0.009	Small change to moderate flow depths
04.	0.491	0.491	0.000	
05.	-	-	-	
06.	-	-	-	
07.	-	-	-	
08.	-	-	-	
09.	-	-	-	
10.	-	-	-	
13.	-	-	-	
14.	-	-	-	
16.	-	-	-	
17.	-	-	-	
18.	-	-	-	
19.	-	-	-	
21.	0.656	0.656	0.000	
22.	-	-	-	
23.	-	-	-	
24.	-	-	-	
26.	-	-	-	
27.	-	-	-	
28.	0.421	0.434	0.013	Small change to moderate flow depths
29.	-	-	-	
30.	-	-	-	
31.	-	-	-	

Table 11 Flood model results at sensitive receivers - 1%AEP event

Receiver	Peak flood level (m AHD)		Change (m)	Comments
	Existing	Conf. 3		
01.	-	-	-	
02.	0.541	0.541	0.000	
03.	0.315	0.333	0.018	Small change to moderate flow depths
04.	0.555	0.555	0.000	
05.	-	-	-	
06.	-	-	-	
07.	-	-	-	
08.	-	-	-	
09.	-	-	-	
10.	-	-	-	
13.	-	-	-	
14.	0.489	0.464	-0.026	Small change to moderate flow depths
16.	-	-	-	
17.	-	-	-	
18.	-	-	-	
19.	0.017	0.017	0.000	
21.	0.700	0.700	0.000	
22.	-	-	-	
23.	-	-	-	
24.	-	-	-	
26.	0.060	0.068	0.007	Small change to shallow flow depths
27.	-	-	-	
28.	0.593	0.606	0.013	Small change to deep flow depths
29.	-	-	-	
30.	-	-	-	
31.	-	-	-	

Table 12 Flood model results at sensitive receivers PMF event

Receiver	Peak flood level (m AHD)		Change (m)	Comments
	Existing	Conf. 3		
01.	0.511	0.525	0.014	
02.	0.667	0.667	0.000	
03.	0.852	0.860	0.008	Small change to deep flow depths
04.	0.652	0.652	0.000	
05.	0.016	0.016	0.000	
06.	-	-	-	
07.	0.504	0.505	0.001	Small change to deep flow depths
08.	-	-	-	
09.	-	-	-	
10.	-	-	-	
13.	-	-	-	
14.	1.259	1.255	-0.004	Small change to deep flow depths
16.	-	-	-	
17.	-	-	-	
18.	-	-	-	
19.	0.430	0.430	0.000	
21.	0.842	0.848	0.005	Small change to deep flow depths
22.	-	-	-	
23.	-	-	-	
24.	-	-	-	
26.	0.342	0.345	0.004	Small change to moderate flow depths
27.	0.273	0.277	0.004	Small change to moderate flow depths
28.	0.951	0.956	0.005	Small change to deep flow depths
29.	0.840	0.841	0.001	Small change to deep flow depths
30.	0.825	0.827	0.001	Small change to deep flow depths
31.	1.015	1.017	0.002	Small change to deep flow depths

5.9 Sensitivity analysis

The 1%AEP events were simulated with different Manning's n coefficients, as described in Section 4.4.3, and an allowance for Climate Change, as described in Section 4.3.5. The results over the Site indicate the following:

- The average difference in flood depths between the Smooth Crop and Normal Crop flood levels is about 0.25m
- The average difference in flood depths between the Normal Crop and Rough Crop flood levels is about 0.20m
- The average difference in flood depths between the Rough Crop and Rough Crop with Climate Change flood levels is about 0.25m.

These results are illustrated in Appendix B Figure B20, Figure B21 and Figure B22.

The results of the sensitivity analysis provide an indication of the confidence limits of the model. They indicate that the state of the crops can influence flood levels by about ± 0.25m, or that flood depths could be as much as 0.45m higher than the flood levels estimated in the fence configurations modelled above (which relate to "smooth" crop conditions). As discussed above, the impacts (relative changes to flood levels) are expected to be more pronounced with "smooth" crop conditions hence these conditions were adopted to present a conservative assessment of change.

Allowances for Climate Change could increase flows by 20%, which will increase flood levels by about 0.25m.

6. Effects of Solar Farm on flood behaviour

The construction of security fences of any configuration will affect flood levels in the flood plain because of the flood debris mats on the fences that are expected to accumulate on the fences that will partially obstruct or hinder flows. The blockages will cause flows to back up on the upstream sides of the fences and to drop on the downstream sides of the fences. The degree of flood debris blockage is difficult to predict and is likely to be uneven in the horizontal and vertical dimensions. The range of impacts is indicated by the impacts for the different Fence Configurations described above.

The increases in water levels shown in the flood models reflect the partial blockage or hindrance to flow created by the fences, which tend to cause the floodwaters to back up on their upstream faces. Correspondingly, the reductions in water levels reflect areas that are downstream of the fences.

The distribution of areas of increased flood levels and decreased flood levels changes with the direction of flow across the flood plain, which changes according to the AEP of the event, and the timing within the event. For instance, in the 10% AEP event, flow breaks out of the Namoi River, approaches the site from the south and is hindered from escaping to low ground to the north by the fence, thus creating an area of increased flood levels to the south and west of the site. Likewise, in the 1% AEP, flow approaches from the south and east at different times in the flood event, and it is the hindrance to the eastern flows that causes an increase to flood levels to the east of the site.

There is a law of diminishing returns associated with benefit of mitigation options targeted at the reduction of blockage and consequent reduction of the impacts on flood levels. The greatest benefit occurs when the blockage is reduced from 100% by a small amount, and the least benefit occurs when the blockage is reduced from 50% by a small amount. Relatively large benefits result from the inclusion of the laneways in the fences, because they provide pathways for water to pass through the site and allow floodwaters to find an easier route through the site rather than having to circumnavigate it.

Impacts could be reduced further by the inclusion of gates, but the benefits are typically a reduction of about 0.1m directly adjacent to the fence. There are practical, and workplace health and safety considerations associated with opening a large number of gates in advance of a predicted or forecast flood event. For these reasons, the option of gates has been discounted as being impracticable, given the relatively small benefit they achieve.

Fence Configuration 3 represents a likely configuration of the fences and debris blockages. It presents a conservative estimate of the impact of fence blockage while incorporating laneways that are a practicable mitigation solution and achieve a demonstrable reduction in flood impacts. Modelling of Fence Configuration 3 indicates that the fences and their debris blockages could increase 1%AEP upstream flood levels by about 340mm directly adjacent to the fence, about 0.11m at the upstream property boundary and up to about 0.018m (18mm) at the most affected sensitive receiver. Some areas could experience reduced flood levels, particularly to the north and west of the Solar Farm.

Based on these results it is considered that the overall impacts of the Solar Farm result in small changes to overall flood depths at the receivers. These changes are conservatively estimated to be less than about 18mm.

Based on the small changes in modelled flood behaviour as a result of the development, it is considered that the development:

- Would not adversely affect beneficial inundation. The modelling predicts no appreciable change to inundation area
- Would not cause changes to erosion, siltation and riparian vegetation. As the site is not located close to the Namoi River, it is considered that the proposed development will not appreciably change erosion, siltation, riparian vegetation or the stability of river banks
- Would not affect existing flood Emergency Management and access procedures in place for the region
- Would not increase the risk to life from flood
- Would not have appreciable adverse social or economic costs to the community. The economic costs relate to the changes to flooding, which are mapped in Appendix A. There are many social and economic benefits associated with the construction and operation of the proposed Solar Farm, however a more comprehensive economic assessment in the context of flooding is beyond the scope of the current study.

It is concluded that the proposed development is compatible with the hydraulic function of flood storage. Though the proposed security fences create a hindrance to flow as it is distributed through the site, there is no appreciable reduction in flood storage as there would be with, for instance, the placement of a significant volume of fill in the area. It is expected that floodwaters will continue to seep or flow through the fences to occupy the same volume of flood storage as is currently available.

7. Further improvements to flood modelling

7.1 Terrain

It is acknowledged that the accuracy and quality of the flood modelling results depends chiefly on the quality of the terrain data. The current model uses the SRTM-H digital elevation model (DEM), which comprises a grid of about 30m with a vertical accuracy of about ±9.8m (see discussion in Section 4.3.2). This terrain data do not fully describe fine details such as irrigation drains and bunds, many which have been constructed recently and may be too small to be captured in the SRTM survey. Though there are better terrain data to the south of the Oxley Highway, they do not extend to the northern edges of the flood plain, and do not cover the site of the proposed Solar Farm.

If the modelling were to be improved to provide more accurate results for flood levels, depths and velocities at a higher resolution, then better terrain data should be acquired. It is recommended that this be done by commissioning further LiDAR survey (laser scanning from an airplane) of the Namoi Floodplain to the north of the Oxley Highway. The LiDAR survey will provide ground levels to an accuracy of about ±100mm, and at a resolution that is fine enough to describe farm channels and bunds. Ground-truthing of the LiDAR could also be used to survey floor levels of houses and buildings.

If such a LiDAR survey were to be commissioned, and the flood modelling improved, questions concerning the local effects of farm channels, levees and the smaller flow paths could be addressed directly, and impacts could be related to the actual floor levels of houses and buildings.

7.2 Hydrology

The current model has a single inflow at the upstream boundary of the Namoi River, based on an aggregation of flows and using the 1984 flood as a template (see discussion in Section 4.4.1). The Mooki River and its flood plain are included in the terrain data, but the current model does not split inflows between the Namoi and Mooki rivers.

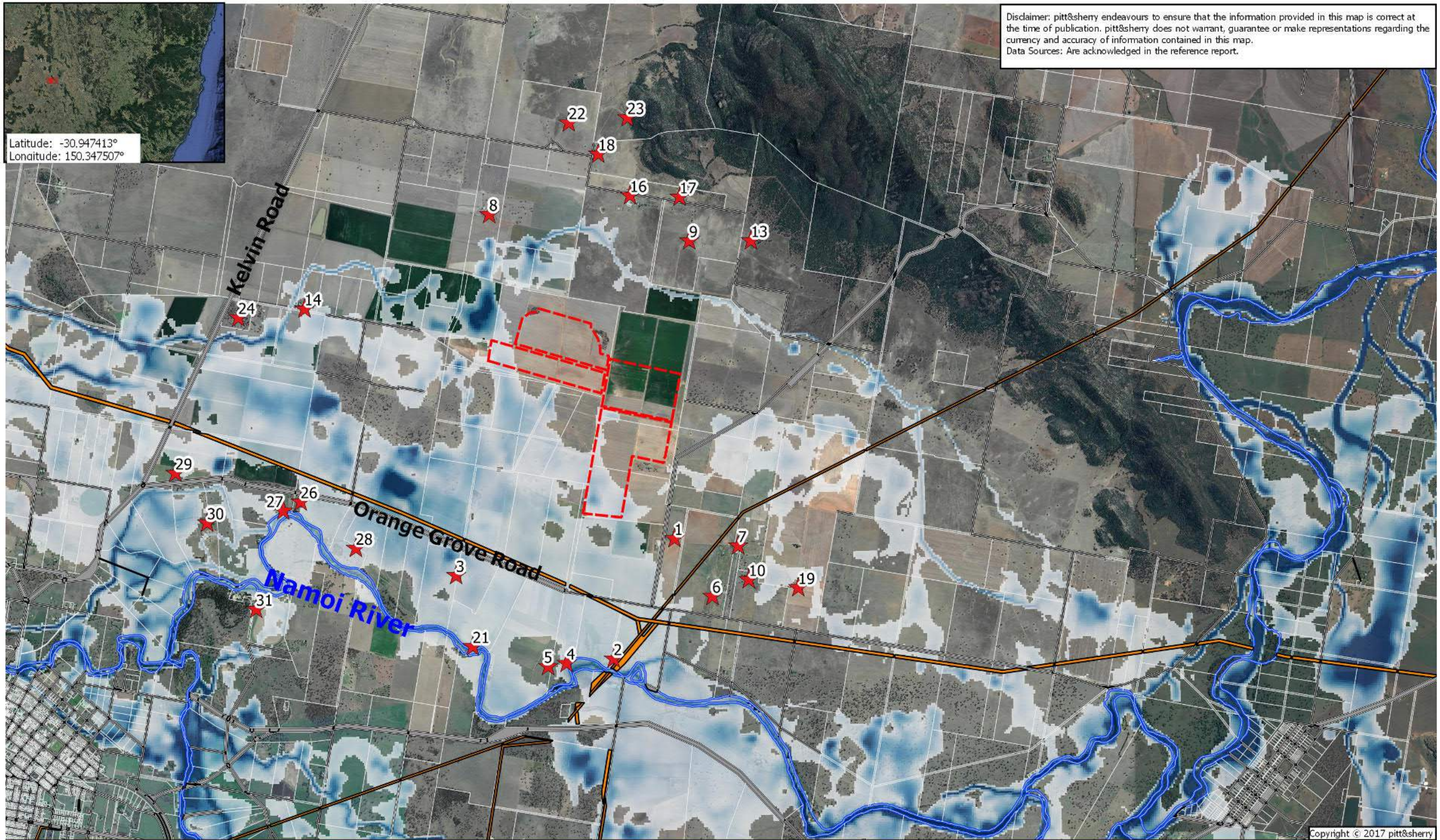
If the flood modelling were to be improved, the hydrology (the estimation of flood flows) could be further developed to separate flows from the Namoi and Mooki Rivers by hydrological modelling, but further work will be needed to identify which combination of flows should be used in design events.

Residents have observed that flooding at their properties may not coincide with flooding at Gunnedah. This observation indicates that the pattern of flooding in the flood plain is affected by which catchments are contributing and which are not, which complicates the hydrology and the identification of design floods. The hydrological component of the modelling should therefore identify representative combinations of flooding, which are related to the annual exceedance probability of flood heights at key locations being reached, rather than the probability of rainfall events being exceeded.

