Environmental Impact Statement

Glenellen Solar Farm

Appendix I: Flood Hydrology Assessment

October 2020

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Glenellen Solar Farm
Hydrological Assessment Report

Glenellen Solar Farm Pty Ltd

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Executive Summary

Eco Logical Australia (ELA) was engaged by CWP Renewables Pty Ltd on behalf of Glenellen Solar Farm Pty Ltd (the 'Proponent') to undertake a hydrological and hydraulic assessment for existing and proposed conditions for the proposed Glenellen Solar Farm (GSF, the Proposed Development) located within the Greater Hume Shire Local Government Area (LGA) approximately 4 kilometres north-east of Jindera.

This assessment was undertaken to identify potential hydrological and hydraulic impacts on the Site for the Proposed Development.

This document provides:

- A summary of existing topography and streams across the Site and the adjoining landscape
- Digital classification of the watercourses using the Strahler Stream Order
- Technical details of modelling undertaken using the rain-on-grid model in HEC-RAS
- Areas and extents of periodic inundation from the modelling outcomes
- A comparison of discharge and water levels between the existing and proposed conditions.

The flood modelling undertaken in this report was based on all available topographic and regional rainfall data, supplemented by ground-based observations of selected hydraulic structures within the Site such as culverts. While this information is fit-for-purpose, confidence in model results could be further improved with the compilation of additional site specific geometric and rainfall-runoff details.

ELA has modelled peak inundation extents for the following Annual Exceedance Probability (AEP) design events; 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5 AEP%, 0.2% AEP and 0.1% AEP (essentially equivalent to the 1 in 10-year, 20-year, 50-year, 100-year, 200-year, 500-year and 1000-year Average Recurrence Interval (ARI), respectively) and produced inundation maps for the Site.

A comparison between existing and proposed conditions showed negligible changes to peak water surface elevations, discharge rates, and flow volumes downstream of the Proposed Development.

An area of approximately 3 hectares is proposed to be raised above the flood levels for temporary construction activities. The Proposed Development is not expected to create adverse effects to beneficial inundation of the floodplain environment on, adjacent to or downstream of the Site during these activities.

The Proposed Development is not expected to affect the hydraulic functions of flow conveyance in floodways, nor the storage in flood storage areas on adjacent lands. As a result, no detrimental increases in the potential flood levels are expected within the Site, or in surrounding properties, assets and infrastructure outside of the Site. Flood hazards under proposed conditions are low and can be managed using localised scour protection where needed. No increase in flood hazard is predicted on neighbouring tenement areas.

1. Flooding and drainage characterisation

1.1 Introduction

An assessment of drainage associated with the existing and proposed Site conditions has been undertaken for the proposed Glenellen Solar Farm (GSF, the 'Proposed Development') and surrounding area with a high-level flood risk assessment carried out using the most recently available databases.

1.1.1 Background

The topography of the Proposed Development and surrounding areas is generally undulating, sloping downward in a west-to-east direction, with mostly cleared and relatively flat areas within the Site (**Figure 1-1**). Localised, relatively higher elevation areas are located to the north, south and south-west outside the Site (**Figure 1-1**).

The Proposed Development falls within the Upper Murray catchment (NOW, 2011). Bowna Creek, a 4th-order channel, runs just outside the south-east boundary of the Site. A 3rd -order watercourse, Kilnacroft Creek, enters from the west boundary, runs through the middle section of the Site and exits the Site to the north-west. Dead Horse Creek, a 4th- order watercourse flows north of the Site, joining Bowna Creek beyond the northeast boundary and draining eventually into Gerogery Creek, a 5th- order watercourse.

Primary overland flow-paths and the sub-catchments were delineated using the ArcHydro package within the ArcGIS ESRI software.

Figure 1-2 shows the delineated sub-catchments and the modelled overland flow paths in and around the Proposed Development.

