Environmental Impact Statement

Uungula Wind Farm

Appendix P: Hydrology Assessment (Eco Logical Australia, 2020)

May 2020

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Uungula Wind Farm EIS – Hydrology Assessment

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DOCUMENT TRACKING

Project Name	Uungula Wind Farm EIS
Project Number	ARM13867
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Approved by	Richard Cresswell
Status	**Final**
Version Number	**2**
Last saved on	**20 May 2020**

This report should be cited as 'Eco Logical Australia (2020). *Uungula Wind Farm EIS – Hydrology Assessment*. Prepared for CWP Renewables Pty Ltd.'

ACKNOWLEDGEMENTS

This document has been prepared by Eco Logical Australia Pty Ltd with support from CWP Renewables Pty Ltd and Zenviron Pty Ltd

Executive Summary

Eco Logical Australia Pty Ltd (ELA) has been engaged by CWP Renewables Pty Ltd to assess hydrological conditions associated with the existing and proposed development conditions for the proposed Uungula Wind Farm near Burrendong Dam, New South Wales under 10%, 1%, 0.5%, 0.2% and 0.1% Annual Exceedance Probability (AEP) flood events. This report forms an appendix to the Environmental Impact Statement (EIS) for the proposed development of the Uungula Wind Farm.

This report provides the modelling approach and modelling results for potential flow rates, flood depths and inundation extents under existing and proposed conditions across the Uungula Wind Farm development footprint.

FLOW RATE MODELLING

Flow rate modelling was undertaken using the RORB software package to determine sub-catchment flows. These flows were used as inputs to verify the flow rates derived from the separate water level modelling. A Digital Elevation Model (DEM) was used to create the overall catchment boundary and sub-catchment boundaries.

The site-specific modelled results fit within the confidence limits of the Regional Flood Frequency Estimation (RFFE) modelling and were close to the expected discharge rates. Therefore, the flow rates modelled by RORB were considered applicable for use for constraining the roughness rates used in the subsequent water level modelling (using the HEC-RAS software).

Under the proposed development conditions, proposed infrastructure will create an additional impervious area within the catchment. This would result in a maximum overall change in imperviousness across the full model domain of less than 1%. The majority of this increase in impervious area will be on the ridgelines of the terrain, away from any concentrated water flow paths. Hence, the impact of impervious area on the resulting flows is considered negligible.

WATER LEVEL MODELLING

Hydraulic modelling was subsequently conducted for existing and proposed development conditions using the HEC-RAS software package. HEC-RAS models were developed using a two-dimensional (2D) rain-on-grid analysis to determine flood extents, flood levels and flow velocities.

Two model terrains were developed to model existing conditions and proposed development conditions, respectively. Refinement regions were specified for the roads and drainage areas adjacent to the roads. Roughness coefficients were used to define how quickly water moves across the terrain and to control the shape of flow hydrographs resulting from the rainfall and upstream flow. Rainfall was applied to the 2D area based on the intensity-frequency-duration (IFD) data and the RORB results.

For each of the model runs undertaken, flow depth and velocity were extracted across the model domain. The existing conditions flood depths showed that, in general, the flows are concentrated to the waterways in the region with enough terrain relief to limit the amount of sheet flow. An example of this is shown in Figure 1-1 for the 10% AEP event.

The inclusion of the wind turbines, roads/hardstands and drainage in the proposed conditions showed that the drains distribute flows away from the roads. While some of the turbine areas show water inundation in the 10% AEP event, these depths are less than 0.05 metres and are typically excluded from the analysis to account for model error. An example of this is shown in Figure 1-2.

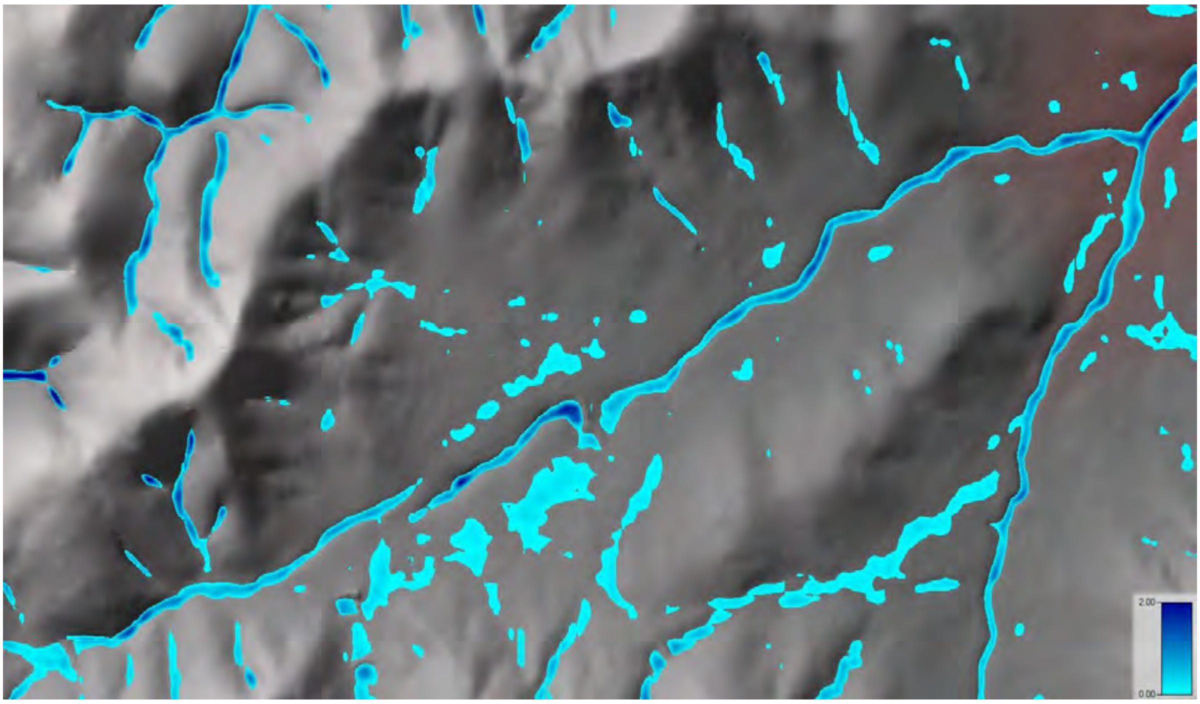

Figure 1-1 Existing conditions 10% AEP flood depths for a region of the development footprint. Depth scale between 0 metres and 2 metres.

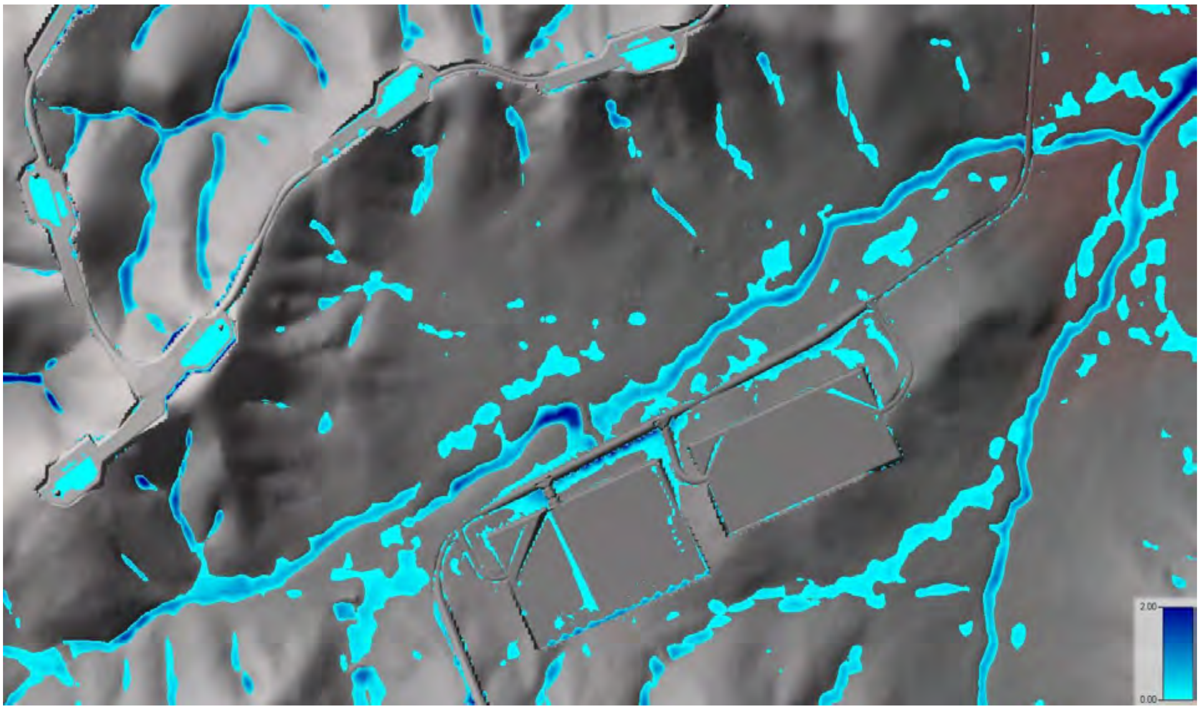

Figure 1-2 Developed conditions 10% AEP flood depths for the same region of the development footprint as shown in Figure 1-1. Depth scale between 0 metres and 2 metres.

For the 1% and rarer events, flows exceed road drainage capacities and show some impact from the roads and hardstands. During detailed design, roads should be graded such that flows cannot pond around the wind turbines, compounds and any electrical infrastructure.

The results also show that some of the Energy Storage Facility (ESF) and storage compounds are currently located very close to watercourses. Modelled flood levels are likely to impact, or be close to impacting, on this infrastructure. During detailed design, these areas could be relocated, or raised, to create a freeboard above the relevant flood depth.

The roads have been modelled without culverts; in the models, water can back up behind these roads. This would not occur to the same degree once appropriate drainage was included. Depending on the location, this may either decrease flood depths (e.g. from water being moved downstream) or increase flood depths (e.g. from water which was held upstream now passing downstream) and would need to be re-modelled during detailed design.

Under existing conditions, in general, the flows are of low velocity in the lower order waterways. Once the water reaches higher order, more major waterways, the velocities increase towards and over critical velocities for which stream protection may be required (generally >2 m/s). This is dependent on the local geomorphology. An example of isolated locations where this may occur is shown in Figure 1-3.

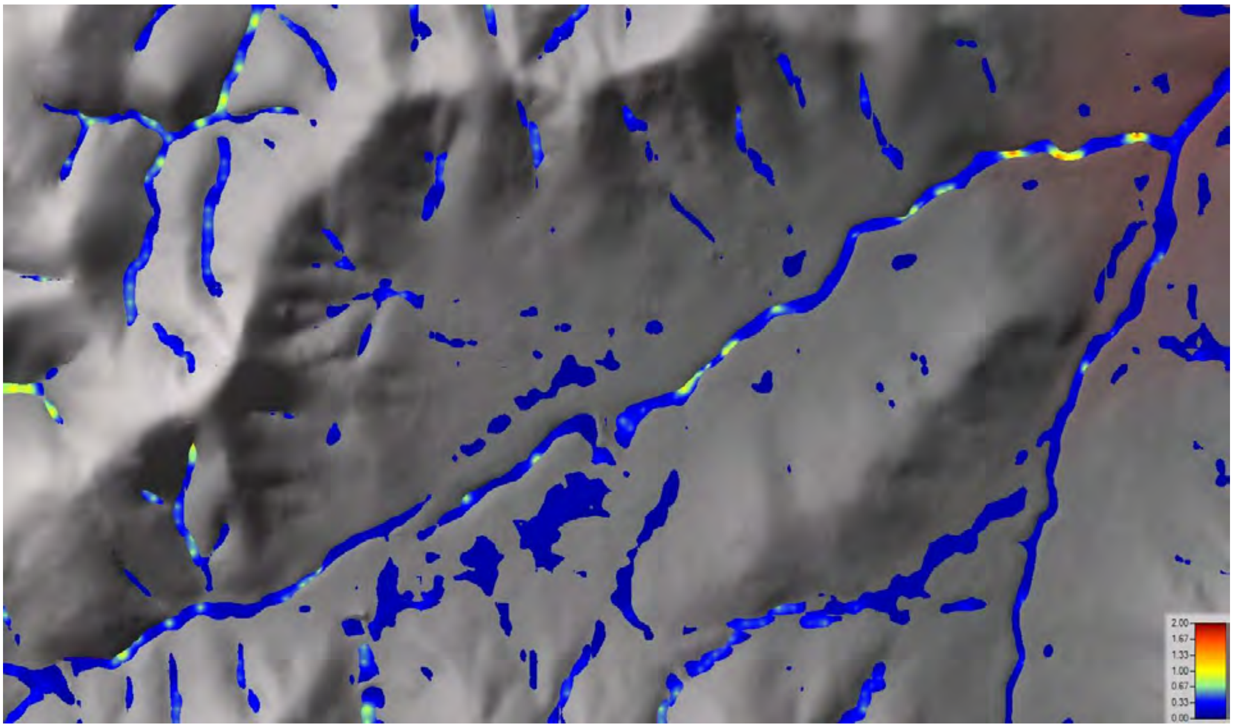

Figure 1-3 Existing conditions 10% AEP velocities for a region of the development footprint. Velocity scale between 0 m/s and 2 m/s.

The inclusion of the wind turbines, roads/hardstands and drainage in the proposed conditions resulted in higher velocities along the edge of the roads near the drains. These higher velocities may not be realistic, however, as they have been modelled without batters as the steep slopes require specific geotechnical studies which will be undertaken during detailed design post-Development Consent (standard-grade batters of 1:3 are not suitable in some places due to the relief and topography). At detailed design the finalised earthworks design and the regional DEM would be combined with a smooth transition to correct this. An example is shown in Figure 1-4, where higher velocities are seen at the edge of the pad in the lower centre of the figure and along the edge of the road in the upper right.

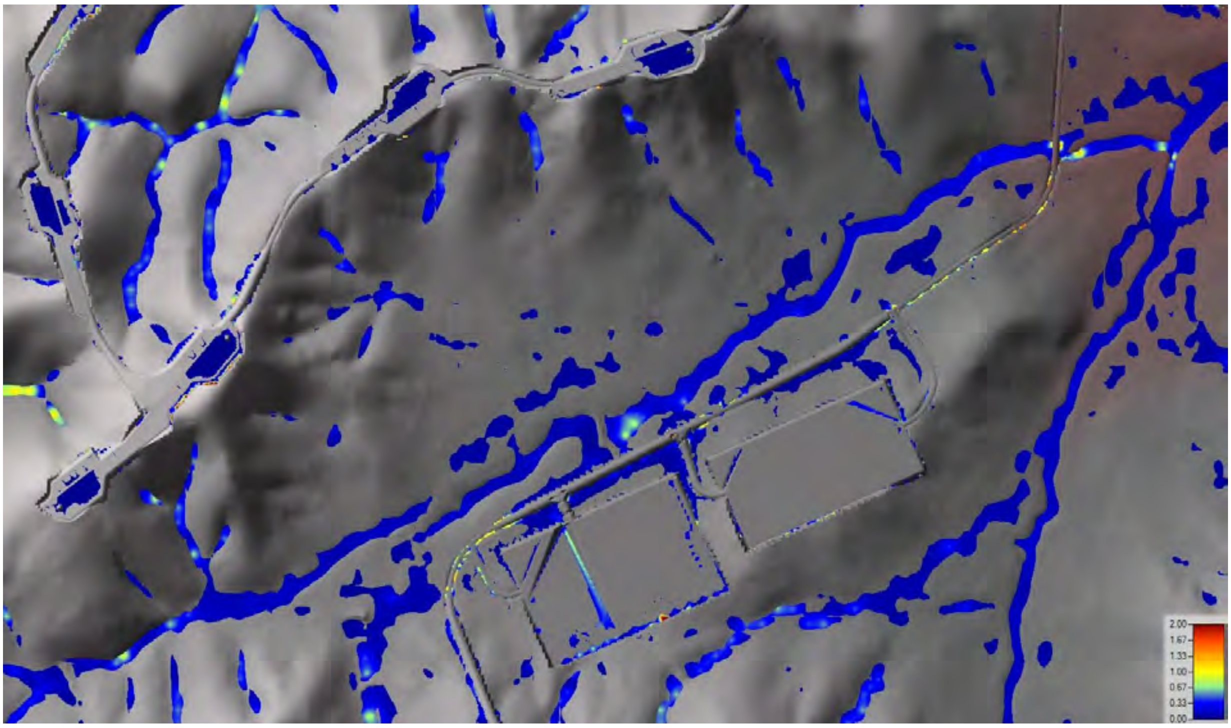

Figure 1-4 Developed conditions 10% AEP velocities for a region of the development footprint. Velocity scale between 0 m/s and 2 m/s.

Flow velocities within the watercourses vary such that some areas are below the level that might be expected to require artificial protection (i.e. rock armouring), while others would benefit from protection of stream banks using armouring. Given the current conditions of the site, this could be limited to the vicinity of the proposed infrastructure and its local discharge into the receiving environment. During detailed design, this should be reviewed to ensure appropriate waterway protection is in place.

CONCLUSIONS AND DISCUSSION

Hydrological modelling showed that the majority of the site is not prone to sheet flow and the proposed development will not pose undue stress on the waterways. The site is generally not prone to high velocity flows and hence not prone to erosion. Within the drainage lines themselves, modelling indicates some local potential for high flow rates and possible erosion and this should be considered as part of detailed design. Aerial photography, however, indicates good ground-cover vegetation and a corresponding lack of erosion under current management practices.

The proposed infrastructure (less than 1% of the model domain) for the Uungula Wind Farm are unlikely to significantly affect flows and downstream erosion or sedimentation, provided appropriate design considerations (culverts, rock armouring, etc.) are considered at detailed design. Some scour protection may be warranted where concentrated flow paths enter some defined drainage channels.

The likelihood for impacts to downstream receivers is low and may be further reduced through the management of flow velocities using flow detention basins and/or other mitigation structures before the flows leave the roads and hardstands and enter the receiving environment. Effective design and location of such structures during detailed design would ensure that flows would not differ significantly from current conditions.

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Abbreviations

Abbreviation	Description
2D	Two dimensional
3D	Three dimensional
AEP	Annual Exceedance Probability
ARF	Areal Reduction Factor
ARI	Average Recurrence Interval
AR&R	Australian Rainfall and Runoff
BoM	Bureau of Meteorology
DEM	Digital Elevation Model
EIS	Environmental Impact Statement
ELA	Eco Logical Australia
ELVIS	Elevation and Depth – Foundation Spatial Data
ESF	Energy Storage Facility
HEC-RAS	Hydrologic Engineering Centre River Analysis System
ICSM	Australian Government's Intergovernmental Committee on Surveying and Mapping
IFD	Intensity-Frequency-Duration
IL/CL	Initial Loss and Continuing Loss
RFFE	Regional Flood Frequency Estimation
RORB	Runoff-Routing Model
TIN	Triangular Irregular Network

1. Introduction

Eco Logical Australia Pty Ltd (ELA) has been engaged by CWP Renewables Pty Ltd. to assess hydrological conditions associated with the existing and proposed conditions under 10%, 1%, 0.5%, 0.2% and 0.1% Annual Exceedance Probability (AEP) flood events for the proposed Uungula Wind Farm near Burrendong Dam, New South Wales (Figure 1-1). This report is an appendix to the Environmental Impact Statement (EIS) for the proposed development of the Uungula Wind Farm.

This report provides the modelling approach and modelling results for potential flow rates, flood depths and inundation extents under existing and proposed conditions across the Uungula Wind Farm development footprint.

This report is presented in three sections, describing the flood assessment process:

1. Data requirements: What data was sourced and used as part of the modelling.
2. Flow rate modelling: Modelling undertaken to determine flow rates within the catchment and any adjacent waterways under different rainfall regimes.
3. Water level modelling: The modelling undertaken to determine water levels across the site and any adjacent waterways under different flow regimes.

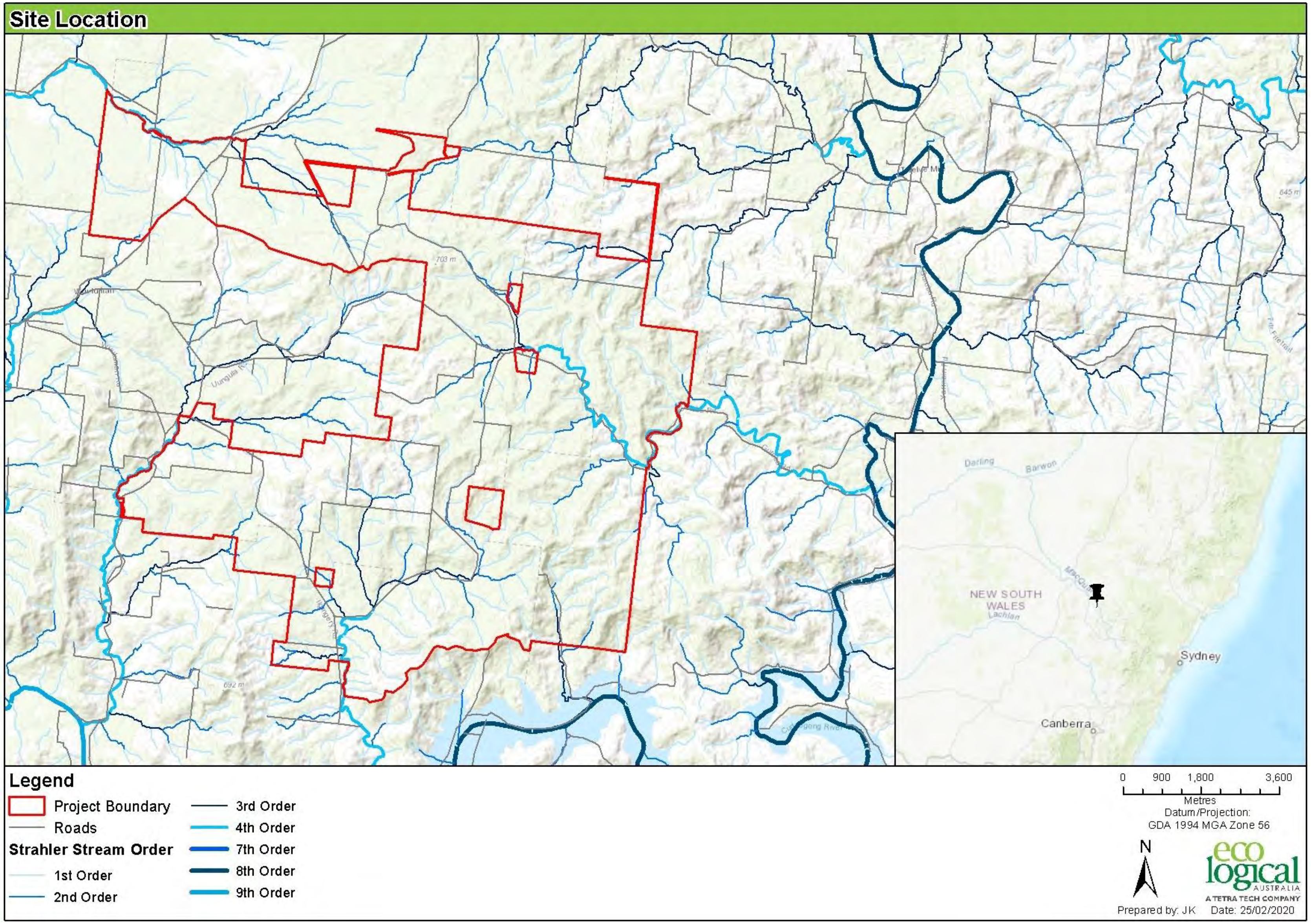

Figure 1-1 Site Location

2. Data Requirements

The following datasets were sourced for use in this project:

- Digital Elevation Model (DEM) datasets to represent the watershed (catchment) that drains the site and any adjacent waterways under existing conditions
- DEM datasets to represent the site for proposed conditions (e.g. roads or infrastructure pads)
- Shapefiles of infrastructure and 3D design of the development footprint for the proposed conditions
- Specific design criteria the development needs to meet
- Intensity Frequency Duration (IFD) data representing the rainfall intensities for design rainfall events specific for this catchment
- Australian Rainfall and Runoff (AR&R) information: for rainfall patterns and loss information for use in the flow rate modelling
- Regional Flood Frequency Estimation (RFFE) modelling to validate the flow rate model results for design storm events
- (Optional, if gauged flow data also available) Gauged sub daily rainfall data (pluviograph) representing observed local rainfall falling on the catchment for use in at site calibration of runoff characteristics
- (Optional, if gauge located nearby in same catchment as the site) Gauged flow data representing flows in the catchment for us in at site calibration of runoff characteristics

2.1 Digital Elevation Models (DEMs)

DEMs were sourced to determine runoff catchments for waterways that drain to or through the Uungula Wind Farm project area. Elevation information was sourced from the Australian Government's Intergovernmental Committee on Surveying and Mapping (ICSM) Elevation and Depth – Foundation Spatial Data (ELVIS) website. The most detailed DEM available that covered the entire site and its catchment was at a resolution of 5 metres by 5 metres.

For the project two DEM extents were computed (extracted) from the overall 5 metre by 5 metre DEM (Figure 2-1). The first is the full model extent for use in the water level modelling that incorporates the Project Area and its catchments. The second is a single catchment used for determining expected flow rates from the modelling (Figure 2-2). From available GIS information it is understood that there are some existing roads present within the catchment. For the purpose of the modelling, however, the existing conditions assume no roads as the roads are farm tracks or minor roads with minimal surface relief. The existing conditions also assume no other man-made structures, e.g. culverts, within the catchment.

The proposed conditions DEM information (Figure 2-3) was created from a Triangular Irregular Network (TIN) model provided by Zenviron Pty. Ltd., a shapefile of the point location of the wind turbines, a shapefile of the road and hardstand areas and a shapefile of the drainage locations. The resulting 1 metre by 1 metre DEM for the roads/hardstands and a 0.1 metre by 0.1 metre DEM for the drainage was incorporated with the full model extent DEM shown in Figure 2-1 to model the proposed conditions.