Appendix A

Model results

List of Figures



Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P Rev02

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:87,922 When printed at A4

Legend

- Solar Farm
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

10% AEP Existing Scenario (m)

2
1.5
1
0.5
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F001
Revision	1
Author	mdugan
Reviewer	mjacobs
Date	21-03-2018

Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

10% AEP Flood Depth
Existing Scenario

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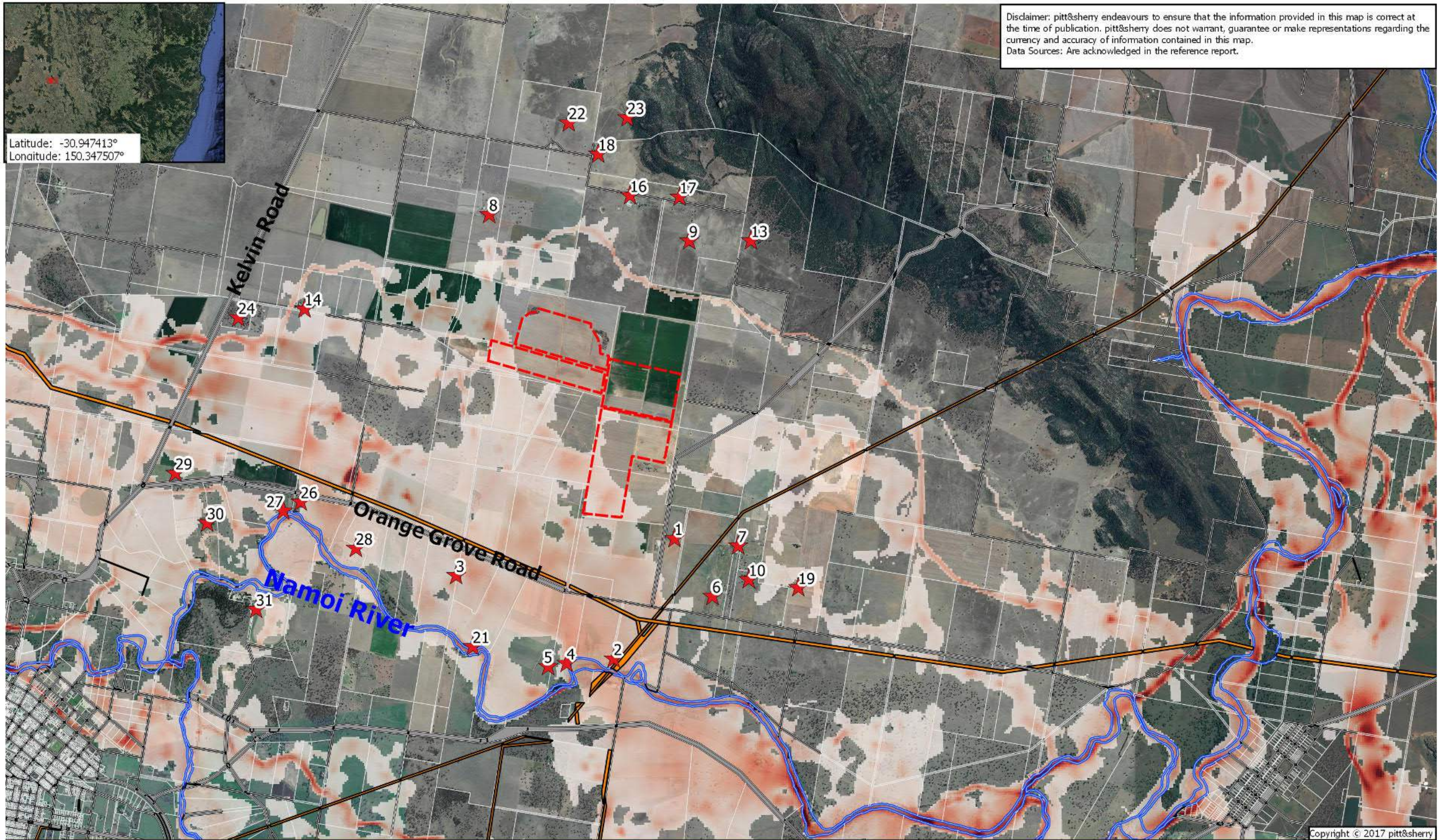


Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P Rev02

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:87,922 When printed at A4

Legend

- Solar Farm
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

10% AEP Existing Scenario (m/s)

2.2
1.6
1
0.4
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F002
Revision	2
Author	mdugan
Reviewer	mjacobs
Date	21-03-2018

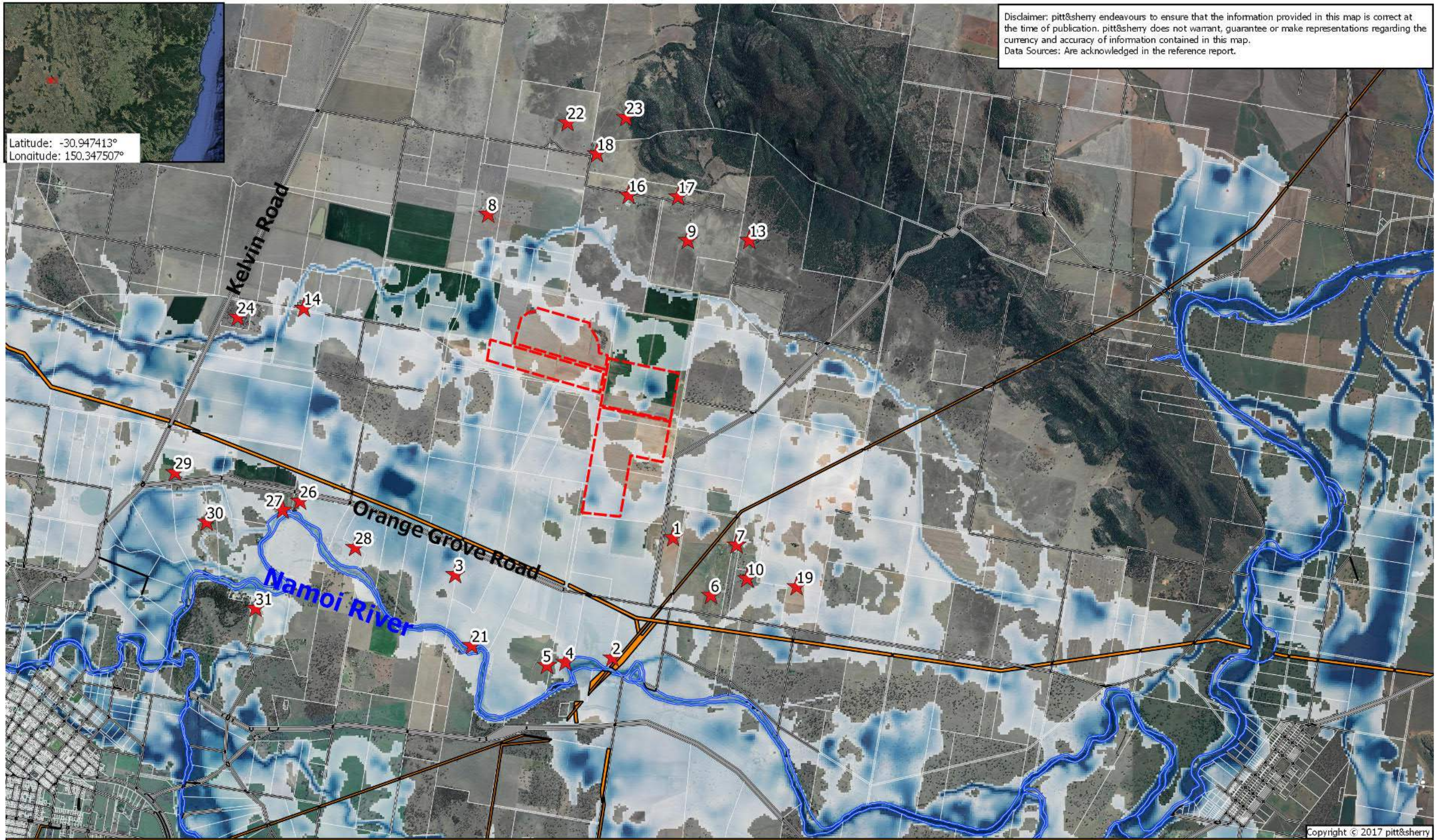
Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

10% AEP Flood Velocity Existing Scenario

File: C:/dms/1/SY17199 - Gunnedah Solar Farm/GIS/SY17199-F002.qgsSY17199-F002.qgs



Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P Rev02

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:87,922 When printed at A4

Legend

	Solar Farm		Road
	Easement		Water Corridor
	Cadastre		SensitiveRecievers

5% AEP Existing Scenario (m)

2
1.5
1
0.5
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F003
Revision	1
Author	mdugan
Reviewer	mjacobs
Date	21-03-2018

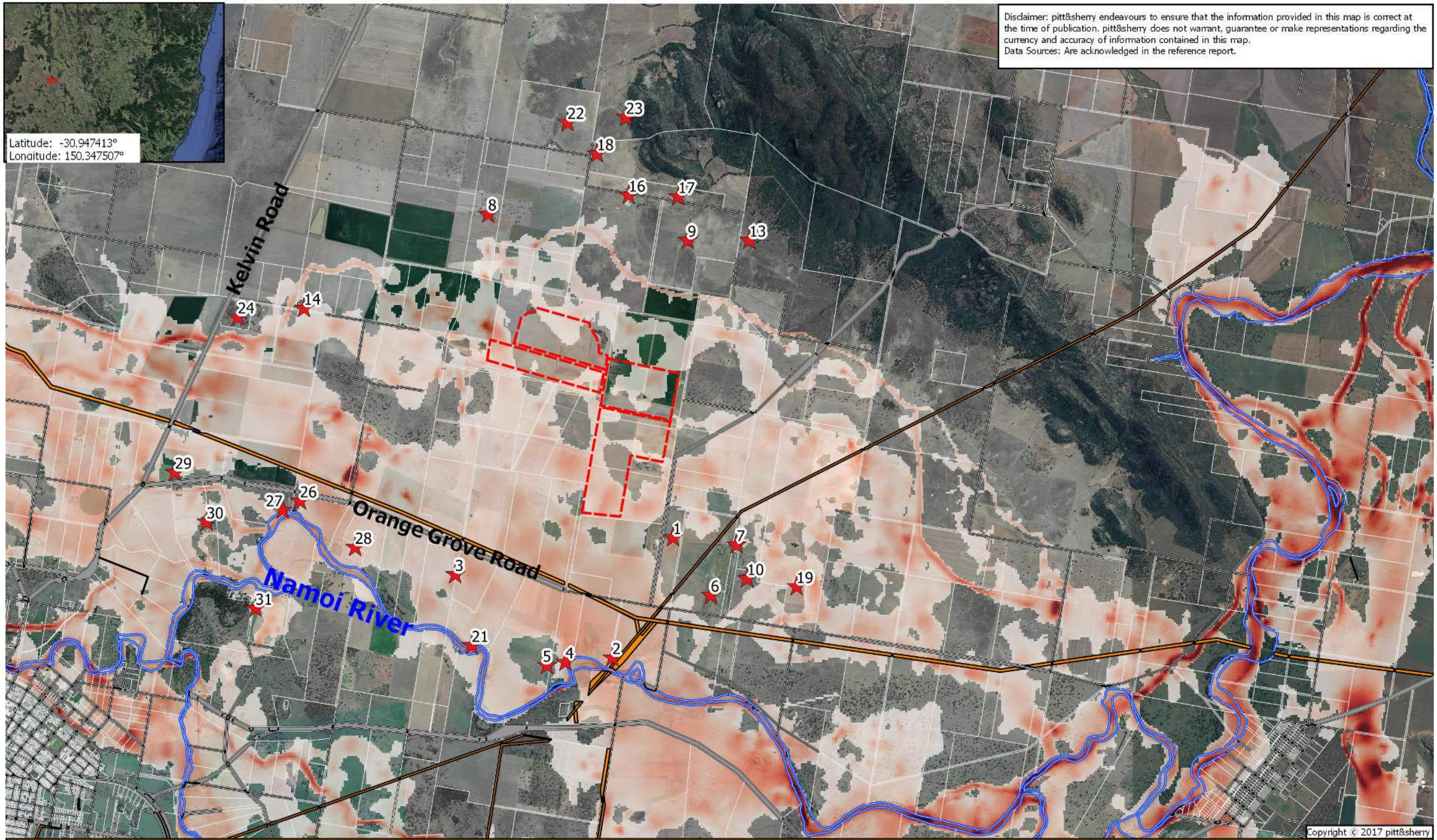
Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

5% AEP Flood Depth
Existing Scenario

File: C:/dms/1/SY17199 - Gunnedah Solar Farm/GIS/SY17199-F003.qgsSY17199-F003.qgs



Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P Rev02

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:87,922 When printed at A4

Legend

	Solar Farm		Road
	Easement		Water Corridor
	Cadastre		SensitiveRecievers

5% AEP Existing Scenario (m/s)

2.2
1.6
1
0.4
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F004
Revision	2
Author	mdugan
Reviewer	mjacobs
Date	21-03-2018

Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

5% AEP Flood Velocity
Existing Scenario

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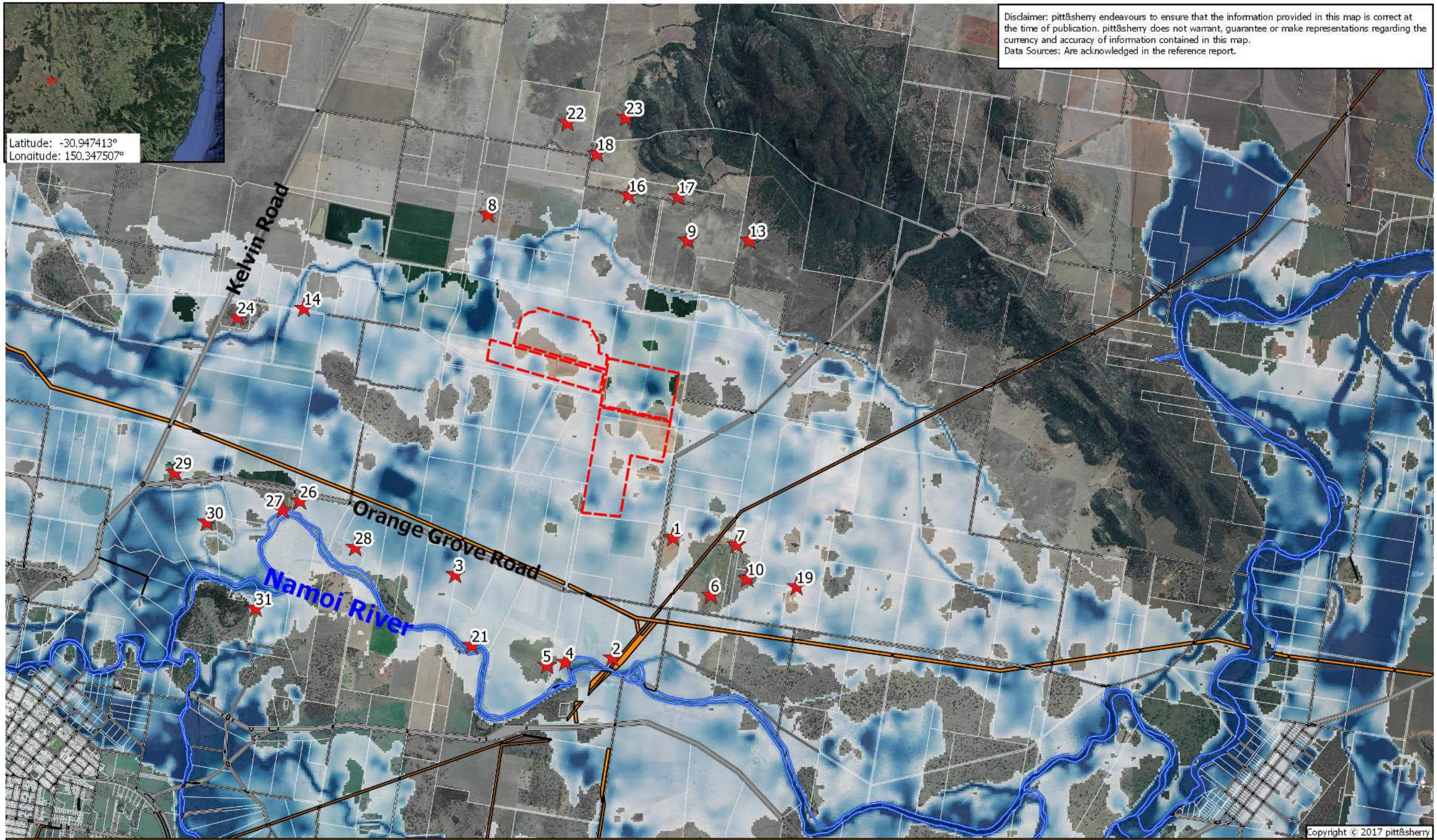

Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P Rev02

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:87,922 When printed at A4

Legend

- Solar Farm
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

1% AEP Existing Scenario (m)

2 – 1.5 – 1 – 0.5 – 0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F005
Revision	1
Author	mdugan
Reviewer	mjacobs
Date	21-03-2018