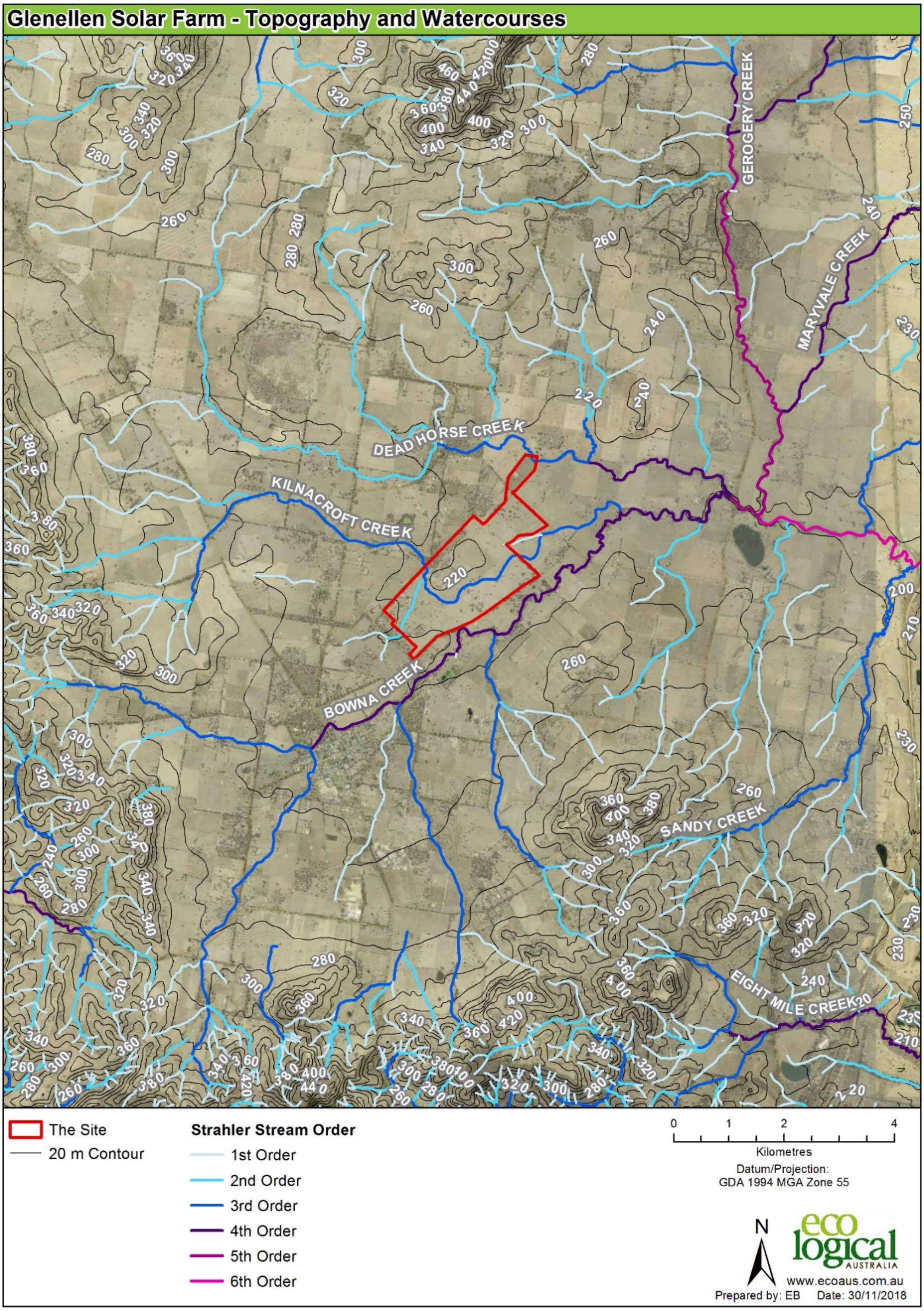

Figure 1-1 The Site and surrounding topography and watercourses

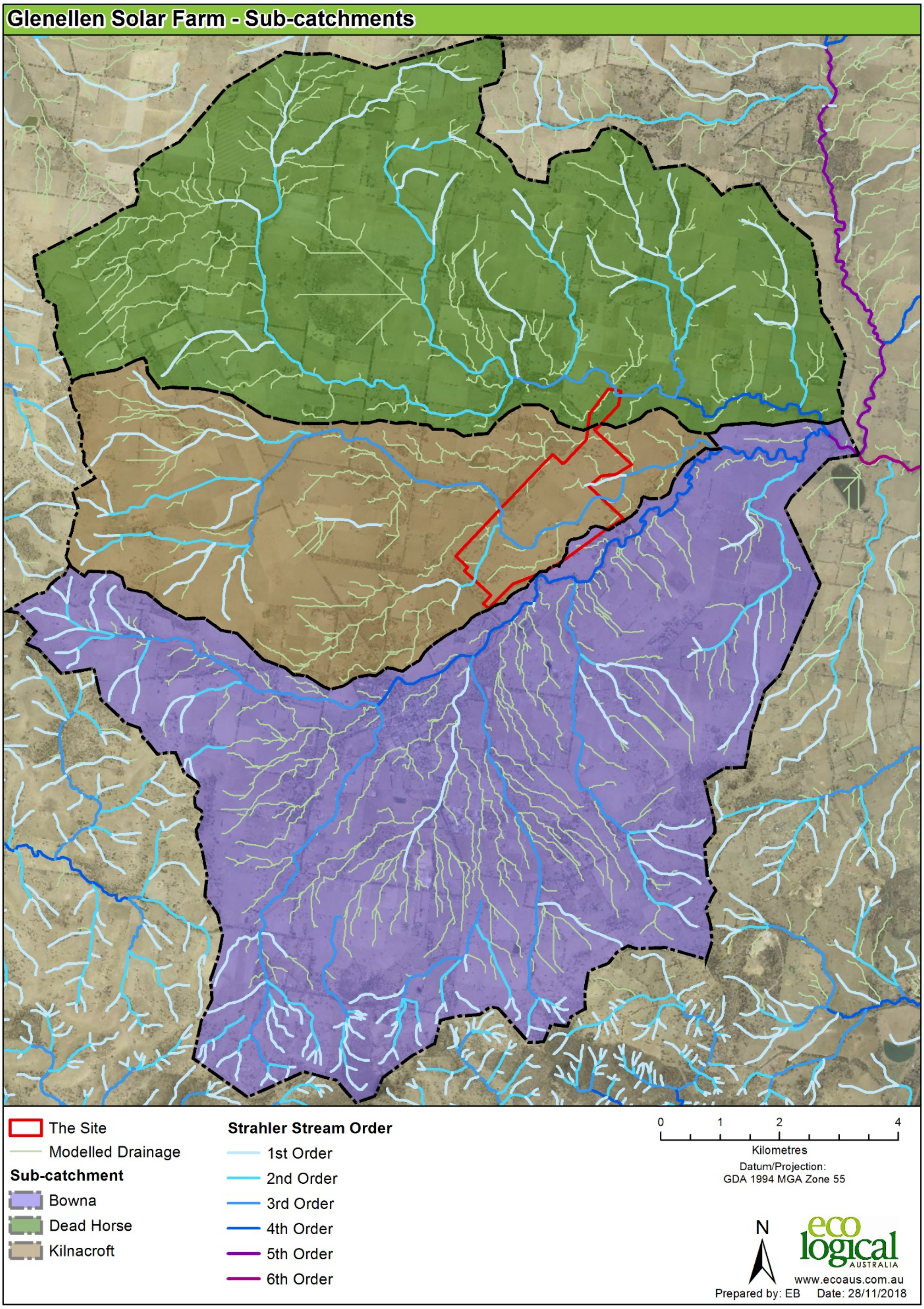

Figure 1-2 Modelled drainage lines and sub-catchments

1.2 Model setup and application

1.2.1 Terrain

The modelled terrain is a composite of a 1-metre by 1-metre digital elevation model (DEM) of the Site derived from survey data and a 5-metre by 5-metre DEM of the remaining catchment compiled from Geoscience Australia's elevation foundation database using the New South Wales Land and Property Information terrain data (Geosciences Australia, 2018). The terrain coverage is shown in **Figure 1-3**.

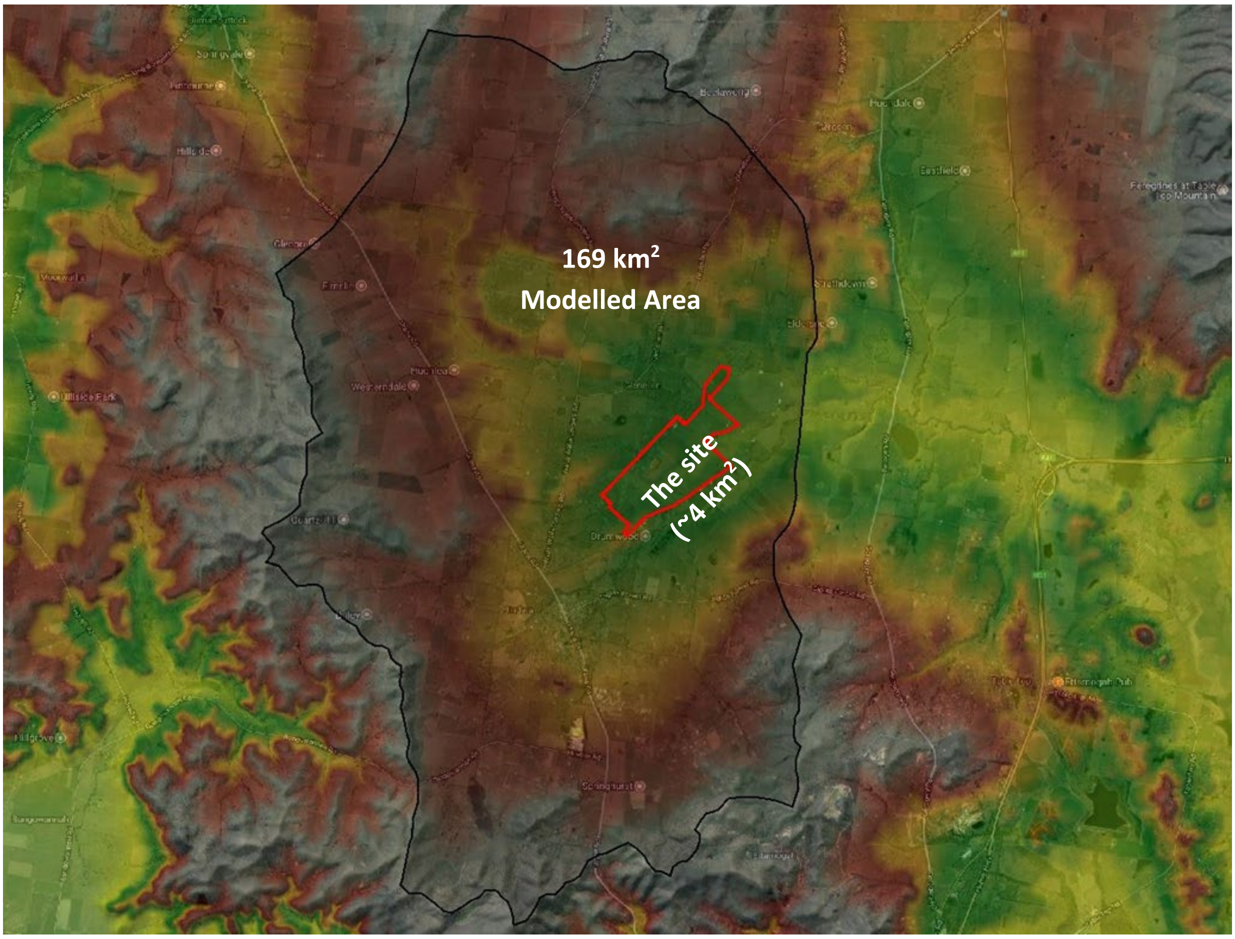

Figure 1-3 Terrain coverage and two-dimensional flood area extent for model input

1.2.2 Two-dimensional flow area

A two-dimensional (2D) flow area was delineated in the Hydrologic Engineering Centre's River Analysis System (HEC-RAS) modelling platform (U.S. Army Corps of Engineers, 2018) as shown in **Figure 1-3**. The 2D flow area was delineated to coincide with the catchment boundaries of Dead Horse, Kilnacroft, and Bowna Creeks, terminating just downstream of the Site. The 2D flow area covers approximately 169 km^2 (**Figure 1-3**).

1.2.3 Computational Mesh

A computational mesh spacing of 10-metres by 10-metres was applied across the Site area, increasing to 50-metres by 50-metrrs in the upper catchment areas. As shown in an example in **Figure 1-4**, HEC-RAS recognises the sub-grid terrain resolution within individual computational cells, and the flow transfer calculations between individual grid cells account for the geometry of the underlying surface at the terrain resolution (up to 1-metre by 1-metre where applicable across the Site).

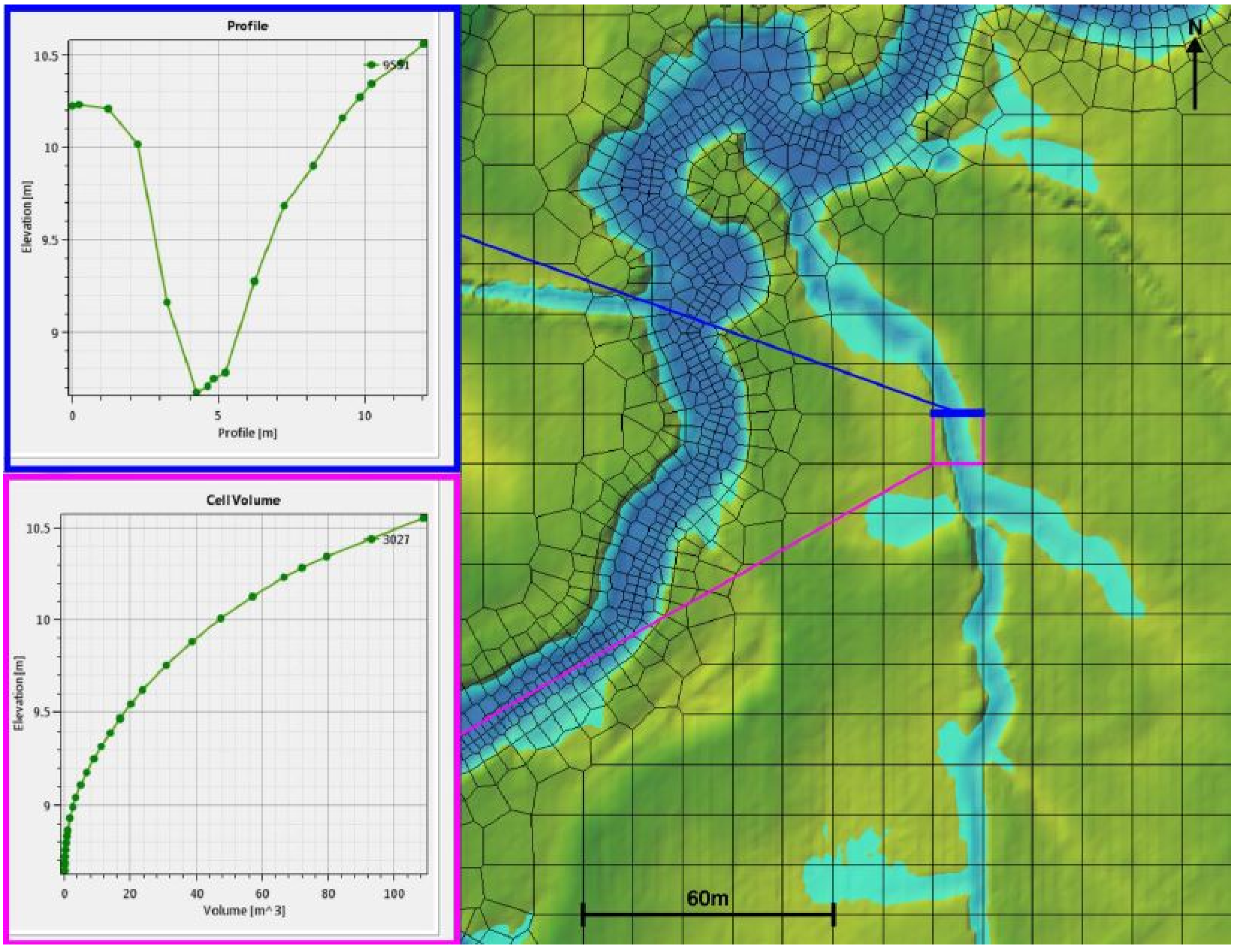

Figure 1-4 Computational mesh with subgrid cell volume and edge profiles (Lintott 2017)

1.2.4 Roughness

Based on an assessment of Site and aerial photographs, a Manning's roughness coefficient of 0.06 was applied uniformly across the 2D flow area for baseline models (HEC-RAS hydraulic reference manual, U.S. Army Corps of Engineers, 2018). A summary of model input parameters is presented in **Table 1**. A range of Manning's roughness coefficients were applied to the model as a sensitivity analysis, with coefficients ranging from 0.04 to 0.08, to account for uncertainties due to the lack of local calibration data. Water surface levels were found to be relatively non-sensitive to the roughness coefficient, with predicted changes of only +/- 1 cm across the range in roughness.