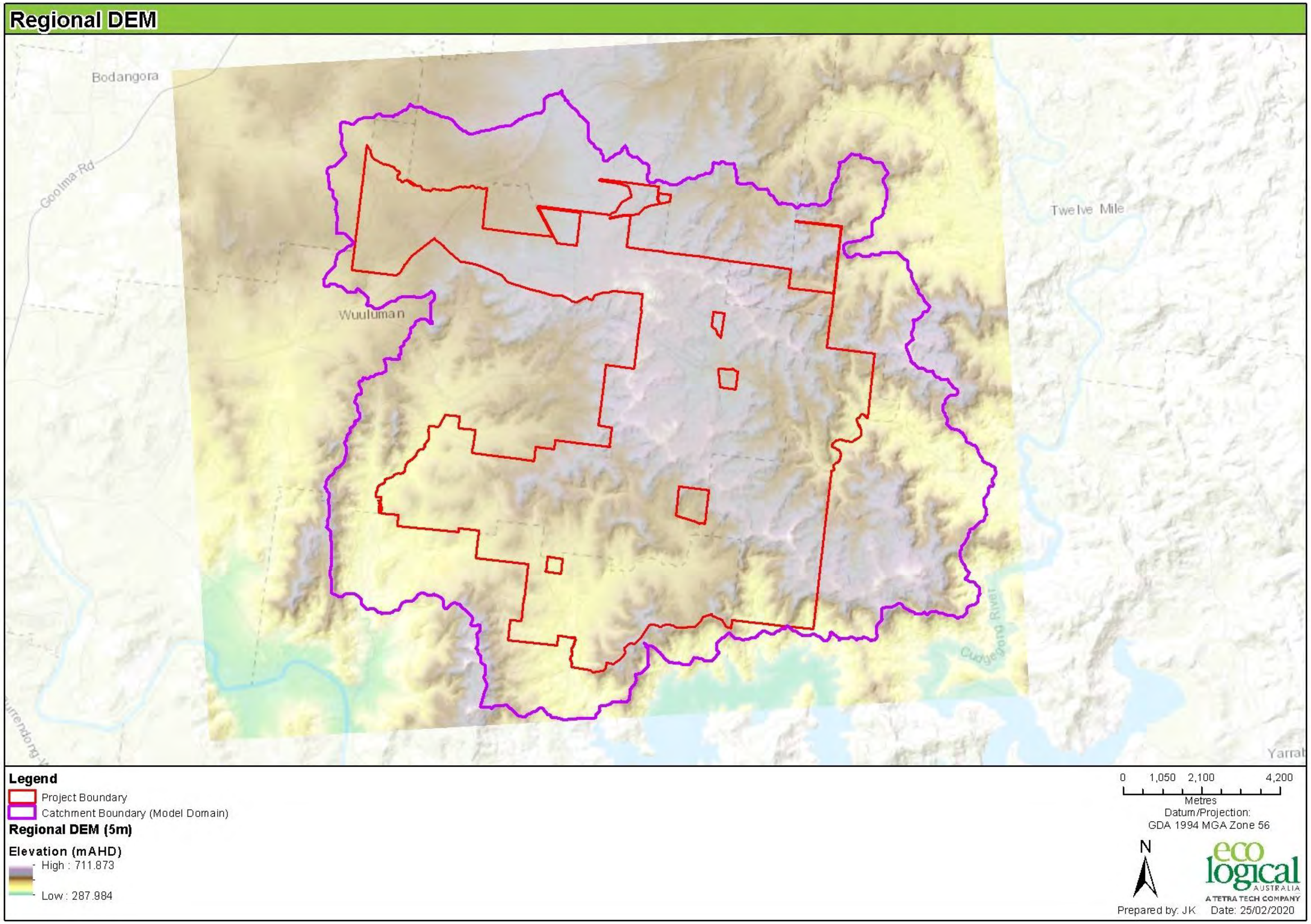

Figure 2-1 Project DEM extent

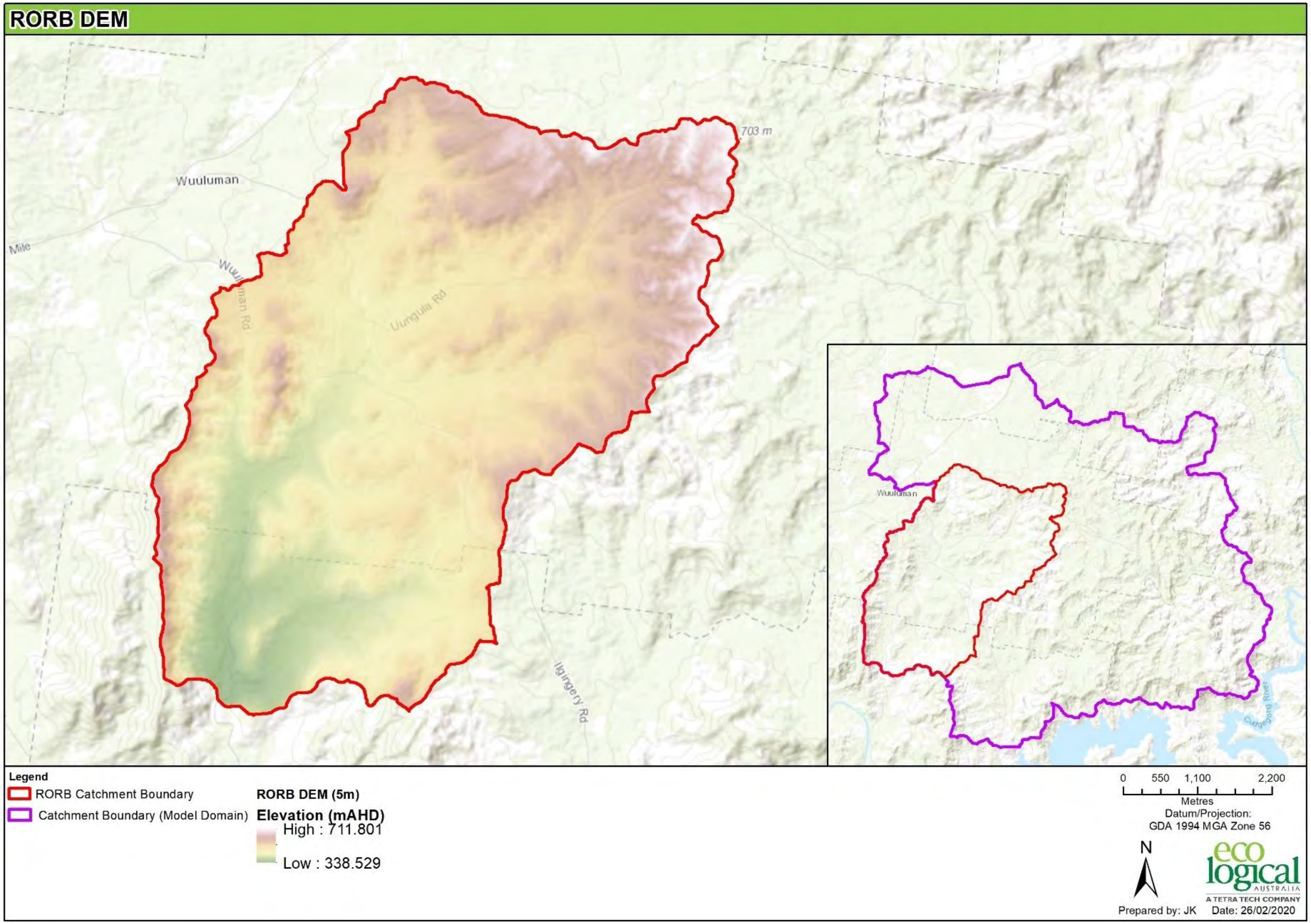

Figure 2-2 RORB DEM extent

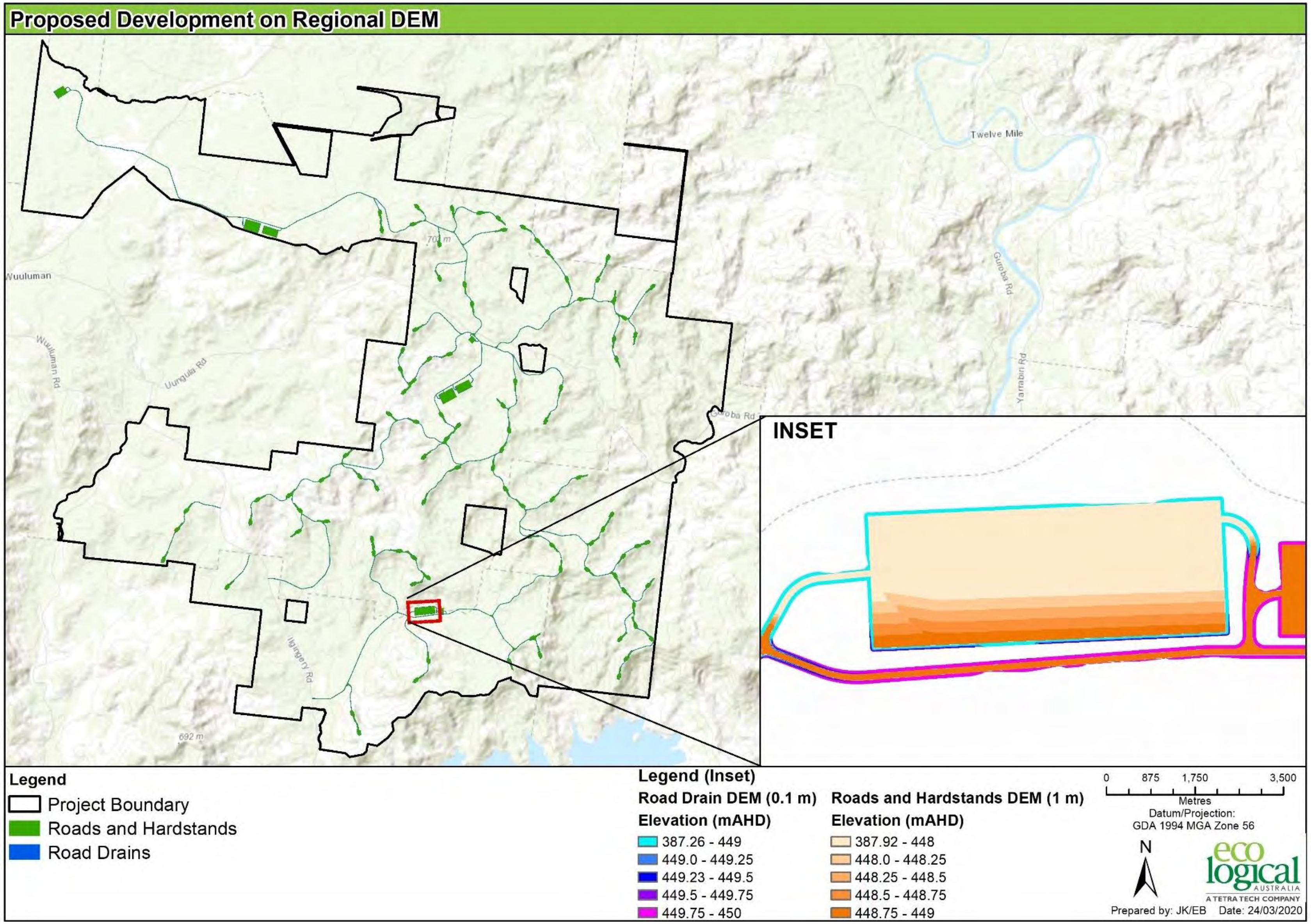

Figure 2-3 Proposed Development DEM extent with an insert showing the change in gradient across one of the pads (tan colours) and its associated drain (red to green colours)

2.2 Design Criteria

No specific hydrology design criteria were supplied for the proposed development.

2.3 Intensity-Frequency-Duration (IFD) Information

The Intensity-Frequency-Duration (IFD) information was sourced from the Bureau of Meteorology (BoM) IFD curves (retrieved December 16th 2019) at coordinate 32.5375˚ (S) and 149.1125˚ (E), as the centroid of the RORB catchment area (Figure 2-2). Full data is provided in Appendix A.

2.4 Australian Rainfall and Runoff Information

Additional information required to set up the flow model was sourced from the Australian Rainfall and Runoff (AR&R) data hub[1] (retrieved December 16th 2019) at the coordinate location specified in Section 2.3. The key information obtained were the temporal patterns (pattern rainfall occurs in for each event duration) and losses for the initial loss and continuing loss (IL/CL) model used to generate flows. Relevant parameters were sourced from the Murray-Darling Basin, with the particular (sub) region being the Macquarie-Bogan Rivers.

Retrieved parameters include:

- Initial loss of 25.0 mm and continuing loss of 3.3 mm/hr
- Point and areal temporal patterns. Available durations of point and areal temporal patterns, compared with the IFD durations, are shown in Appendix B1.
- Areal reduction factor (ARF) parameters from the Central NSW zone
    - a = 0.265
    - b = 0.241
    - c = 0.505
    - d = 0.321
    - e = 0.00056
    - f = 0.414
    - g = 0.021
    - h = 0.015
    - I = -0.00033

The full information from the data hub is provided in Appendix B2 with relevant information directly imported into the flow modelling software.

2.5 Regional Flood Frequency Estimation (RFFE) Modelling

The Regional Flood Frequency Estimation (RFFE) model[2] was run on February 16th 2020 and used to provide an estimate of the likely design flow volumes from the RORB catchment (Figure 2-4). This model

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[1] http://data.arr-software.org

[2] http://rffe.arr-software.org

uses information from nearby similar catchments to provide an estimation of the peak flow rates. The details required for this are:

- Catchment outlet: location at -32.5798° (E) and 149.0697° (S);
- Catchment centroid at location as per Section 2.3; and
- Catchment area: 50.0 km^2

The full information from the RFFE analysis is provided in Appendix C.

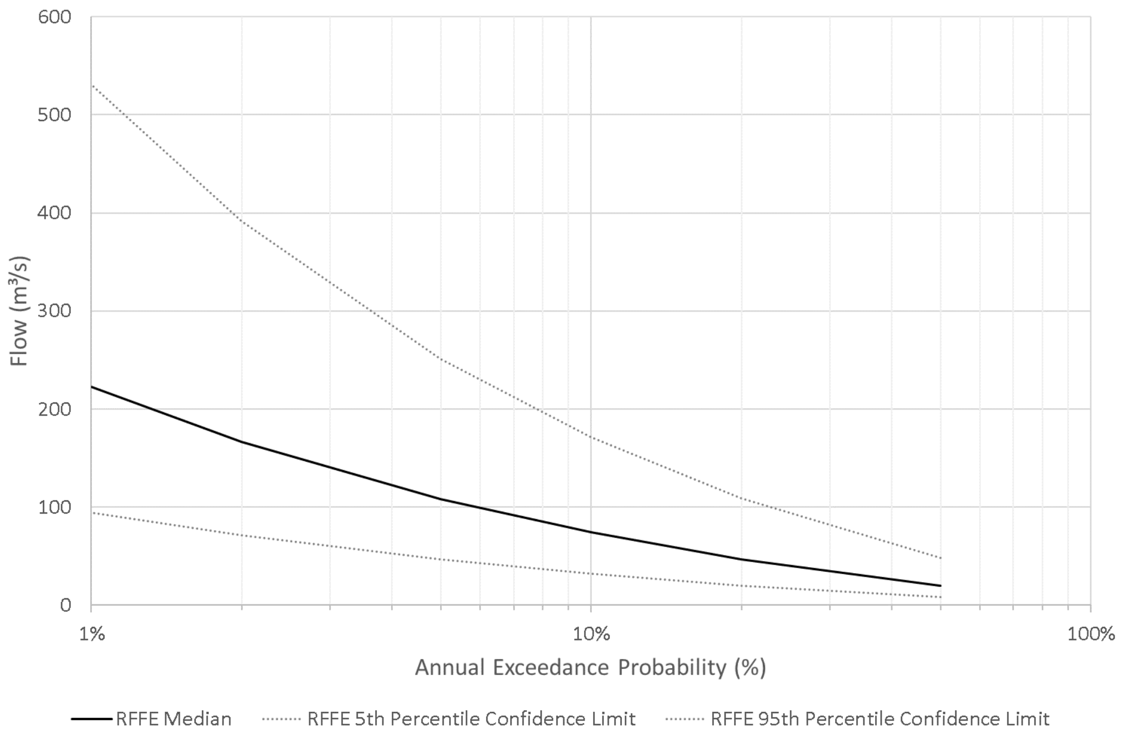

Figure 2-4 Regional Flood Frequency Estimation (RFFE) flow estimates including 5% and 95% confidence intervals

2.6 Sub Daily Rainfall

Sub daily rainfall was not required in this region as there were no relevant observed flow data for use in at site calibration of runoff characteristics.

2.7 Sub-Daily Flow

Sub daily flow was not required in this region as there were no relevant observed flow data for use in at site calibration of runoff characteristics.

3. Flow Rate Modelling

Flow rate modelling was undertaken using the RORB software package[3] to determine sub-catchment flows for the region shown in Figure 2-2. These flows were used as inputs to verify the flow rate from the subsequent water level modelling (Section 4).

3.1 Model Setup

3.1.1 Catchment and Sub catchments

The digital elevation model presented in Figure 2-2 was used as input to create the overall catchment boundary and sub-catchment boundaries for use in the RORB modelling process. The Arc Hydro add-in to ArcGIS was applied to generate the catchment and sub catchment boundaries. Figure 3-1 shows the streamlines derived from Arc Hydro processing.

3.1.2 Catchment Input File

The RORB model requires a catchment file to specify how rainfall is applied to the area of interest and how water is routed through the catchment to the outlet. An add-in to ArcGIS, ArcRORB[4], was used to develop the catchment input file through detailing the following information into shapefiles that are exported into a catchment input file for RORB (Figure 3-2):

- Sub-catchment areas
- Fraction of impervious surface area of each sub catchment
- Distance from sub-catchment centroid to outlet or stream junction
- Reach (stream) types
- Stream lengths

The catchment being modelled is considered to be in a natural condition (i.e. no artificially formed waterways/channels/drains) and all reach types within the catchment file were set to “Natural” and the ‘fraction impervious’ for the whole domain was set to 0%. The fraction impervious in this context refers to impervious areas directly connected to waterways. There is no measurable amount (if any) within the catchment under existing conditions. The distances from the centroid of each sub-catchment were determined based on the following:

- For sub-catchments that had no upstream sub-catchment, the distance was calculated as the distance from the centroid to the outlet of the sub-catchment
- For sub-catchments that had upstream sub-catchments, the distance was calculated as the distance from the centroid to the mid-point of the stream within that sub-catchment.
- For any sub-catchments (with an upstream sub-catchment) where the centroid fell on an existing streamline, the distance was set to zero.

Reach and sub catchment details along with the catchment file layout are outlined in Appendix D.

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[3] Monash University and Hydrology and Risk Consulting https://www.harc.com.au/software/rorb/, version 6.45
[4] https://www.harc.com.au/software/arcrorb/

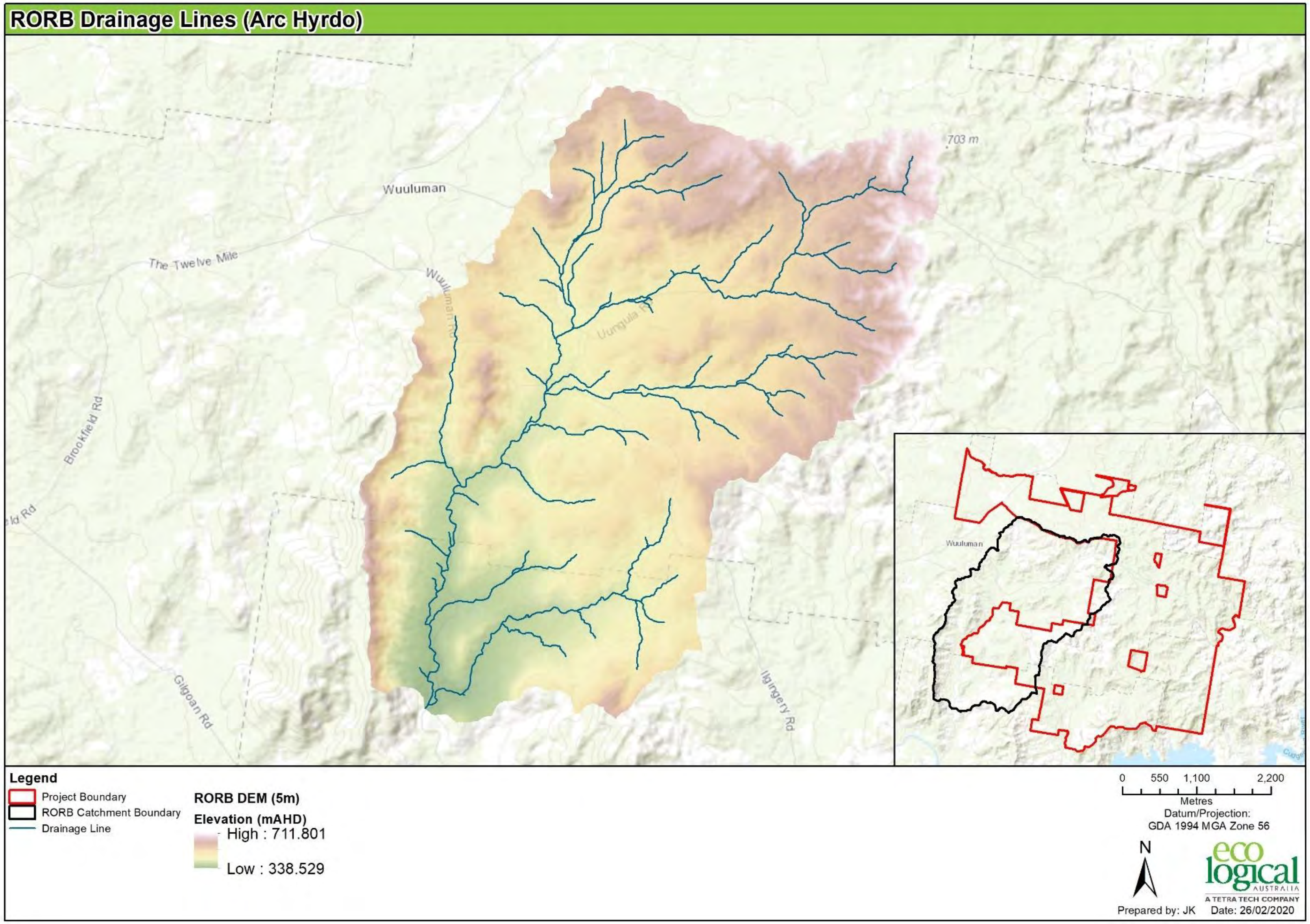

Figure 3-1 Drainage lines for RORB modelling

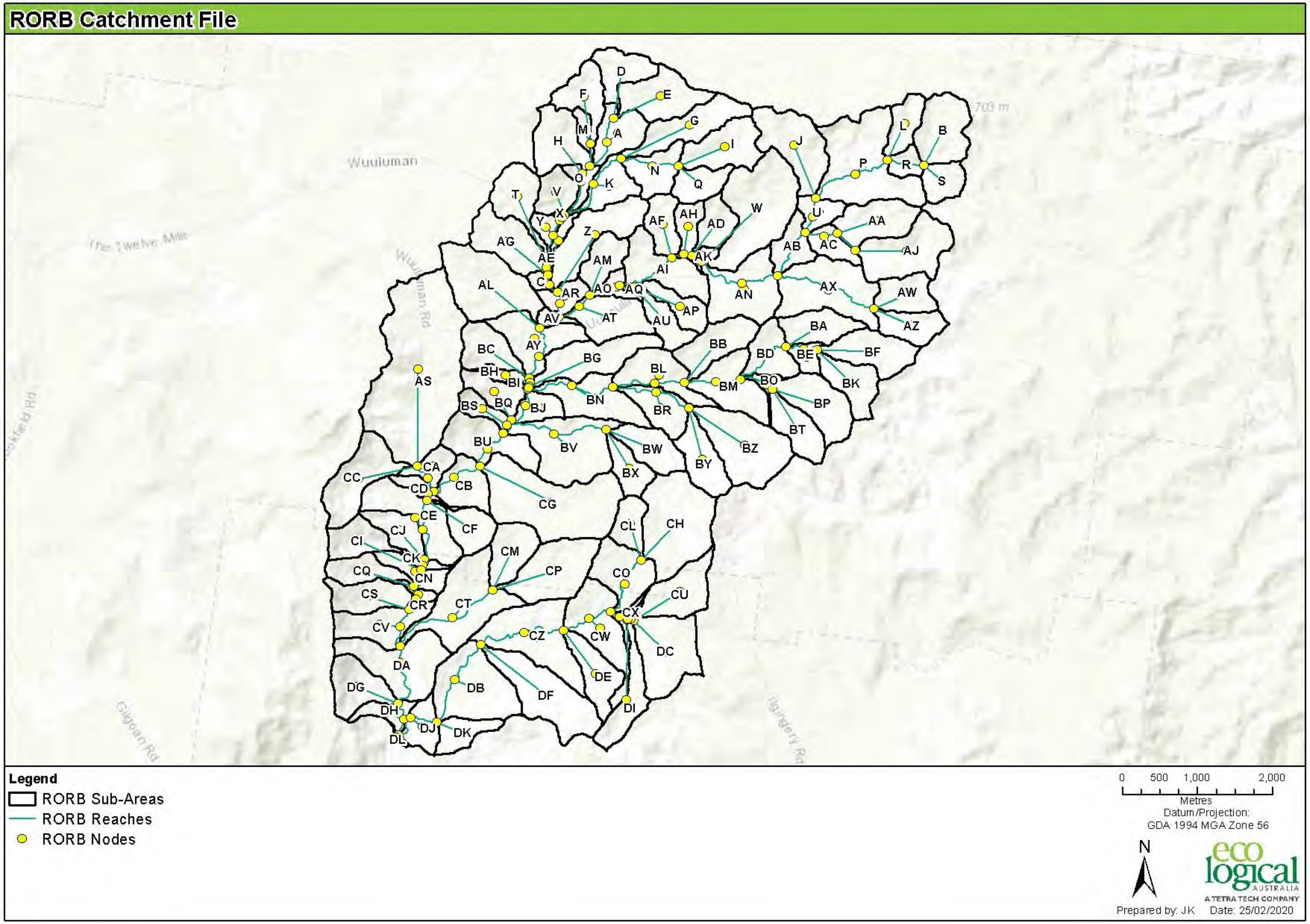

Figure 3-2 RORB Catchment File, as specified by ArcRORB.

3.1.3 Design Storm Parameter File

RORB requires a parameter file to specify the model run to generate the design storms (e.g. 1% AEP). For calibration/verification with the Regional Flood Frequency Estimation (RFFE) and for use in producing the simulated design storms for the water level modelling, the RORB parameter file was set-up using the "Separate catchment and generated design storm(s)" option. Under this configuration, the model operates using a single set of routing parameters for the whole model and an initial loss/continuing loss model. It uses a Monte Carlo framework to examine the impact of different temporal patterns upon the design flow rate results. The parameter options are detailed in Table 3-1.

Table 3-1 RORB Parameter file specification for design storms

Parameter File Section	Detail
Data Hub Files	• Data hub file as discussed in Section 2.4 • Temporal patterns as discussed in Section 2.4 • Use regional losses is unchecked[5] • Use ARFs from file is checked
Design Rainfall Specification	• A user defined IFD (Appendix A) • Monte Carlo simulation from 10 minute to 168-hour durations • Default time increments of 200 • Uniform areal pattern • No pre burst • Constant losses
Parameter Specification	• k_c: 7.14 from NSW equation in RORB • m: 0.8 • IL/CL 25 mm and 3.3 mm respectively
Monte Carlo Specification	• Number of rainfall divisions: 50 (default) • Number of samples per division: 20 (default) • Temporal patterns as described above • No pattern censoring • Fixed initial loss.

3.1.4 Storm Files

No storm files were produced for calibration of losses and k_c values, as there were no relevant observed flow data for use in site calibration of runoff characteristics.

3.1.5 Storm File Parameter File

No storm file parameter files were produced for calibration of losses and k_c values, as there were no relevant observed flow data for use in site calibration of runoff characteristics.