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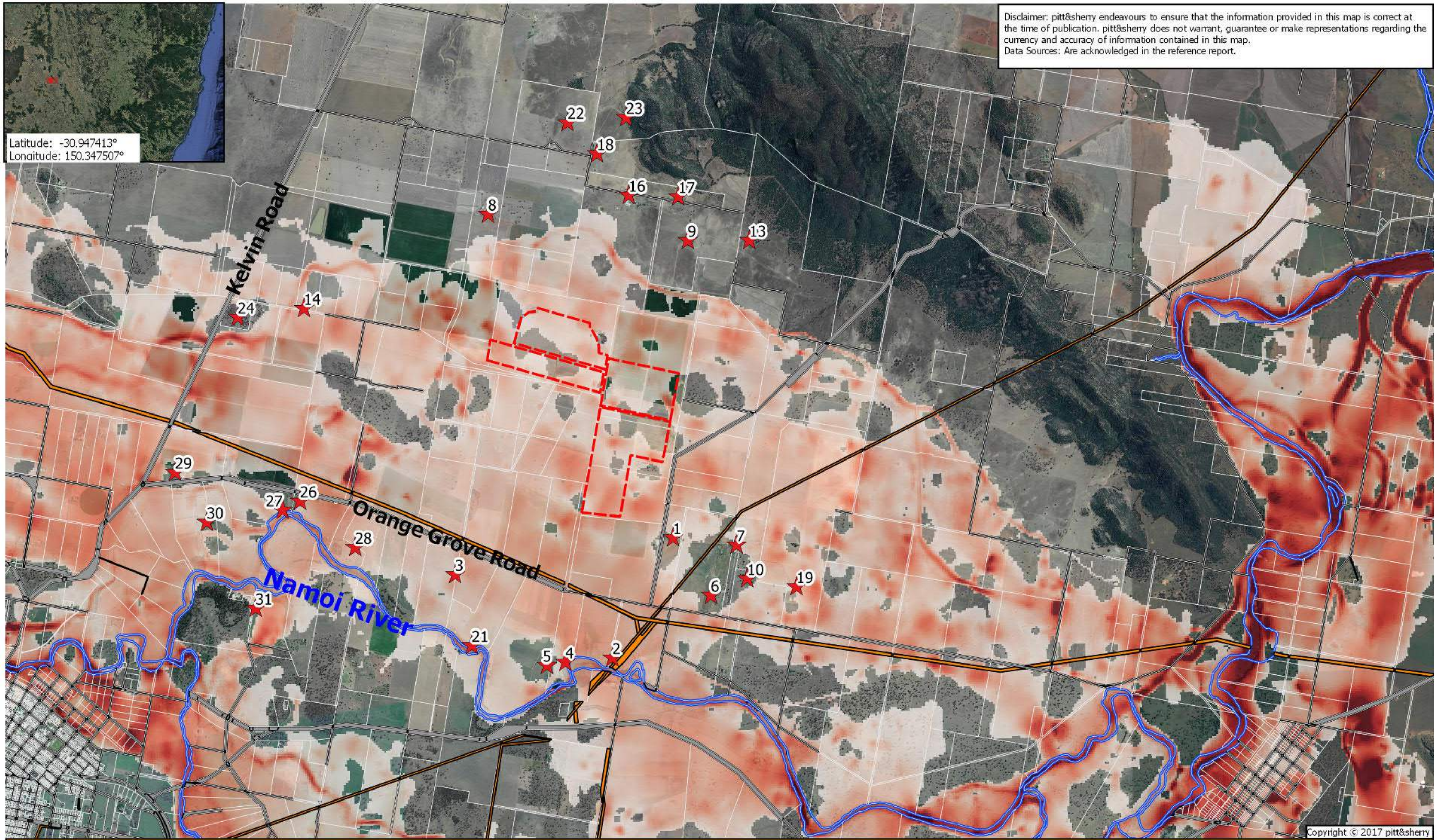
PHOTON ENERGY

Orange Grove Road, Gunnedah

1% AEP Flood Depth
Existing Scenario

File: C:/dms/1/SY17199 - Gunnedah Solar Farm/GIS/SY17199-F005.qgsSY17199-F005.qgs



Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P Rev02

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55

1:87,922 When printed at A4

Legend

- Solar Farm
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

1% AEP Existing Scenario (m/s)

2.2
1.6
1
0.4
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F006
Revision	2
Author	mdugan
Reviewer	mjacobs
Date	21-03-2018

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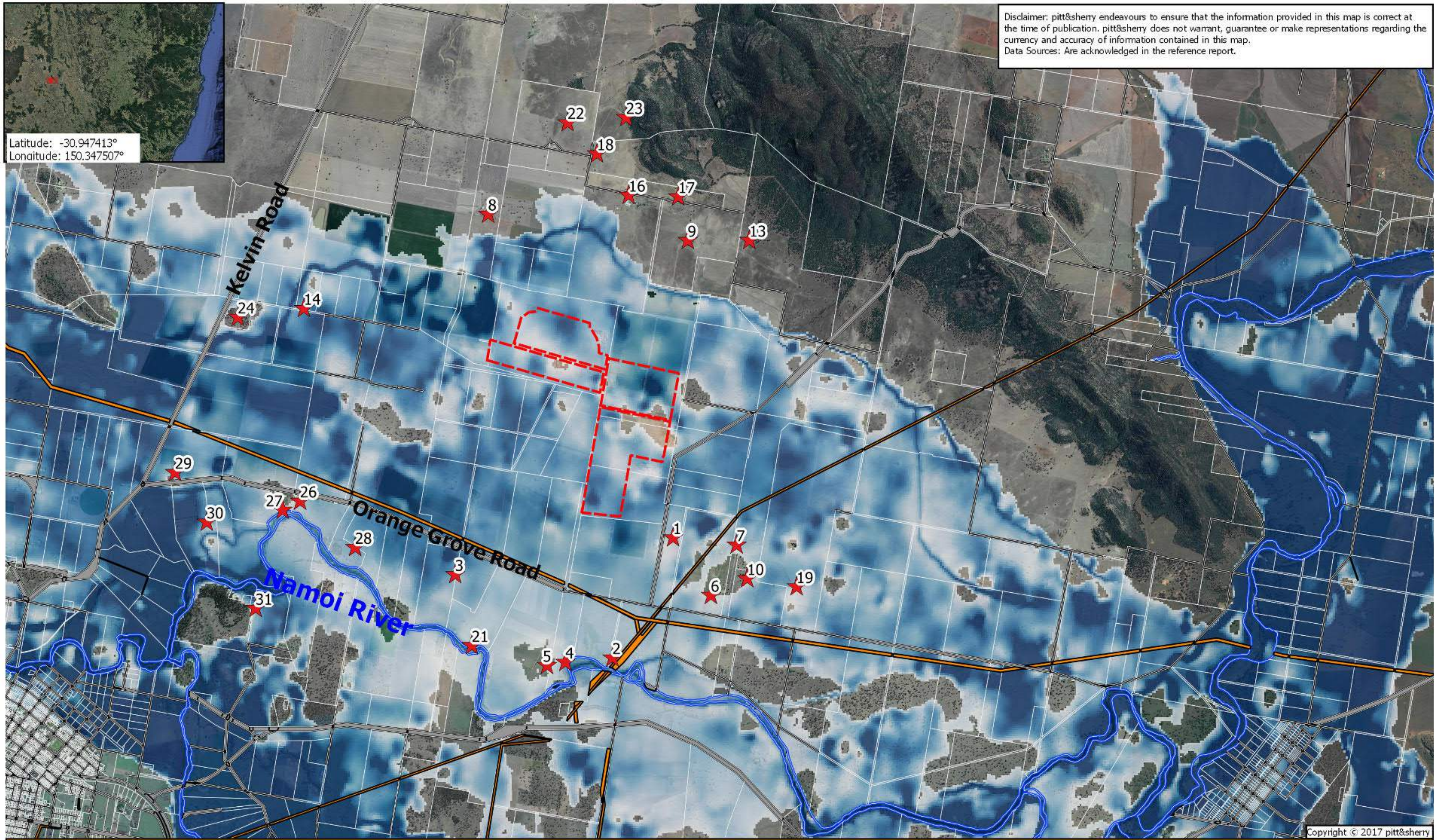
PHOTON ENERGY

Orange Grove Road, Gunnedah

1% AEP Flood Velocity Existing Scenario

File: C:/dms/1/SY17199 - Gunnedah Solar Farm/GIS/SY17199-F006.qgsSY17199-F006.qgs



Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P Rev02

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:87,922 When printed at A4

Legend

- Solar Farm
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

PMF Existing Scenario (m)

2, 1.5, 1, 0.5, 0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F007
Revision	1
Author	mdugan
Reviewer	mjacobs
Date	21-03-2018

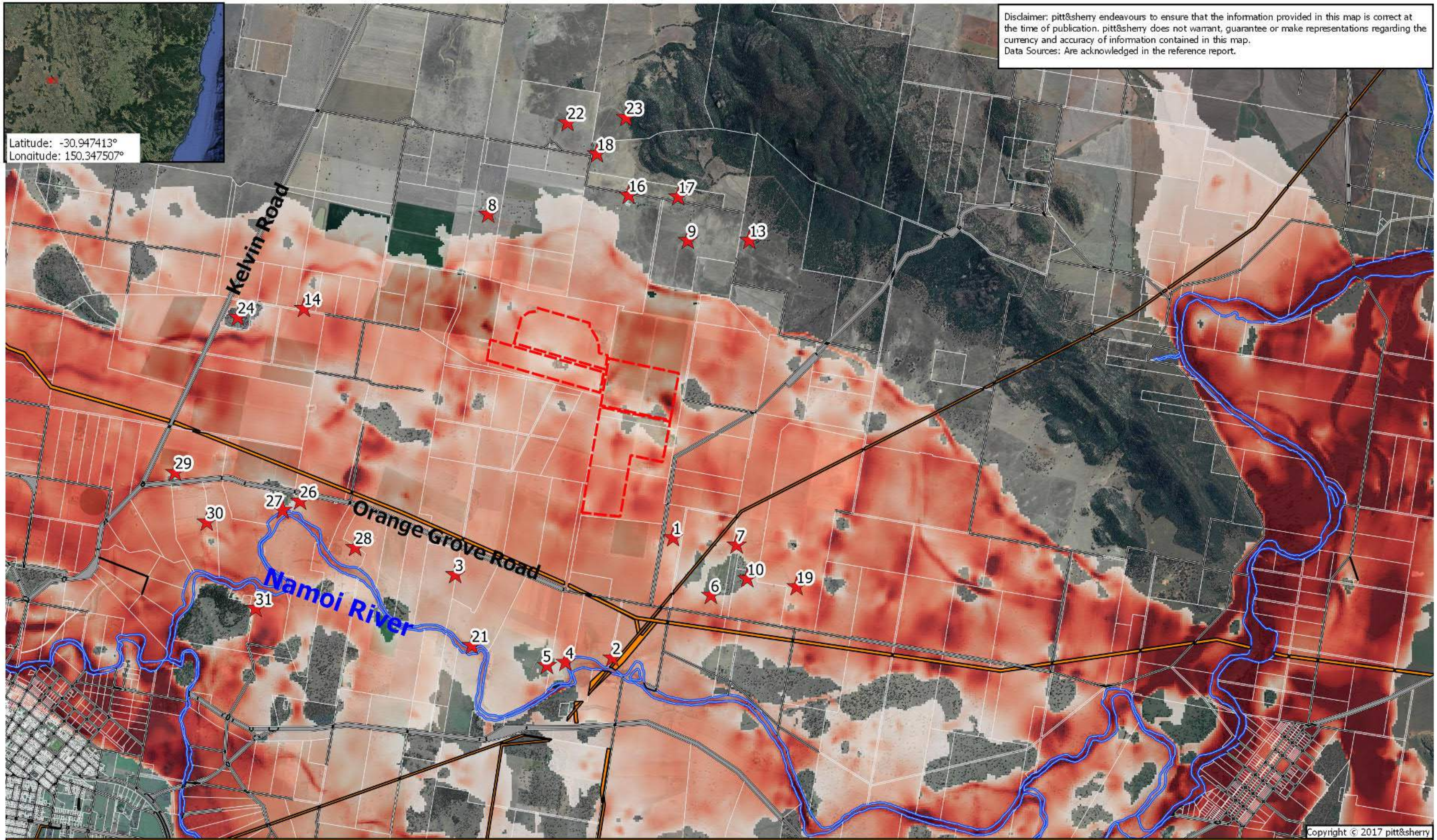
Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

Probable Maximum Flood Depth Existing Scenario

File: C:/dms/1/SY17199 - Gunnedah Solar Farm/GIS/SY17199-F007.qgsSY17199-F007.qgs



Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P Rev02

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:87,922 When printed at A4

Legend

- Solar Farm
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

PMF Existing Scenario (m/s)

2.2
1.6
1
0.4
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F008
Revision	2
Author	mdugan
Reviewer	mjacobs
Date	21-03-2018

Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

Probable Maximum Flood Velocity Existing Scenario

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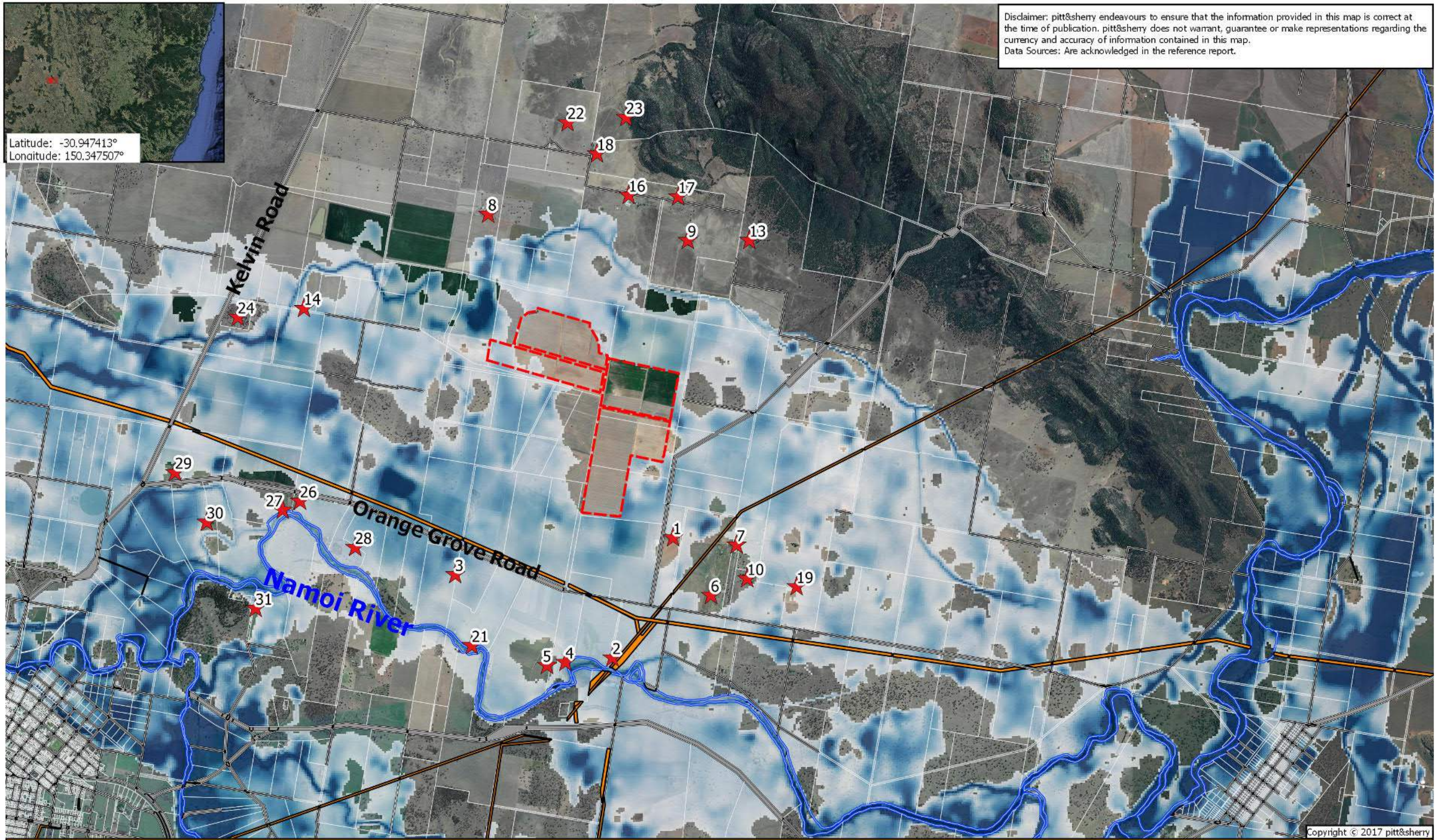