1.2.5 Inflow

No localised rainfall data, water levels, or discharge data were identified at the Site. Therefore, flood modelling parameters in HEC-RAS were based on regionalised information (including regional rainfall intensity, frequency and duration information, storm initial and continuing losses). This means that the flow volumes and water depths determined by the models should be examined with more reliance on the relative comparison of results rather than in absolute terms. It is noted that the presented results are based on regional rainfall-runoff estimation that has not been calibrated for local Site conditions. Improved local calibration would help provide better recommendations for protection of Site infrastructure from any flood inundation and scour. Options to improve the local calibration include: (i) Future observations of high-water marks associated with flood events; (ii) Installation of streamflow gauges in Kilnacroft Creek, and (iii) further analysis of available rainfall gauge data, or installation of a rainfall gauge near the Site.

Intensity-Frequency-Duration (IFD) rainfall data were compiled across the catchment area using the Bureau of Meteorology (BoM) 2016 data set. **Figure 1-5** shows the BoM IFD data (left panel showing frequent design rainfall and right panel showing infrequent design rainfall). Based on the IFD data, a centrally loaded, nested frequency storm was developed for use in the hydraulic model. This storm pattern is developed by placing the highest 1-minute-duration rainfall (highest intensity) in the centre of the storm and adding each increasing duration (with successively lower intensities) to the precipitation hyetograph. Preliminary model runs were developed to determine the catchment response time, leading to the adoption of a 6-hour synthetic storm, with the peak rainfall intensity occurring 3 hours from the beginning of the simulation.

An initial loss of 26 mm, and a continuing loss of 4.6 mm/hour, runoff were removed from the precipitation hyetograph due to ground infiltration based on values taken from the Australian Rainfall and Runoff (ARR) data hub (http://data.arr-software.org/, Ball *et al.*, 2016). **Figure 1-6** shows the resulting precipitation excess hyetograph applied across the entire catchment in HEC-RAS as an unsteady flow boundary condition.

It should be noted that BoM IFD data are provided for individual points in the catchment; areal reduction factors are then typically applied to average the intensities across large catchments. In this case, a conservative approach was taken without applying an areal reduction factor. This approach assumes that the point rainfall intensities occur across the entire catchment.

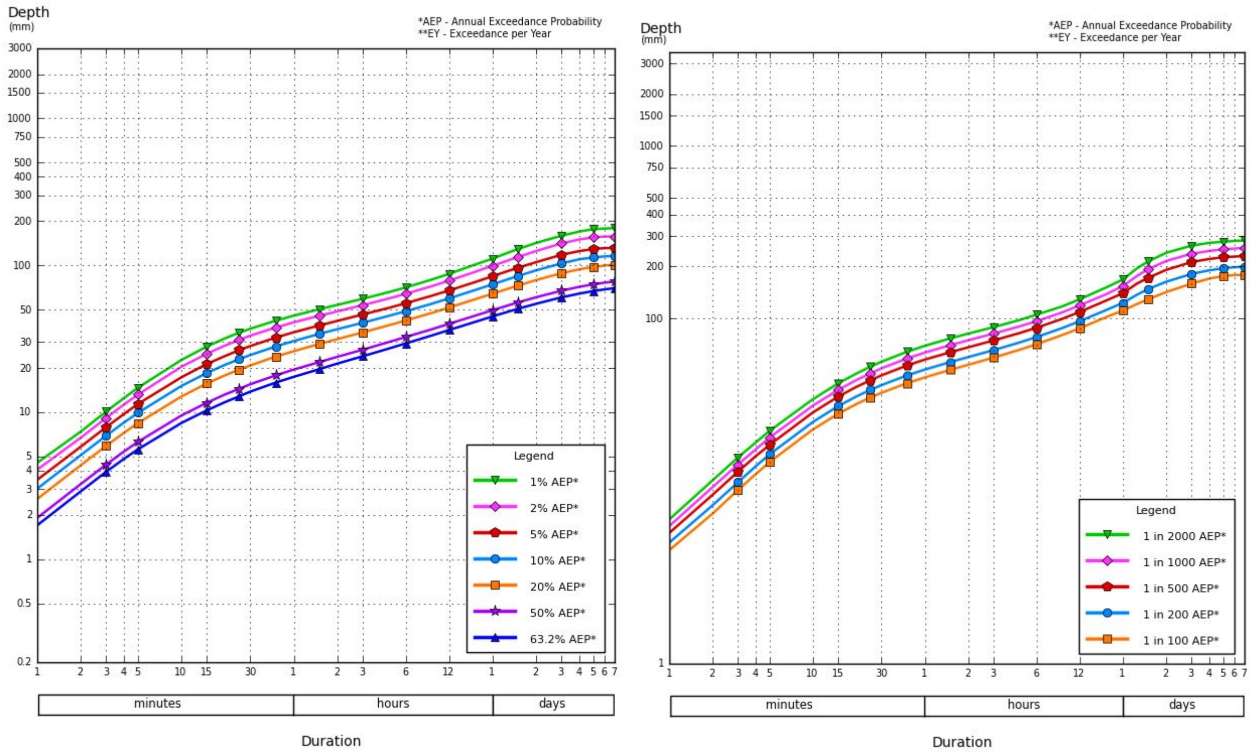

Figure 1-5 BoM IFD data for frequent (left) and infrequent and rare (right) design rainfalls

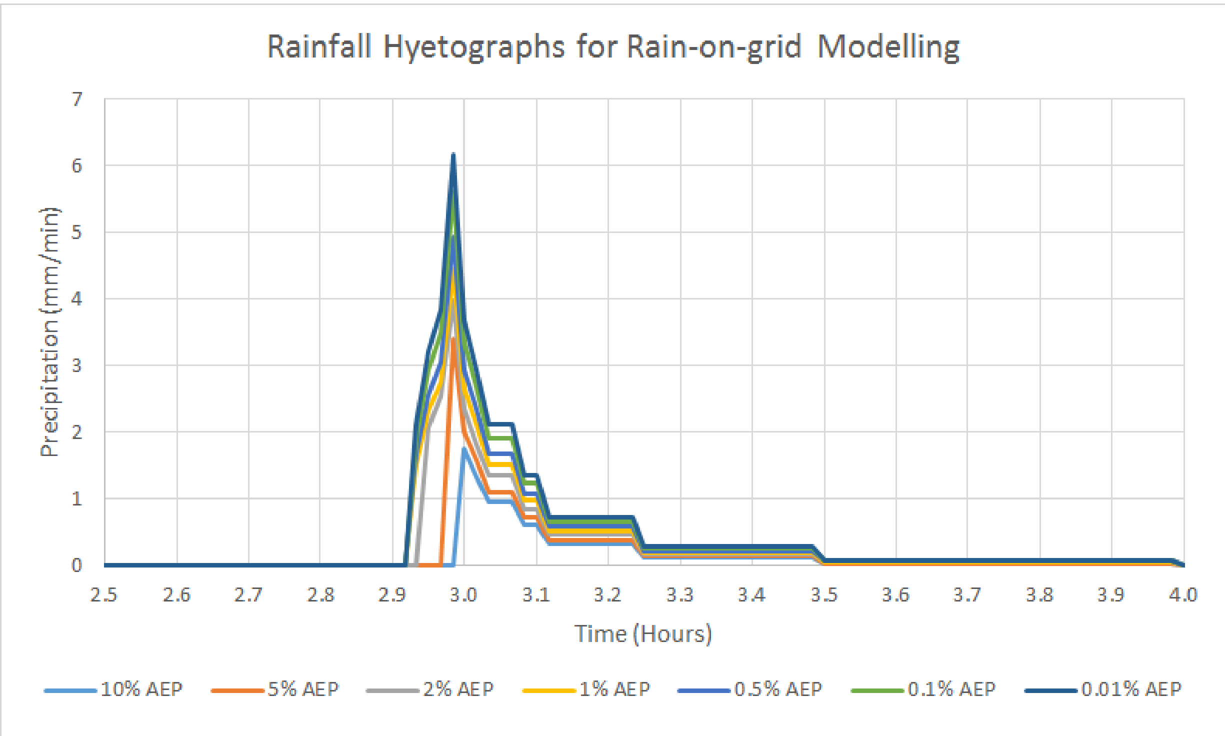

Figure 1-6 Frequency storm values applied to 2D flow area

1.2.6 Outflow

The downstream outlet was set to a normal depth boundary condition, using the uniform bed slope of 0.3% as the estimated energy slope derived from the gradient measurable in the DEM.

1.2.7 Computational Settings

A computational time step of 10 seconds was applied for the model runs. Sensitivity analyses confirmed that finer time steps did not significantly affect the results. Additional sensitivity analyses were performed using the Full Momentum equation set and the Diffusion Wave simplification within HEC-RAS. Although some differences in arrival times were apparent between the two equation sets, the maximum water surface elevation results did not differ significantly, and the diffusion wave simplification was adopted for baseline runs. Mass balance errors and water surface elevation convergence errors were checked for model stability and to confirm that imbalances remained below reasonable thresholds for model stability (in this case within 0.1% for mass balance and within 1 cm for water surface elevation convergence). A 12-hour simulation window was applied in the model runs to allow the peak discharge to propagate through the model.