[5] Due to a bug (identified from model use) in the RORB software, this needs to be unchecked, so the loss values are not reset every time the model is run

3.2 Calibration Results

The RORB model was calibrated/validated to the RFFE analysis to fit within the confidence limits of the results. The object of the calibration/validation process is to obtain the best possible fit across the 1%, 2%, 5%, 20% and 50% AEP RFFE results (i.e. closest to best estimate). Comparison of the optimised RORB results to the RFFE analysis are shown in Figure 3-3. Modelled results fit within the confidence limits of the RFFE modelling and are close to the median/expected discharge rate. For the rarer events, the RFFE modelling shows an increasing upward trend that is not reflected in the RORB modelling. Sensitivity analysis and an investigation of the nearby catchments (discussed below) indicates that the RFFE modelling produces higher flow rates for the rarer events than would be expected for a catchment of this size in this location. Therefore, the modelled RORB flow rates are considered applicable for use for constraining the roughness rates in the subsequent velocity (HEC-RAS) modelling outlined in Section 4.

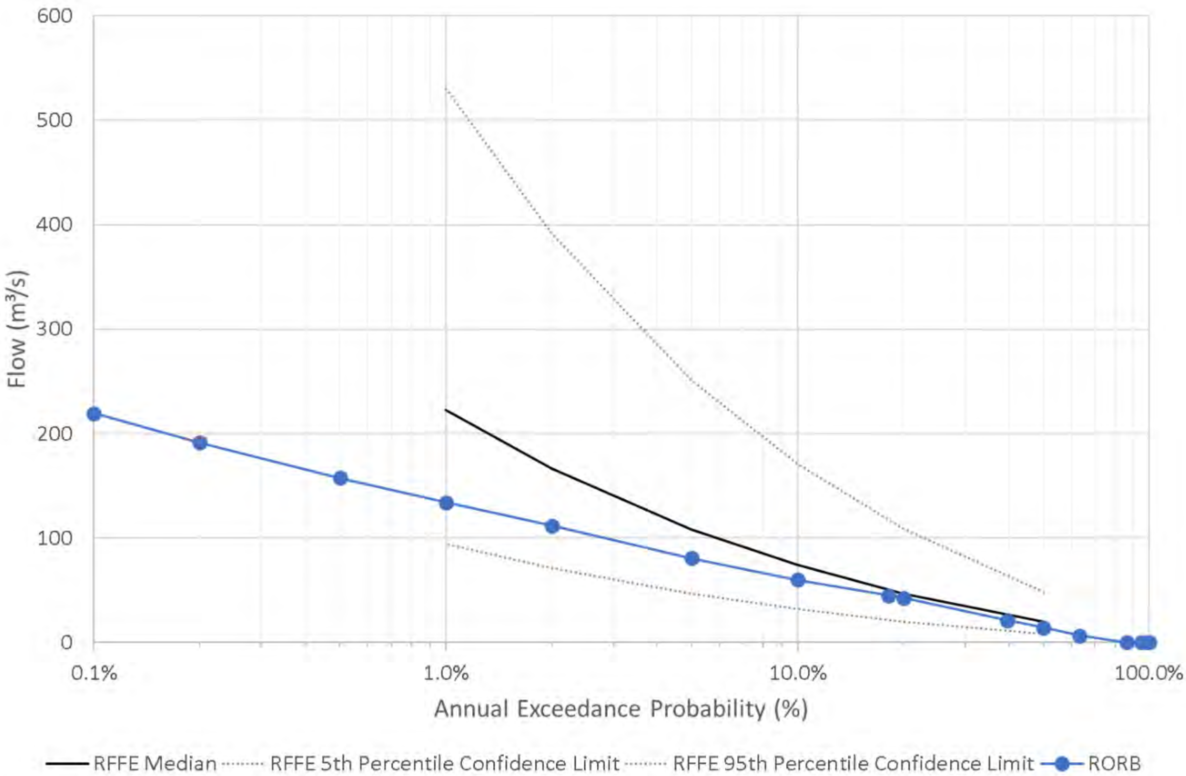

Figure 3-3 RFFE – RORB calibration/validation results

A sensitivity analysis was undertaken to compare the effects of changing the loss values in the IL/CL model, applying pre-burst rainfall and changing the k_c value. The results of the sensitivity analysis are presented in Figure 3-4 and Figure 3-5.

Adjustment of the kc value had the greatest impact on the peak flow rates produced by the RORB model (Figure 3-4). The two changes made to kc, 15.56 and 3.57, compared to the 7.14 adopted value, are too high or too low, respectively, compared with the expected/median RFFE result. The changes in the IL/CL model and the application of pre-burst show similar trends within the model results that are banded around the expected/median RFFE result. It should be noted that the Final and the No pre-burst results have the same parameter sets applied, but as the modelling is run using a Monte-Carlo framework, different results are obtained. As this difference is comparable to the adjustments made to the IL/CL model and as there is no additional justification to change the IL/CL parameters from those obtained from the ARR Data Hub, no additional changes were made to the RORB model.

Figure 3-5 compares the expected/median RFFE result for this catchment with the expected results from nearby gauged catchments (are- weighted to match the target catchment). It can be seen that flow rates for both the RFFE analysis and the RORB modelling results are higher than equivalent flows in the majority of the nearby catchments.

Whilst catchment flows cannot always be linearly scaled based on areas, this comparison provides an indication of nearby runoff characteristics. These results in conjunction with the parameter sensitivity discussed above, were used to inform the final RORB model parameterisation. The comparison suggests the modelling is conservative in its flow considerations. That is, the model is likely to over-predict flooding impacts for the catchment under consideration.

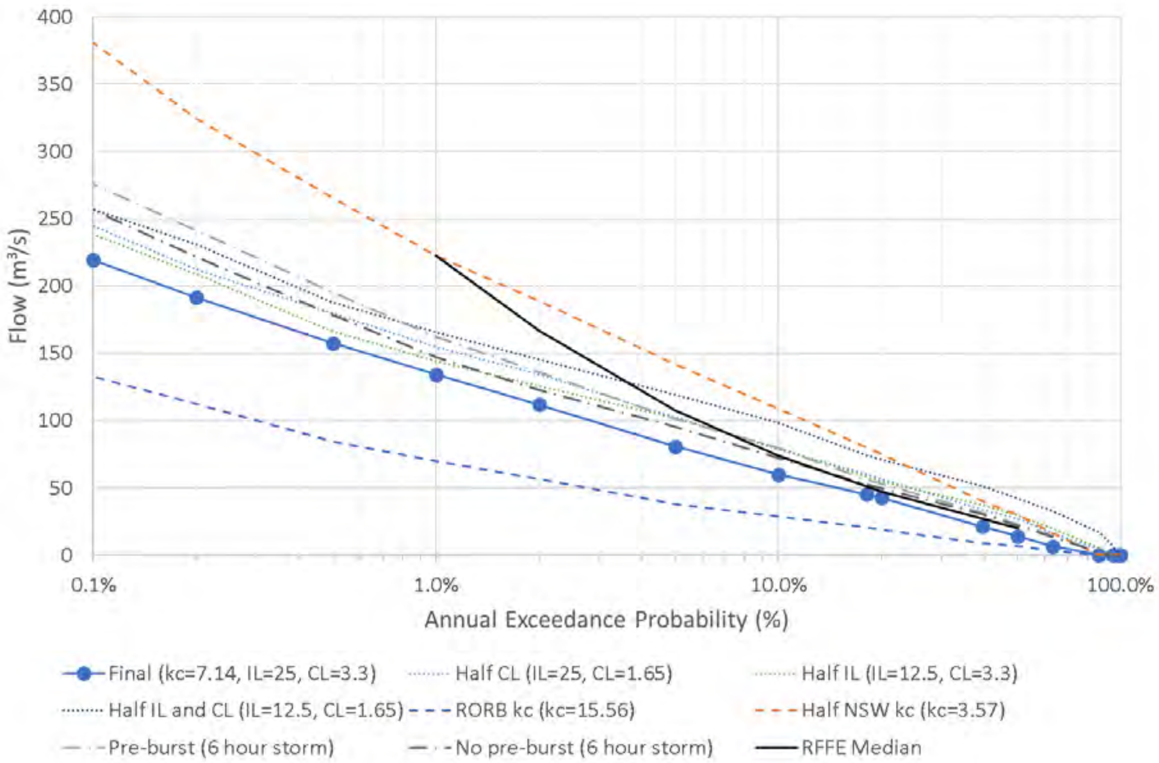

Figure 3-4 RORB sensitivity analysis – changing parameters

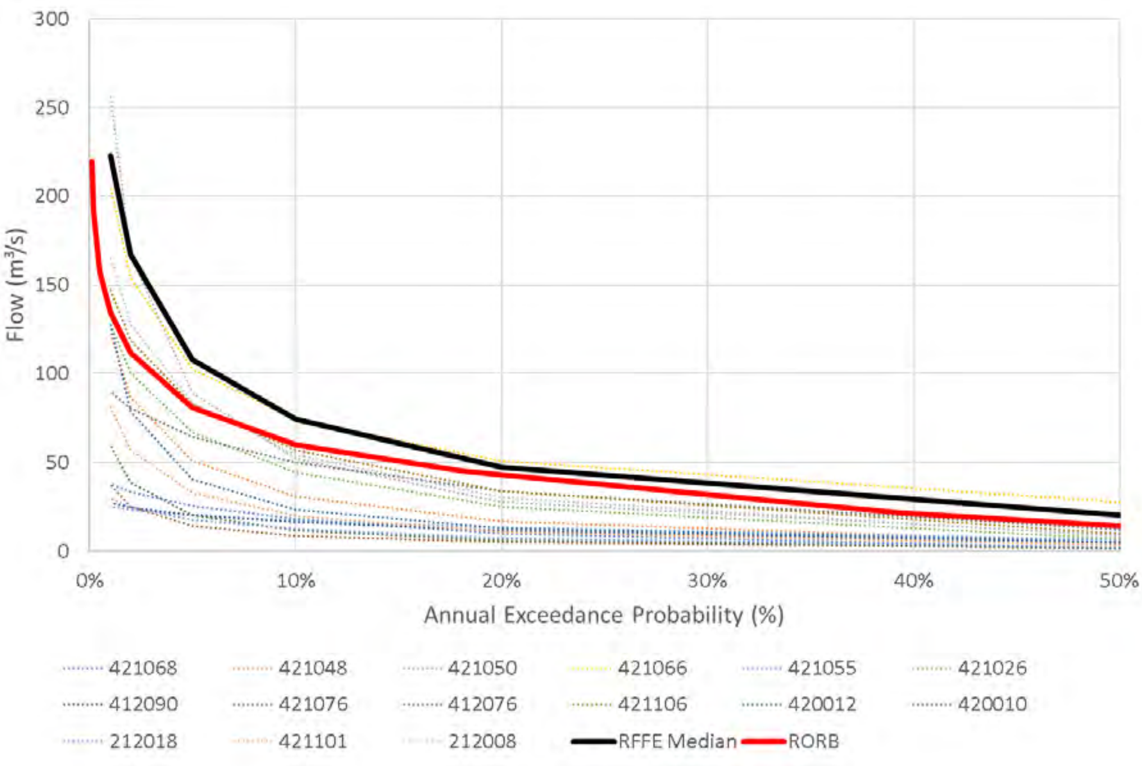

Figure 3-5 RORB sensitivity analysis – RFFE nearby gauges

3.3 Hydrology Results

3.3.1 Existing Conditions

The RORB model was run to provide verification flows for the water level modelling. A summary of the peak flows for each exceedance probability at the catchment outlet is provided in Table 3-2. Noting that some multiple design storm durations have the same peak flow rate, the longest one is taken as the critical duration. Using the Monte Carlo framework to produce the peak flows sometimes results in the flow rates changing between runs (even with the same parameterisations). Therefore, the results presented as the peak flows exhibit some minor differences to those run as part of the sensitivity analysis (reported above).

Table 3-2 RORB design event peak flow rates

AEP (%)	Critical Duration	Peak flow (m^3/s)
6EY	24 hour	0.109
4EY	24 hour	0.109
3EY	24 hour	0.109
2EY	24 hour	0.109
63.2%	12 hour	6.587
50%	12 hour	14.207
0.5EY	9 hour	21.41
20%	6 hour	42.764

AEP (%)	Critical Duration	Peak flow (m^3/s)
0.2EY	6 hour	45.263
10%	6 hour	60.114
5%	6 hour	80.96
2%	6 hour	111.888
1%	6 hour	134.344
0.5%	12 hour	157.516
0.2%	12 hour	191.545
0.1%	12 hour	219.376

3.3.2 Proposed Development Conditions

Under the proposed conditions, there will be additional impervious areas within the catchment associated with infrastructure, such as access tracks, wind turbine pads, ESF, compounds and Substations. This additional infrastructure may change the runoff characteristics of the catchment.

Under proposed development conditions, less than 1% (i.e. 1.81 km^2 of 210.33 km^2) of the catchment will become impervious. Most, if not all, of the imperviousness added by any infrastructure is considered indirectly impervious (i.e. not directly connected to waterways), as the majority of this increase in impervious area will be on the ridgelines of the terrain, away from the concentrated flow paths. Even consideration of direct imperviousness, whereby all infrastructure is considered fully impervious and directly connected to the waterways (i.e. a worst-case scenario), would consider the impact of less than a 1% increase in impervious area to be negligible.

4. Water Level Modelling

Hydraulic modelling was conducted for existing and proposed conditions using the HEC-RAS[6] software package. HEC-RAS models were developed using a two-dimensional (2D) rain-on-grid analysis to determine flood extents and flood levels and flow velocities.

4.1 Model Setup

4.1.1 Terrains

Two model terrains were developed to model:

1. Existing conditions: Based on the DEM outlined in Figure 2-1.
2. Proposed conditions: Combining the Existing conditions DEM (Figure 2-1) and the proposed conditions DEM outlined in Figure 2-3.

HEC-RAS has the ability to combine terrains at multiple resolutions within the model which allows multiple input DEMs to be input to represent the proposed conditions.

4.1.2 Computational Mesh

A two-dimensional (2D) flow area was delineated in HEC-RAS to coincide with the catchment boundary. A computational mesh spacing of 25 metres by 25 metres was applied across the catchment. 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. This computational mesh was applied to the existing and proposed conditions terrains (except as noted in the refinement regions for the proposed conditions, discussed in Section 4.1.2.2).

4.1.2.1 Break lines

Break lines are used to alter the direction of grid cells to align with features within the catchment. Break lines were implemented to model:

- Creek lines in both the existing and proposed conditions mesh based on the Arc Hydro analysis discussed in Section 3.1.1.
- Road centre lines in the refinement region (Section 4.1.2.2) proposed conditions mesh
- Drainage centre lines of the proposed channel drains along the roads in the refinement region (Section 4.1.2.2) proposed conditions mesh

4.1.2.2 Refinement regions

Refinement regions are used to denote areas where the computation mesh resolution needs to be at a finer scale than the overall mesh. Refinement regions were specified for the roads and drainage areas adjacent to the roads. The refinement region was specified with a computational mesh spacing of 5 metres by 5 metres.

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[6] U.S. Army Corps of Engineers' HEC-RAS Version 5.0.7 (USACE 2019)

4.1.2.3 Applied Computational Meshes

Figure 4-1 and Figure 4-2 outline the meshes applied for the existing and proposed conditions and show the mesh spacing, break lines and refinement regions applied.

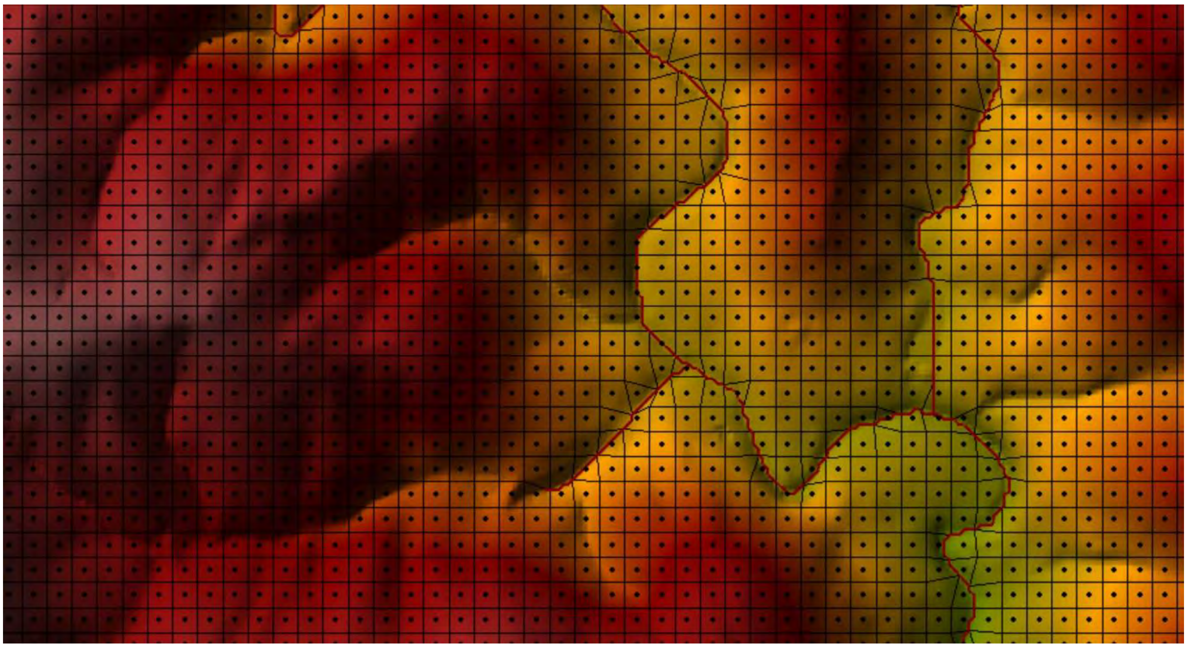

Figure 4-1 Existing conditions mesh showing the 25m by 25m mesh (black lines), computational points within the mesh (black dots) and break lines representing streams (red lines)

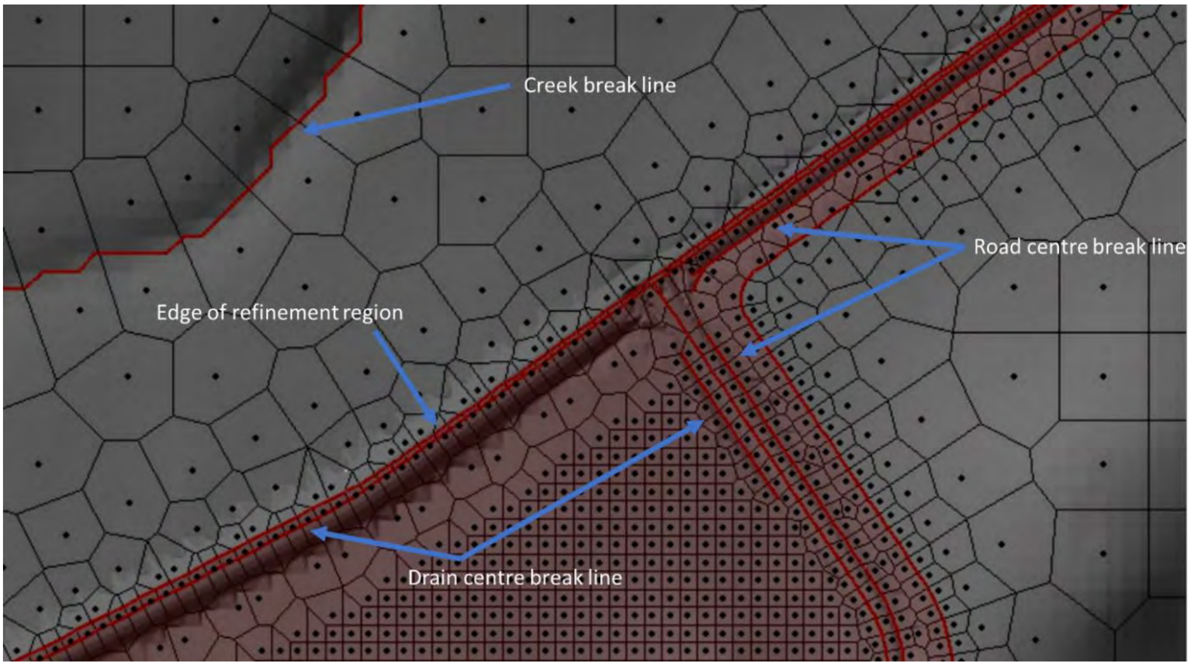

Figure 4-2 Proposed conditions mesh showing refinement region mesh (5 metres by 5 metres) and full mesh (25 metres by 25 metres) both as black lines with their computational points (back dots); refinement region boundary, stream break lines, road centre break lines, drain centre break lines all as red lines.

4.1.3 Roughness

Roughness coefficients are used to define how quickly water moves across the terrain and controls the shape of flow hydrographs resulting from the rainfall and upstream flow. Typical roughness values are defined for the range of flow path extents, i.e. from concrete channels to floodplains. Modelling the full 2D catchment area which extends outside of normal channels and their corresponding slopes requires much larger roughness values than are typically applied to models that just model stream flow.

An initial roughness coefficient of 0.05, representing a natural channel condition, was applied to the whole model. This roughness was used in combination with a 10% AEP rainfall event to define waterway channel extents.

HEC-RAS has the ability to apply different roughness coefficients spatially across the model domain. This is achieved through applying a shapefile of “land use” roughness values to the model. To calibrate the flow rate of the runoff with the flow rates obtained from the RORB modelling (as shown in Figure 4-3), land use representing the channels (roughness of 0.05) and the broader catchment were applied to the model with the broader catchment roughness being altered. Roughness values of 0.2 and 0.4 were applied to broader catchment area within the model domain in combination with the 1% AEP rainfall to determine the change in flow rates, as shown in Figure 4-4.

To examine the sensitivity of the model to changes in roughness across the entire model domain, roughness values of 0.1, 0.2, 0.3, 0.4 and 0.5 were applied to the model for a typical 1% AEP rainfall event. Flow rate results were extracted corresponding to the catchment outlet from the RORB model detailed in Section 3, and shown in Figure 4-3.

A power curve relationship is observed between flow and roughness for this catchment. A version of this relationship, adjusted for specific roughness values within the waterway channels, will be used to define the calibrated catchment roughness values.

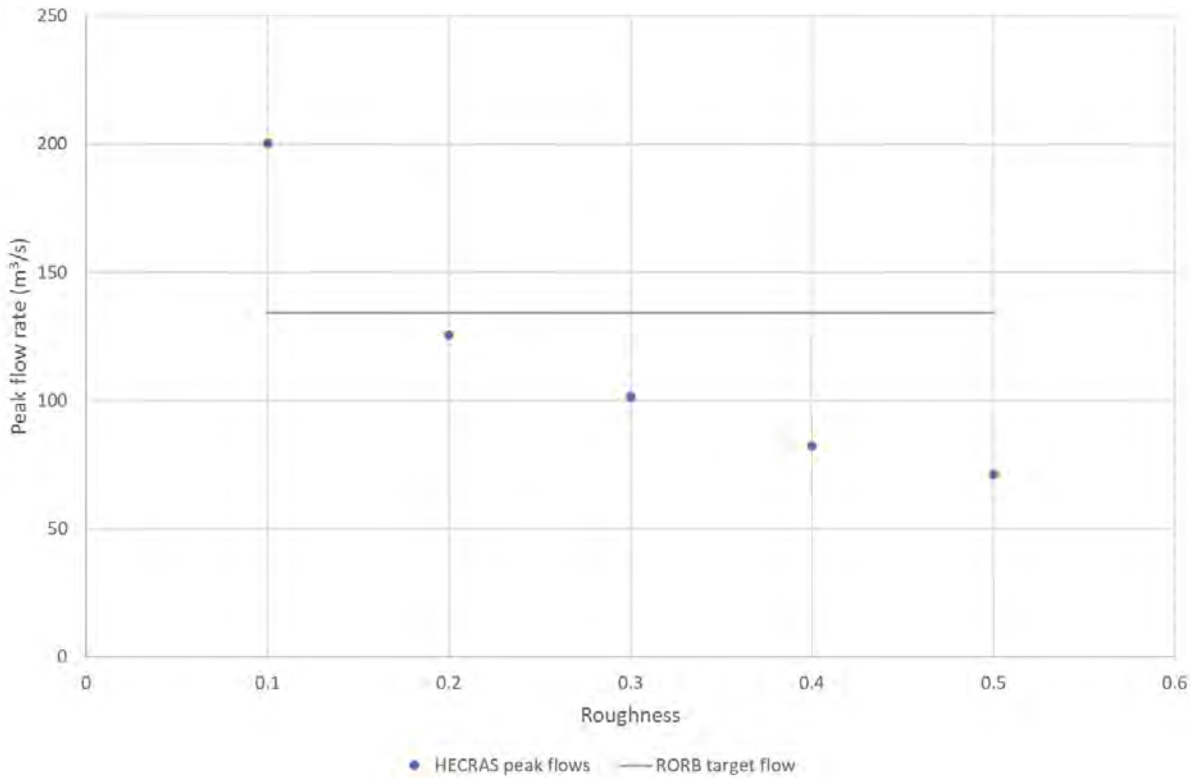

Figure 4-3 Sensitivity of flow rates to changes in roughness values

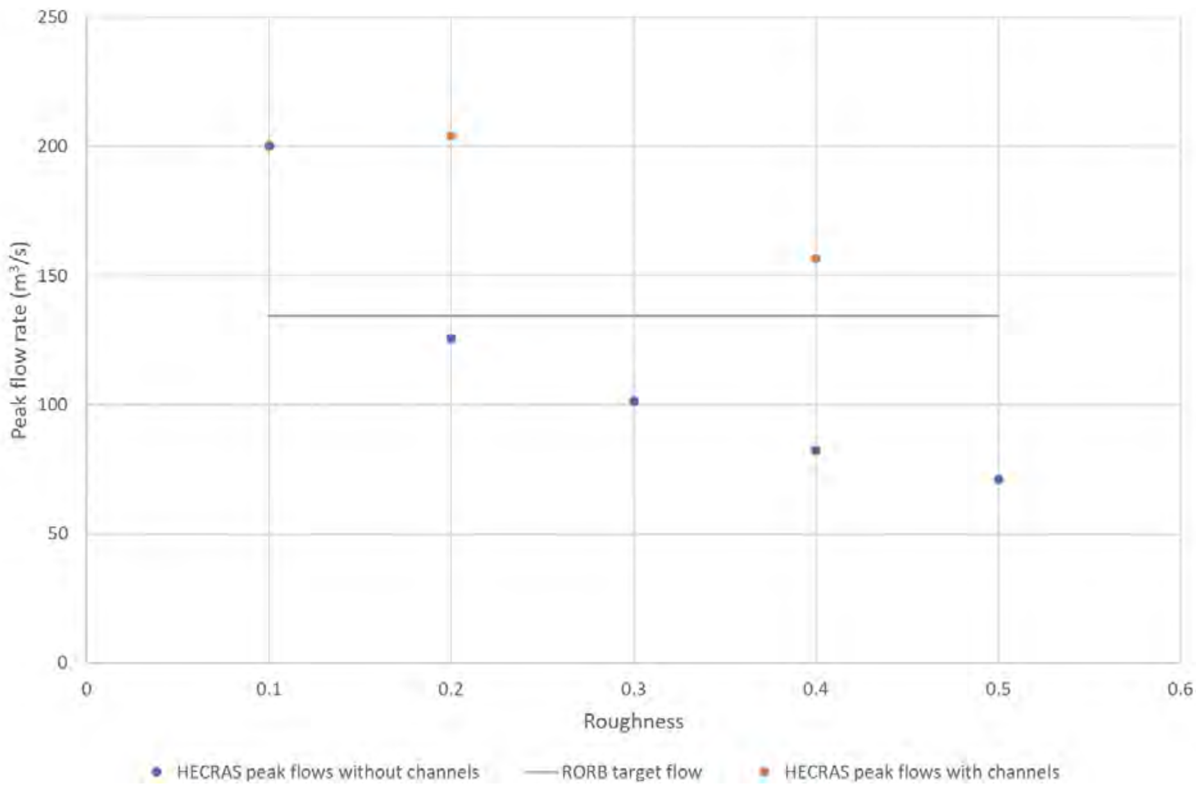

Figure 4-4 HEC-RAS Peak flow rates with channels

A power curve function was then fitted to the peak flows against channel roughness to obtain the representative roughness to match the flows modelled by RORB in Section 3.3.1. The representative roughness determined, as shown in Figure 4-5, was 0.6.