Data sources:
Base image from Google Earth
Reference Report:
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N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:87,922 When printed at A4

Legend

Solar Farm		Road	
Easement		Water Corridor	
Cadastre		SensitiveRecievers	

1% AEP Configuration 1 Scenario (m)

2 – 1.5 – 1 – 0.5 – 0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F105
Revision	1
Author	mdugan
Reviewer	mjacobs
Date	21-03-2018

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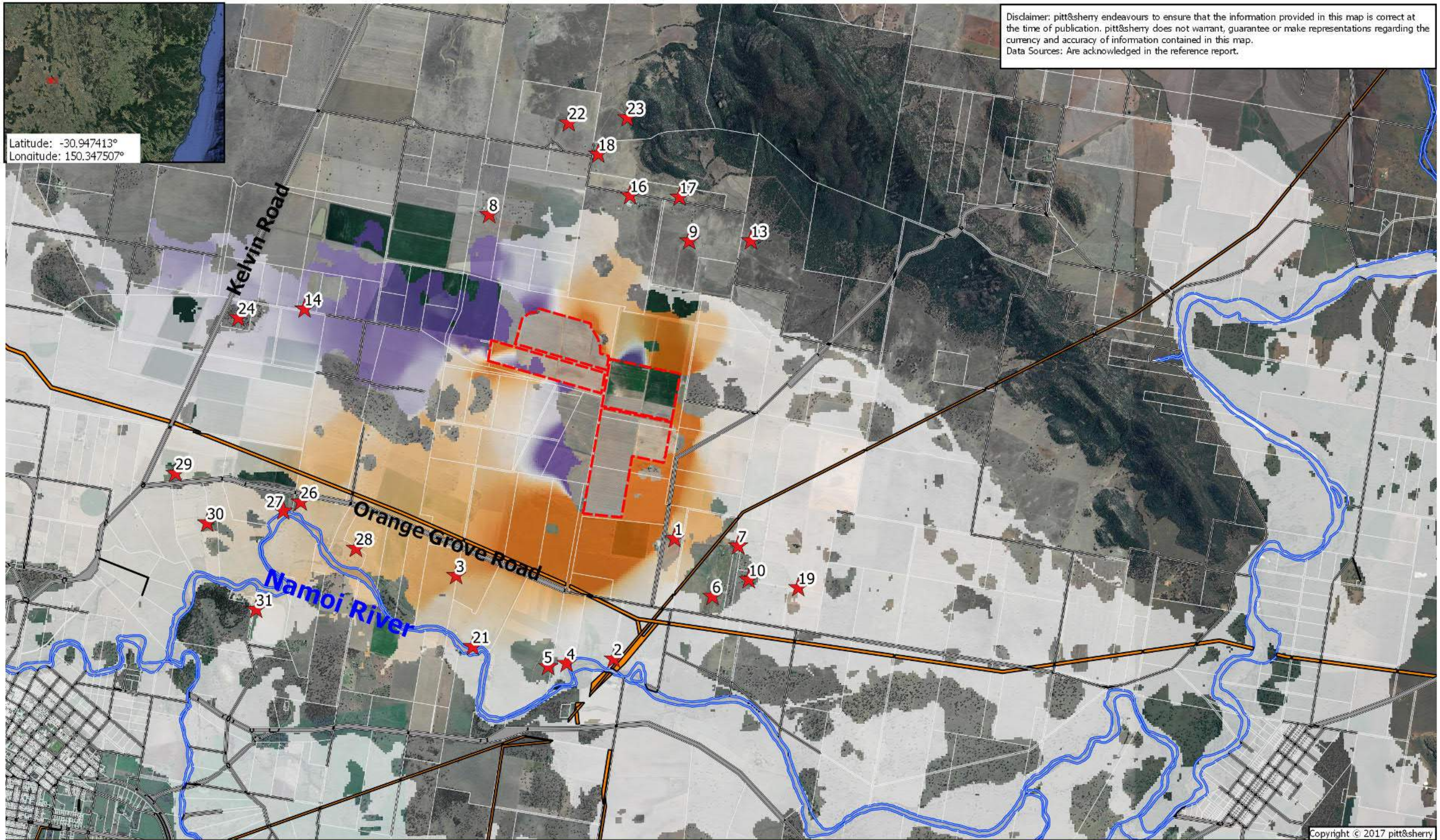
PHOTON ENERGY

Orange Grove Road, Gunnedah

1% AEP Flood Depth Configuration 1 Scenario

File: C:/dms/1/SY17199 - Gunnedah Solar Farm/GIS/SY17199-F105.qgsSY17199-F105.qgs



Data sources:
Base image from Google Earth
Reference Report:
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N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:87,922 When printed at A4

Legend

Solar Farm		Road	
Easement		Water Corridor	
Cadastre		SensitiveRecievers	

1% AEP Configuration 1 Difference (m)

0.1
0.05
0
-0.05
-0.1

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F111
Revision	1
Author	mdugan
Reviewer	mjacobs
Date	21-03-2018

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PHOTON ENERGY

Orange Grove Road, Gunnedah

1% AEP Flood Depth change, Existing to Configuration 1

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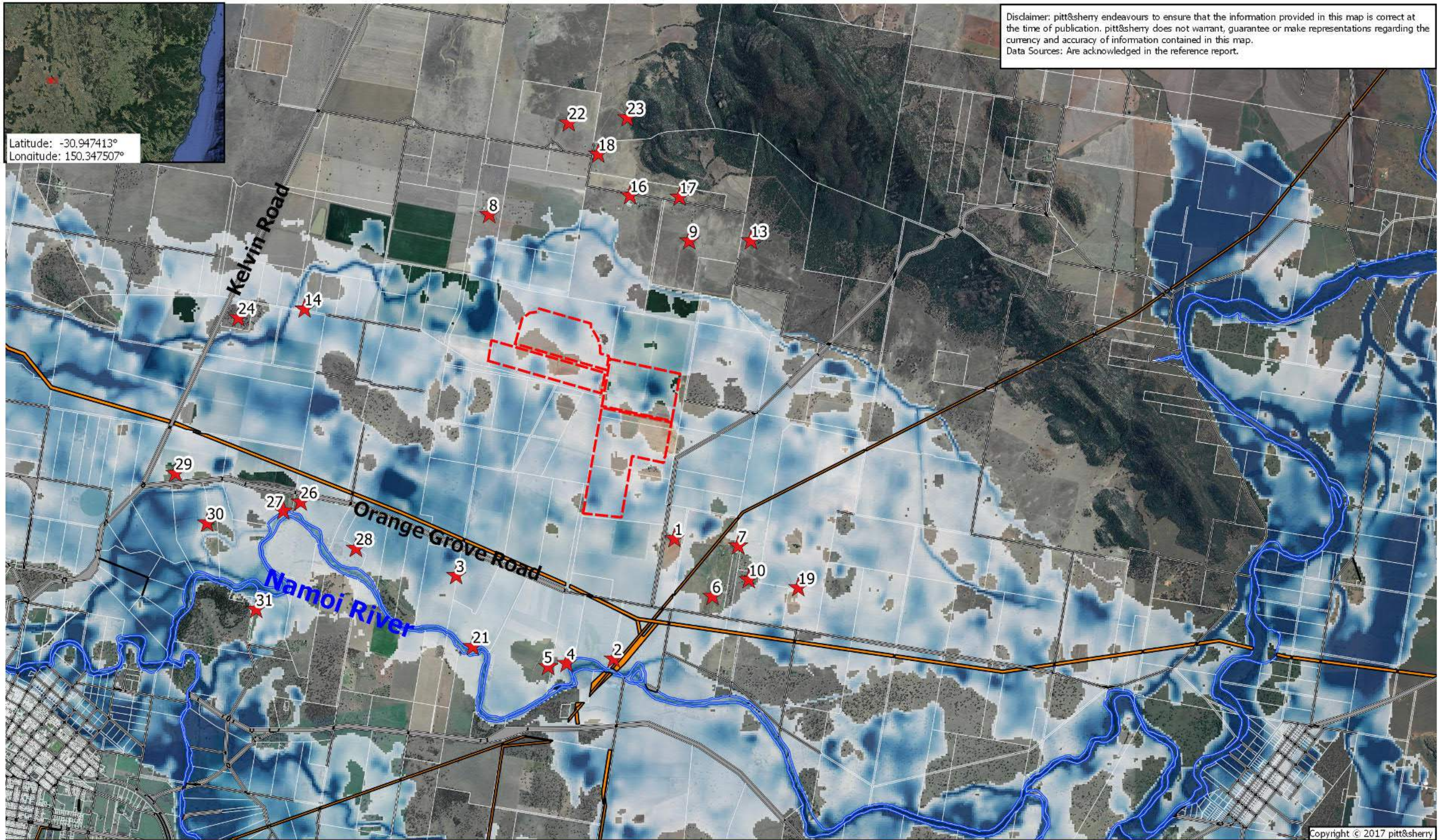

Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P Rev02

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:87,922 When printed at A4

Legend

Solar Farm	Road
Easement	Water Corridor
Cadastre	SensitiveRecievers

1% AEP Configuration 2 Scenario (m)

2
1.5
1
0.5
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F205
Revision	1
Author	mdugan
Reviewer	mjacobs
Date	21-03-2018

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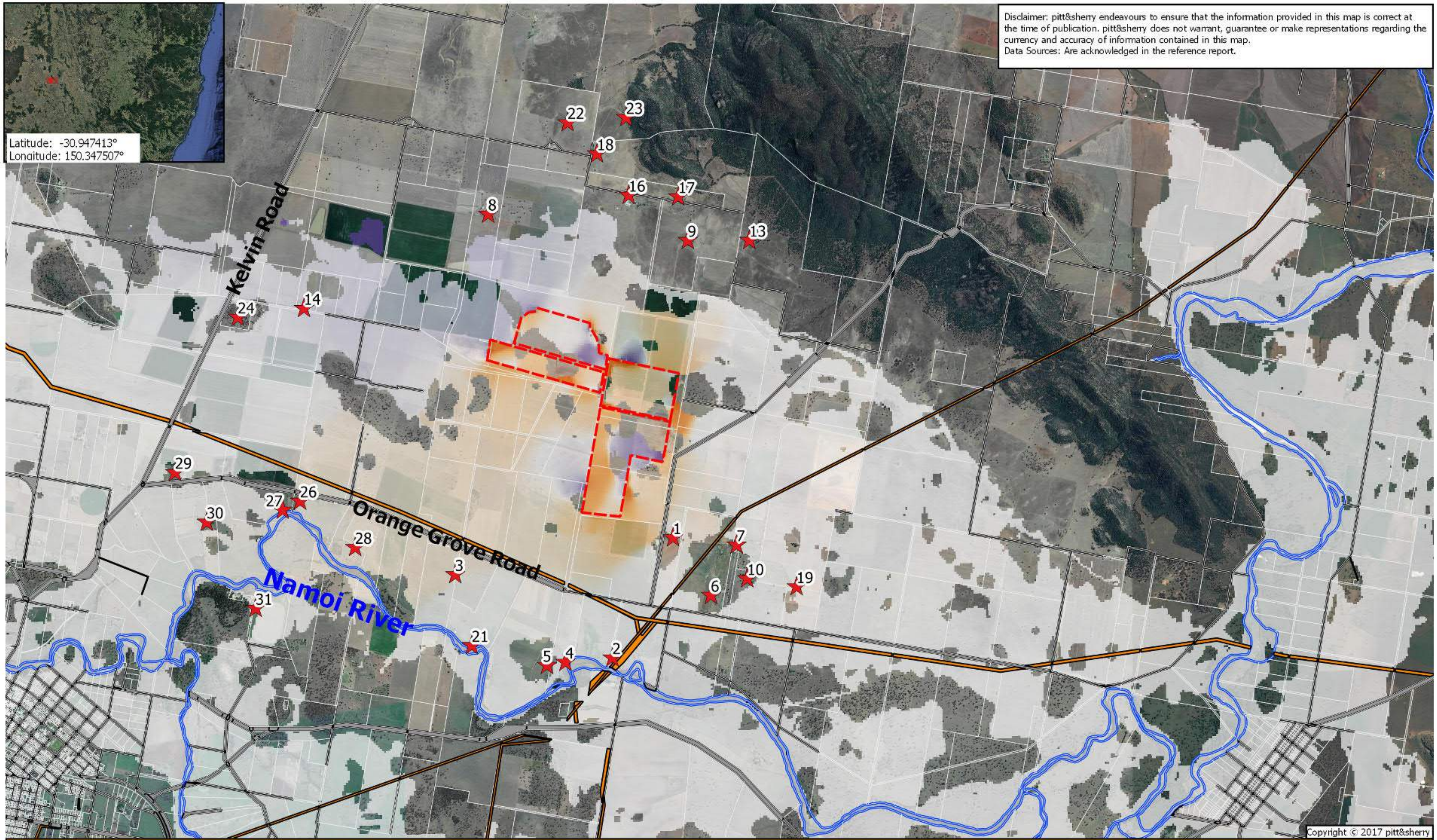
PHOTON ENERGY

Orange Grove Road, Gunnedah

1% AEP Flood Depth Configuration 2 Scenario

File: C:/dms/1/SY17199 - Gunnedah Solar Farm/GIS/SY17199-F205.qgsSY17199-F205.qgs



Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P Rev02

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:87,922 When printed at A4

Legend

- Solar Farm
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

1% AEP Configuration 2 Difference (m)

0.1
0.05
0
-0.05
-0.1

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F211
Revision	1
Author	mdugan
Reviewer	mjacobs
Date	21-03-2018