Except where otherwise noted, program defaults were applied to all remaining coefficients, options, tolerances and model settings.

1.2.8 Structures

As no structures are currently known to significantly affect the hydrology and hydraulics of the Site, the model does not include any culverts, bridges, or other hydraulic structures. In addition, farm dams were not captured in the terrain model used for the hydraulic model development, likely due to their small size, relatively shallow depth and being full at the time of terrain model capture. Given their small size relative to the size of the Proposed Development, their presence in the landscape is likely to have minimal influence on flow rates and water levels during flooding. As such, the flood modelling represents a conservative approach with limited farm dam flood storage incorporated.

1.2.9 Scenarios (HEC-RAS Plans)

Table 1 summarises the model parameters used for the selected model runs. The following plan files were developed for 2D model simulations:

- Existing conditions:
    - 10% AEP (~10-year ARI)
    - 5% AEP (20-year ARI)
    - 2% AEP (50-year ARI)
    - 1% AEP (100-year ARI)
    - 0.5% AEP (200-year ARI)
    - 0.2% AEP (500-year ARI)
    - 0.1% AEP (1,000-year ARI)
- Proposed conditions:
    - 10% AEP (10-year ARI)
    - 2% AEP (50-year ARI)
    - 1% AEP (100-year ARI)

Table 1 Summary of model parameters

Model Parameter	Value
Inflow	Nested frequency storm excess precipitation hyetographs
Outflow	Normal depth slope of 0.3%
Simulation window	12 hours
Computational time step	10 seconds
Computational mesh grid (length and width)	10 x 10 metres to 50 x 50 metres
Roughness	0.06
Equation set	Diffusion wave
DEM grid resolution (length and width)	1 x 1 metre – 5 x 5 metres

1.3 Results

1.3.1 Flooding assessment for existing conditions

Existing conditions inundation extent maps were generated for 10% AEP, 1% AEP, 0.5 AEP%, 0.2% AEP and 0.1% AEP (1 in ~10-year, 100-year, 200-year, 500-year and 1000-year ARI, respectively).

The Regional Flood Frequency Estimation (RFFE) Model (http://rffe.arr-software.org/, Ball *et al.,* 2016) was applied as a comparison of predicted peak flow rates downstream of the GSF Site. The RFFE model predicted a 1% AEP (100-year ARI) peak discharge of 199 m^3/s, with a lower confidence limit of 77 m^3/s at the 5% confidence level. As a comparison, the HEC-RAS direct precipitation model yielded a discharge rate of 149 m^3/s at the same location, which is approximately 25% lower than the median RFFE prediction but lies within a reasonable range of values given the significant floodplain storage and out-of-bank flow in the upstream catchment.

Figure 1-7 through **Figure 1-13** shows the maximum inundation depths and extents for the selected events across the Site. Sheet flow inundation depths of less than 1 cm are not shown in the figures.

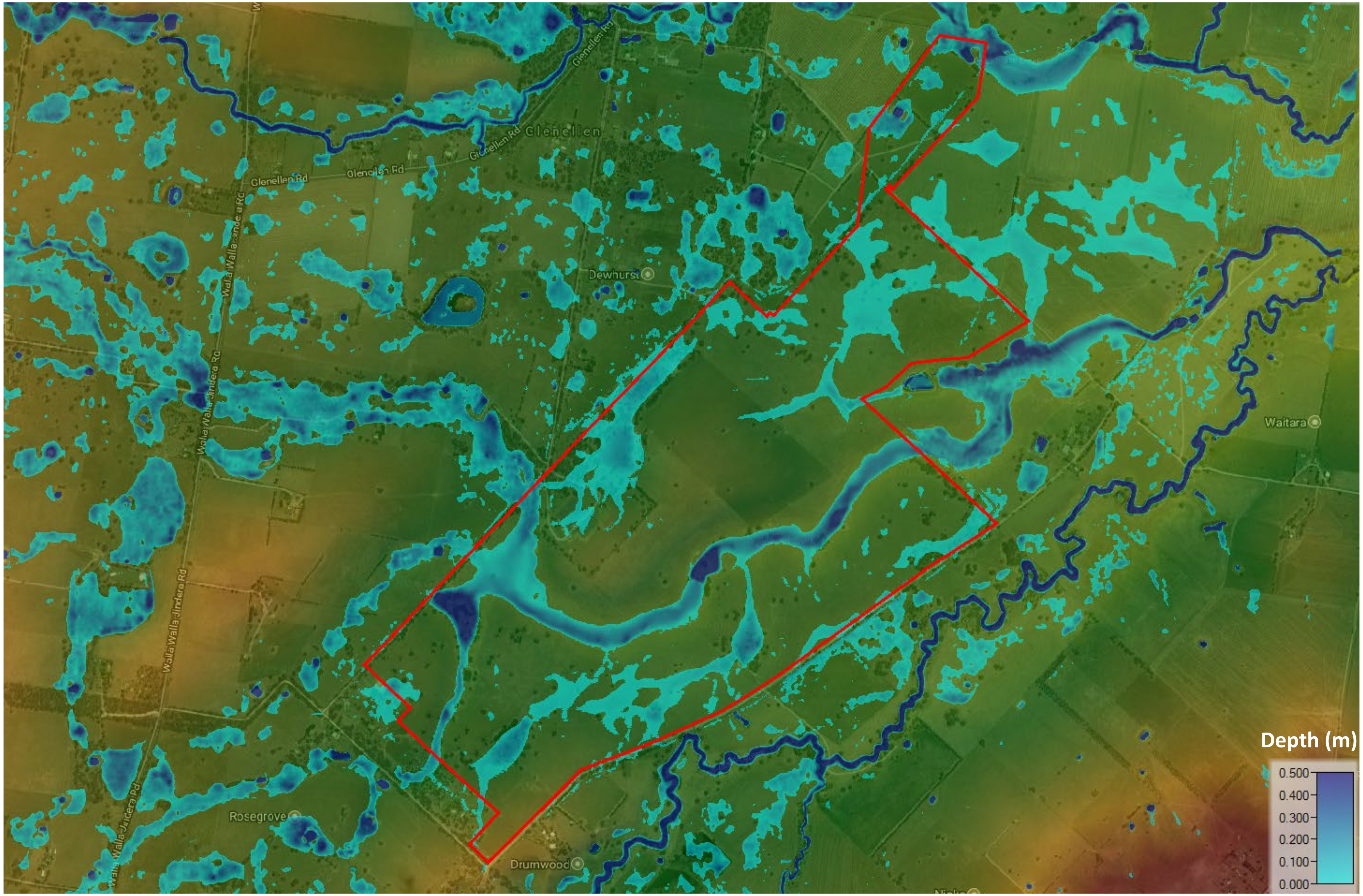

Figure 1-7 10% AEP (10-year ARI) maximum flood extent with depths in metres for existing conditions. Red polygon represents the Site

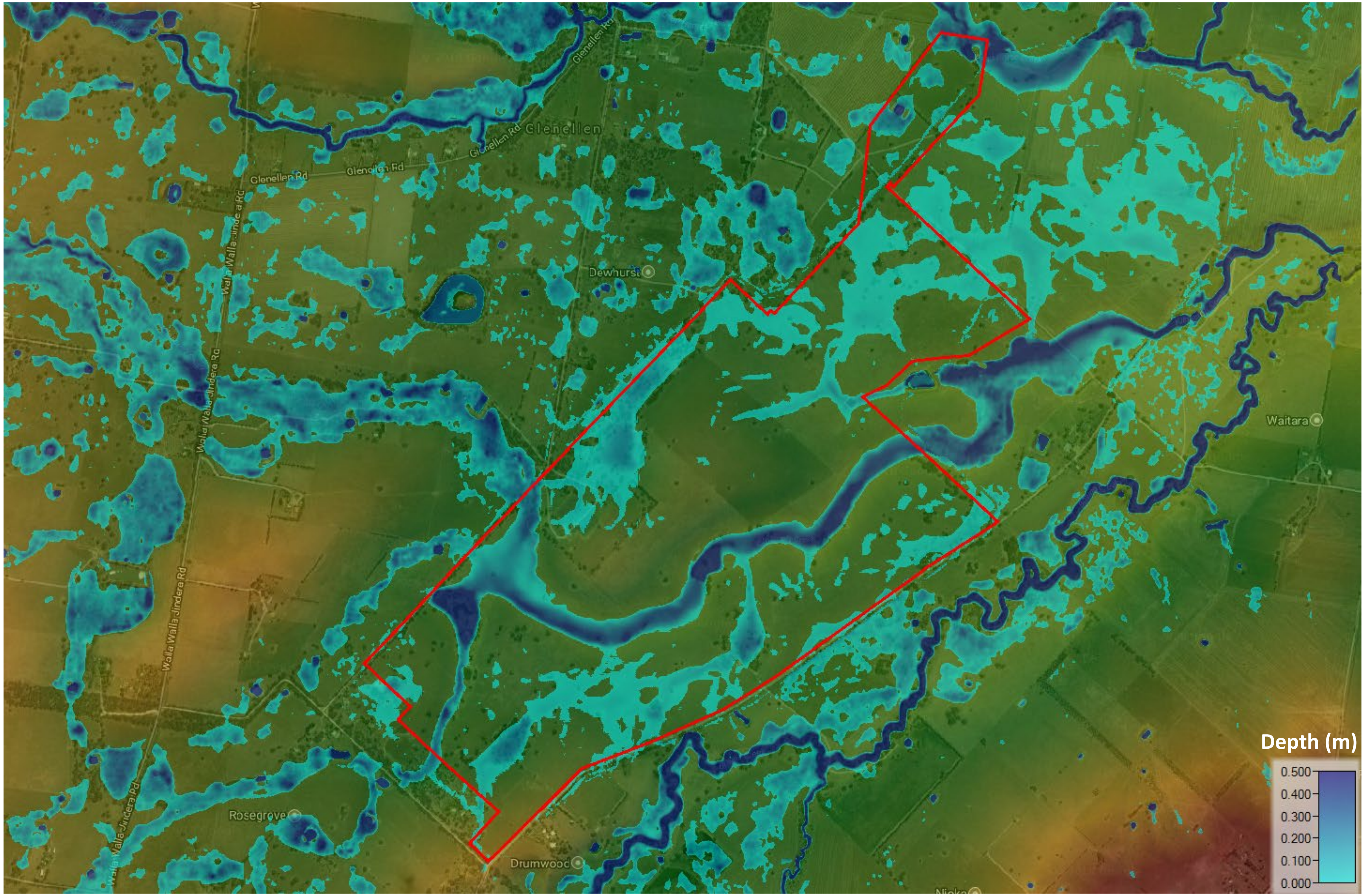

Figure 1-8 5% AEP (20-year ARI) maximum flood extent with depths in metres for existing conditions. Red polygon represents the Site