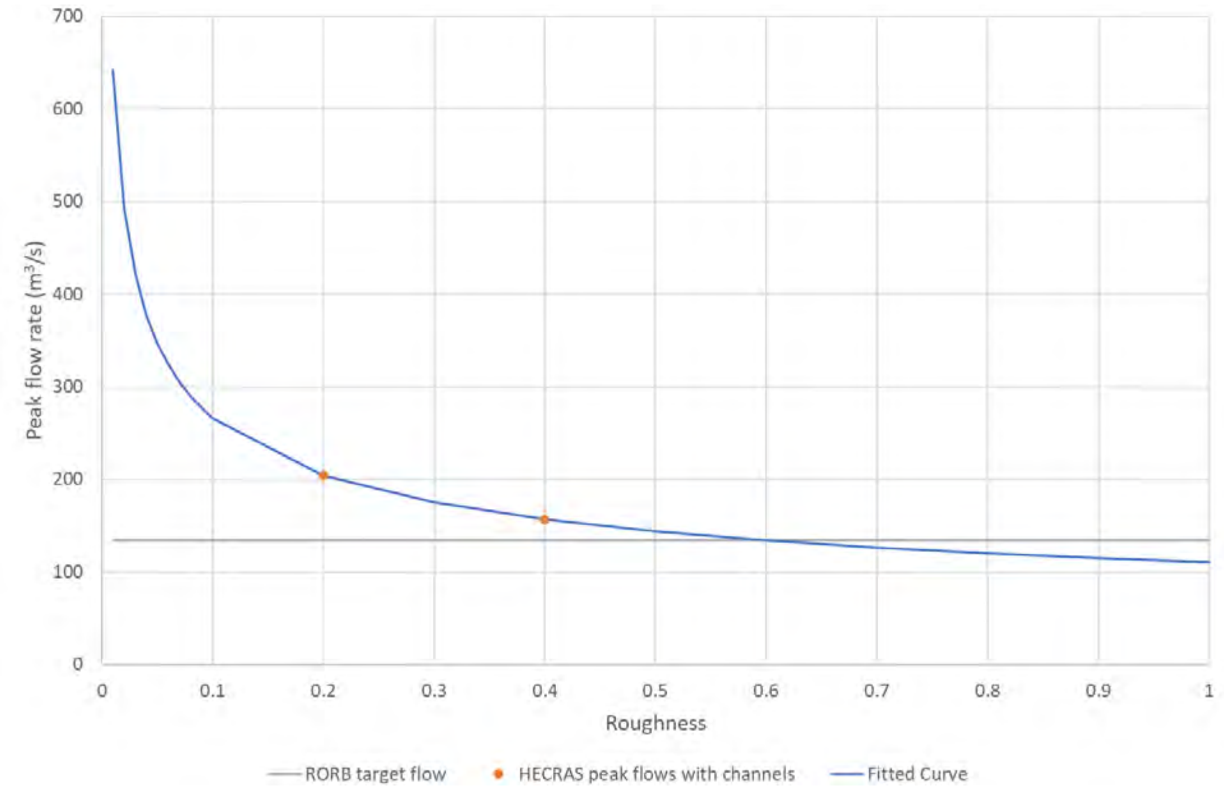

Figure 4-5 Fitted roughness values to match RORB flows

For the proposed conditions roughness values of 0.025 and 0.03 were adopted for the roads/hardstands and road drains respectively based on the information from the Engineering Toolbox (2014).

In summary the following roughness values were adopted:

- Existing Conditions
  - Creek lines: 0.05
  - Upstream of creek lines: 0.6
- Proposed conditions
  - Creek lines: 0.05
  - Upstream of creek lines: 0.6
  - Roads and hard stands: 0.025
  - Road drains: 0.03

4.1.4 Inflows/Rainfall

No inflow hydrographs were required as inputs to this model as the entire catchment is within the model domain and there are no water transfers into the catchment.

Rainfall is applied to the 2D area based on the IFD data and the RORB results. That is, the rainfall temporal pattern that produced the peak storm in the RORB model was used in conjunction with the IFD rainfall depth to provide the rainfall input to the hydraulic model as an unsteady time series inflow boundary condition. The patterns (prior to having rainfall depth applied) for the design storms are shown in Figure 4-6. Note that the 10% and 1% AEP events are 6 hours in duration, with the remainder of the AEP events being 12 hours in duration, as determined from IFD data.

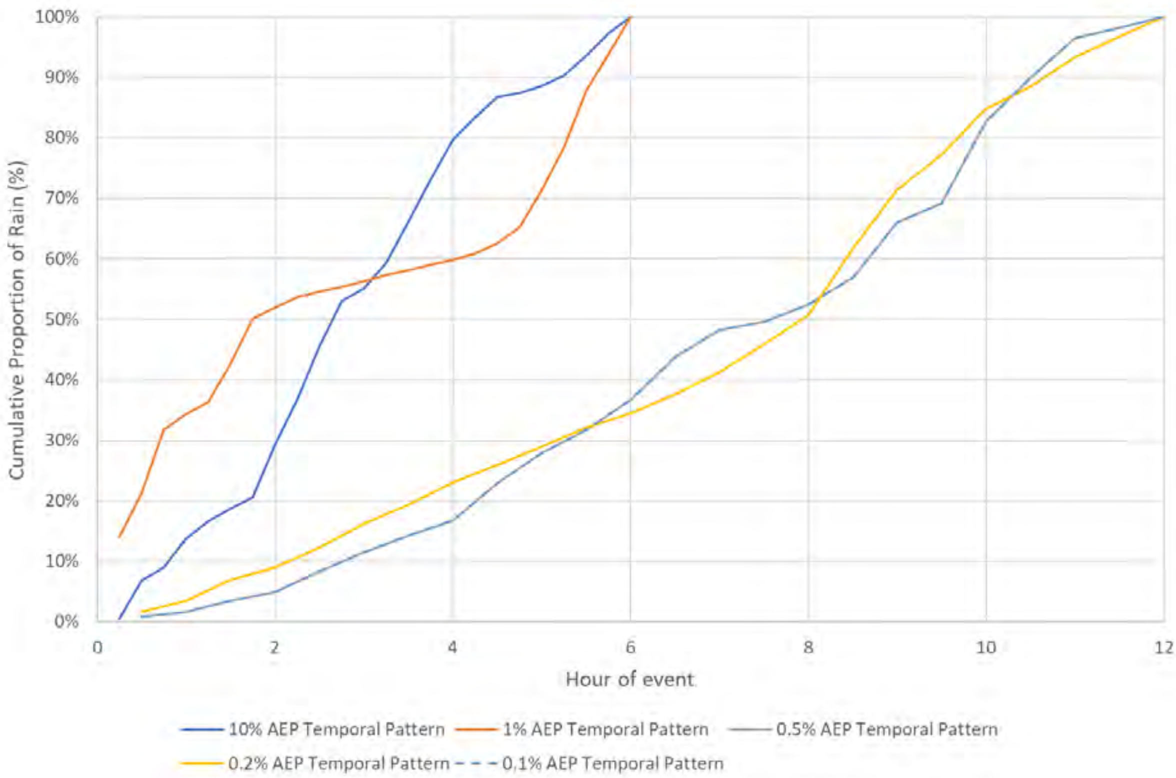

Figure 4-6 Rainfall proportions applied to 2D flow area for 10%, 1%, 0.5%, 0.2% and 0.1% AEP storms

The current version of HEC-RAS (5.0.7) does not include a loss function, therefore a rainfall excess time series (the amount of rain that runs off after the losses) is directly applied to the model. An example of this is outlined in Figure 4-7 below for the 10% AEP event. It shows the initial loss consuming the rainfall at the start of the event and the continuing loss being applied across the rest of the event.

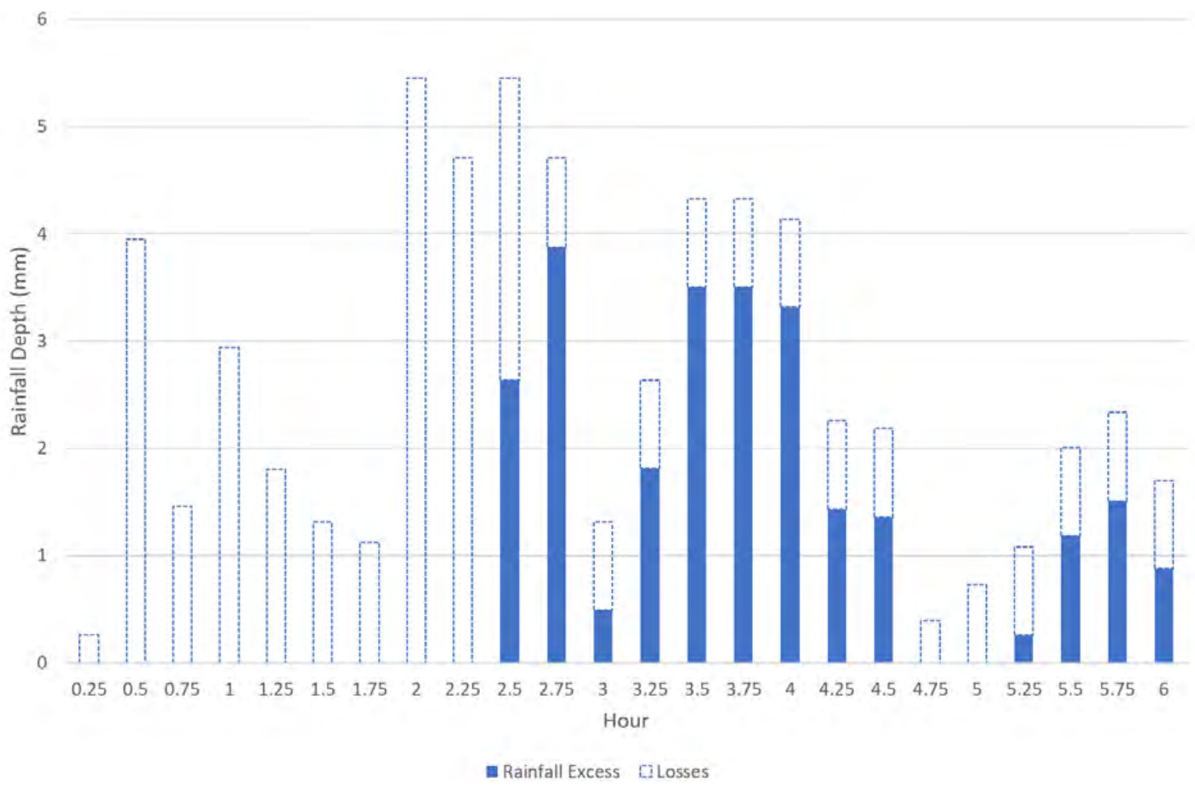

Figure 4-7 Example of rainfall pattern applied to HEC-RAS after losses removed

4.1.5 Outflows

Locations where water exits the model domain (outflows) require boundary conditions to be specified. Concentrated flow paths that exit the model domain were set to a normal depth boundary condition, using the uniform bed slope of that flow path as the estimated energy slope, as measured from the available terrain data. The locations and their slopes are specified in Table 4-1 in conjunction with Figure 4-8.

Table 4-1 Normal depth boundary condition slopes (locations shown in Figure 4-8).

Location	Slope
Ilgingerry Creek	0.9%
Unnamed Creek 1	3.9%
Unnamed Creek 2	4.1%
Unnamed Creek 3	2.1%
Unnamed Creek 4	1.3%
Unnamed Creek 5	1.4%
Unnamed Creek 6	2.7%
Unnamed Creek 7	1.6%
Unnamed Creek 8	11.3%
Sawpit Gully	2.0%
Unnamed Creek 9	5.1%

Location	Slope
Uungula Creek	0.6%
Guroba Creek	1.0%
Unnamed Creek 10	0.8%
Ben Buckley Creek	1.0%
Unnamed Creek 11	1.1%
Mitchell Creek	0.1%
Unnamed Creek 12	0.5%
Unnamed Creek 13	2.0%
Poggy Creek	1.8%
Wuuluman Creek	1.5%

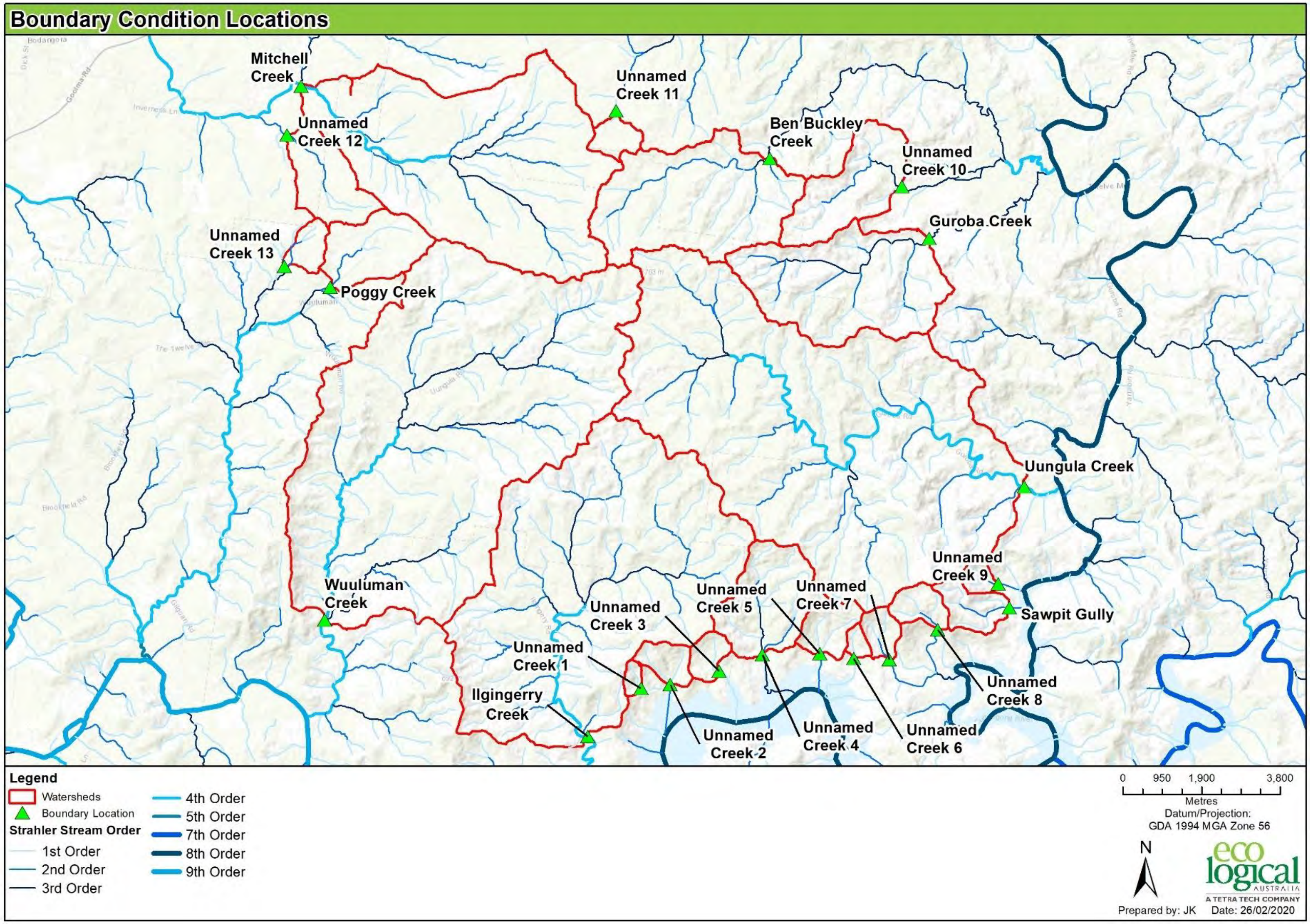

Figure 4-8 Location of normal depth boundary conditions (see Table 4-1 for details).

4.1.6 Computational Settings

For existing conditions' models, a computation time-step of 5 seconds was adopted. This was reduced to 1 second for the proposed conditions models. The Full Momentum equation set was adopted for flow/level calculations. A 12-hour simulation window was applied to the 10% and 1% AEP events and an 18-hour window applied to the remaining AEP events to capture critical-duration peak discharges and allow the flood peaks to propagate through the model.

Default threshold depths were decreased by one order of magnitude to capture the flow transfer effects of direct precipitation sheet flow across the catchment.

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

4.1.7 Summary Model Parameterisation

Table 4-2 summarises the model parameters used for the selected HEC-RAS model runs.

Table 4-2 Summary of model parameters

Model Parameter	Value
Inflow	10%, 1%, 0.5%, 0.2% and 0.1% AEP frequency storm excess precipitation hyetographs
Outflow	Normal depth slopes of between 0.5% and 11.3%
Simulation window	12 hour or 18 hour
Computation time step	5 seconds or 1 second
Computation mesh grid	5 metre by 5 metre to 25 metre by 25 metre
Roughness	0.025 to 0.6
Equation set	Full momentum
DEM grid resolution	0.1 metre by 0.1 metre to 5 metre by 5 metre

4.2 Hydraulic Results

For each model run, depth and velocity were extracted across the model domain. A selection of results at one location in the model domain for existing and proposed conditions are presented below for illustrative purposes. The full results for all AEP events are outlined in Appendix E and Appendix F.

4.2.1 Depths

The existing conditions' flood depths (Appendix E1) and Figure 4-9 to Figure 4-13 below, modelled using HEC-RAS, show that, in general, the flows are concentrated to the waterways in the region with sufficient terrain relief to limit the amount of sheet flow.

The inclusion of the wind turbines, roads/hardstands and drainage for the proposed conditions (Appendix F1) and Figure 4-14 to Figure 4-18 below, show that the drains distribute the flows away from the roads in the 10% AEP event.

Some of the turbine areas show some water inundation from the 10% AEP event. Water depths are less than 0.05 metres, which is within model error and hence these areas are typically excluded from further analysis.

For the 1% and rarer events, however, flows exceed road drainage (as expected) and have some impact on the roads and hardstands. During detailed design, roads should be graded such that flows cannot pond around the wind turbines, compounds and any electrical infrastructure. Some of the Energy Storage Facility (ESF) and storage compounds are located close to watercourses and modelled flood levels are likely to impact or be close to impacting on this infrastructure. If during detailed design, these areas are impacted, adjustment should be made to these locations to create a freeboard above the relevant flood depth.

The roads have currently been modelled without any drainage to convey flows under any roads that cross watercourses (i.e. without culverts). Therefore, water can back up behind these roads in the model, a situation that would not occur to the same degree once drainage features were included. Depending on the location, this could either decrease flood depths (water being moved downstream) or increase flood depths (water which was held upstream is now passed downstream) and would need to be modelled during detailed design.

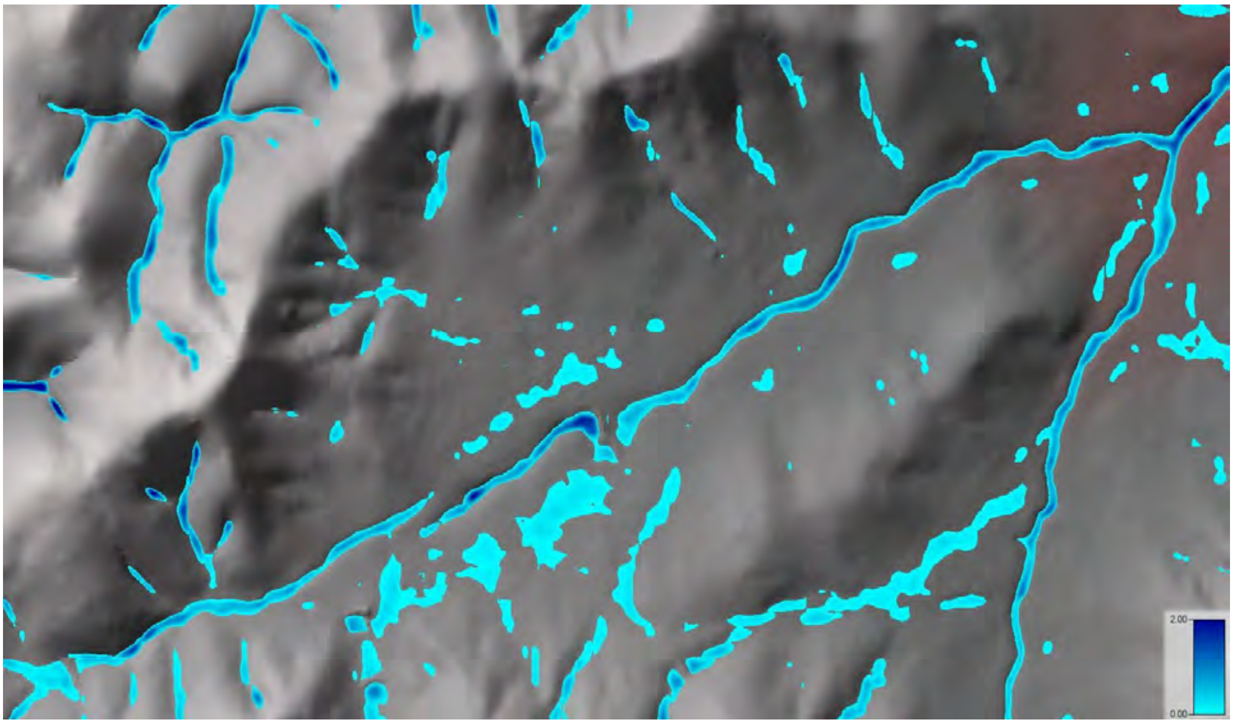

Figure 4-9 Existing conditions 10% AEP flood depths for a region of the development footprint. Depth scale between 0 metres and 2 metres.

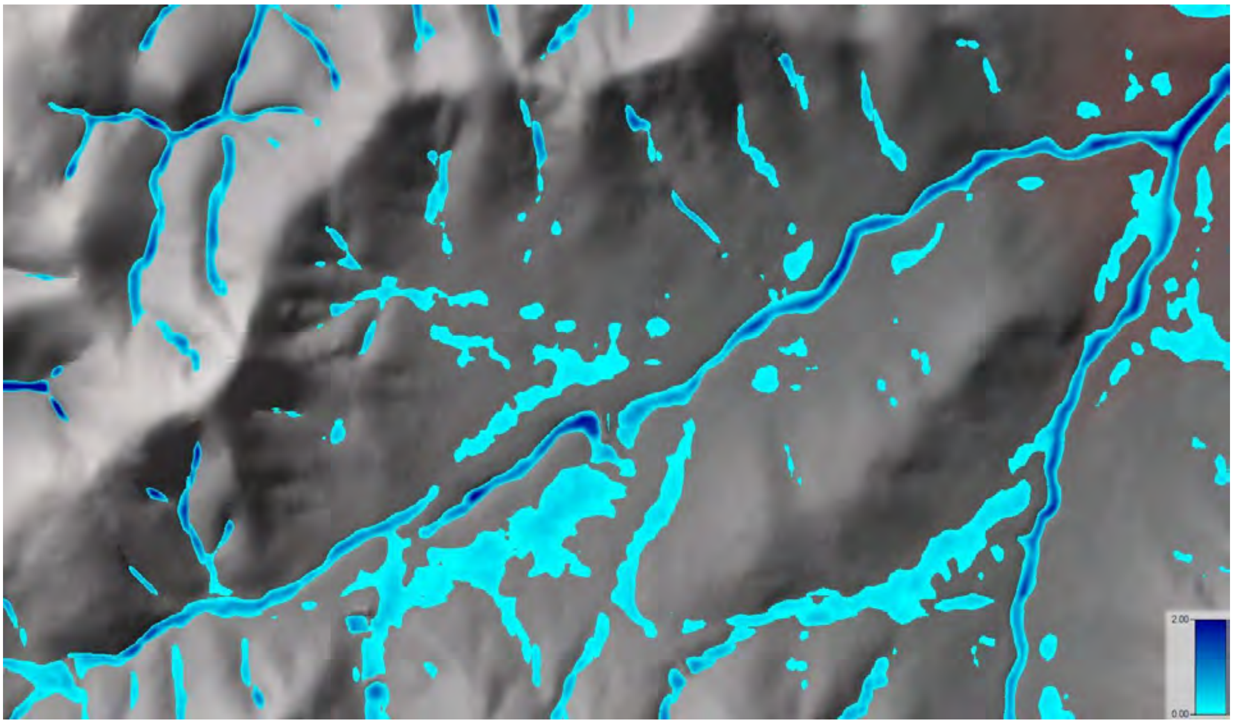

Figure 4-10 Existing conditions 1% AEP flood depths for a region of the development footprint. Depth scale between 0 metres and 2 metres.