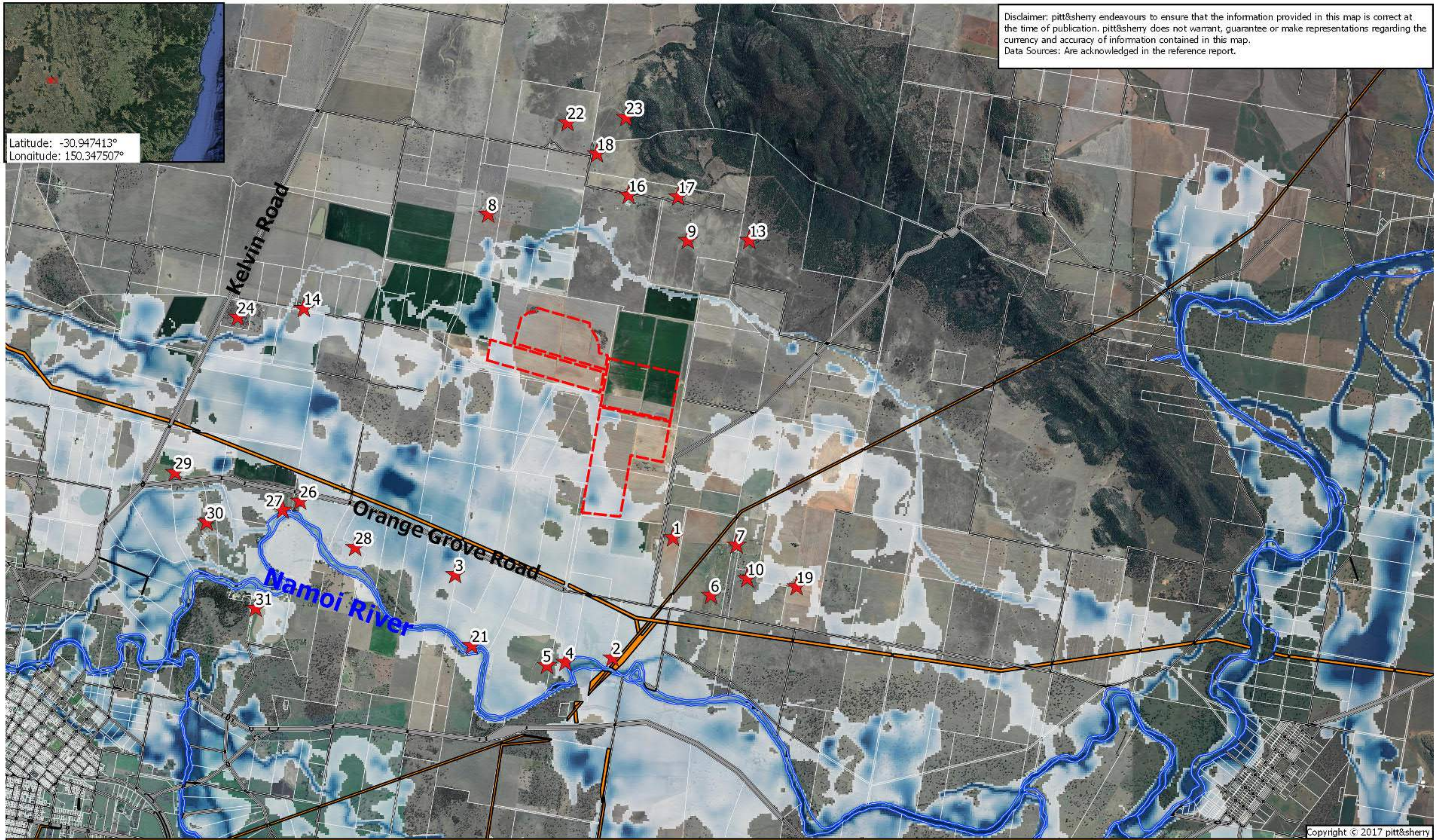
Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

1% AEP Flood Depth change, Existing to Configuration 2

File: C:/dms/1/SY17199 - Gunnedah Solar Farm/GIS/SY17199-F211.qgsSY17199-F211.qgs



Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P Rev02

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:87,922 When printed at A4

Legend

- Solar Farm
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

10% AEP Configuration 3 Scenario (m)

2 – 1.5 – 1 – 0.5 – 0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F301
Revision	1
Author	mdugan
Reviewer	mjacobs
Date	21-03-2018

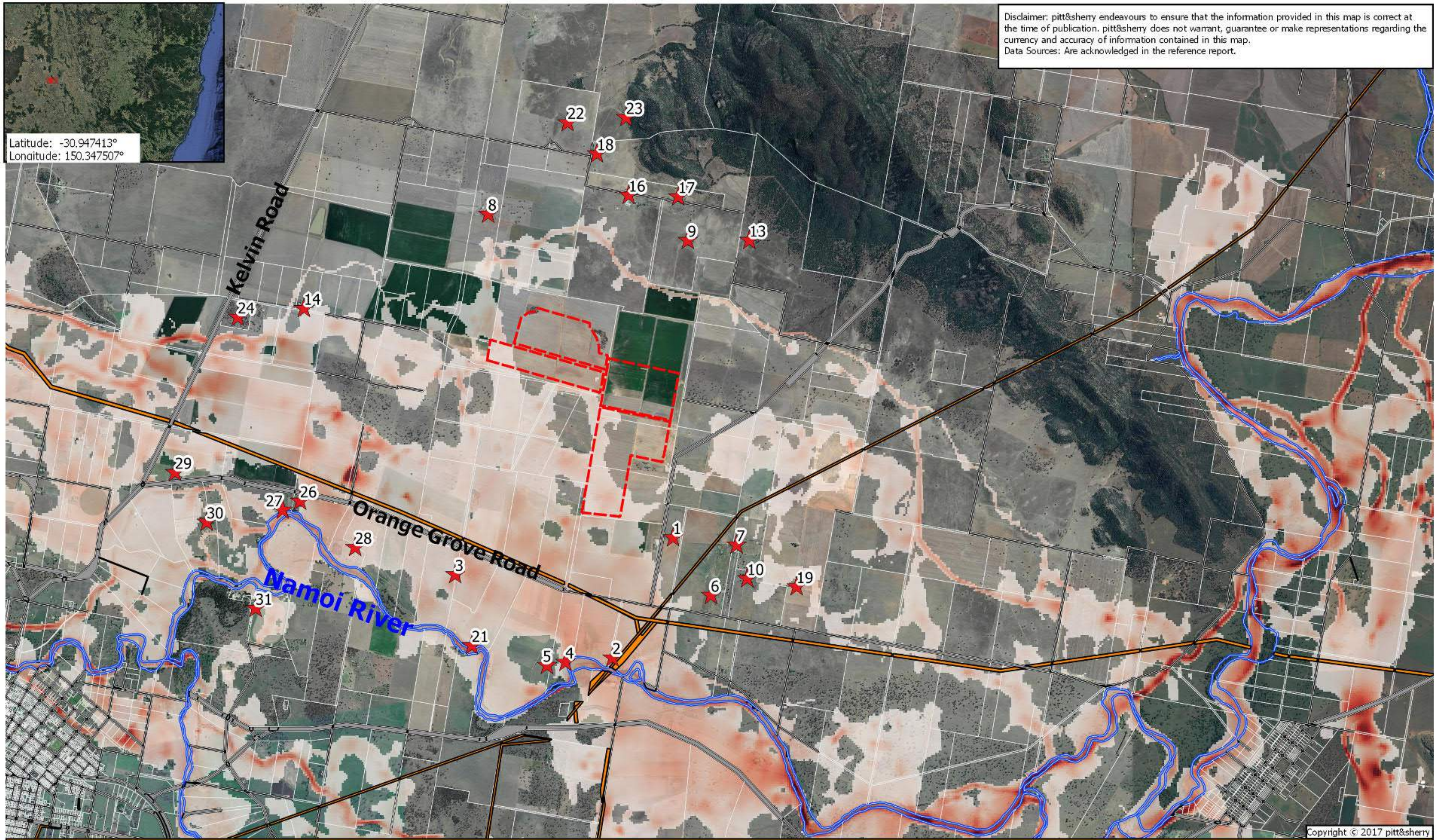
Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

10% AEP Flood Depth
Configuration 3 Scenario

File: C:/dms/1/SY17199 - Gunnedah Solar Farm/GIS/SY17199-F301.qgsSY17199-F301.qgs



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Base image from Google Earth
Reference Report:
SY17199B005 REP 31P Rev02

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:87,922 When printed at A4

Legend

	Solar Farm		Road
	Easement		Water Corridor
	Cadastre		SensitiveRecievers

10% AEP Configuration 3 Scenario (m/s)

2.2
1.6
1
0.4
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F302
Revision	2
Author	mdugan
Reviewer	mjacobs
Date	21-03-2018

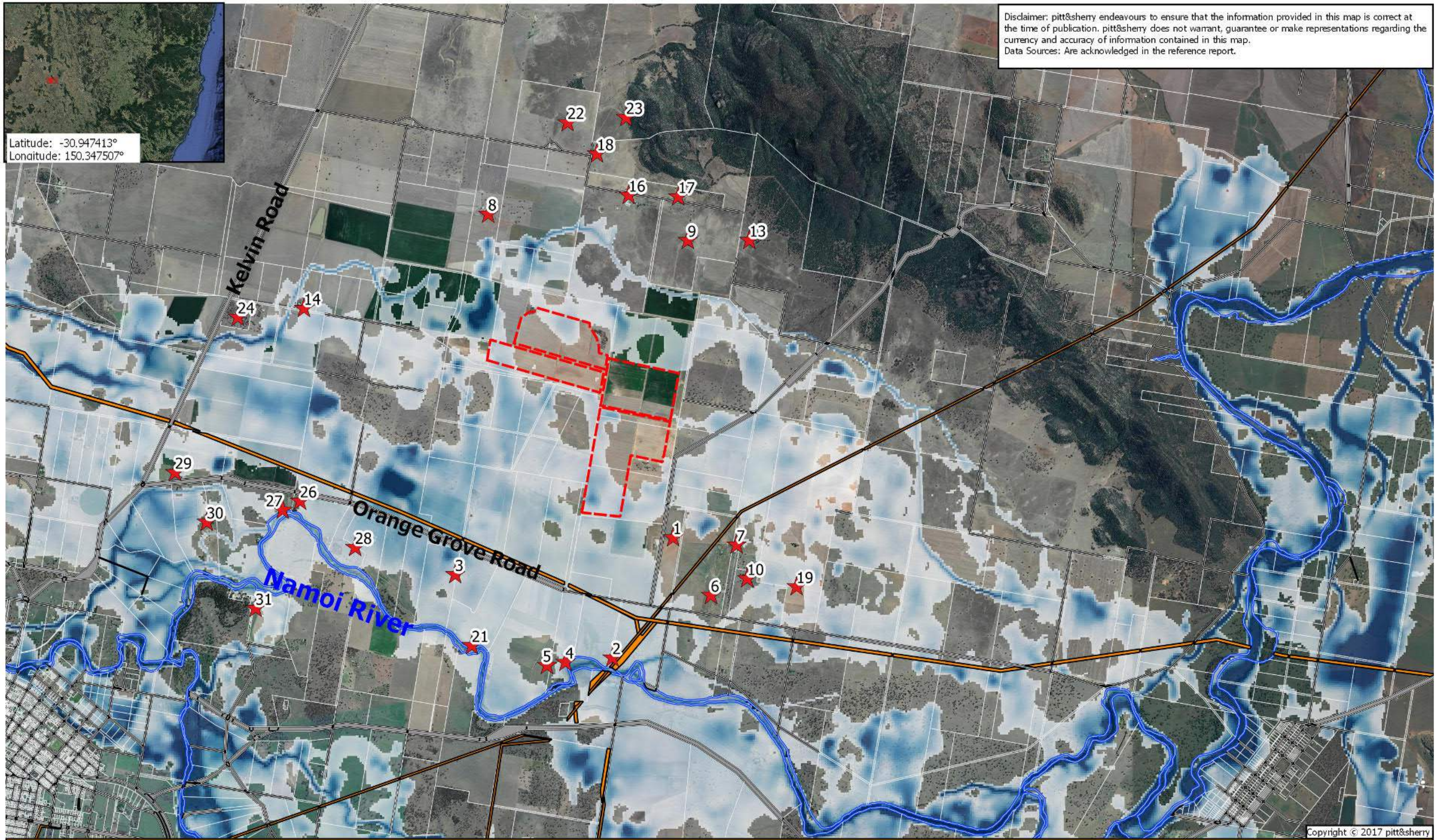
Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

10% AEP Flood Velocity Configuration 3 Scenario

File: C:/dms/1/SY17199 - Gunnedah Solar Farm/GIS/SY17199-F302.qgsSY17199-F302.qgs



Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P Rev02

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:87,922 When printed at A4

Legend
- Solar Farm
- Road
- Easement
- Water Corridor
- Cadastre
- SensitiveRecievers

5% AEP Configuration 3 Scenario (m)

2
1.5
1
0.5
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F303
Revision	1
Author	mdugan
Reviewer	mjacobs
Date	21-03-2018

Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

5% AEP Flood Depth Configuration 3 Scenario

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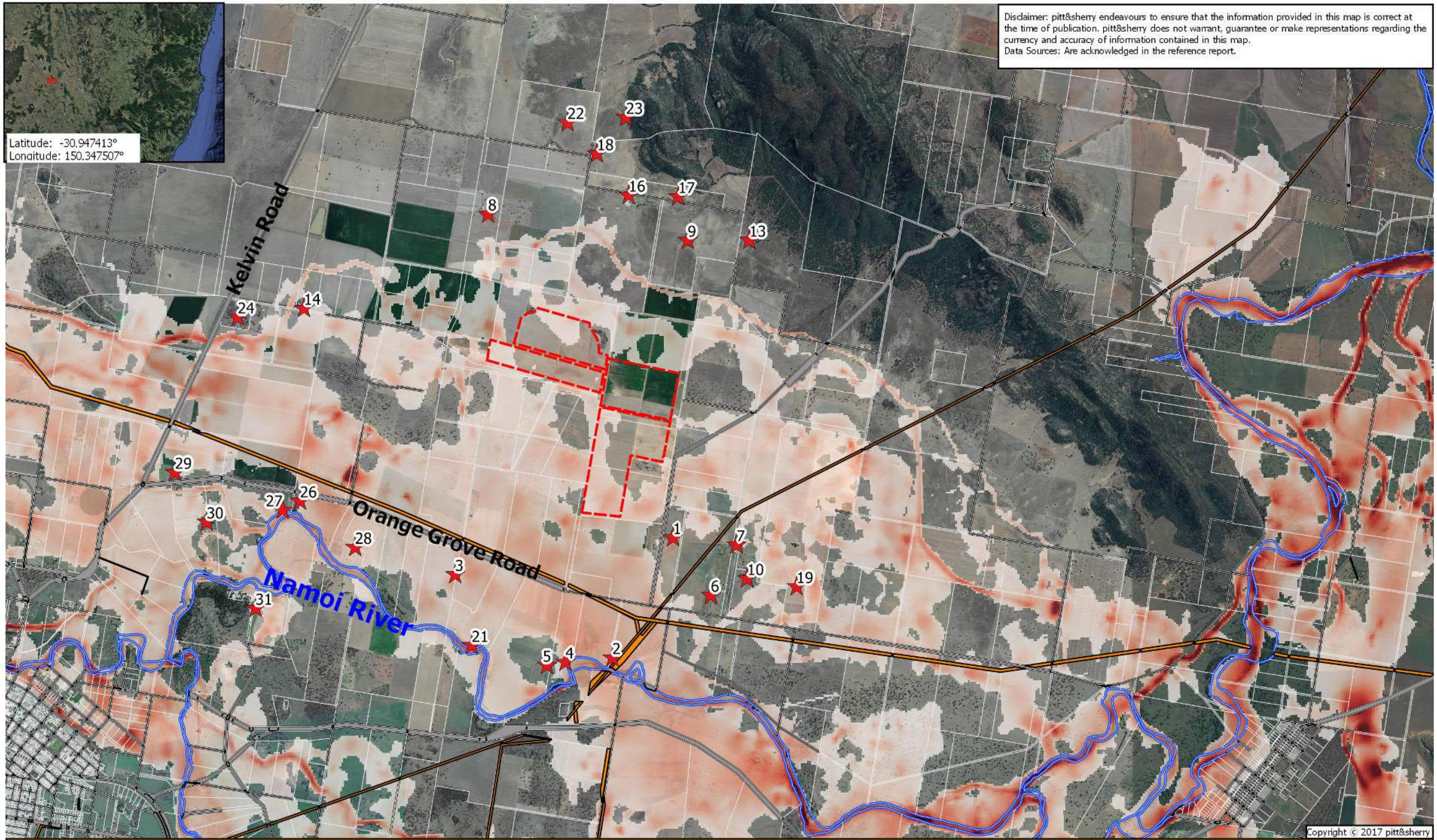


Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P Rev02

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55

1:87,922 When printed at A4

Legend

- Solar Farm
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

5% AEP Configuration 3 Scenario (m/s)

2.2
1.6
1
0.4
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F304
Revision	2
Author	mdugan
Reviewer	mjacobs
Date	21-03-2018

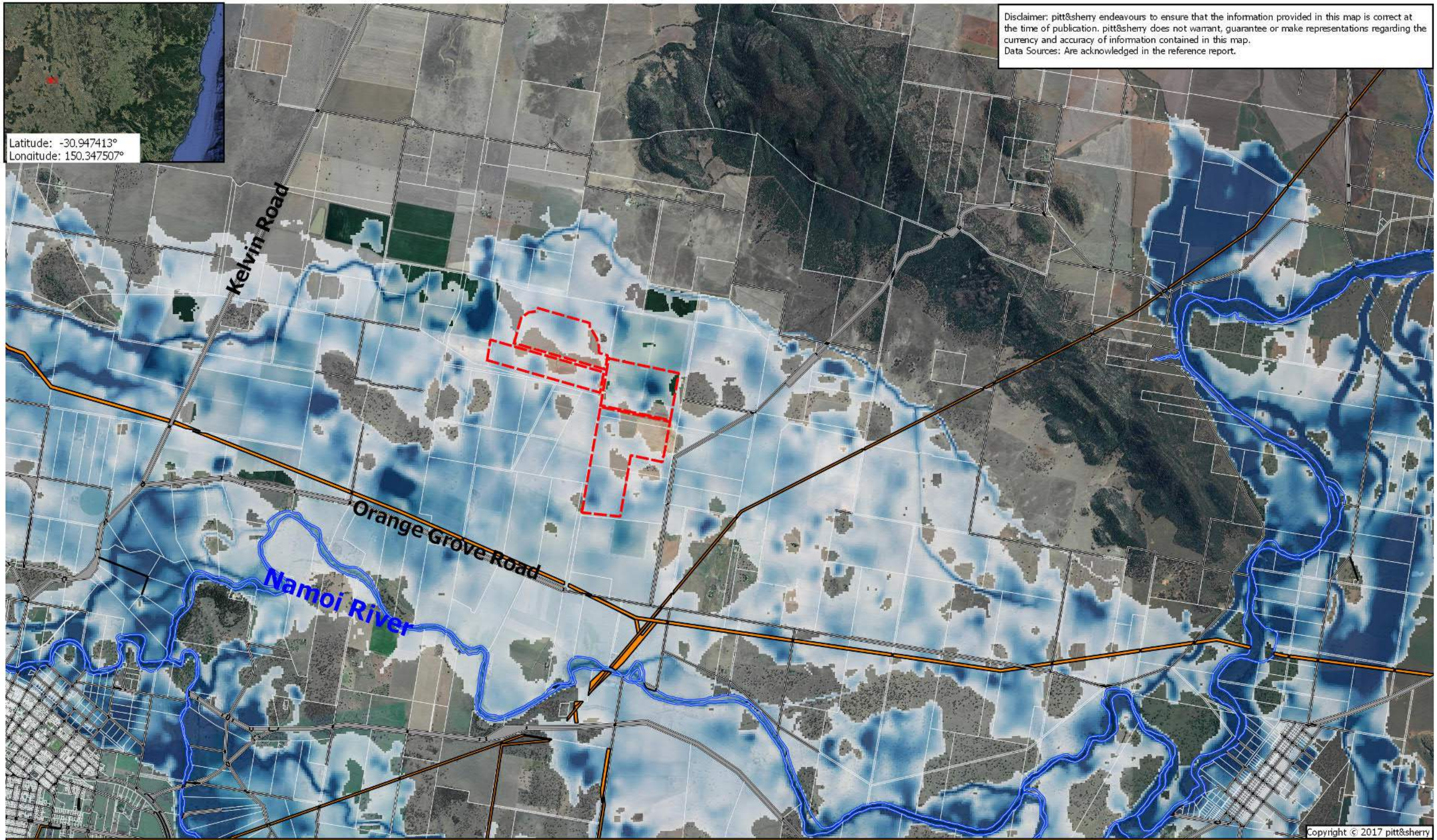
Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

5% AEP Flood Velocity Configuration 3 Scenario

File: C:/dms/1/SY17199 - Gunnedah Solar Farm/GIS/SY17199-F304.qgsSY17199-F304.qgs



Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P Rev02

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:87,922 When printed at A4

Legend

- Solar Farm
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

1% AEP Configuration 3 Scenario (m)

2 – 1.5 – 1 – 0.5 – 0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F305
Revision	1
Author	mdugan
Reviewer	mjacobs
Date	21-03-2018

Photon Energy Engineering Australia Pty Ltd

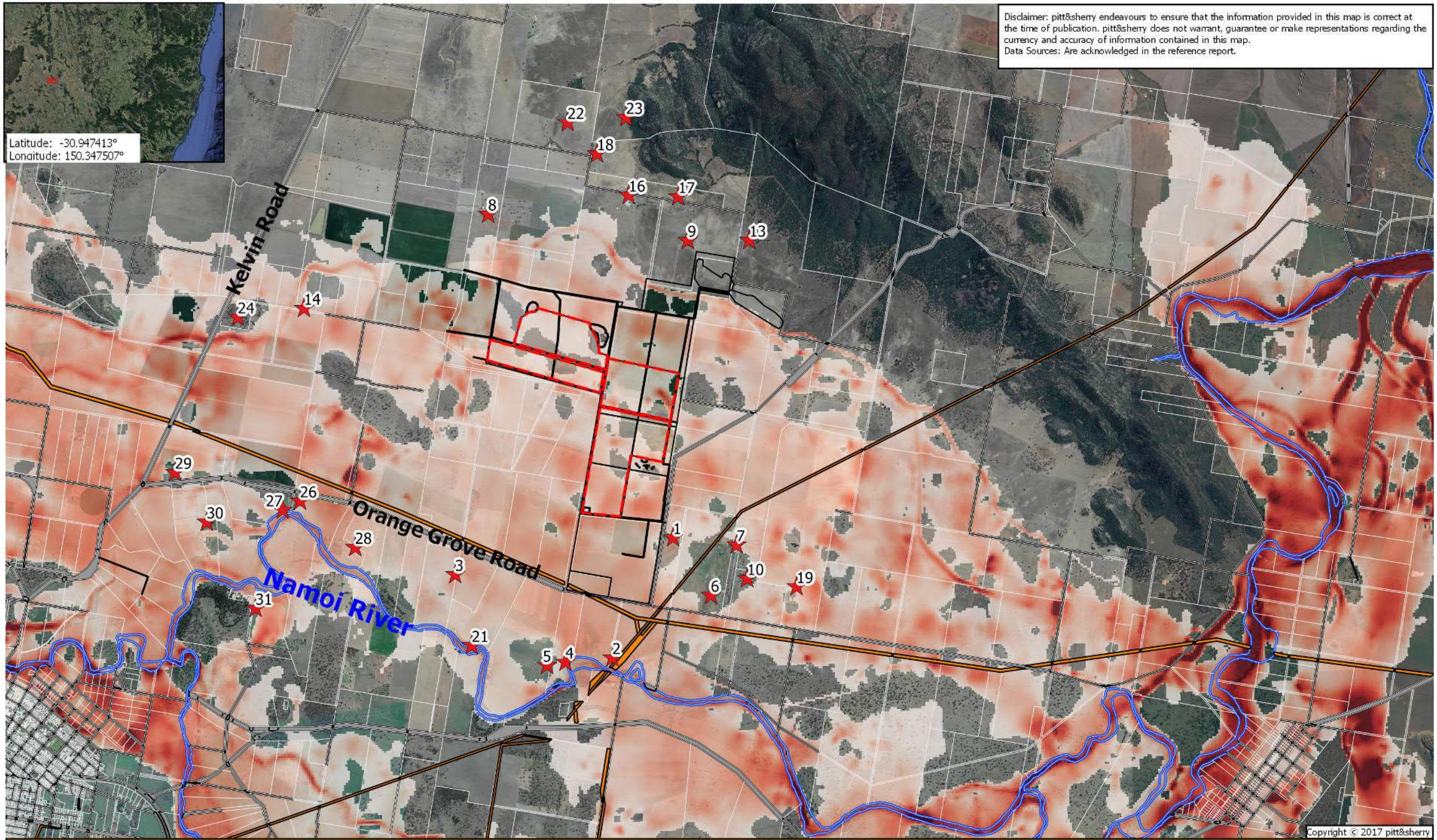
PHOTON ENERGY

Orange Grove Road, Gunnedah

1% AEP Flood Depth Configuration 3 Scenario

File: C:/dms/1/SY17199 - Gunnedah Solar Farm/GIS/SY17199-F305.qgsSY17199-F305.qgs

Disclaimer: pitt&sherry endeavours to ensure that the information provided in this map is correct at the time of publication. pitt&sherry does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
Data Sources: Are acknowledged in the reference report.



Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P Rev02

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:87,922 When printed at A4

Legend

	Solar Farm		Road
	Easement		Water Corridor
	Cadastre		SensitiveRecievers

1% AEP Configuration 3 Scenario (r

2.2
1.6
1
0.4
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F306
Revision	2
Author	mdugan
Reviewer	mjacobs
Date	21-03-2018

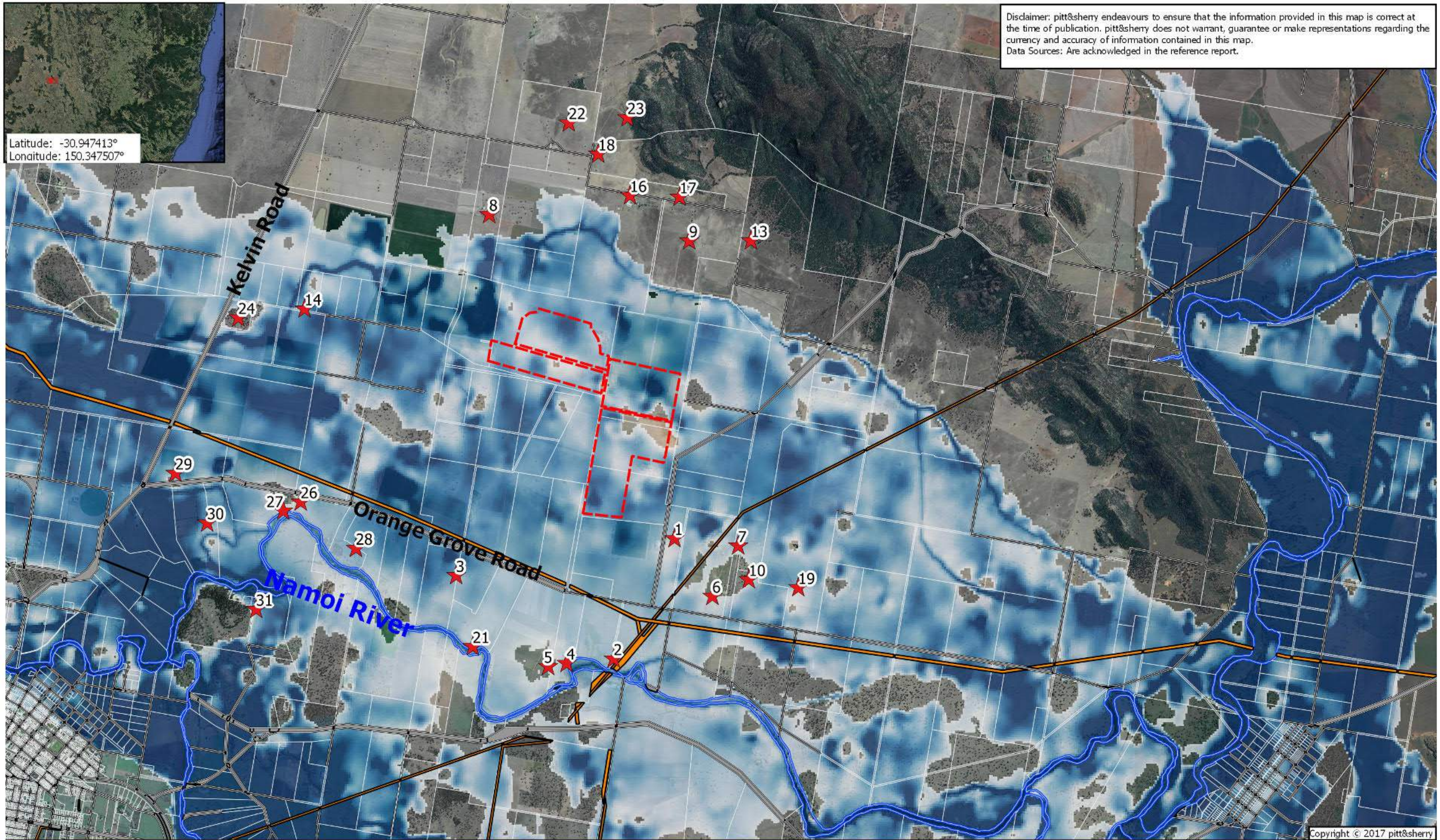
Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

1% AEP Flood Velocity Configuration 3 Scenario

File: C:/dms/1/SY17199 - Gunnedah Solar Farm/GIS/SY17199-F306.qgsSY17199-F306.qgs



Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P Rev02

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:87,922 When printed at A4

Legend

- Solar Farm
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

PMF Configuration 3 Scenario (m)

2, 1.5, 1, 0.5, 0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F307
Revision	1
Author	mdugan
Reviewer	mjacobs
Date	21-03-2018