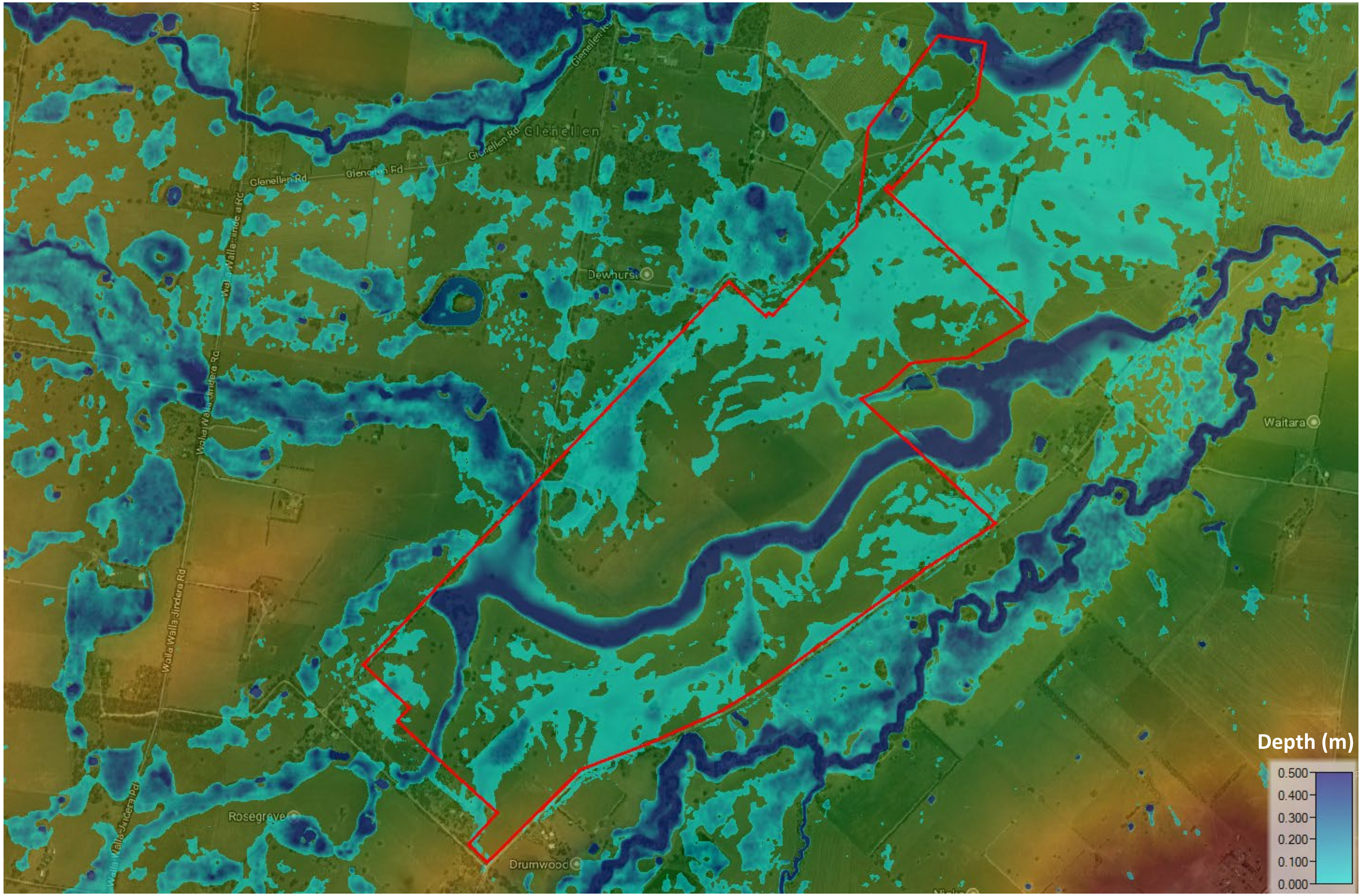

Figure 1-9 2% AEP (50-year ARI) maximum flood extent with depths in metres for existing conditions. Red polygon represents the Site

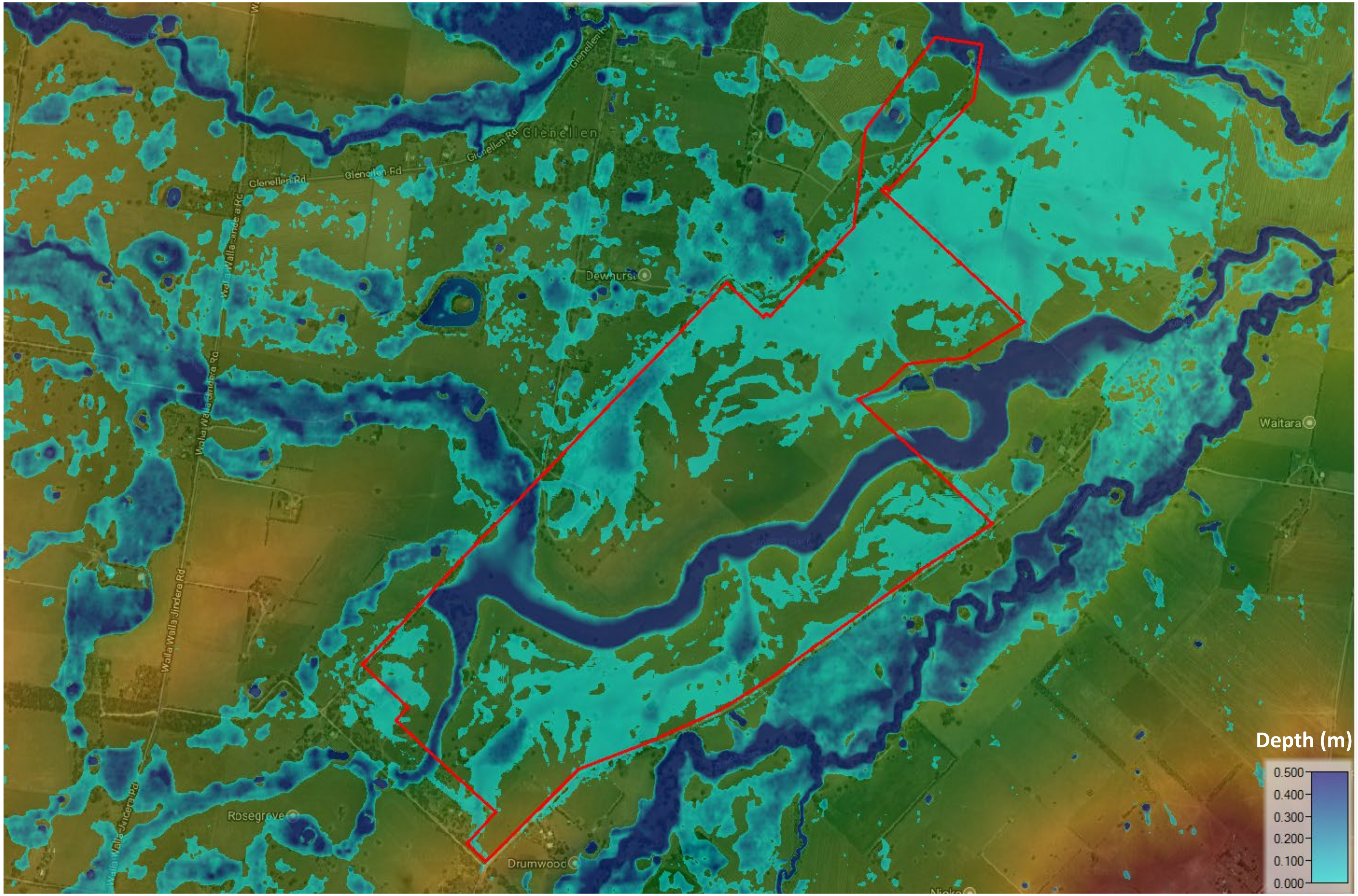

Figure 1-10 1% AEP (100-year ARI) maximum flood extent with depths in metres for existing conditions. Red polygon represents the Site