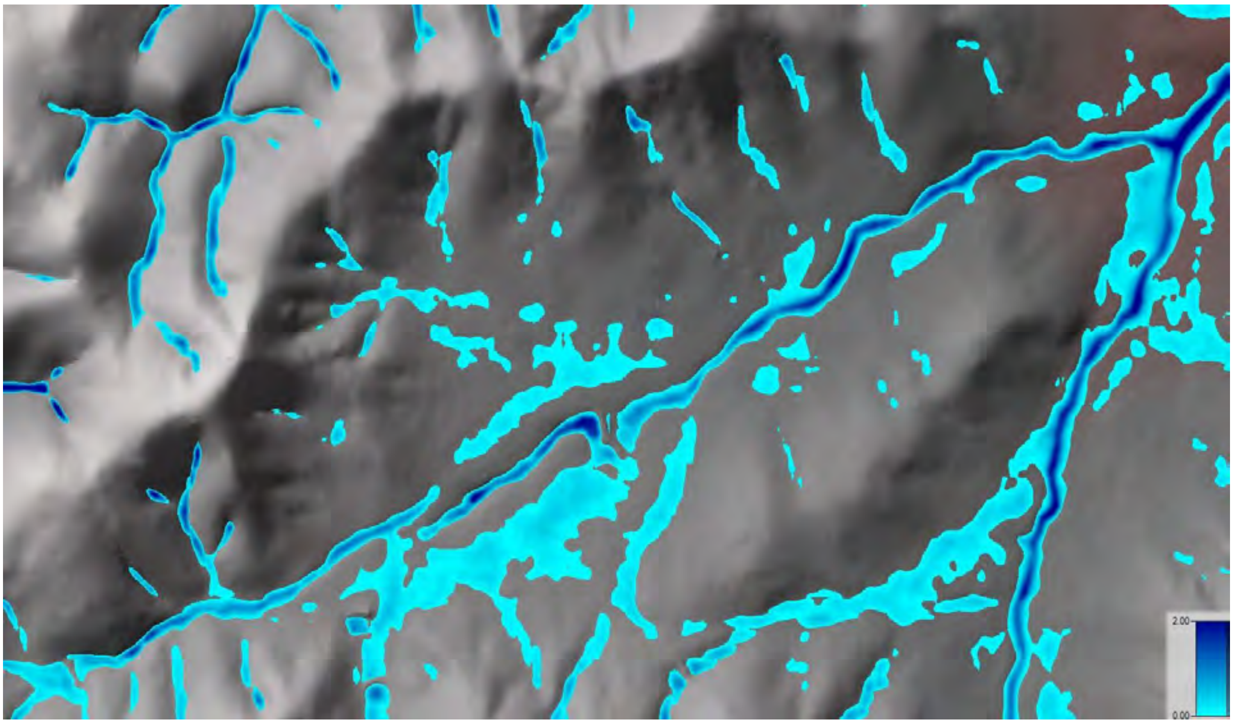

Figure 4-11 Existing conditions 0.5% AEP flood depths for a region of the development footprint. Depth scale between 0 metres and 2 metres.

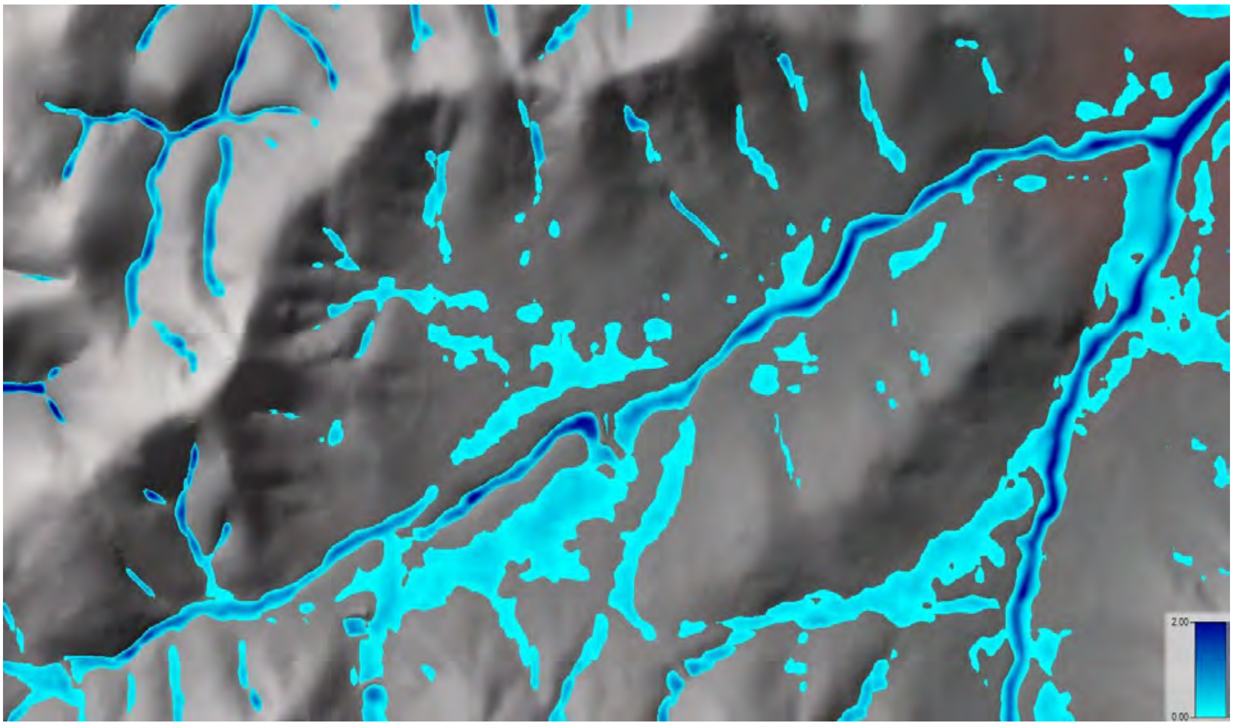

Figure 4-12 Existing conditions 0.2% AEP flood depths for a region of the development footprint. Depth scale between 0 metres and 2 metres.

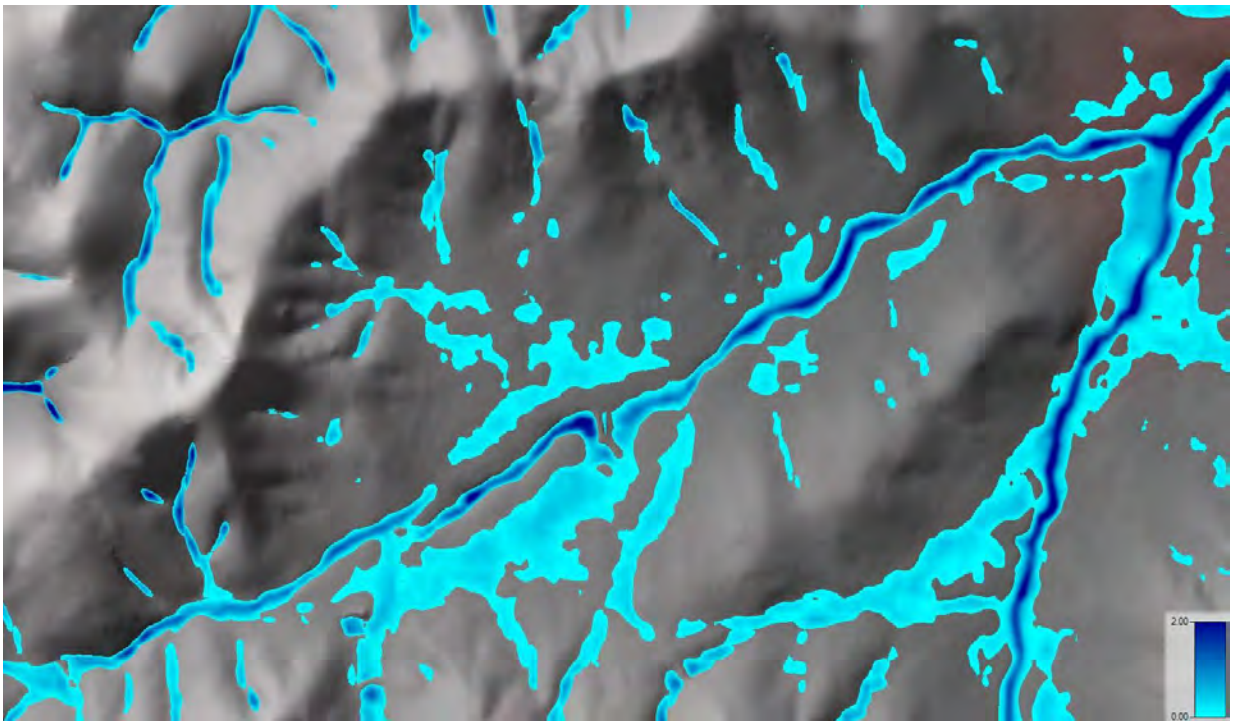

Figure 4-13 Existing conditions 0.1% AEP flood depths for a region of the development footprint. Depth scale between 0 metres and 2 metres.

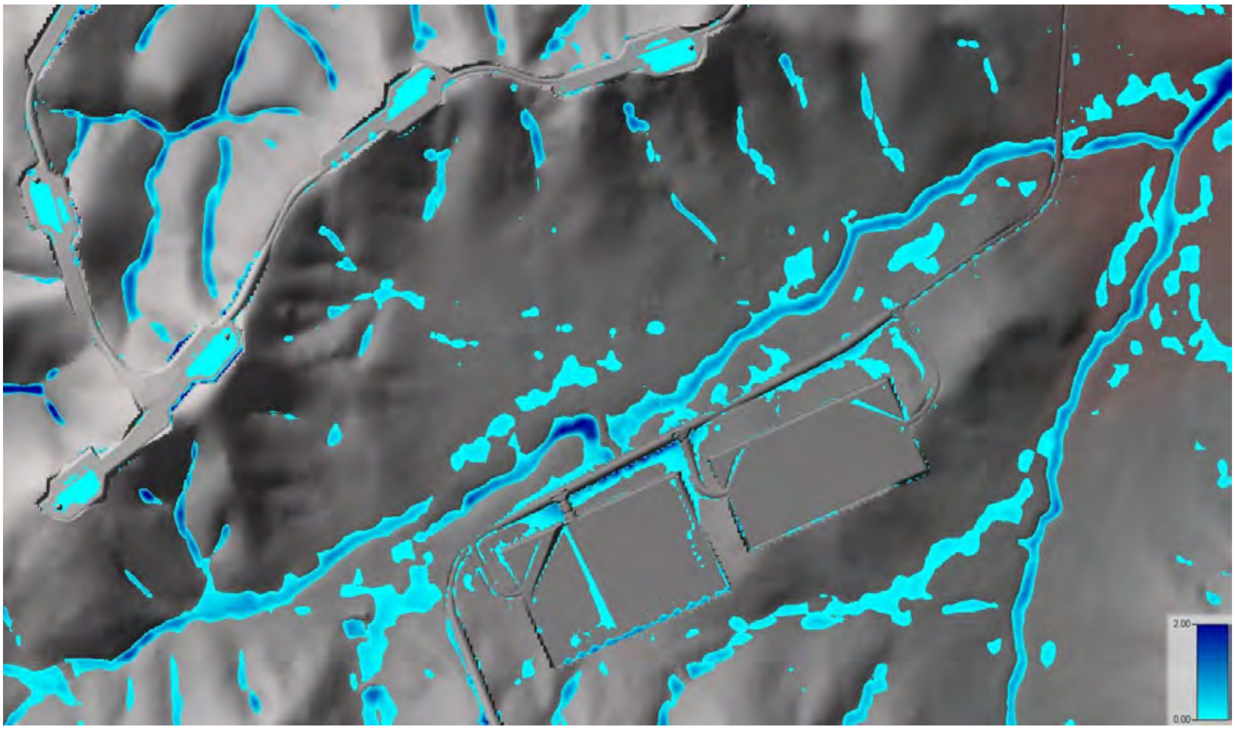

Figure 4-14 Developed conditions 10% AEP flood depths for a region of the development footprint. Depth scale between 0 metres and 2 metres.

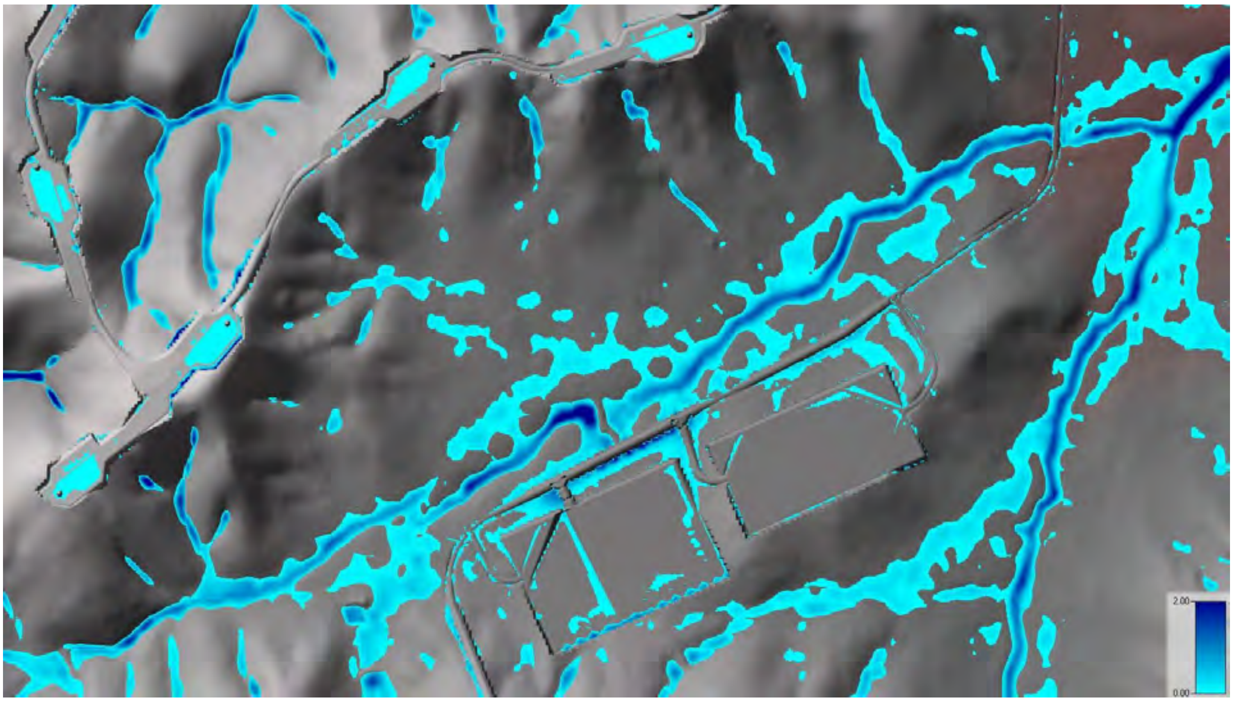

Figure 4-15 Developed conditions 1% AEP flood depths for a region of the development footprint. Depth scale between 0 metres and 2 metres.

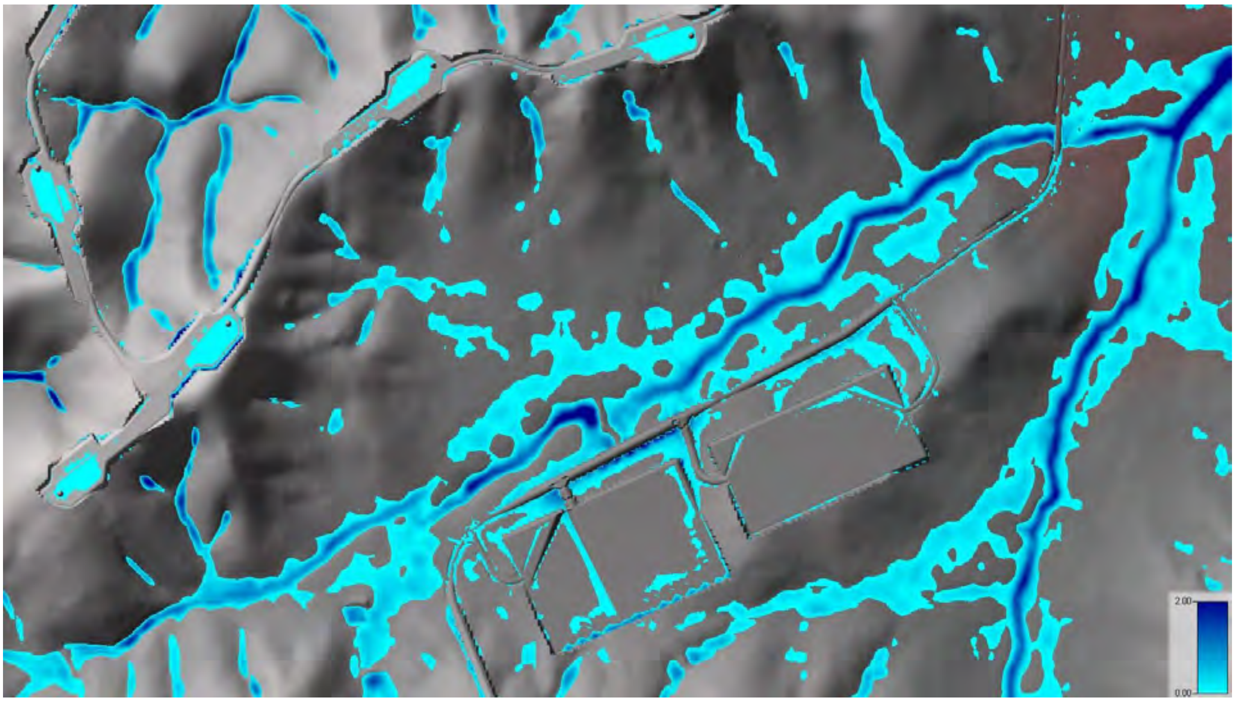

Figure 4-16 Developed conditions 0.5% AEP flood depths for a region of the development footprint. Depth scale between 0 metres and 2 metres.

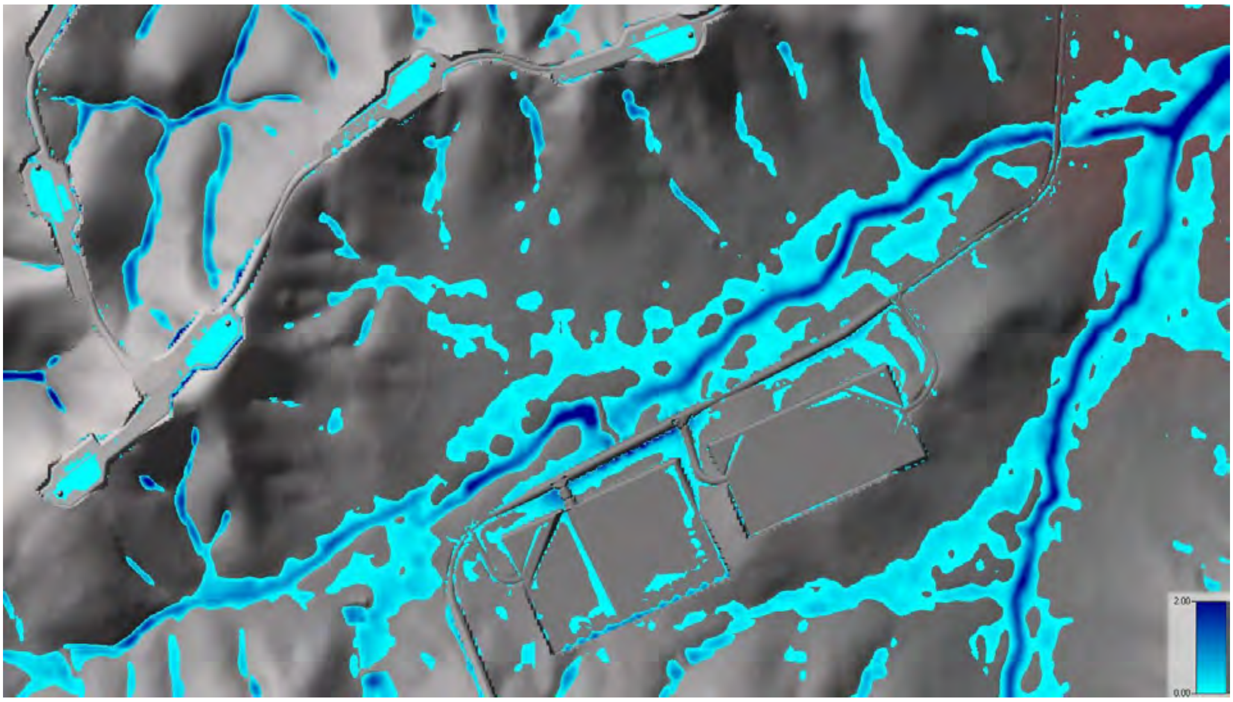

Figure 4-17 Developed conditions 0.2% AEP flood depths for a region of the development footprint. Depth scale between 0 metres and 2 metres.

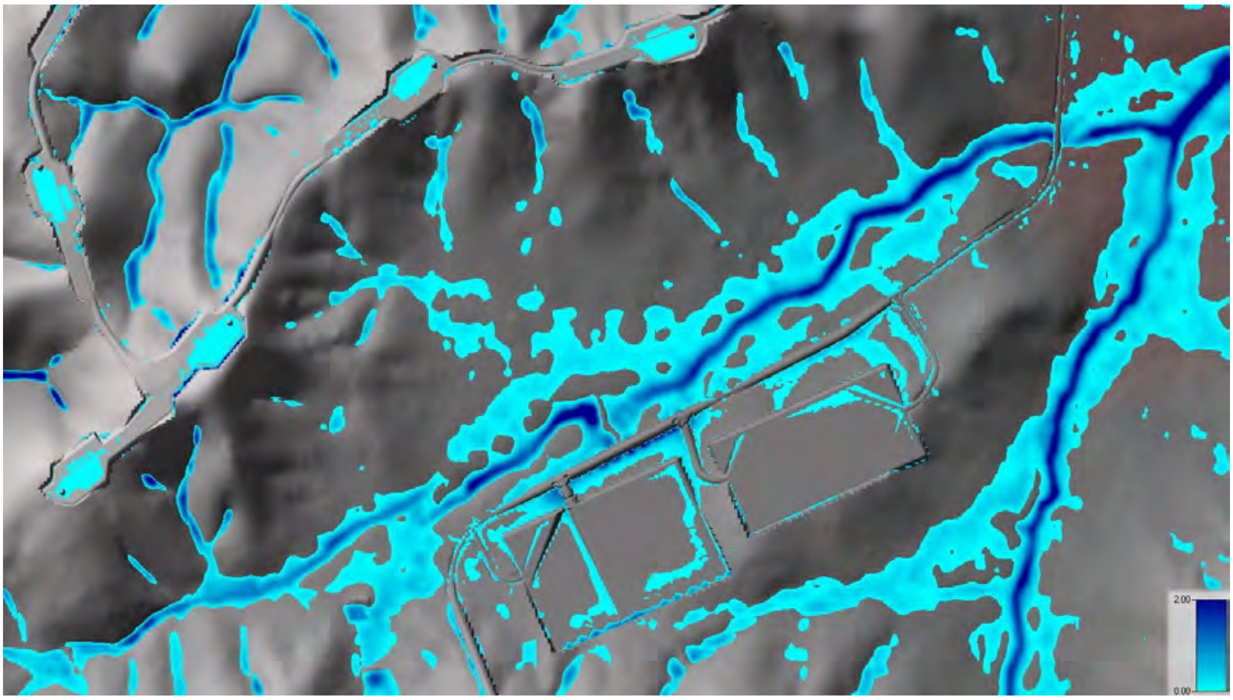

Figure 4-18 Developed conditions 0.1% AEP flood depths for a region of the development footprint. Depth scale between 0 metres and 2 metres.

4.2.2 Velocities

The existing conditions' modelled velocities (Appendix E2) and Figure 4-19 to Figure 4-23 below, show that, in general, flows are of low velocity in the lower order waterways, with velocities increasing in higher order streams and can increase towards critical velocities whereby stream protection (armouring) may be required, depending on the local geomorphology.

The inclusion of the wind turbines, roads/hardstands and drainage in the proposed conditions (Appendix F2) and Figure 4-24 to Figure 4-28 below, generate higher velocities along the edge of the roads, near the drains. It is noted that these higher velocities may not be realistic, as they have been modelled without batters as the steep slopes require specific geotechnical studies which will be undertaken during detailed design post-Development Consent (standard-grade batters of 1:3 are not suitable in some places due to the relief and topography). This generates a small discontinuity in the cross section between the proposed development DEM and the regional DEM. During detailed design the finalised earthworks design and the regional DEM should be combined with a smooth transition to remove this artefact.

For the 1% and rarer events, flows cover road drainage (as expected) and may have higher velocities, depending on the drainage design, potentially impacting the roads, hardstands and receiving environments. During detailed design, roads should be graded such that velocities are minimised and transition from proposed infrastructure to the receiving environment has negligible impact.

As for current conditions, the roads have currently been modelled without any drainage to convey flows under any roads that cross watercourses (i.e. without culverts). Therefore, water can back up behind these roads in the model, a situation that would not occur to the same degree once drainage features were included. Depending on the location, this could either decrease velocities (flow conveyance designed to maintain similar graded terrain) or increase velocities (water which was held upstream is now passed downstream) and would need to be modelled during detailed design. It should be noted that the 0.5% AEP velocity result presented in Figure 4-26 show overly high velocities. In the context of the velocity results for the other AEP events, this result is conserved an anomaly and not representative of the velocities for 0.5% AEP event. It is expected that there was an instability within a time step of the HEC-RAS model that caused this result.

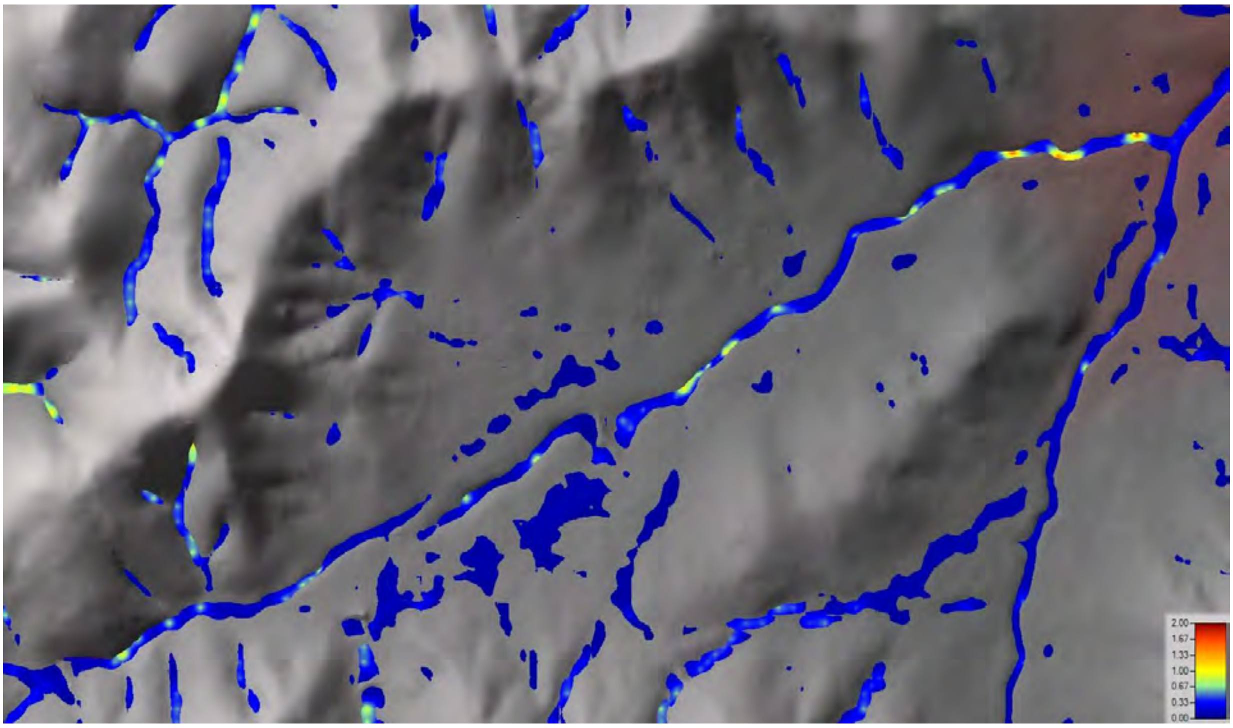

Figure 4-19 Existing conditions 10% AEP velocities for a region of the development footprint. Velocity scale between 0 m/s and 2 m/s.