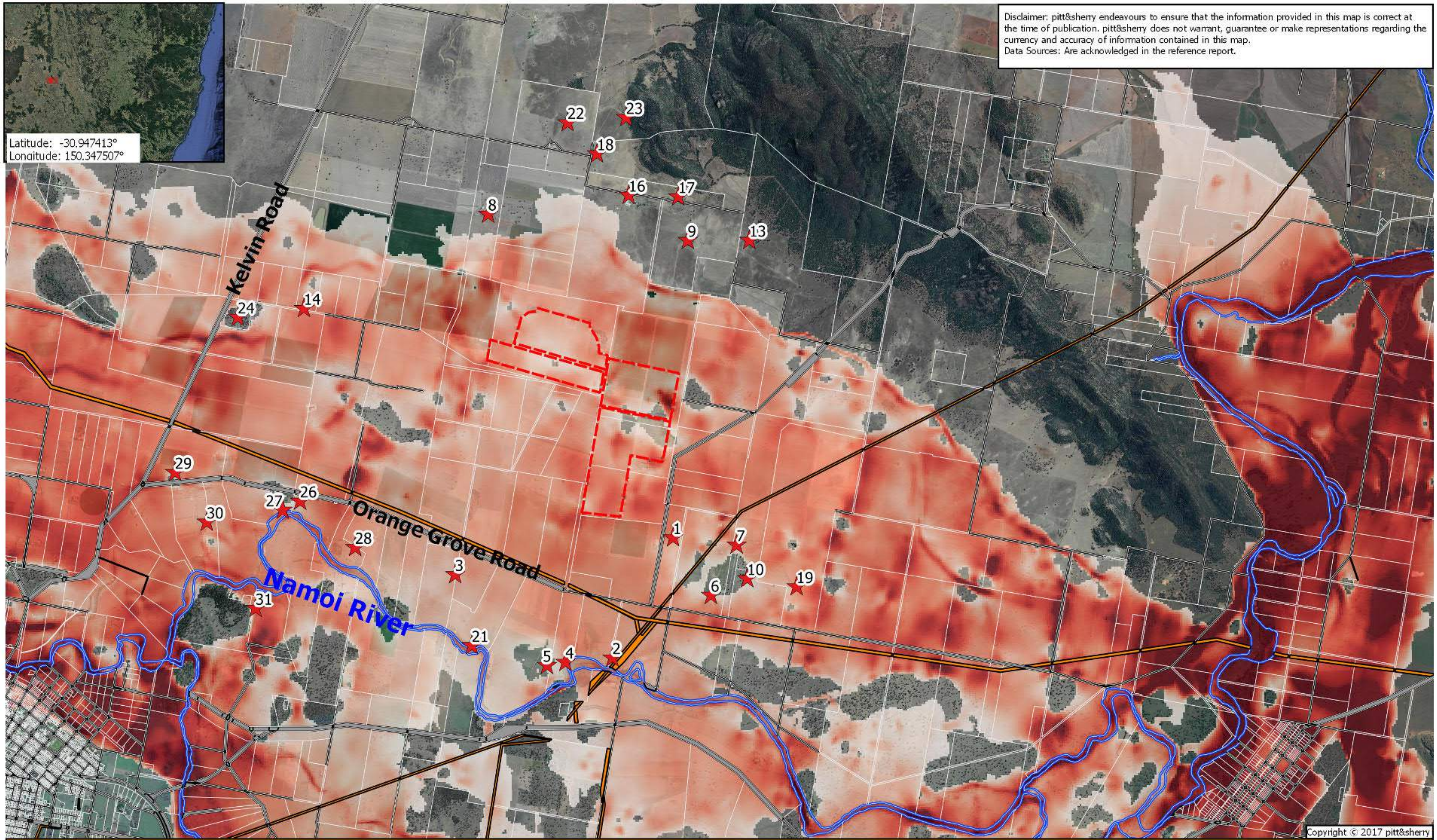
Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

Probable Maximum Flood Depth Configuration 3 Scenario

File: C:/dms/1/SY17199 - Gunnedah Solar Farm/GIS/SY17199-F307.qgsSY17199-F307.qgs



Data sources:
Base image from Google Earth
Reference Report:
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N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
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Legend

Solar Farm		Road	
Easement		Water Corridor	
Cadastre		SensitiveRecievers	

PMF Configuration 3 Scenario (m/s)

2.2
1.6
1
0.4
0

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F308
Revision	2
Author	mdugan
Reviewer	mjacobs
Date	21-03-2018

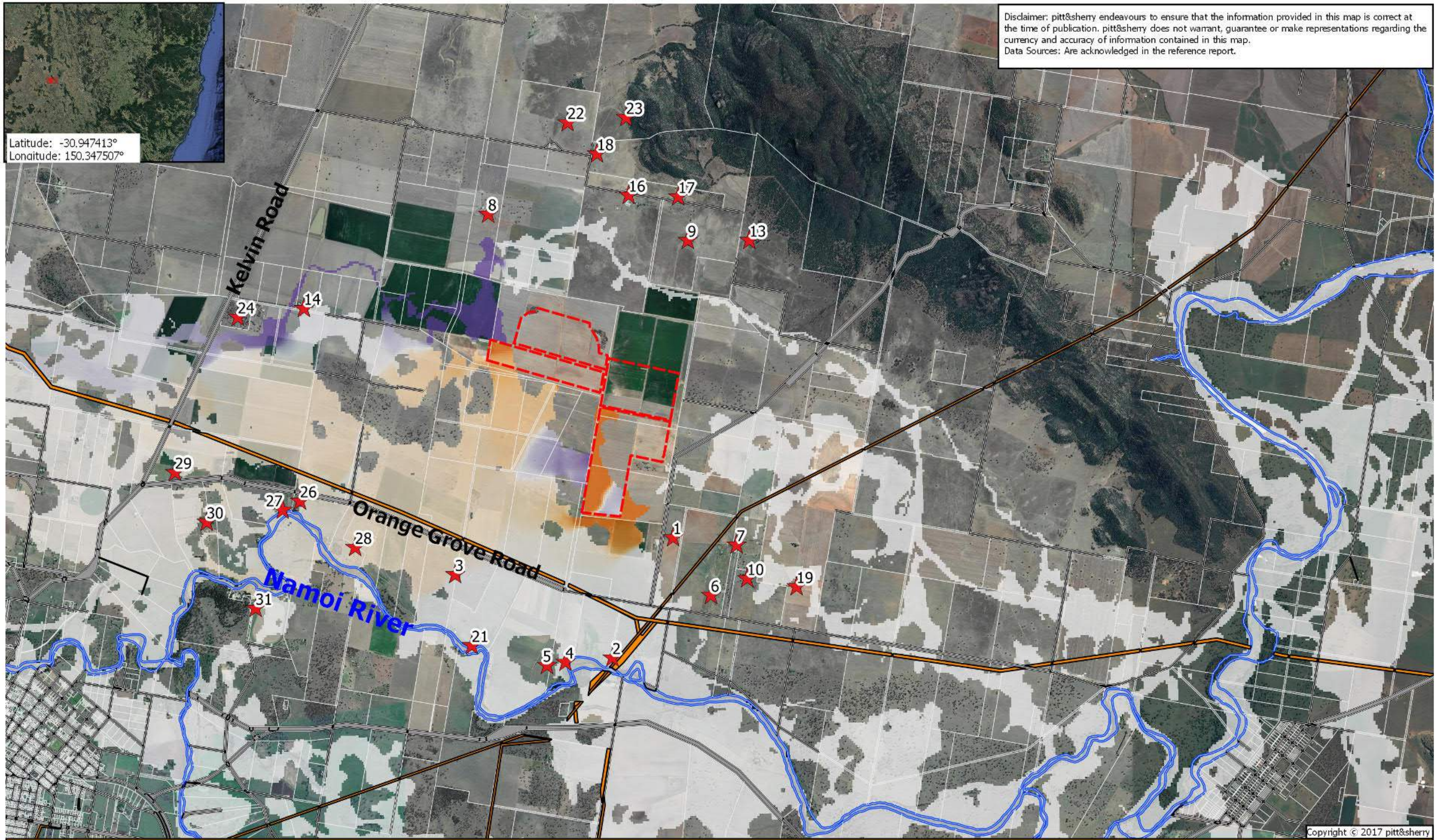
Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

Probable Maximum Flood Velocity Configuration 3 Scenario

File: C:/dms/1/SY17199 - Gunnedah Solar Farm/GIS/SY17199-F308.qgsSY17199-F308.qgs



Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P Rev02

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:87,922 When printed at A4

Legend

- Solar Farm
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

10% AEP Configuration 3 Difference (m)

0.1
0.05
0
-0.05
-0.1

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F309
Revision	1
Author	mdugan
Reviewer	mjacobs
Date	21-03-2018

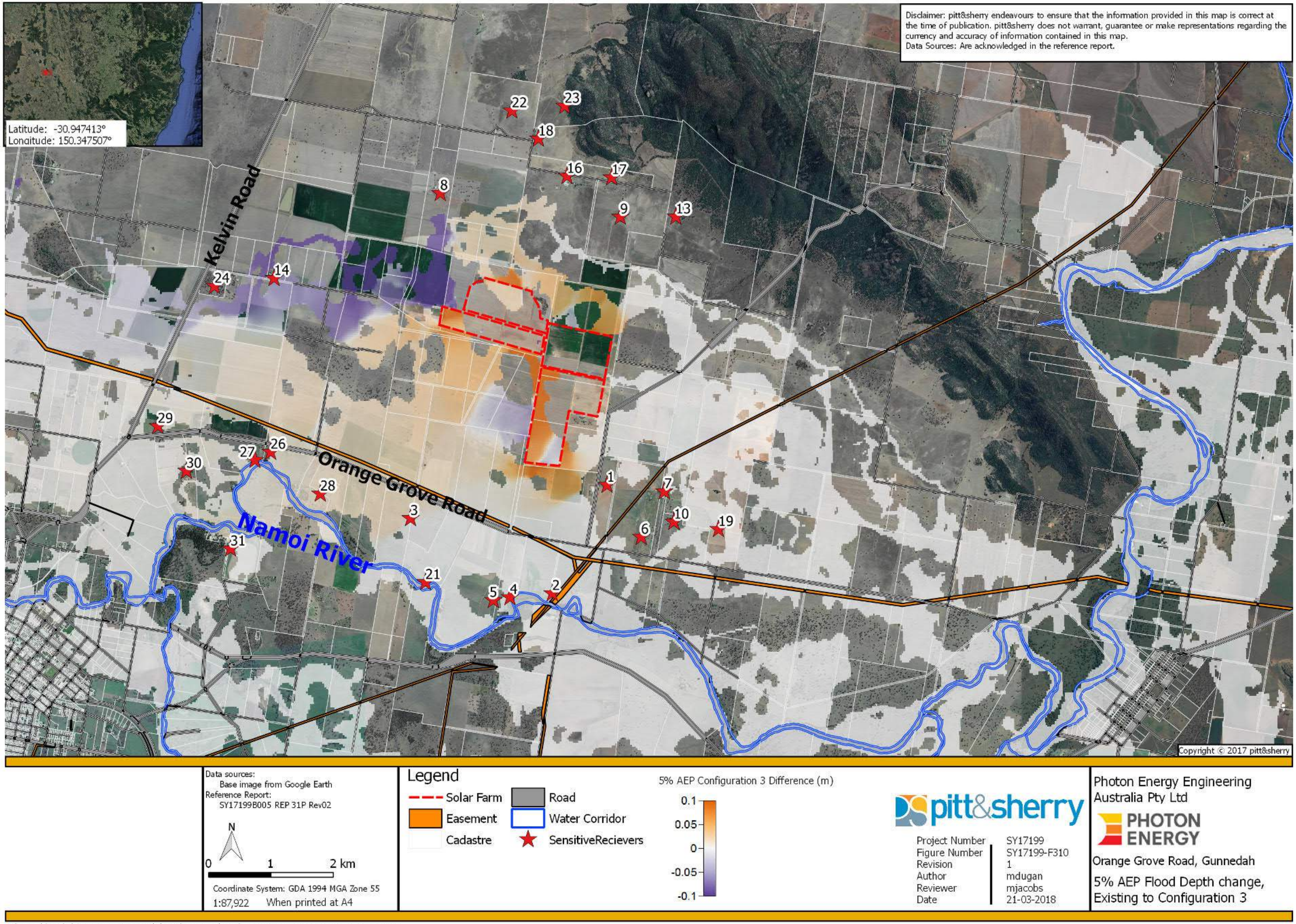
Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

10% AEP Flood Depth change, Existing to Configuration 3

File: C:/dms/1/SY17199 - Gunnedah Solar Farm/GIS/SY17199-F309.qgsSY17199-F309.qgs



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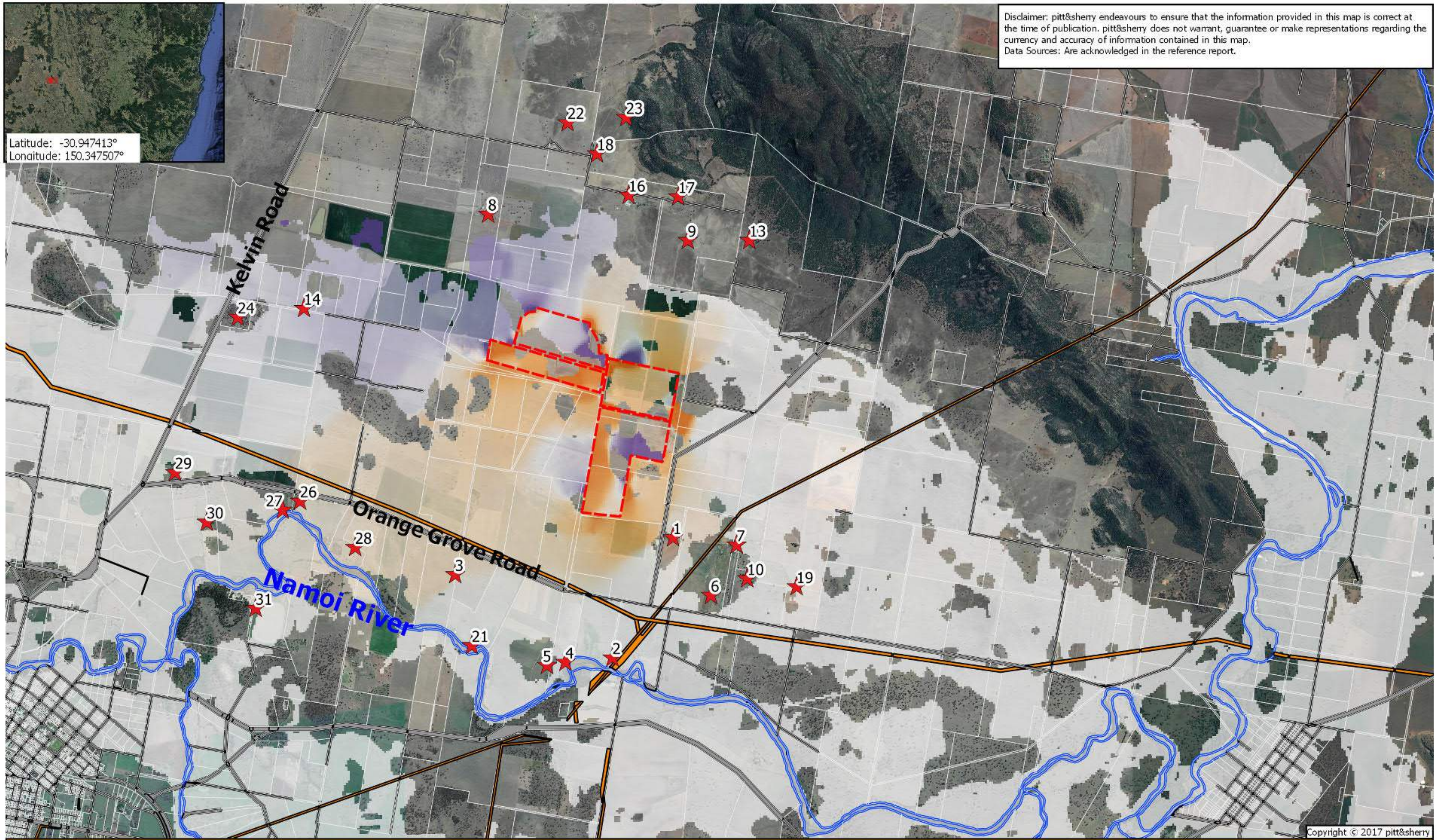


Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P Rev02

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:87,922 When printed at A4

Legend

Solar Farm | Road
Easement | Water Corridor
Cadastre | SensitiveRecievers

1% AEP Configuration 3 Difference (m)

0.1
0.05
0
-0.05
-0.1

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F311
Revision	1
Author	mdugan
Reviewer	mjacobs
Date	21-03-2018