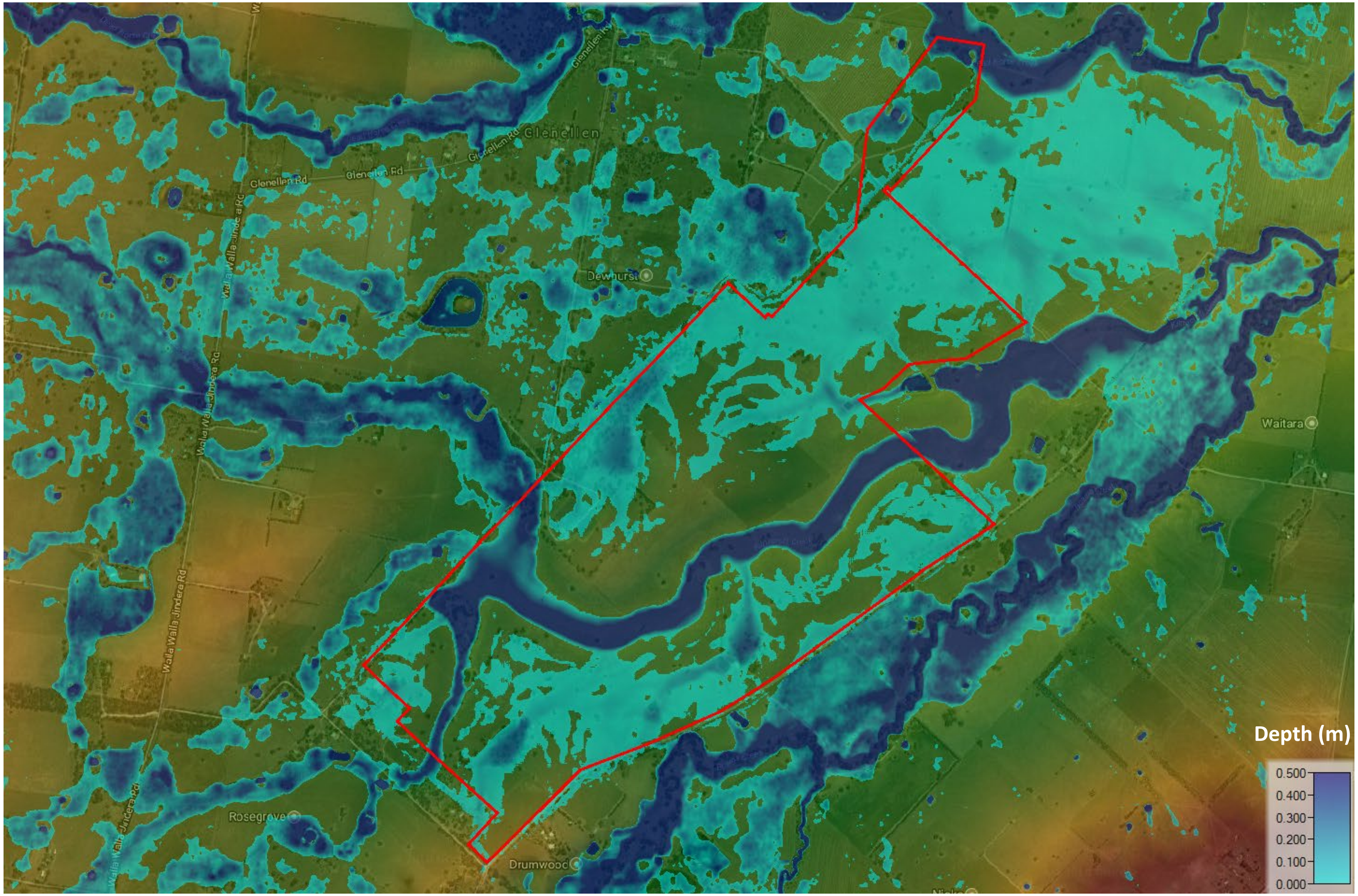

Figure 1-11 0.5% AEP (200-year ARI) maximum flood extent with depths in metres for existing conditions. Red polygon represents the Site

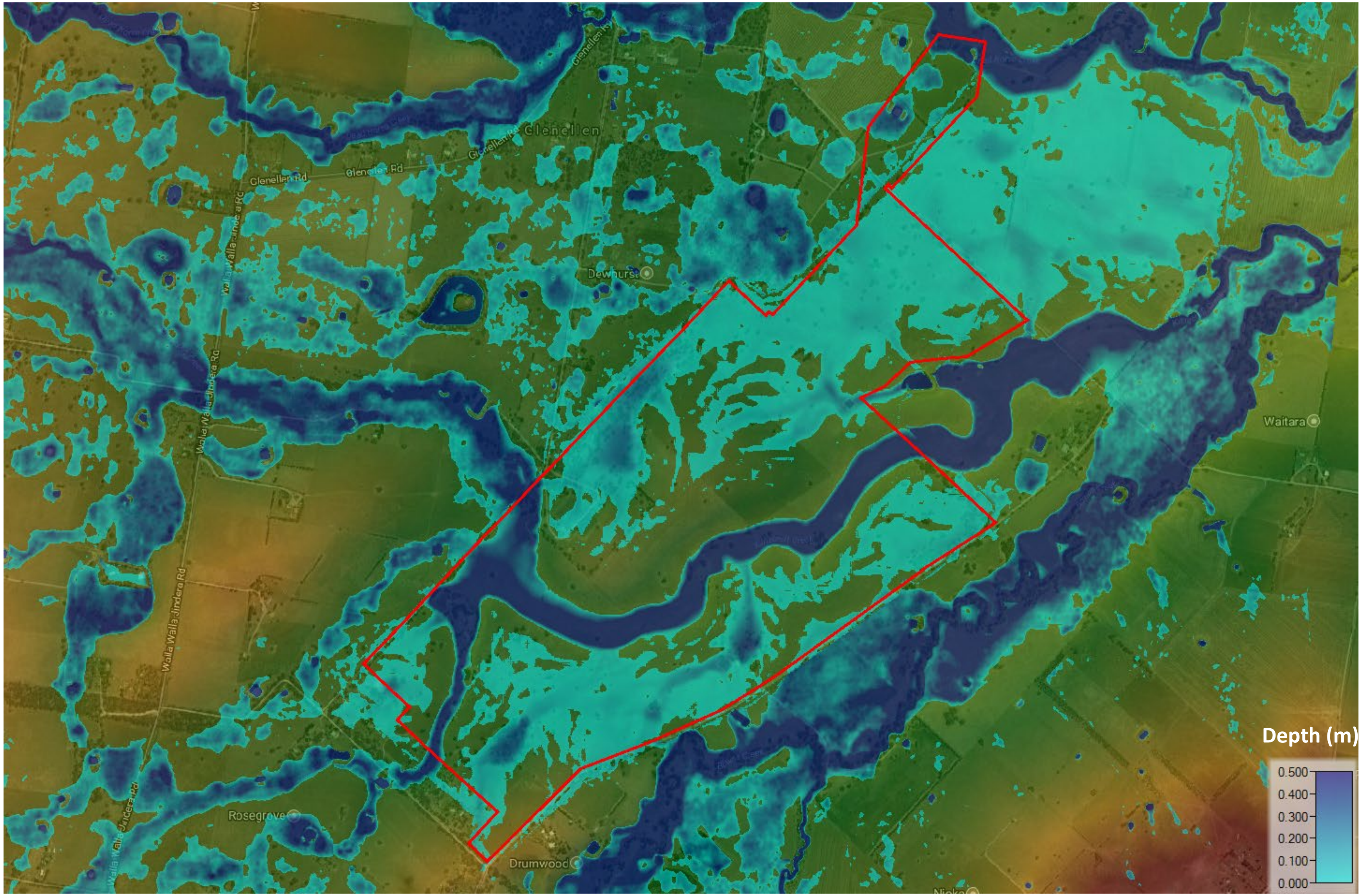

Figure 1-12 0.2% AEP (500-year ARI) maximum flood extent with depths in metres for existing conditions. Red polygon represents the Site

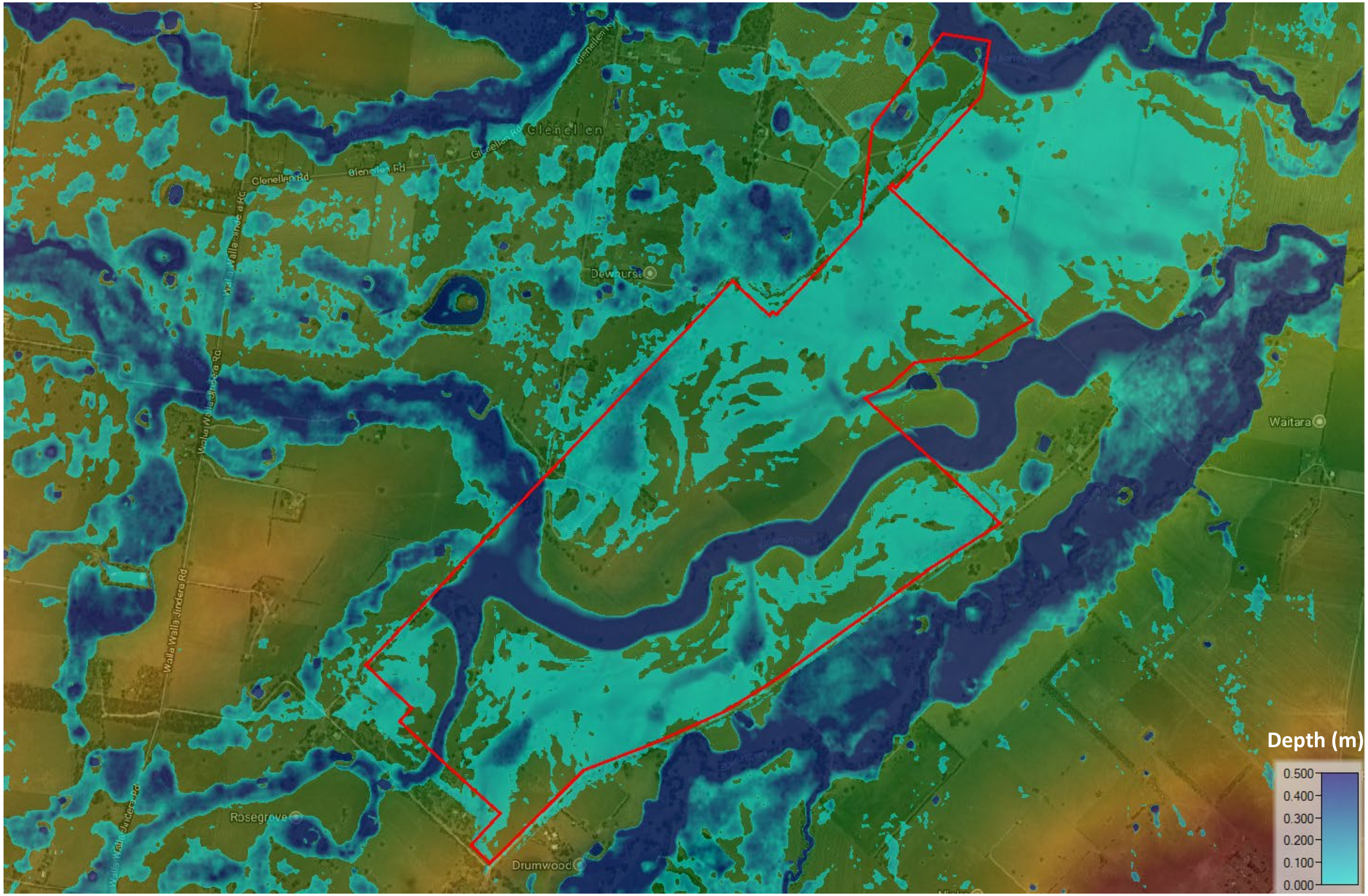

Figure 1-13 0.1% AEP (1,000-year ARI) maximum flood extent with depths in metres for existing conditions. Red polygon represents the Site

1.3.2 Flooding assessment for proposed conditions

To determine the impact of the Proposed Development on flooding, indicative temporary construction pads, substation and BESS areas were added to the rain-on-grid model as raised terrain to assess potential changes in flood hydrology. These have been placed in arbitrarily chosen locations for modelling purposes and may not be constructed in those locations (subject to detailed design). The solar array itself was not included in the modelling, as the installed solar panels will be raised above the ground on piers (and therefore not an obstruction to the flow of water across the Site) and the ground elevations, vegetation, and infiltration properties of the soil in the array area are likely to remain unchanged in the proposed condition. In addition, because the array at GSF is proposed to be located in locally ponded areas only, without significant flow conveyance, the piers would not significantly affect the flow. The decision to omit the solar array from impact modelling is supported by research on the hydrological effects of solar arrays by Cook and McCuen (2013). These authors found that there was little influence of solar panels on runoff volumes, peak flows or the time to peak flows, when the groundcover under the solar array was unchanged.