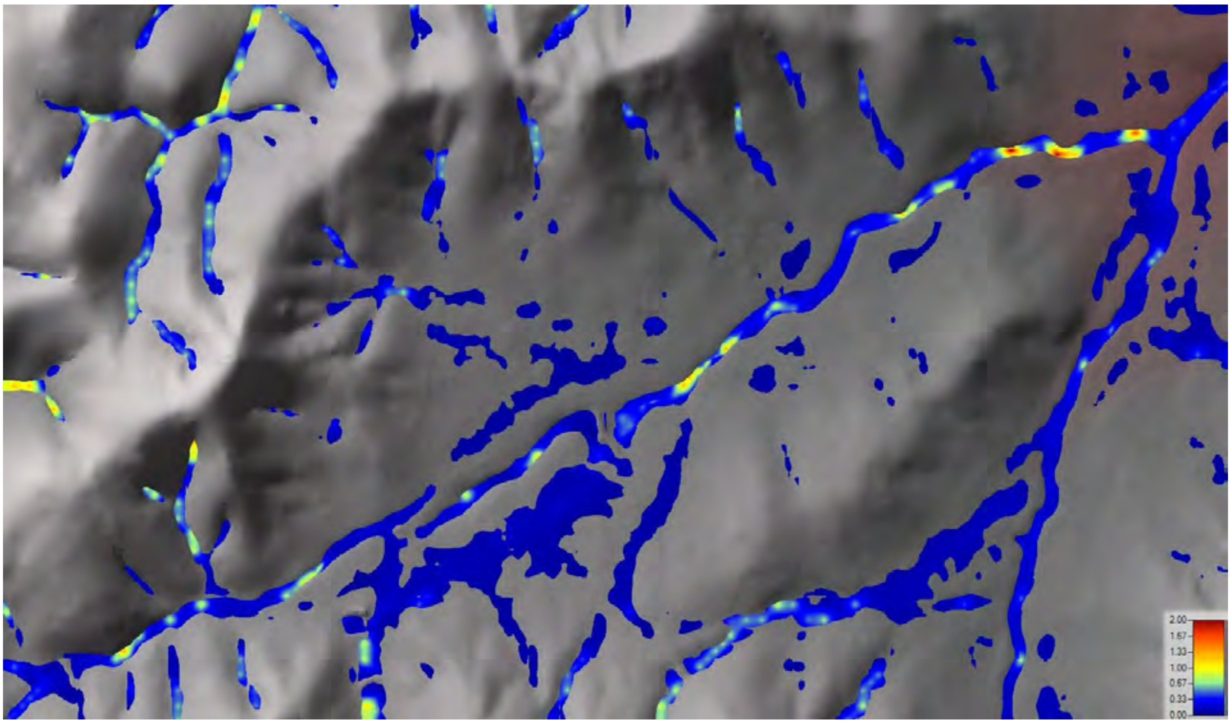

Figure 4-20 Existing conditions 1% AEP velocities for a region of the development footprint. Velocity scale between 0 m/s and 2 m/s.

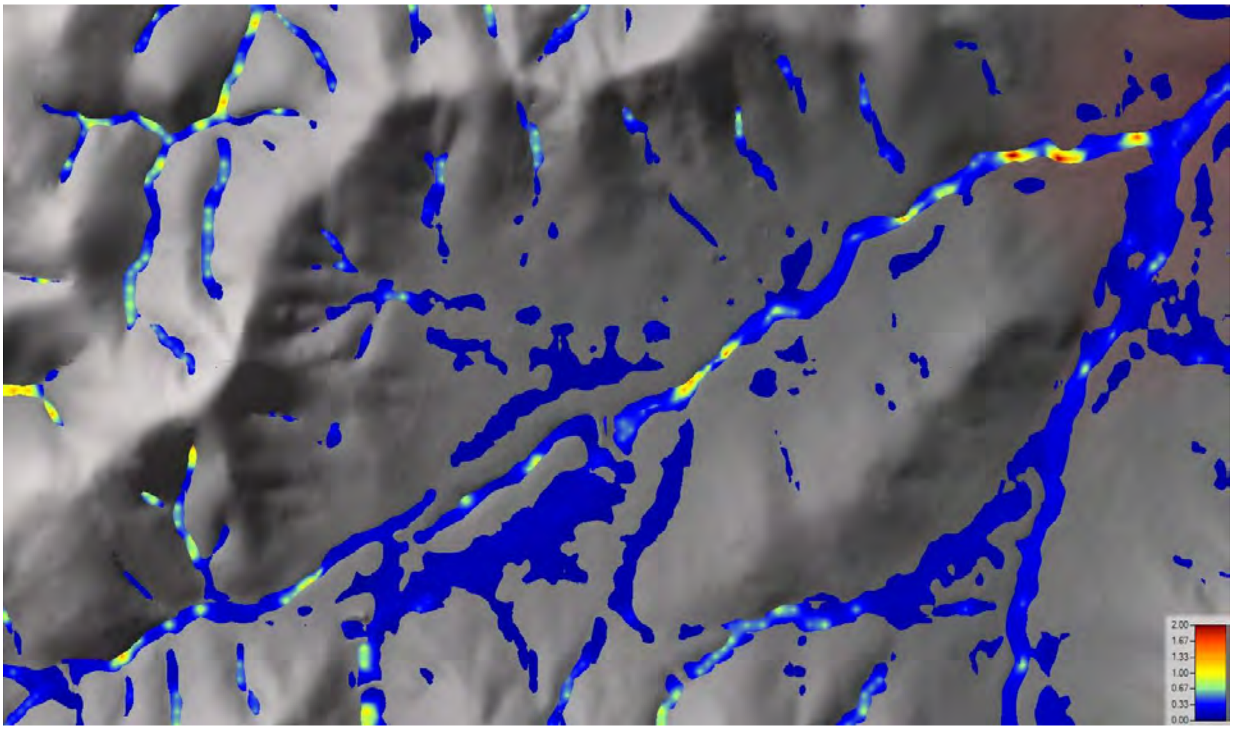

Figure 4-21 Existing conditions 0.5% AEP velocities for a region of the development footprint. Velocity scale between 0 m/s and 2 m/s.

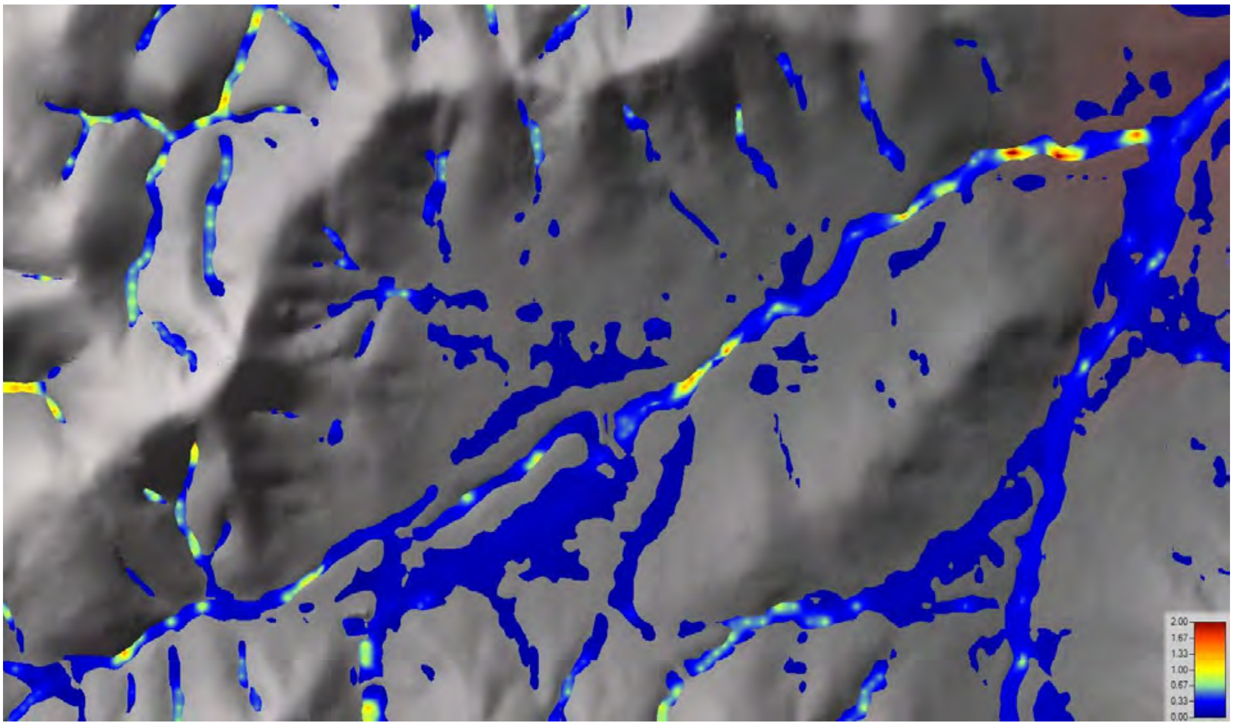

Figure 4-22 Existing conditions 0.2% AEP velocities for a region of the development footprint. Velocity scale between 0 m/s and 2 m/s.

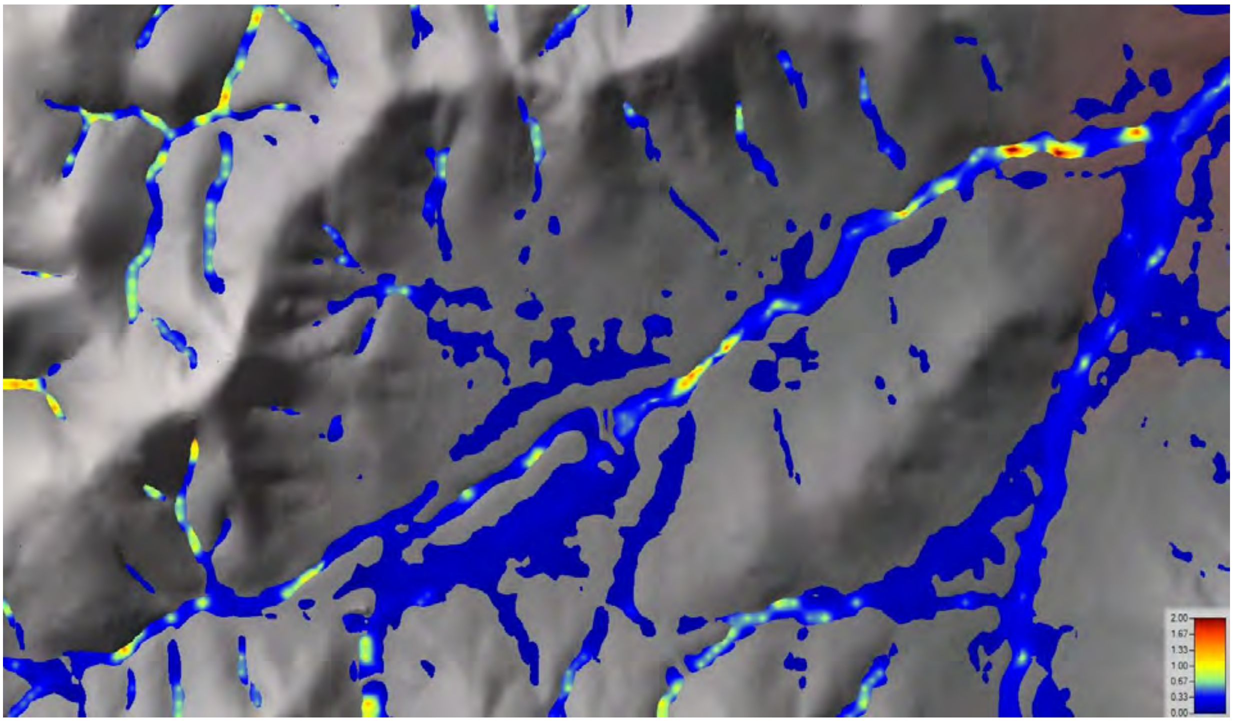

Figure 4-23 Existing conditions 0.1% AEP velocities for a region of the development footprint. Velocity scale between 0 m/s and 2 m/s.

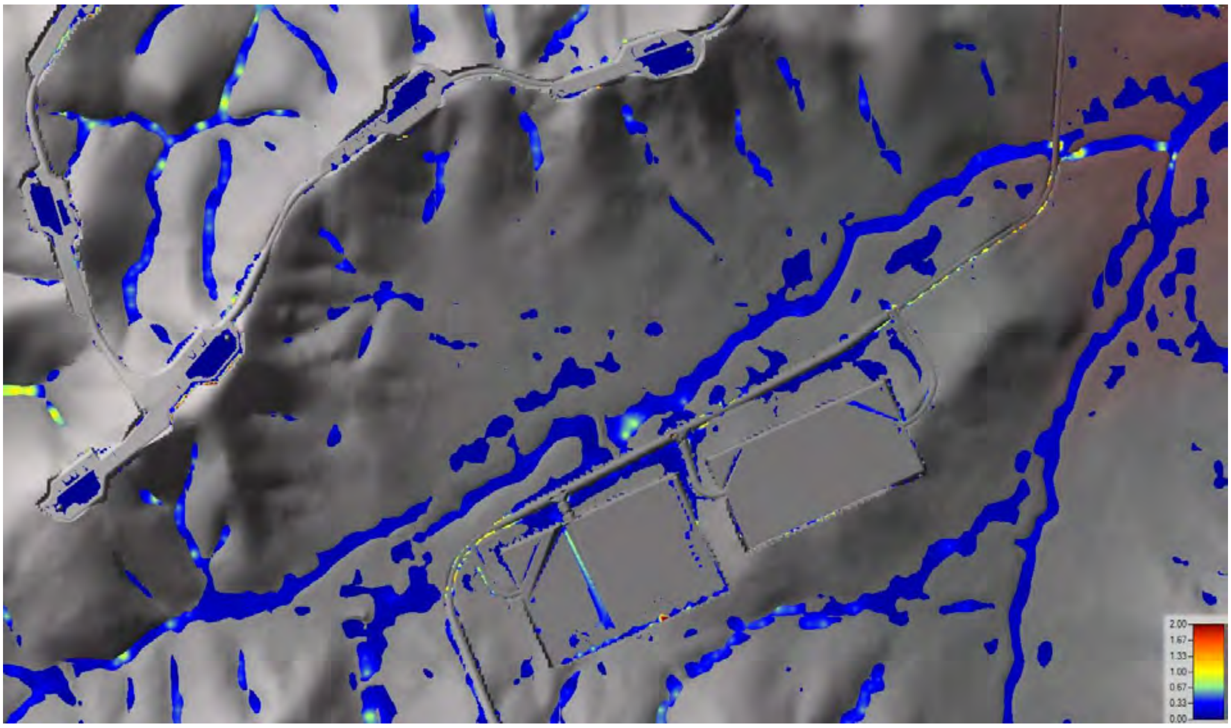

Figure 4-24 Developed conditions 10% AEP velocities for a region of the development footprint. Velocity scale between 0 m/s and 2 m/s.

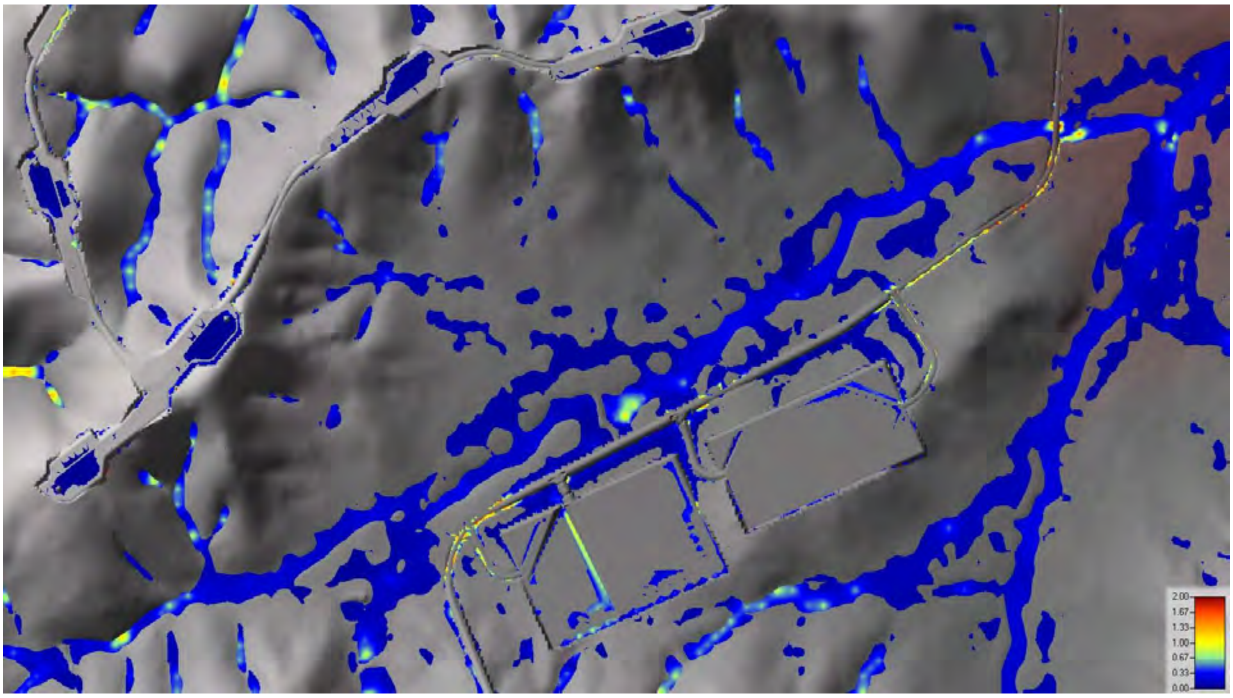

Figure 4-25 Developed conditions 1% AEP velocities for a region of the development footprint. Velocity scale between 0 m/s and 2 m/s.

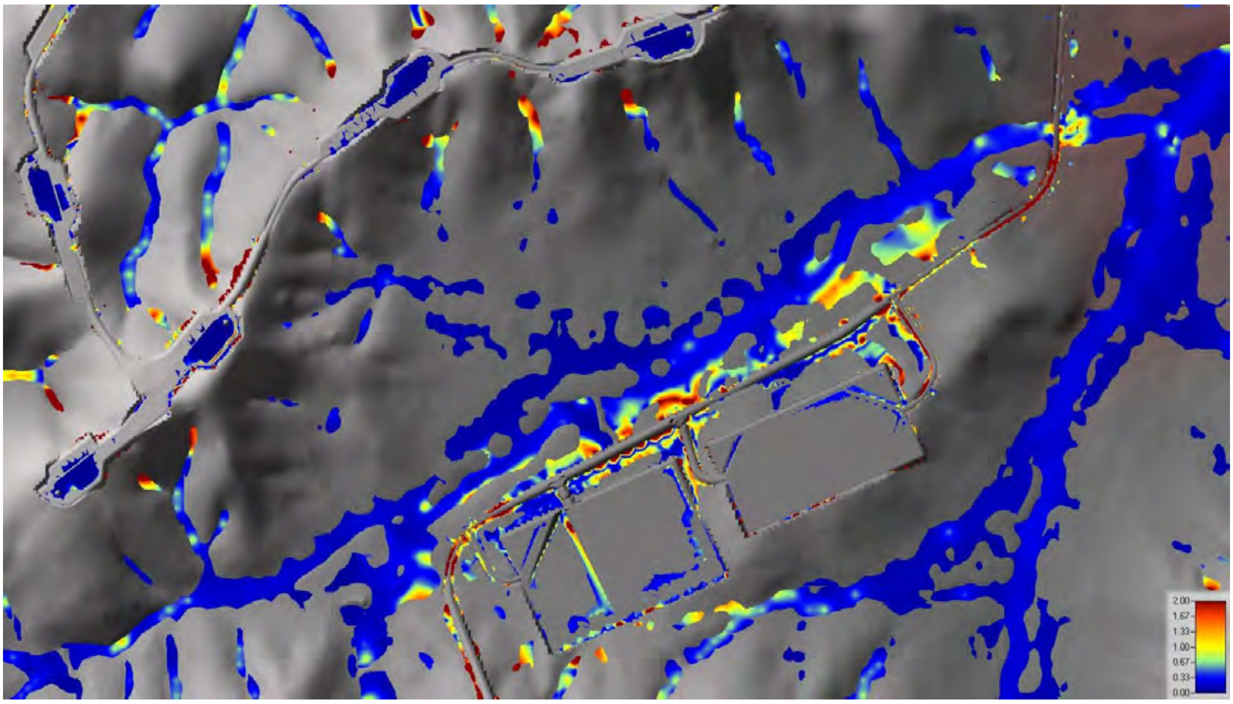

Figure 4-26 Developed conditions 0.5% AEP velocities for a region of the development footprint. Velocity scale between 0 m/s and 2 m/s.

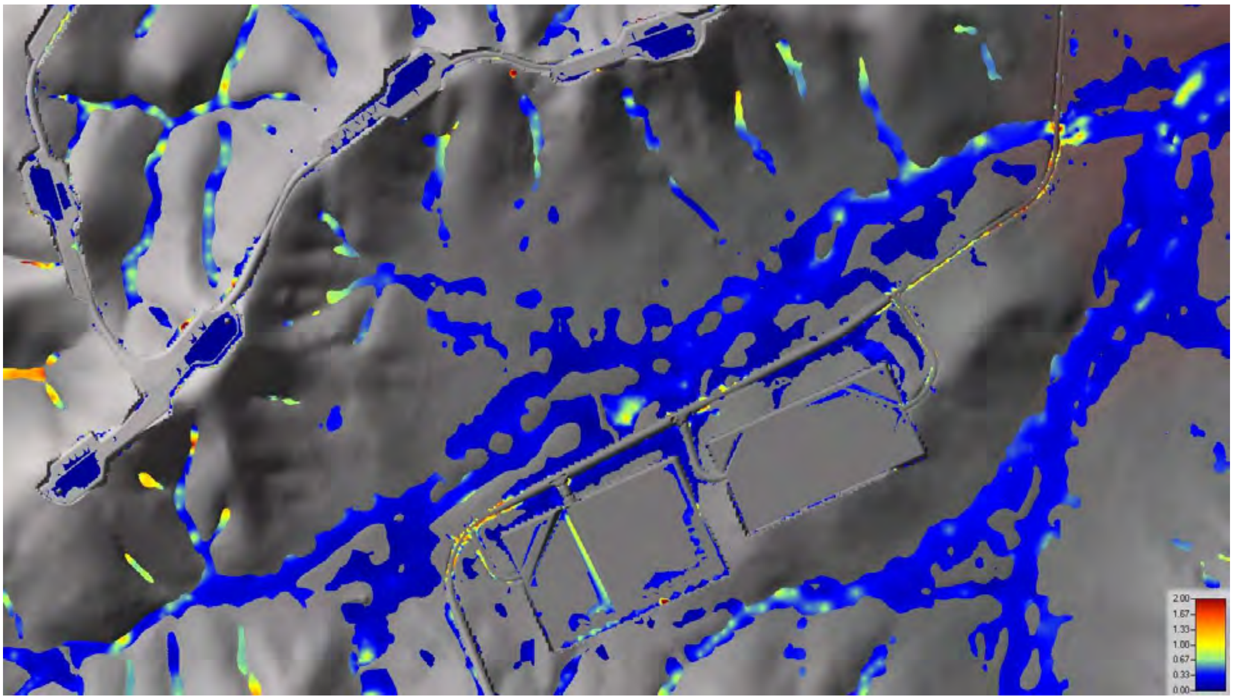

Figure 4-27 Developed conditions 0.2% AEP velocities for a region of the development footprint. Velocity scale between 0 m/s and 2 m/s.

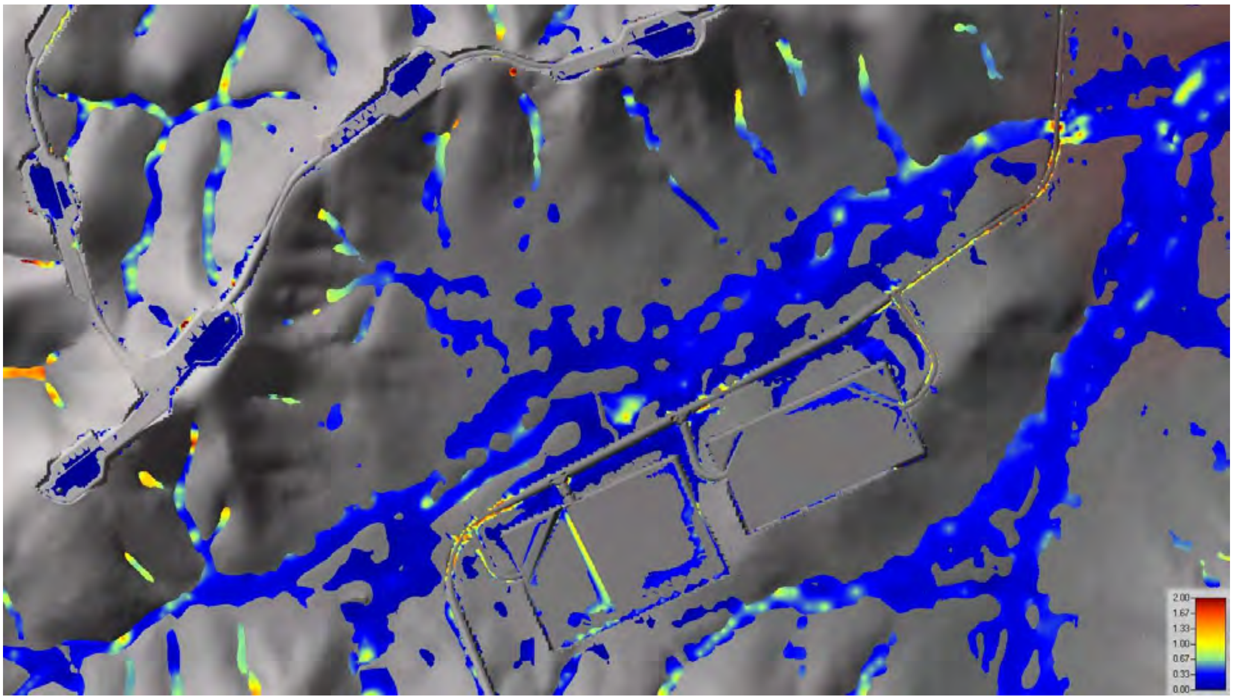

Figure 4-28 Developed conditions 0.1% AEP velocities for a region of the development footprint. Velocity scale between 0 m/s and 2 m/s.