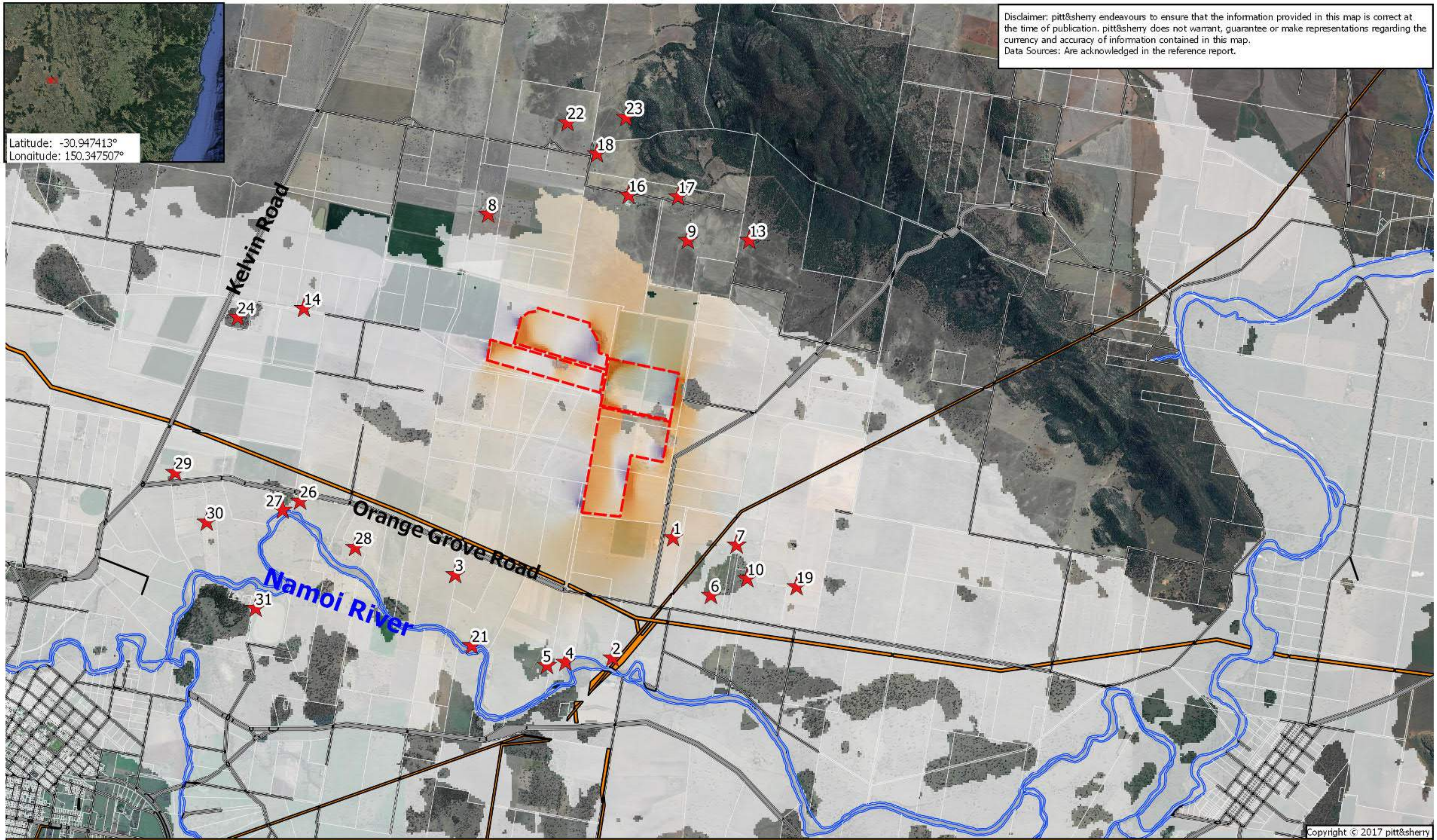
Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

1% AEP Flood Depth change, Existing to Configuration 3

File: C:/dms/1/SY17199 - Gunnedah Solar Farm/GIS/SY17199-F311.qgsSY17199-F311.qgs



Data sources:
Base image from Google Earth
Reference Report:
SY17199B005 REP 31P Rev02

N

0 1 2 km

Coordinate System: GDA 1994 MGA Zone 55
1:87,922 When printed at A4

Legend

- Solar Farm
- Easement
- Cadastre
- Road
- Water Corridor
- SensitiveRecievers

PMF Configuration 3 Difference (m)

0.1
0.05
0
-0.05
-0.1

pitt&sherry

Project Number	SY17199
Figure Number	SY17199-F312
Revision	1
Author	mdugan
Reviewer	mjacobs
Date	21-03-2018

Photon Energy Engineering Australia Pty Ltd

PHOTON ENERGY

Orange Grove Road, Gunnedah

Probable Maximum Flood Depth change, Existing to Configuration 3

File: C:/dms/1/SY17199 - Gunnedah Solar Farm/GIS/SY17199-F312.qgsSY17199-F312.qgs

Appendix B

Sensitivity analysis

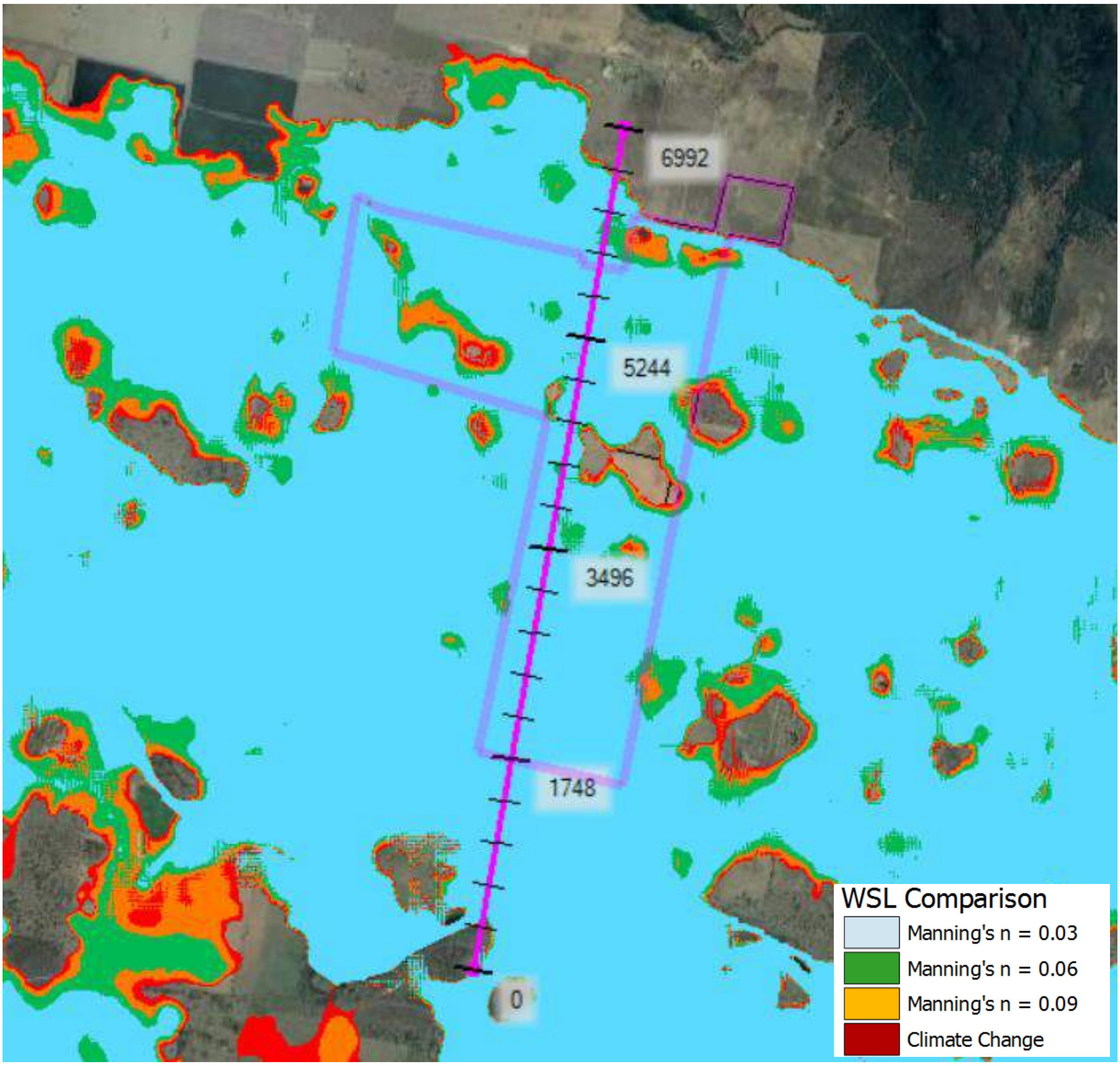


Figure B20: Plan showing extent of 1% AEP flooding with varying Manning's n and Climate Change and location of cross section through site

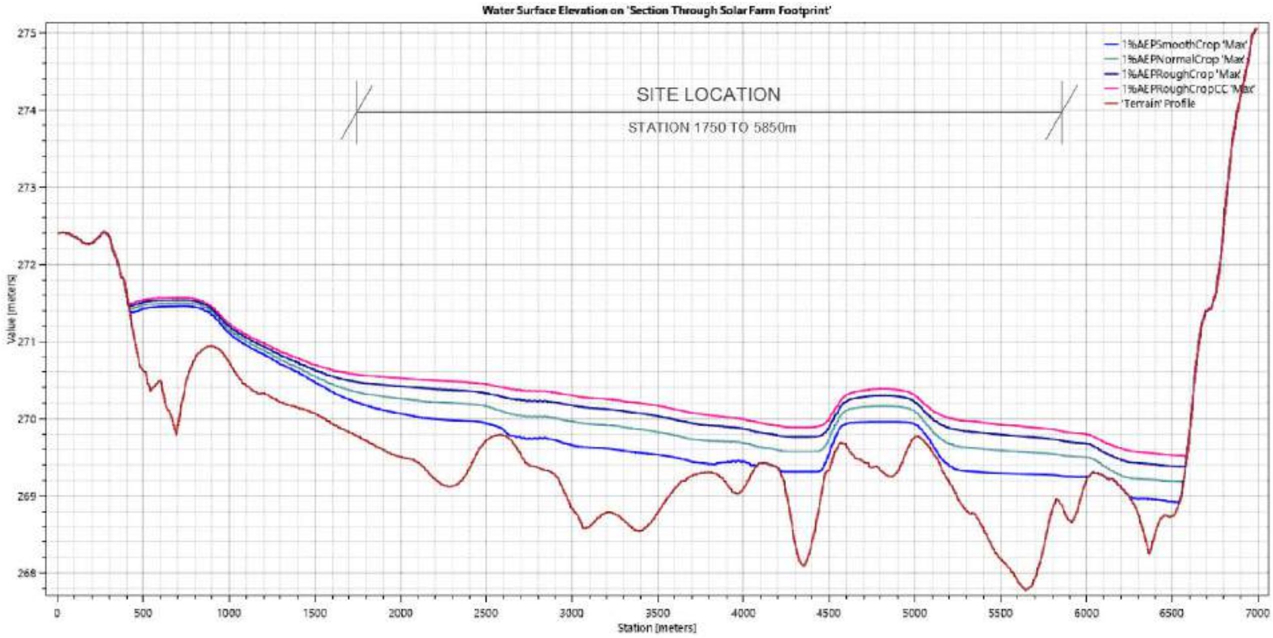


Figure B21:: Cross section through site (Station 1750 to 5850m looking downstream) showing elevation of 1% AEP flooding with varying Manning's n and Climate Change

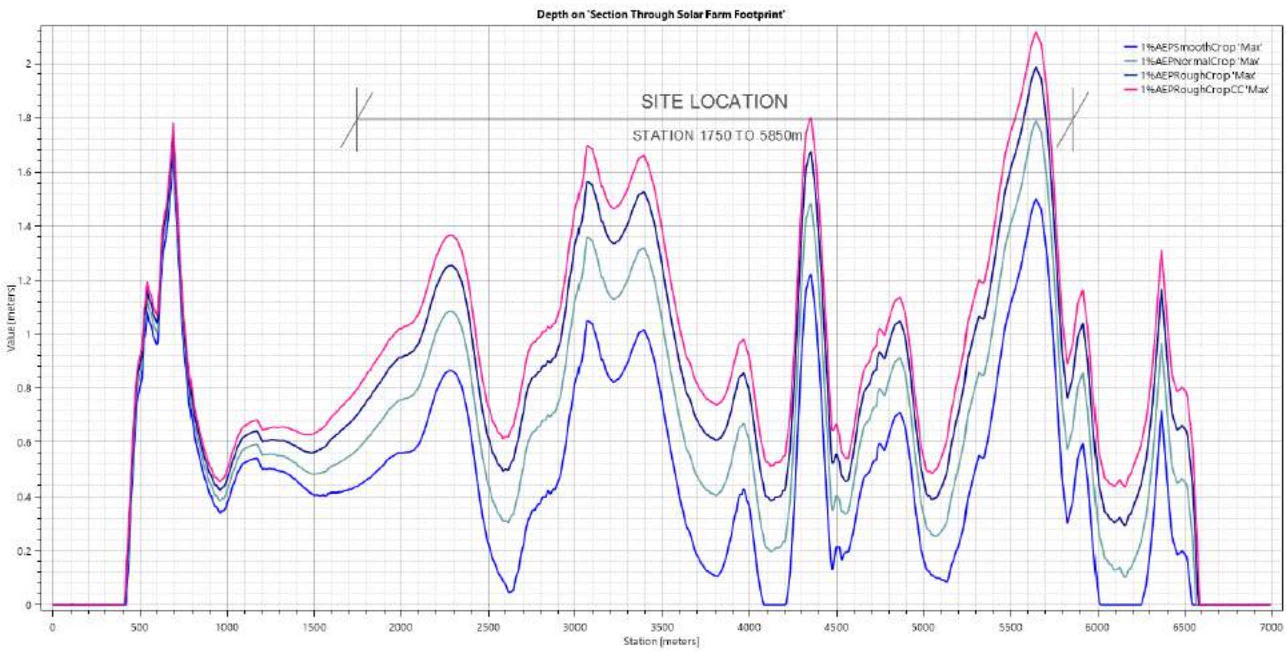


Figure B22:: Cross section through site (Station 1750 to 5850m looking downstream) showing depth of 1% AEP flooding with varying Manning's n and Climate Change

Contact
Martin Jacobs
mjacobs@pittsh.com.au

transport | community | mining | industrial | food & beverage | energy

Brisbane
Level 2
276 Edward Street
Brisbane QLD 4000
T: (07) 3221 0080
F: (07) 3221 0083

Devonport
Level 1
35 Oldaker Street
PO Box 836
Devonport TAS 7310
T: (03) 6424 1641
F: (03) 6424 9215

Hobart
199 Macquarie Street
GPO Box 94
Hobart TAS 7001
T: (03) 6210 1400
F: (03) 6223 1299

Launceston
Level 4
113 Cimitiere Street
PO Box 1409
Launceston TAS 7250
T: (03) 6323 1900
F: (03) 6334 4651

Melbourne
Level 1, HWT Tower
40 City Road
Southbank VIC 3006
PO Box 259
South Melbourne VIC 3205
T: (03) 9682 5290
F: (03) 9682 5292

Newcastle
Level 1
81 Hunter Street
Newcastle NSW 2300
T: (02) 4910 3600

Sydney
Suite 902, Level 9,
1-5 Railway Street
Chatswood NSW 2067
PO Box 5487
West Chatswood NSW 1515
T: (02) 9468 9300

E: info@pittsh.com.au
W: www.pittsh.com.au

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