Figure 1-14 shows the proposed building pads and the location of the cross section used to assess downstream changes in water surface elevations and flood hydrographs. In the immediate vicinity of the building pads, stormwater runoff will be routed around the pad, and some localised increases in water surface elevation (up to 200 mm) and velocities are predicted, especially around the western most pad, which lies closer to Kilnacroft Creek (**Figure 1-15)**. These impacts can be managed onsite through the implementation of the stormwater management plan and may require the use of armour rock to prevent local scour (Austroads 1994 and Austroads 2013a, 2013b).

Comparisons of maximum water surface elevation (**Figure 1-16**) and the flood hydrographs (**Figure 1-17**) for the selected modelled events, under existing and proposed conditions at the downstream cross section, suggest negligible differences between scenarios. These differences amount to less than 1% across a range of event sizes for both peak discharge and maximum water level (**Table 2**).

Modelling indicates that the localised effects do not propagate to the boundary of the Site and no hydrological or hydraulic effects on neighbouring lands are anticipated.

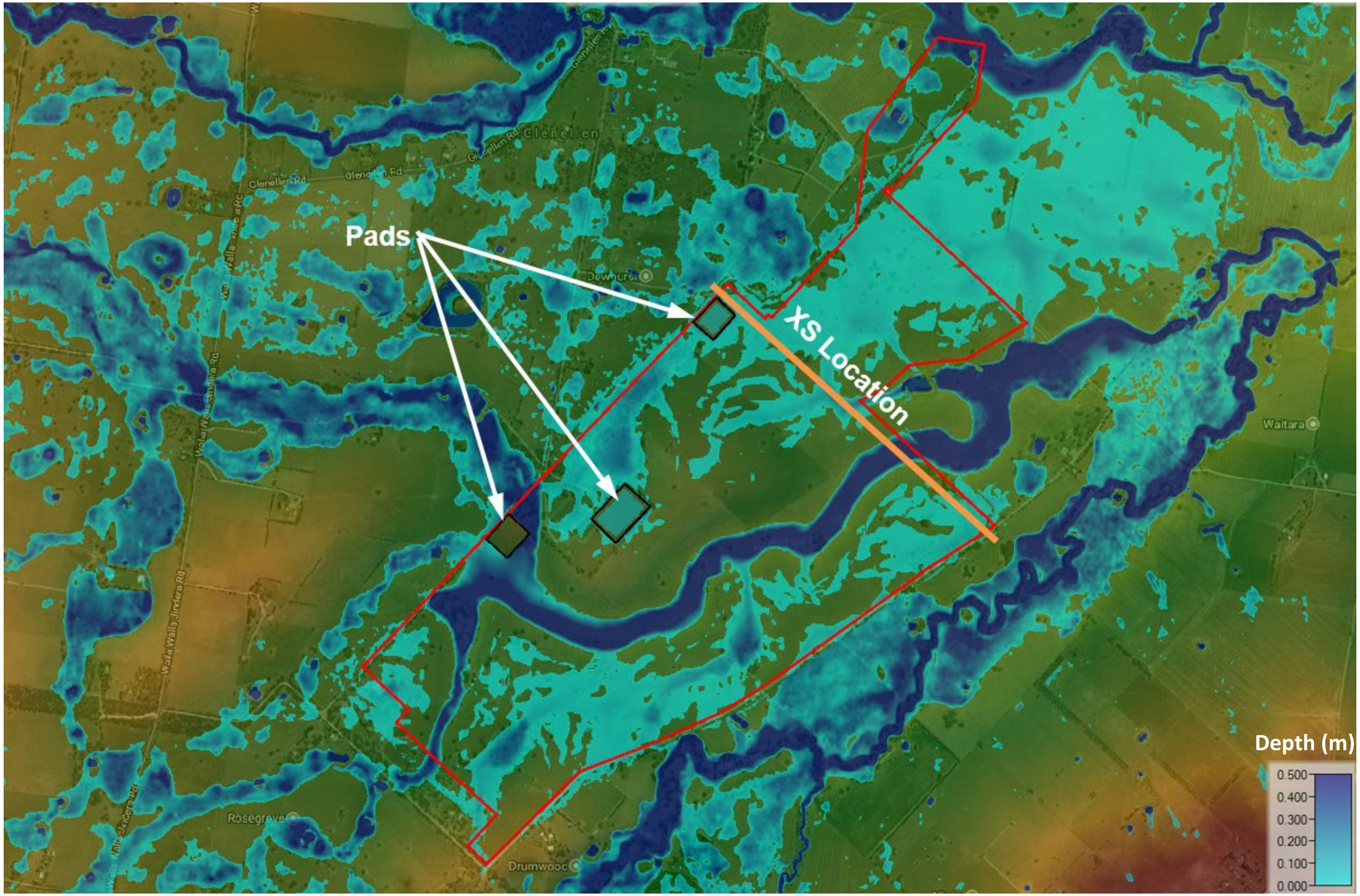

Figure 1-14 Locations of proposed building pads and the modelled water depths in metres for the 1% AEP (100 year ARI) event. The cross section used for downstream impact assessment is also shown ('XS Location'). Red polygon represents the Site

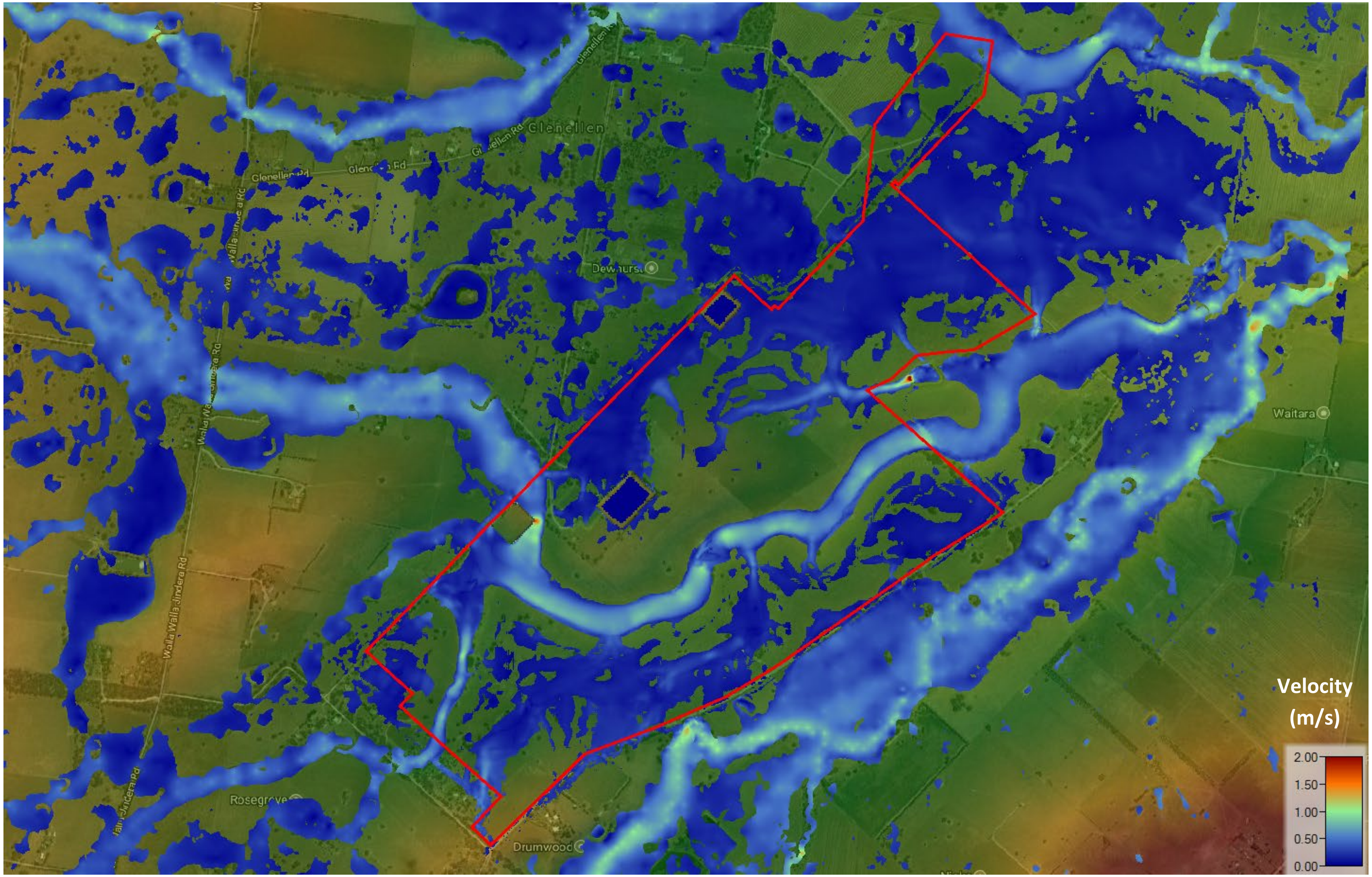

Figure 1-15 Maximum velocities (m/s) for 1% AEP (100-year ARI) event under the proposed conditions. Red polygon represents the Site