4.2.3 Shear Stress

Flow velocities within the watercourses vary such that some areas are below the level that might be expected to require artificial protection (i.e. rock armouring), while others would benefit from protection of stream banks using armouring. Thus, flows range from below (< 2 m/s) to within (4 m/s) tabulated thresholds for armour rock. Given the current conditions of the site, this could be limited to the proposed infrastructure and its local discharge into the receiving environment (e.g. in the immediate vicinity of any culvert outfalls, where flow is concentrated). During detailed design, this should be reviewed to ensure appropriate waterway protection is in place.

Some facing material, as classified in Table 4-3 and Figure 4-29 and described in Table 4-4, may be beneficial for reducing localised scour and erosion along specific drainage lines or waterways within the development footprint. For example, sediment bunds along drainage lines are recommended to avoid the accumulation of excessive sedimentation in these channels. Some ongoing maintenance requirements would be expected where eroded material accumulates against the sediment bunds.

Table 4-3 Design of rock slope protection (from Table 3.11, Austroads 2013, Table 5.1, MRWA 2006)

Velocity (m/s)	Class of rock protection (tonnes)	Section thickness (m)
< 2	None	N/A
2 – 2.6	Facing	0.5
2.6 – 2.9	Light	0.75
2.9 – 3.9	0.25	1
3.9 – 4.5	0.5	1.25
4.5 – 5.1	1	1.6
5.1 – 5.7	2	2
5.7 – 6.4	4	2.5
> 6.4	Special	N/A

Table 4-4 Standard classes of rock slope protection (from Table 406.1, MRWA 2006)

Rock Class	Diameter of rock sizes within rock class (m)	Rock mass for rock sizes (kg)	Minimum proportion of rock sizes [rocks larger than] (%)
Facing	0.4	100	0
	0.3	35	50
	0.15	2.5	90
Light	0.55	250	0
	0.4	100	50
	0.2	10	90
0.25 tonne	0.75	500	0
	0.55	250	50
	0.3	35	90
0.5 tonne	0.9	1000	0
	0.7	450	50
	0.4	100	90

Rock Class	Diameter of rock sizes within rock class (m)	Rock mass for rock sizes (kg)	Minimum proportion of rock sizes [rocks larger than] (%)
1 tonne	1.15	2000	0
	0.6	1000	50
	0.55	250	90
2 tonne	1.45	4000	0
	1.15	2000	50
	0.75	500	90
4 tonne	1.8	8000	0
	1.45	4000	50
	0.9	100	90

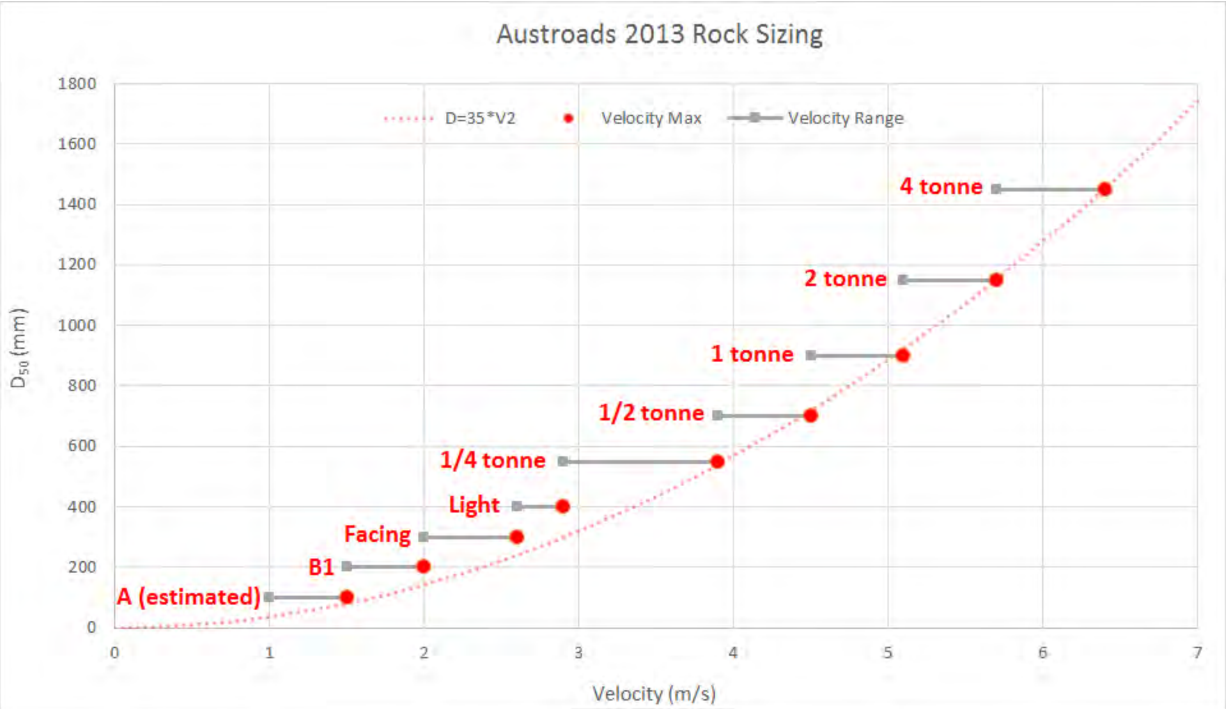

Figure 4-29 Velocity vs median stone size (based on Austroads 2013 Rock Sizing)

5. Summary and Conclusion

Hydrological conditions associated with the existing and proposed development conditions under 10%, 1%, 0.5%, 0.2% and 0.1% Annual Exceedance Probability (AEP) flood events have been assessed for the sub-catchments potentially impacted by the proposed Uungula Wind Farm near Burrendong Dam, NSW.

Flow rate modelling was undertaken using the RORB software package to determine sub-catchment flows. These flows were used as inputs to verify the flow rate from the water level modelling. The RORB model was calibrated/validated to the RFFE analysis to fit within the confidence limits of the RFFE results across the 1%, 2%, 5%, 20% and 50% AEP (i.e. closest to best estimate). The modelled results fitted within the confidence limits of the RFFE modelling and were close to the median/expected discharge rate.

For the rarer events, the RFFE modelling showed an upward trend that is not reflected in the RORB modelling. Sensitivity analysis and an investigation of the nearby catchments showed that the RFFE modelling provided higher flow rates for the rarer events than would be expected for a catchment of comparable size at this location. Therefore, the flow rates modelled by RORB were deemed applicable for use for constraining the roughness rates in the subsequent HEC-RAS water level modelling.

Under the proposed development conditions, there will be an additional impervious area within the catchment from infrastructure such as access tracks, wind turbine pads, ESF compounds and Substations. This additional infrastructure may change the runoff characteristics of the catchment. An overall change in imperviousness across the full model domain was determined to be less than 1% (1.81 km^2 of 210.33 km^2). Most, if not all, of the imperviousness added by these features would be as indirect imperviousness (i.e. not directly connected to waterways). Even applying a worst case scenario with all infrastructure being fully impervious and directly connected to the waterways, the impact of impervious area on the resulting flows is considered to be negligible.

Hydraulic modelling was conducted for existing and proposed conditions using the HEC-RAS software package. HEC-RAS models were developed using a two-dimensional (2D) rain-on-grid analysis to determine flood extents, flood levels and flow velocities. Two model terrains were developed: the existing conditions and the proposed conditions. HEC-RAS has the ability to combine terrains at multiple resolutions within the model which allows multiple input DEMs to be input to represent the detail of proposed conditions.

Roughness coefficients were used to define how quickly water moves across the terrain and to control the shape of flow hydrographs resulting from rainfall and upstream flow. Typical roughness values are defined for the range of flow path extents, i.e. from concrete channels to floodplains. Modelling the full 2D catchment area which extends outside of normal channels and their corresponding slopes requires much larger roughness values than are typically applied in 1D modelling or 2D modelling constrained to channels and immediate floodplains only.

An initial roughness coefficient of 0.05, representing a natural channel condition, was applied to the whole model. This roughness was used in combination with a 10% AEP rainfall event to define waterway channel extents. HEC-RAS has the ability to apply different roughness coefficients spatially across the model domain. To calibrate the flow rate of the runoff with the flow rates obtained from the RORB regions (land uses) representing the channels (roughness of 0.05) and the broader catchment were applied to the model with the broader catchment roughness being altered. Roughness values of 0.2 and 0.4 were applied to broader catchment area within the model domain in combination with the 1% AEP rainfall to determine the change in flow rates.

A power curve function was fitted to the peak flows against channel roughness to obtain the representative roughness to match the flows modelled by RORB. The representative roughness determined was 0.6. For the proposed conditions roughness values of 0.025 and 0.03 were adopted for the roads/hardstands and road drains respectively.

To examine the sensitivity of the model to changes in roughness, roughness values of 0.1, 0.2, 0.3, 0.4 and 0.5 were applied to the model for a 1% AEP rainfall. Flow rate results were extracted corresponding to the catchment modelled in RORB. The results showed that there was a power curve relationship between flow and roughness for this catchment. A version of this relationship, adjusted for specific roughness values in waterway channels, was used to define the calibrated catchment roughness values.

Rainfall was applied to the 2D area based on the IFD data and the RORB results. As there is no loss function in the current version of HEC-RAS (5.0.7), rainfall excess (the amount of rain that runs off after the losses) was also applied to the model.

Locations where water exits the model domain (outflows) required boundary conditions to be specified. Concentrated flow paths that exit the model domain were set to a normal depth boundary condition, using the uniform bed slope of that flow path as the estimated energy slope, as measured from the available terrain data.

For each model run, depth and velocity were extracted across the model domain. The existing conditions' flood depths showed that, in general, the flows are concentrated to the waterways in the region with sufficient terrain relief to limit the amount of sheet flow.

The inclusion of the wind turbines, roads/hardstands and drainage in the proposed conditions' model showed that the drains distribute the flows away from the roads up to the 10% AEP event. While some of the turbine areas show water inundation in the 10% AEP event, these depths are less than 0.05 metres, within model error.

For the 1% and rarer events, however, flows exceed road drainage (as expected) and have some impact the roads and hardstands. During detailed design, roads should be graded such that flows cannot pond around the wind turbines, compounds and any electrical infrastructure. Some of the ESF and storage compounds are located close to watercourses and modelled flood levels are likely to impact or be close to impacting on this infrastructure. If during detailed design, these areas are impacted, adjustment should be made to these locations to create a freeboard above the relevant flood depth.

The roads have currently been modelled without any drainage to convey flows under any roads that cross watercourses (i.e. without culverts). Therefore, water can back up behind these roads in the model, a situation that would not occur to the same degree once drainage features were included. Depending on the location, this could either decrease flood depths (water being moved downstream) or increase flood depths (water which was held upstream is now passed downstream) and would need to be modelled during detailed design.

The existing conditions' modelled velocities show that, in general, flows are of low velocity in the lower order waterways, with velocities increasing in higher order streams and can increase towards critical velocities whereby stream protection (armouring) may be required, depending on local geomorphology.

The inclusion of the wind turbines, roads/hardstands and drainage in the proposed conditions generate higher velocities along the edge of the roads, near the drains. It is noted that these higher velocities may not be realistic as they have been modelled without batters as the steep slopes require specific geotechnical studies which will be undertaken during detailed design post-Development Consent (standard-grade batters of 1:3 are not suitable in some places due to the relief and topography). This generates a small discontinuity in the cross section.

For the 1% and rarer events, flows cover road drainage (as expected) and may have higher velocities, depending on the drainage design, potentially impacting the roads, hardstands and receiving environments. During detailed design, roads should be graded such that velocities are minimised and transition from proposed infrastructure to the receiving environment has negligible impact.

As for current conditions, the roads have currently been modelled without any drainage to convey flows under any roads that cross watercourses (i.e. without culverts). Therefore, water can back up behind these roads in the model, a situation that would not occur to the same degree once drainage features were included. Depending on the location, this could either decrease velocities (flow conveyance designed to maintain similar graded terrain) or increase velocities (water which was held upstream is now passed downstream) and would need to be modelled during detailed design.

Flow velocities within the watercourses vary such that some areas are below the level that might be expected to require artificial protection (i.e. rock armouring), while others would benefit from protection of stream banks using armouring. Thus, flows range from below (< 2 m/s) to within (4 m/s) tabulated thresholds for armour rock. Given the current conditions of the site, this could be limited to the proposed infrastructure and its local discharge into the receiving environment (e.g. in the immediate vicinity of any culvert outfalls, where flow is concentrated). During detailed design, this should be reviewed to ensure appropriate waterway protection is in place.

Hydrological modelling shows that the majority of the site is not prone to erosion, as there is minimal sheet flow due to the nature of the terrain concentrating flows in valleys. Within the drainage lines, modelling indicates some potential for erosion that should be confirmed as part of detailed design. Aerial photography, however, indicates good groundcover vegetation and a lack of erosion under current management practices.

Based on the predicted velocities and flood extents, the proposed infrastructure for the Uungula Wind Farm are unlikely to significantly affect downstream erosion, or sedimentation. Some appropriate design considerations (e.g. culverts, rock armouring, etc.) should be investigated during detailed design stage. Scour protection may be warranted where concentrated flow paths enter defined drainage channels.

If required, there is also potential to manage flow velocities using flow detention basins and/or other mitigation structures adjacent to roads and hardstands to restrict impact on the receiving environment. Effective design and location of structures during detailed design would ensure that flows would not differ significantly from current conditions.

6. References

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Appendix A IFD Details

Table 6-1 Rainfall depths for 12EY to 0.2EY design rainfall events

Duration	Annual Exceedance Probability Rainfall Depths (mm)									
	12EY	6EY	4EY	3EY	2EY	63.20%	50%	0.5EY	20%	0.2EY
1 min	0.681	0.8	1.01	1.17	1.41	1.84	2.06	2.29	2.78	2.83
2 min	1.18	1.37	1.72	1.98	2.36	3.08	3.46	3.84	4.66	4.75
3 min	1.64	1.91	2.39	2.76	3.29	4.27	4.79	5.32	6.45	6.58
4 min	2.04	2.39	3.01	3.47	4.13	5.34	5.99	6.65	8.07	8.23
5 min	2.39	2.81	3.56	4.1	4.89	6.29	7.06	7.83	9.5	9.69
10 min	3.75	4.43	5.62	6.48	7.69	9.81	11	12.2	14.8	15.1
15 min	4.71	5.55	7.01	8.06	9.54	12.1	13.6	15.1	18.3	18.7
20 min	5.44	6.39	8.05	9.23	10.9	13.8	15.5	17.2	20.9	21.3
25 min	6.04	7.08	8.87	10.2	12	15.1	17	18.8	22.9	23.3
30 min	6.56	7.65	9.56	10.9	12.8	16.2	18.2	20.2	24.5	25
45 min	7.77	8.99	11.1	12.7	14.8	18.7	21	23.3	28.2	28.8
1 hour	8.68	10	12.3	14	16.3	20.5	23	25.5	30.9	31.6
1.5 hour	10.1	11.5	14.1	15.9	18.6	23.2	26	28.9	35	35.7
2 hours	11.2	12.7	15.5	17.5	20.3	25.3	28.4	31.5	38.1	38.9
3 hours	12.8	14.6	17.6	19.9	23	28.6	32.1	35.6	43	43.9
4.5 hour	14.7	16.7	20.1	22.7	26.2	32.5	36.4	40.4	48.7	49.7
6 hours	16.1	18.3	22.1	24.9	28.8	35.6	39.9	44.3	53.3	54.4
9 hours	18.2	20.8	25.2	28.4	32.9	40.6	45.4	50.4	60.7	62
12 hours	19.8	22.7	27.6	31.1	36.1	44.6	49.8	55.3	66.6	68
18 hours	22.1	25.4	31.1	35.1	40.8	50.6	56.5	62.8	75.7	77.2
24 hours	23.7	27.3	33.5	38	44.2	55.1	61.5	68.3	82.6	84.2
30 hours	24.9	28.7	35.4	40.1	46.9	58.6	65.4	72.6	88	89.8
36 hours	25.8	29.8	36.8	41.8	48.9	61.4	68.6	76.1	92.4	94.3
48 hours	27.1	31.4	38.9	44.3	52	65.7	73.4	81.5	99.4	101
72 hours	28.5	33.2	41.3	47.3	55.9	71.3	79.8	88.5	109	111
96 hours	29.2	34.1	42.8	49.1	58.3	74.9	83.9	93.1	115	117
120 hours	29.6	34.7	43.8	50.5	60.2	77.5	87	96.6	120	122
144 hours	29.7	35.2	44.7	51.7	61.8	79.6	89.6	99.4	124	126
168 hours	29.8	35.5	45.6	52.9	63.3	81.5	91.9	102	127	129

Table 6-2 Rainfall depths for 10% to 0.005% design rainfall events

Duration	Annual Exceedance Probability Rainfall Depths (mm)							
	10%	5%	2%	1%	0.05%	0.02%	0.01%	0.005%
1 min	3.28	3.78	4.47	5.01	5.66	6.56	7.3	8.09
2 min	5.49	6.3	7.36	8.16	9.21	10.7	11.9	13.3
3 min	7.6	8.74	10.2	11.4	12.8	14.9	16.6	18.4
4 min	9.5	10.9	12.8	14.3	16.2	18.7	20.9	23.1
5 min	11.2	12.9	15.2	16.9	19.2	22.2	24.7	27.4
10 min	17.5	20.2	23.9	26.8	30.3	35.1	39.1	43.3
15 min	21.6	25	29.6	33.3	37.6	43.6	48.5	53.7
20 min	24.7	28.5	33.7	37.9	42.9	49.7	55.2	61.2
25 min	27	31.2	36.9	41.5	46.9	54.4	60.5	67
30 min	29	33.4	39.5	44.3	50.2	58.1	64.7	71.7
45 min	33.3	38.4	45.3	50.7	57.3	66.5	74	82
1 hour	36.5	42	49.4	55.2	62.4	72.4	80.6	89.4
1.5 hour	41.2	47.3	55.6	61.9	70	81.2	90.4	100
2 hours	44.8	51.5	60.3	67.1	75.9	88	97.9	109
3 hours	50.5	57.9	67.8	75.4	85.3	98.8	110	122
4.5 hour	57.2	65.5	76.7	85.4	96.6	112	124	138
6 hours	62.6	71.7	84.1	93.8	106	123	136	151
9 hours	71.3	81.9	96.3	108	122	141	157	173
12 hours	78.4	90.1	106	119	135	156	173	192
18 hours	89.3	103	122	138	156	180	200	222
24 hours	97.7	113	135	152	172	200	222	246
30 hours	104	121	145	164	187	217	243	270
36 hours	110	128	153	174	198	231	259	289
48 hours	119	139	167	190	216	252	283	316
72 hours	131	154	185	211	239	279	313	349
96 hours	138	163	197	225	254	297	333	371
120 hours	144	171	206	235	266	311	348	388
144 hours	149	176	213	243	276	323	361	403
168 hours	153	181	219	250	284	333	373	417

Appendix B AR&R Data Hub Results

B1 Available Temporal Patterns

Available durations of point and areal temporal patterns are shown in Table 6-3 and Table 6-4, respectively, compared to available IFD information. The unshaded boxes are those where IFD information is available, but for which no temporal pattern durations are available. Areal temporal patterns are typically used for catchments greater than 75 km² in size. Using the point temporal patterns over the areal patterns will produce a more conservative (higher) estimation of the peak flows within the catchment.

Table 6-3 Available Point Temporal Pattern Durations from Australian Rainfall and Runoff

Durations				
1 minute	15 minutes	1.5 hours	12 hours	72 hours
2 minutes	20 minutes	2 hours	18 hours	96 hours
3 minutes	25 minutes	3 hours	24 hours	120 hours
4 minutes	30 minutes	4.5 hours	30 hours	144 hours
5 minutes	45 minutes	6 hours	36 hours	168 hours
10 minutes	1 hour	9 hours	48 hours	

Table 6-4 Available Areal Temporal Pattern Durations from Australian Rainfall and Runoff

Durations				
1 minute	15 minutes	1.5 hours	12 hours	72 hours
2 minutes	20 minutes	2 hours	18 hours	96 hours
3 minutes	25 minutes	3 hours	24 hours	120 hours
4 minutes	30 minutes	4.5 hours	30 hours	144 hours
5 minutes	45 minutes	6 hours	36 hours	168 hours
10 minutes	1 hour	9 hours	48 hours	

B2 Data Hub Results

Appendix C RFFE Results

Appendix D RORB Catchment File Details

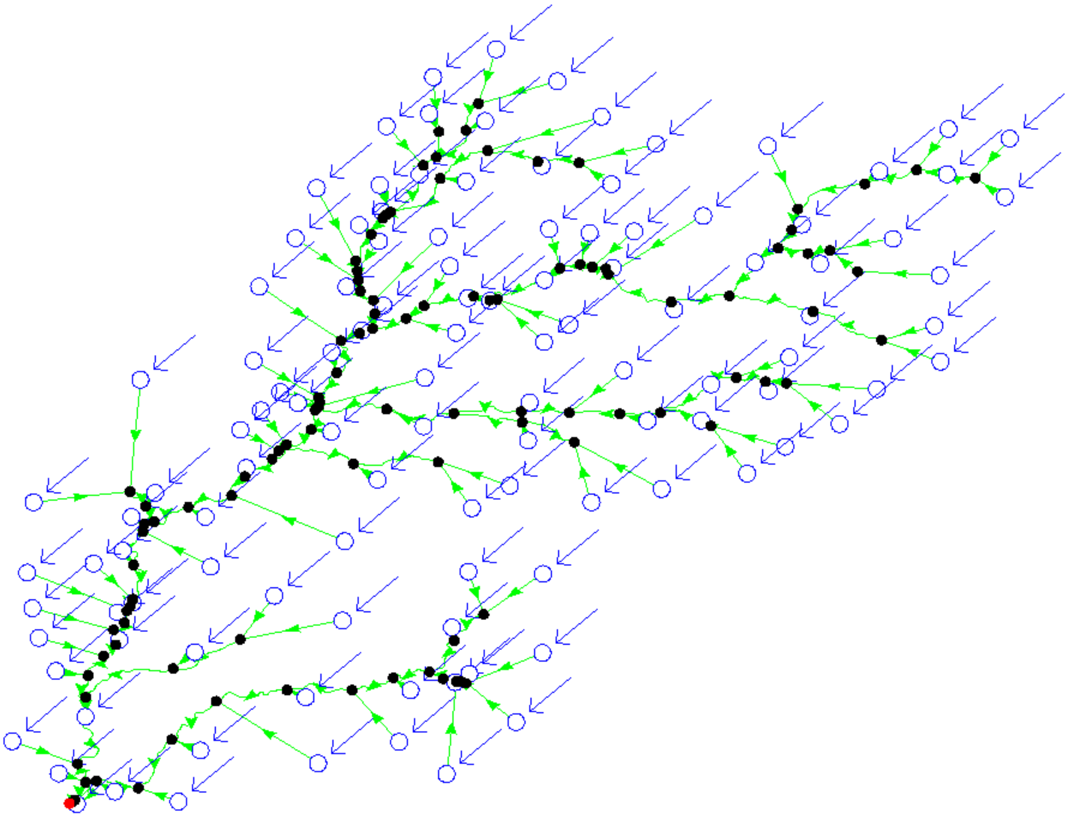

Figure 6-1 RORB catchment file

Table 6-5 RORB reach details

No.	Reach Name	Reach Type	Reach (km)	Length	No.	Reach Name	Reach Type	Reach (km)	Length
1	A DS	1. Natural	0.447		112	X	1. Natural	0.052	
2	N DS	1. Natural	0.484		113	X US	1. Natural	0.047	
3	H US	1. Natural	0.144		114	Y	1. Natural	0.148	
4	R DS	1. Natural	0.292		115	AE	1. Natural	0.388	
5	P DS	1. Natural	0.713		116	T	1. Natural	0.902	
6	O DS	1. Natural	0.541		117	Y US	1. Natural	0.228	
7	X DS	1. Natural	0.072		118	AE DS	1. Natural	0.112	
8	K DS	1. Natural	0.787		119	AG	1. Natural	0.713	

No.	Reach Name	Reach Type	Reach Length (km)	No.	Reach Name	Reach Type	Reach Length (km)
9	U US	1. Natural	0.269	120	C	1. Natural	0.125
10	AC DS	1. Natural	0.288	121	C US	1. Natural	0.131
11	Y DS	1. Natural	0.36	122	Z	1. Natural	0.909
12	AH DS	1. Natural	0.186	123	AR	1. Natural	0.12
13	AK DS	1. Natural	0.118	124	AR US	1. Natural	0.176
14	AE US	1. Natural	0.128	125	AL	1. Natural	0.92
15	AB DS	1. Natural	0.496	126	AV	1. Natural	0.037
16	AI DS	1. Natural	0.693	127	AV US	1. Natural	0.12
17	C DS	1. Natural	0.175	128	AY DS	1. Natural	0.373
18	AQ DS	1. Natural	0.154	129	BC	1. Natural	0.683
19	AN DS	1. Natural	0.762	130	AY	1. Natural	0.243
20	AO DS	1. Natural	0.411	131	BH DS	1. Natural	0.054
21	AR DS	1. Natural	0.21	132	BI US	1. Natural	0.024
22	AT DS	1. Natural	0.333	133	BI	1. Natural	0.169
23	AX DS	1. Natural	0.84	134	BG	1. Natural	0.938
24	AV DS	1. Natural	0.192	135	BH	1. Natural	0.348
25	BE DS	1. Natural	0.294	136	BA	1. Natural	0.496
26	AY US	1. Natural	0.485	137	BF	1. Natural	0.75
27	BH US	1. Natural	0.059	138	BK	1. Natural	0.645
28	BI DS	1. Natural	0.028	139	BE	1. Natural	0.111
29	BD DS	1. Natural	0.602	140	BE US	1. Natural	0.203
30	BL DS	1. Natural	0.647	141	BD US	1. Natural	0.281
31	BM DS	1. Natural	0.44	142	BT	1. Natural	0.628
32	BN DS	1. Natural	0.696	143	BP	1. Natural	0.66
33	BO DS	1. Natural	0.401	144	BO US	1. Natural	0.112
34	BR DS	1. Natural	0.646	145	BM US	1. Natural	0.356
35	BJ DS	1. Natural	0.334	146	BB	1. Natural	0.665
36	BS DS	1. Natural	0.121	147	BM	1. Natural	0.241
37	BV DS	1. Natural	0.891	148	BL US	1. Natural	0.428
38	BU US	1. Natural	0.365	149	BL	1. Natural	0.126
39	CA US	1. Natural	0.258	150	BY	1. Natural	0.708
40	CB US	1. Natural	0.444	151	BZ	1. Natural	0.9
41	CD DS	1. Natural	0.102	152	BR US	1. Natural	0.557
42	CE US	1. Natural	0.529	153	BR	1. Natural	0.218
43	CK US	1. Natural	0.117	154	BN US	1. Natural	0.669
44	CN DS	1. Natural	0.17	155	BN	1. Natural	0.362