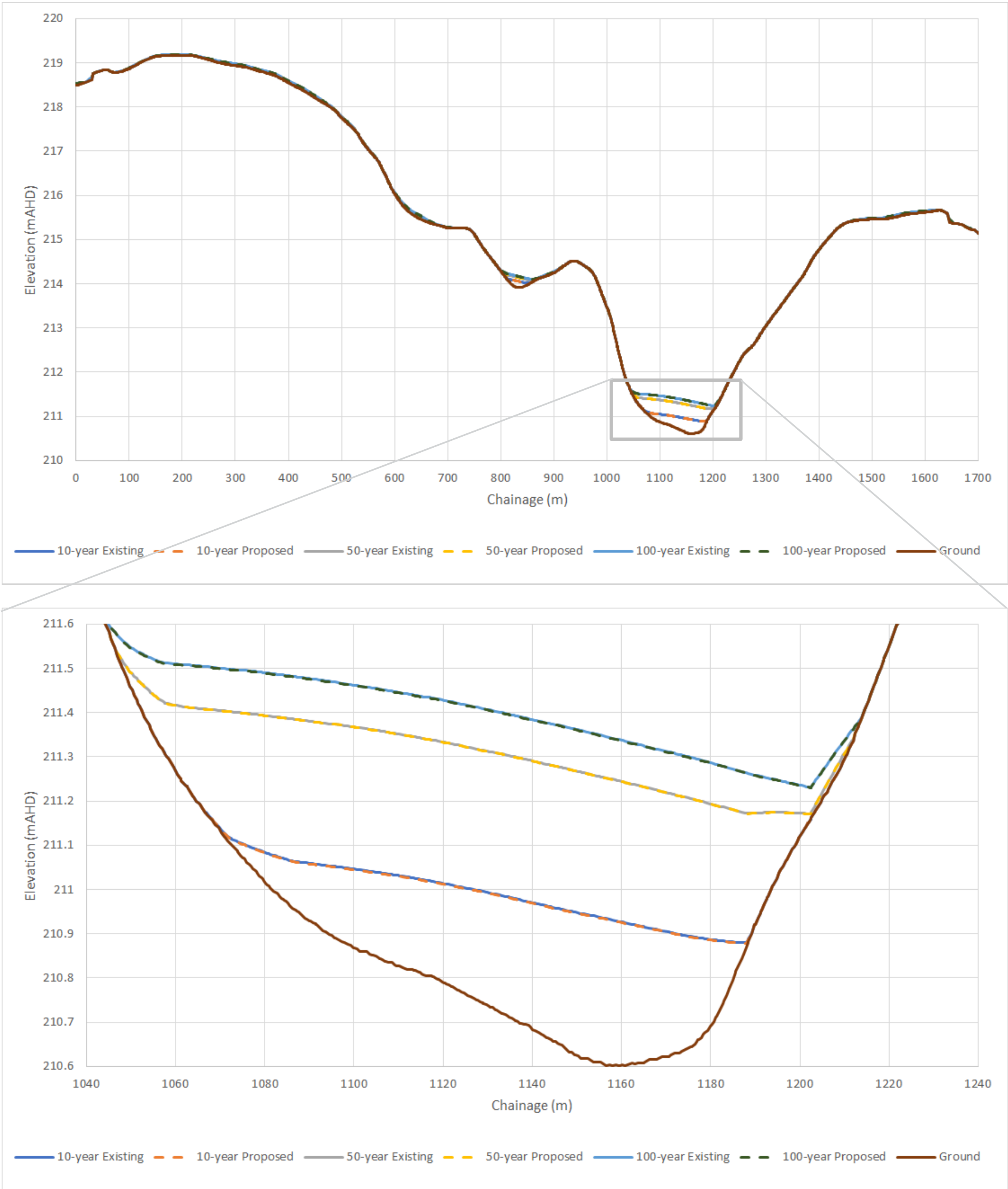

Figure 1-16 Comparison of maximum water surface elevation profiles across the index section (existing vs. proposed conditions)

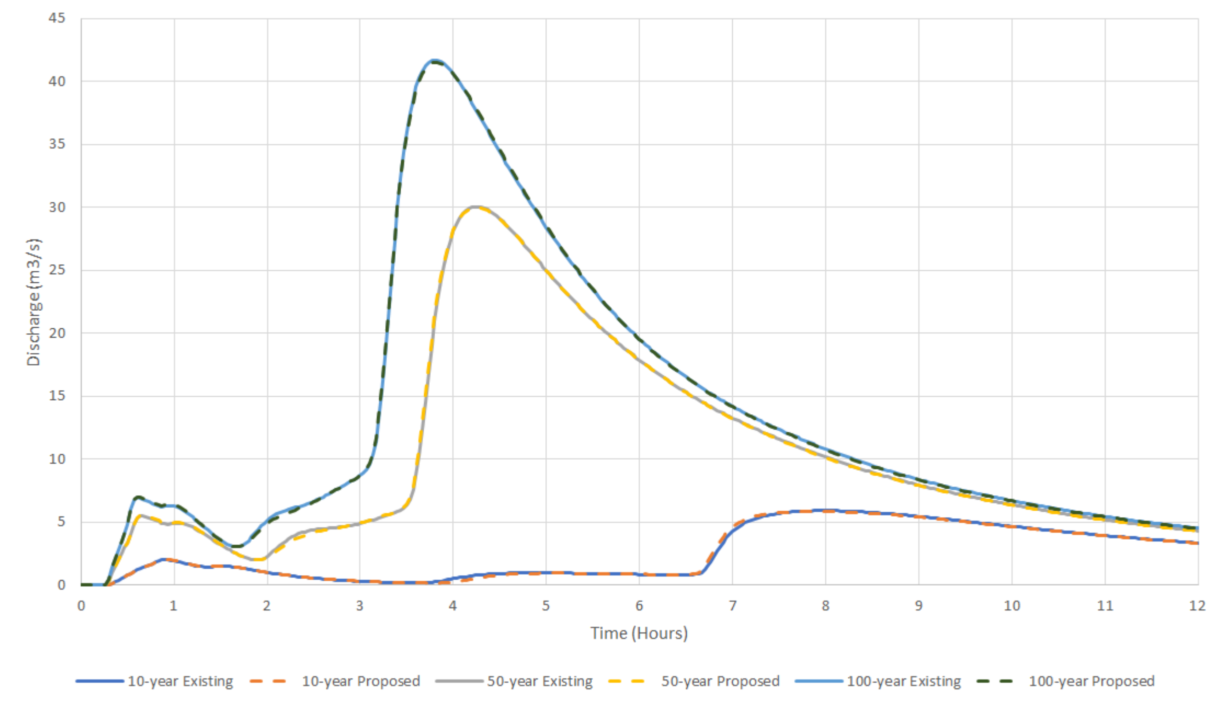

Figure 1-17 Comparison of discharge hydrographs across the index section (existing vs. proposed conditions)

Table 2 Comparison of peak flow and maximum depth across index section (See Figure 1-14 for section location)

Peak discharge (m^3/s)								
10-year ARI (10% AEP)			50-year ARI (2% AEP)			100-year ARI (1% AEP)		
Existing	Proposed	Diff	Existing	Proposed	Diff	Existing	Proposed	Diff
5.917	5.852	1%	30.070	30.016	0.2%	41.716	41.541	0.4%
Maximum water level (m)								
10-year ARI (10% AEP)			50-year ARI (2% AEP)			100-year ARI (1% AEP)		
Existing	Proposed	Diff	Existing	Proposed	Diff	Existing	Proposed	Diff
0.332	0.330	0.5%	0.650	0.649	0.1%	0.744	0.743	0.2%

1.3.3 Impact of climate change

No specific modelling was undertaken to consider potential impacts from climate change. Rather, the results from the 0.1% AEP (1,000-year ARI) event have been taken as a proxy for very rare to extreme events, such as the Probable Maximum Flood (PMP), as a contingency against future climate change.

Peak channel velocities within the Site are approximately 0.9 m/s in the 1% AEP (100 -year ARI) event and 1.2 m/s in the 0.1%AEP (1000 -year ARI) event. Modelled maximum velocities across the Site during the very rare 0.1% AEP event are less than 0.5 m/s, indicating that erosion is unlikely to be an issue even in rare events.

Pad designs need to ensure that the pad elevations include sufficient freeboard to allow for any potential climate change impacts.

1.4 Conclusion and recommendations

This report has investigated the hydraulic effect of installation of proposed infrastructure at the GSF Site and found that the downstream project impact is negligible.

Modelling suggests that there is likely to be small decreases in water surface height and peak flows with the proposed development across all modelled flows. This amounts to less than 1% difference in these measures between modelled scenarios.

For larger events (1 in 100-year ARI, or 1% AEP), in the immediate vicinity of the pads, water surface elevations are likely to increase by up to 200 mm. In some areas around the temporary construction pads, the flow path is likely to be constricted, and the increased flow velocities may require the use of armour rock to prevent local scour (Austroads 1994 and Austroads 2013a, 2013b).

The Proposed Development is not expected to affect the hydraulic functions of flow conveyance in floodways, nor the storage in flood storage areas on adjacent lands. As a result, no detrimental increases in the potential flood levels are expected within the Site, or in surrounding properties, assets and infrastructure outside of the Site. Flood hazards under proposed conditions are low and can be managed using localised scour protection where needed. No increase in flood hazard is predicted on neighbouring tenement areas.

An area of approximately 3 ha is proposed to be raised above the flood levels for temporary construction activities. The Proposed Development is not expected to create adverse effects to beneficial inundation of the floodplain environment on, adjacent to or downstream of the Site during these activities.

Allowing for rehabilitation of locally disturbed areas during construction, no long-term direct or indirect increases in erosion, siltation or destruction of riparian vegetation are expected. The hydraulic modelling indicates that the Proposed Development is not expected to affect the stability of river banks or watercourses.

1.5 Reference

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