No.	Reach Name	Reach Type	Reach Length (km)	No.	Reach Name	Reach Type	Reach Length (km)
45	CR US	1. Natural	0.202	156	BJ US	1. Natural	0.255
46	CO DS	1. Natural	0.535	157	BS US	1. Natural	0.106
47	CX DS	1. Natural	0.156	158	BQ	1. Natural	0.45
48	CY DS	1. Natural	0.044	159	BJ	1. Natural	0.169
49	CW DS	1. Natural	0.43	160	BS	1. Natural	0.396
50	CV DS	1. Natural	0.345	161	BW	1. Natural	0.651
51	CT DS	1. Natural	0.947	162	BX	1. Natural	0.601
52	CZ DS	1. Natural	0.786	163	BV US	1. Natural	0.781
53	DA DS	1. Natural	0.765	164	BV	1. Natural	0.271
54	DB US	1. Natural	0.71	165	BU DS	1. Natural	0.286
55	DH US	1. Natural	0.267	166	BU	1. Natural	0.101
56	DJ US	1. Natural	0.405	167	CG	1. Natural	1.073
57	DL US	1. Natural	0.036	168	CB DS	1. Natural	0.429
58	S	1. Natural	0.33	169	CB	1. Natural	0.18
59	B	1. Natural	0.535	170	AS	1. Natural	1.298
60	L	1. Natural	0.542	171	CC	1. Natural	0.806
61	P	1. Natural	0.189	172	CA DS	1. Natural	0.209
62	J	1. Natural	0.768	173	CF	1. Natural	0.691
63	U	1. Natural	0.104	174	CD US	1. Natural	0.096
64	AJ	1. Natural	0.68	175	CD	1. Natural	0.131
65	AA	1. Natural	0.536	176	CE DS	1. Natural	0.492
66	AA US	1. Natural	0.333	177	CE	1. Natural	0.189
67	AC	1. Natural	0.156	178	CJ	1. Natural	0.523
68	AC US	1. Natural	0.201	179	CK DS	1. Natural	0.069
69	U DS	1. Natural	0.263	180	CK	1. Natural	0.047
70	R US	1. Natural	0.255	181	CI	1. Natural	0.934
71	P US	1. Natural	0.537	182	CN US	1. Natural	0.152
72	AB US	1. Natural	0.269	183	CN	1. Natural	0.134
73	AW	1. Natural	0.468	184	CQ	1. Natural	0.716
74	AZ	1. Natural	0.548	185	CR DS	1. Natural	0.186
75	AX	1. Natural	0.056	186	CS	1. Natural	0.573
76	AX US	1. Natural	0.761	187	CR	1. Natural	0.065
77	AN	1. Natural	0.091	188	CV	1. Natural	0.271
78	AN US	1. Natural	0.566	189	CV US	1. Natural	0.311
79	W	1. Natural	1.033	190	CM	1. Natural	0.577
80	AK	1. Natural	0.057	191	CP	1. Natural	0.871

No.	Reach Name	Reach Type	Reach Length (km)	No.	Reach Name	Reach Type	Reach Length (km)
81	AD	1. Natural	0.536	192	CT	1. Natural	0.263
82	AK US	1. Natural	0.068	193	CT US	1. Natural	0.733
83	AH	1. Natural	0.373	194	DA US	1. Natural	0.249
84	AF	1. Natural	0.464	195	DG	1. Natural	0.6
85	AH US	1. Natural	0.115	196	DH DS	1. Natural	0.238
86	AP	1. Natural	0.662	197	DH	1. Natural	0.244
87	AU	1. Natural	0.627	198	CL	1. Natural	0.509
88	AQ	1. Natural	0.007	199	CH	1. Natural	0.678
89	AQ US	1. Natural	0.066	200	CO US	1. Natural	0.46
90	AI US	1. Natural	0.215	201	CO	1. Natural	0.153
91	AM	1. Natural	0.508	202	CU	1. Natural	0.721
92	AT	1. Natural	0.447	203	DC	1. Natural	0.61
93	AO US	1. Natural	0.054	204	CY US	1. Natural	0.044
94	AT US	1. Natural	0.212	205	CY	1. Natural	0.112
95	Q	1. Natural	0.363	206	DI	1. Natural	1.076
96	N	1. Natural	0.058	207	CX	1. Natural	0.107
97	N US	1. Natural	0.374	208	CX US	1. Natural	0.118
98	G	1. Natural	1.019	209	CW	1. Natural	0.199
99	K	1. Natural	0.214	210	CW US	1. Natural	0.399
100	I	1. Natural	0.671	211	DE	1. Natural	0.713
101	K US	1. Natural	0.578	212	CZ US	1. Natural	0.637
102	E	1. Natural	0.699	213	DF	1. Natural	1.106
103	D	1. Natural	0.643	214	DB	1. Natural	0.269
104	A	1. Natural	0.192	215	DK	1. Natural	0.367
105	A US	1. Natural	0.365	216	DB DS	1. Natural	0.689
106	F	1. Natural	0.637	217	DJ DS	1. Natural	0.386
107	M	1. Natural	0.226	218	DJ	1. Natural	0.196
108	F DS	1. Natural	0.303	219	DL	1. Natural	0.043
109	H	1. Natural	0.545	220	DL DS	1. Natural	0.029
110	O US	1. Natural	0.123	221	CZ	1. Natural	0.175
111	V	1. Natural	0.325	222	CA	1. Natural	0.173

Table 6-6 RORB sub-catchment area details

No.	Node Name	Node Area (km²)	No.	Node Name	Node Area (km²)	No.	Node Name	Node Area (km²)
1	A	0.373	40	AN	0.742	79	CA	0.202
2	B	0.567	41	AO	0.124	80	CB	0.386
3	C	0.071	42	AP	0.271	81	CC	0.642
4	D	0.355	43	AQ	0.011	82	CD	0.123
5	E	0.567	44	AR	0.198	83	CE	0.624
6	F	0.388	45	AS	2.436	84	CF	0.317
7	G	0.559	46	AT	0.505	85	CG	1.377
8	H	0.493	47	AU	0.275	86	CH	1.063
9	I	0.532	48	AV	0.078	87	CI	0.344
10	J	0.688	49	AW	0.348	88	CJ	0.292
11	K	0.339	50	AX	0.892	89	CK	0.07
12	L	0.276	51	AY	0.552	90	CL	0.262
13	M	0.095	52	AZ	0.328	91	CM	0.409
14	N	0.368	53	BA	0.38	92	CN	0.233
15	O	0.131	54	BB	0.476	93	CO	0.521
16	P	1.175	55	BC	0.382	94	CP	0.728
17	Q	0.293	56	BD	0.375	95	CQ	0.301
18	R	0.15	57	BE	0.134	96	CR	0.087
19	S	0.258	58	BF	0.508	97	CS	0.402
20	T	0.432	59	BG	0.607	98	CT	0.924
21	U	0.207	60	BH	0.094	99	CU	0.513
22	V	0.274	61	BI	0.023	100	CV	0.467
23	W	1.095	62	BJ	0.213	101	CW	0.661
24	X	0.015	63	BK	0.401	102	CX	0.078
25	Y	0.118	64	BL	0.496	103	CY	0.016
26	Z	0.651	65	BM	0.564	104	CZ	0.903
27	AA	0.504	66	BN	0.587	105	DA	0.788
28	AB	0.287	67	BO	0.081	106	DB	0.884
29	AC	0.215	68	BP	0.556	107	DC	0.747
30	AD	0.277	69	BQ	0.276	108	DE	0.416
31	AE	0.098	70	BR	0.372	109	DF	0.857
32	AF	0.303	71	BS	0.175	110	DG	0.449
33	AG	0.547	72	BT	0.38	111	DH	0.182
34	AH	0.212	73	BU	0.577	112	DI	0.404
35	AI	0.585	74	BV	0.905	113	DJ	0.265

No.	Node Name	Node Area (km^2)	No.	Node Name	Node Area (km^2)	No.	Node Name	Node Area (km^2)
36	AJ	0.723	75	BW	0.393	114	DK	0.261
37	AK	0.066	76	BX	0.283	115	DL	0.017
38	AL	0.913	77	BY	0.438			
39	AM	0.317	78	BZ	0.872			

Appendix E Existing Conditions HEC-RAS Results

E1 Flood depths

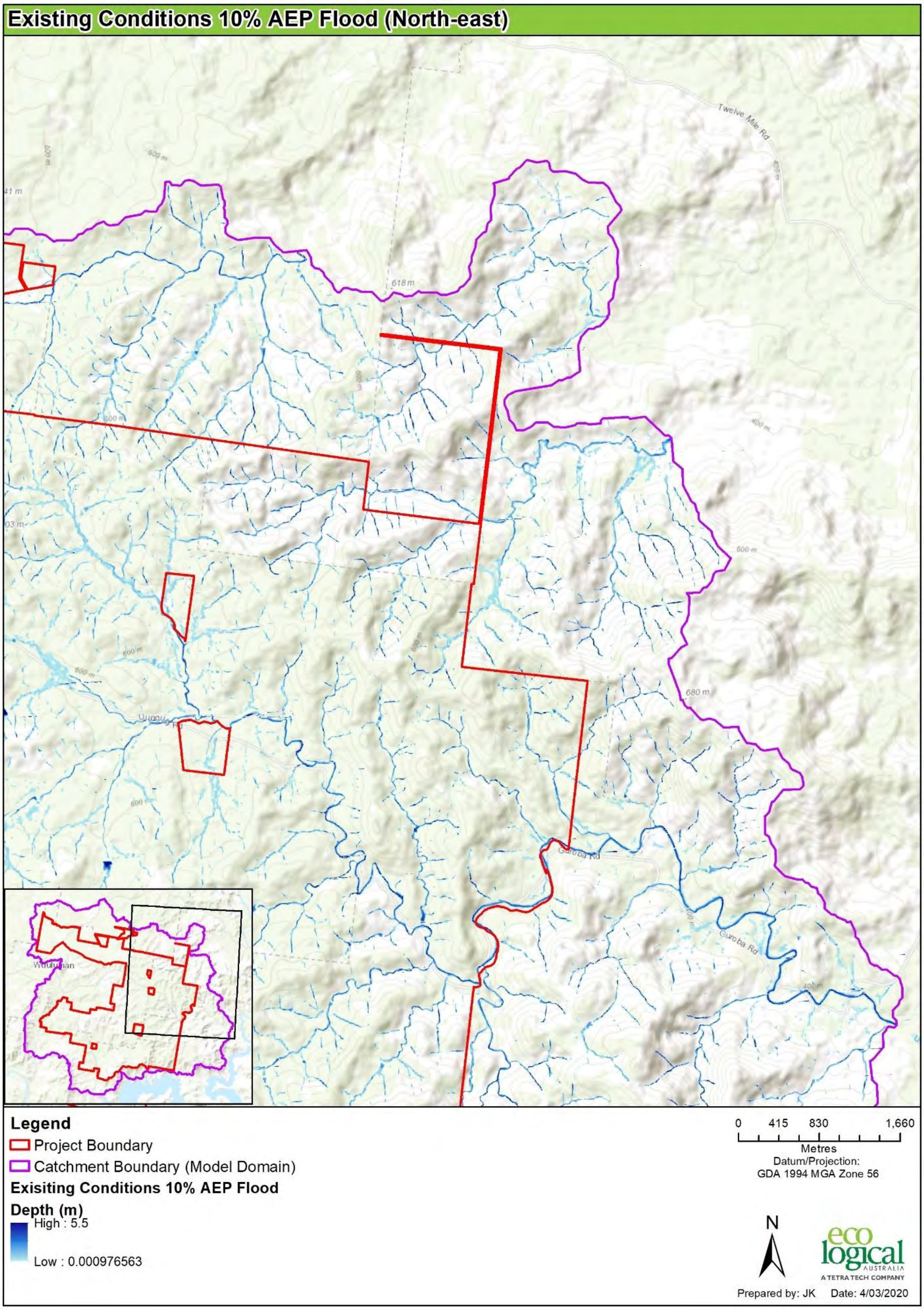

Figure 6-2 10% AEP Existing Conditions Flood Depths - North East

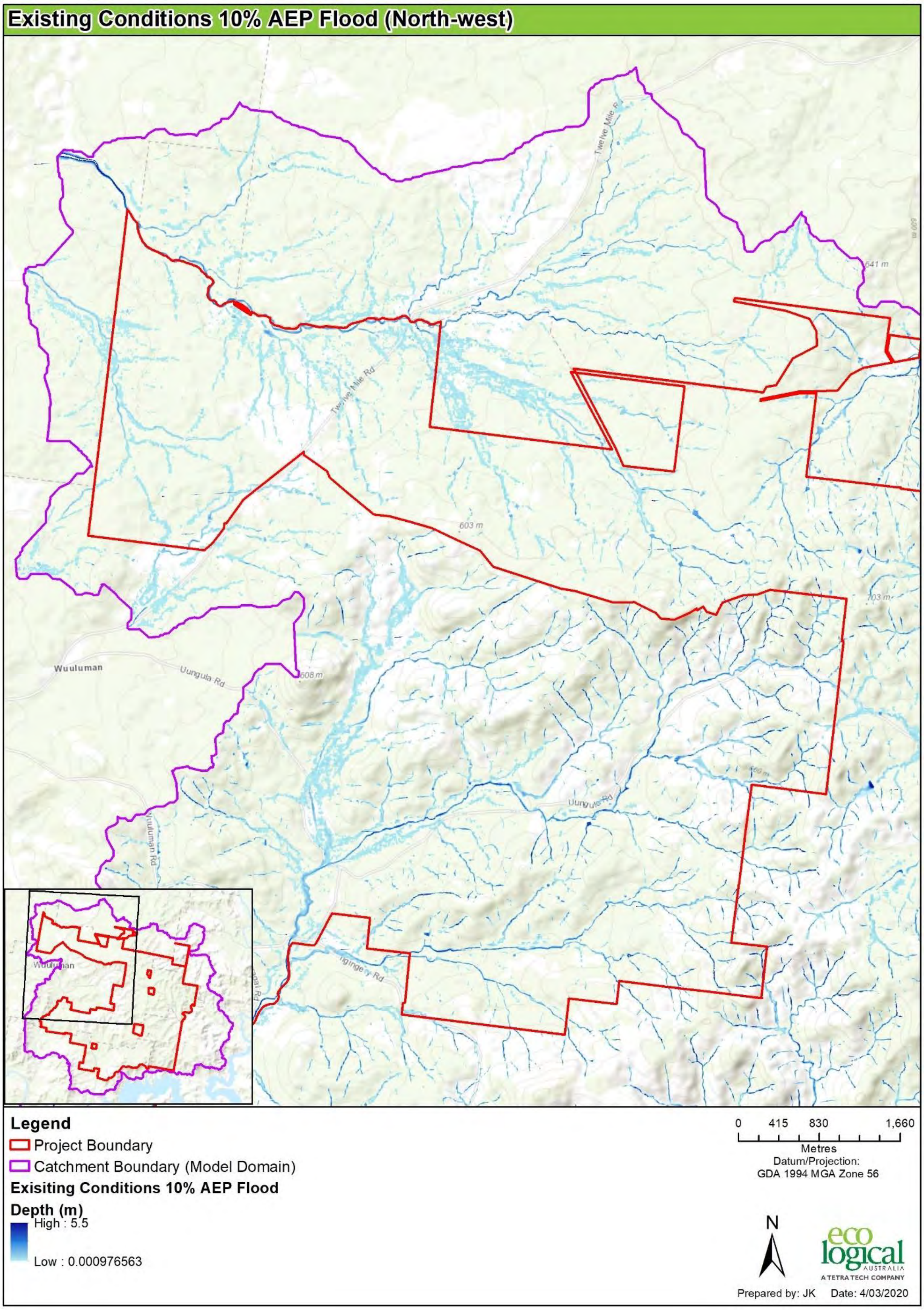

Figure 6-3 10% AEP Existing Conditions Flood Depths - North West

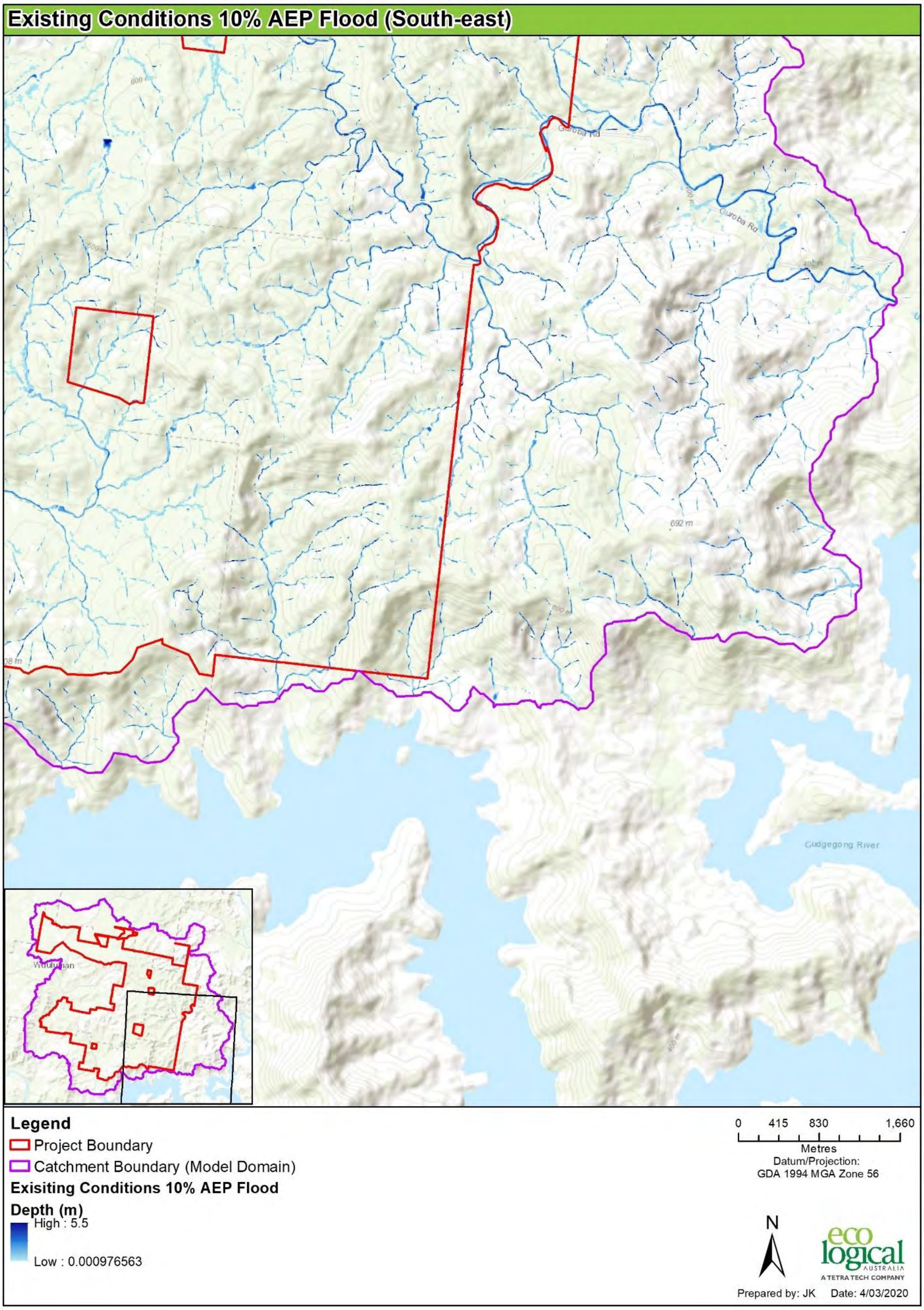

Figure 6-4 10% AEP Existing Conditions Flood Depths - South East

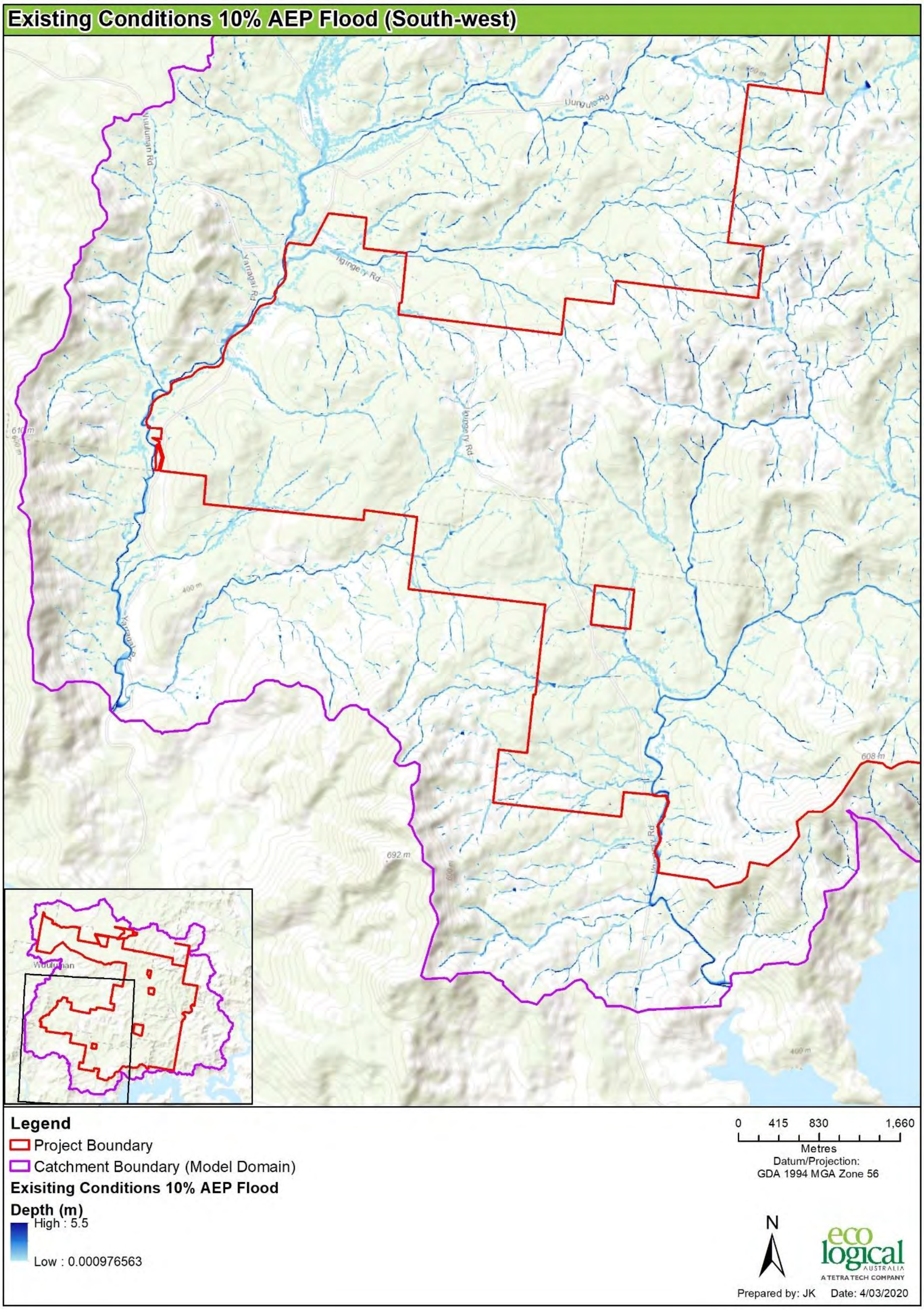

Figure 6-5 10% AEP Existing Conditions Flood Depths - South West

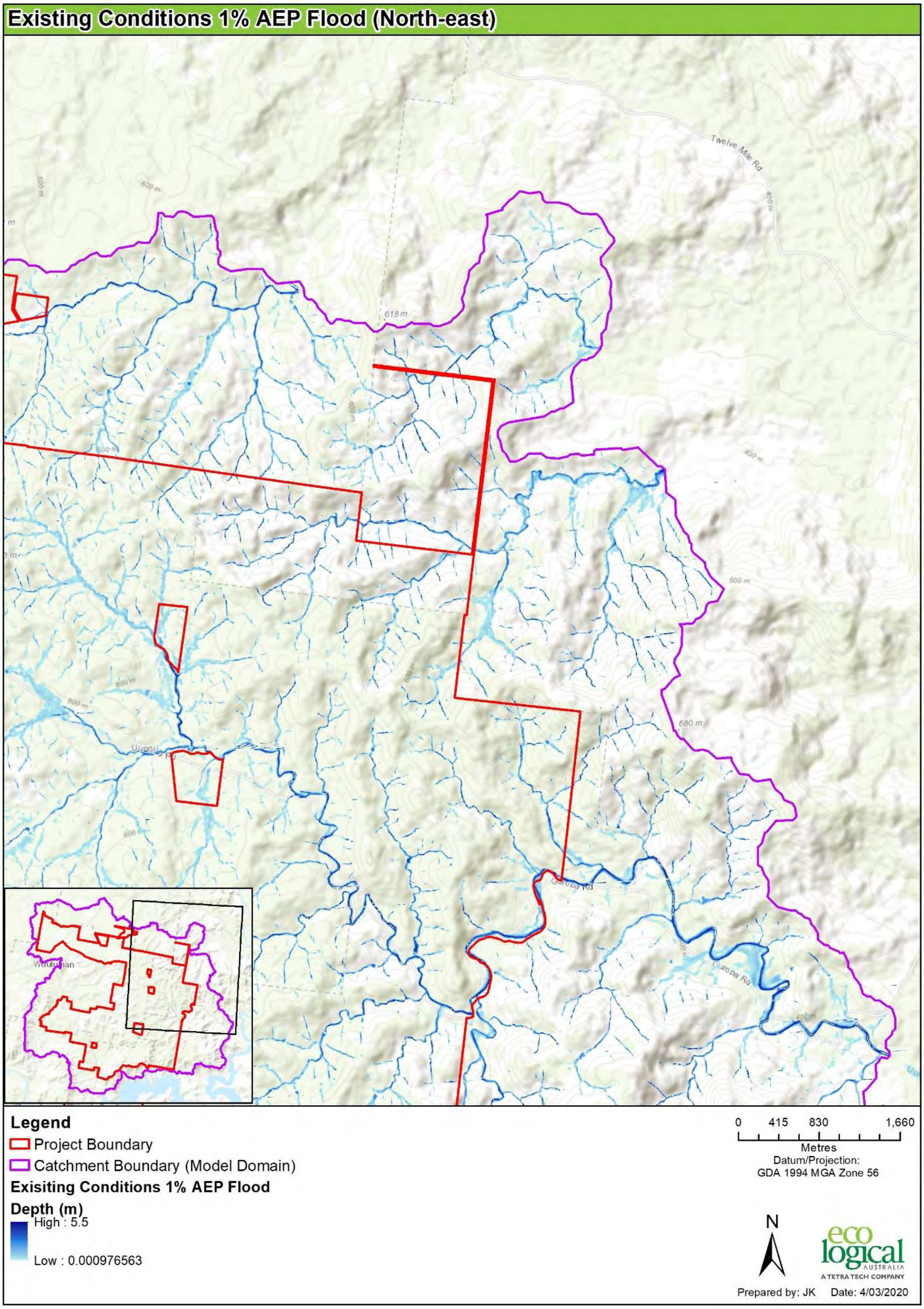

Figure 6-6 1% AEP Existing Conditions Flood Depths - North East

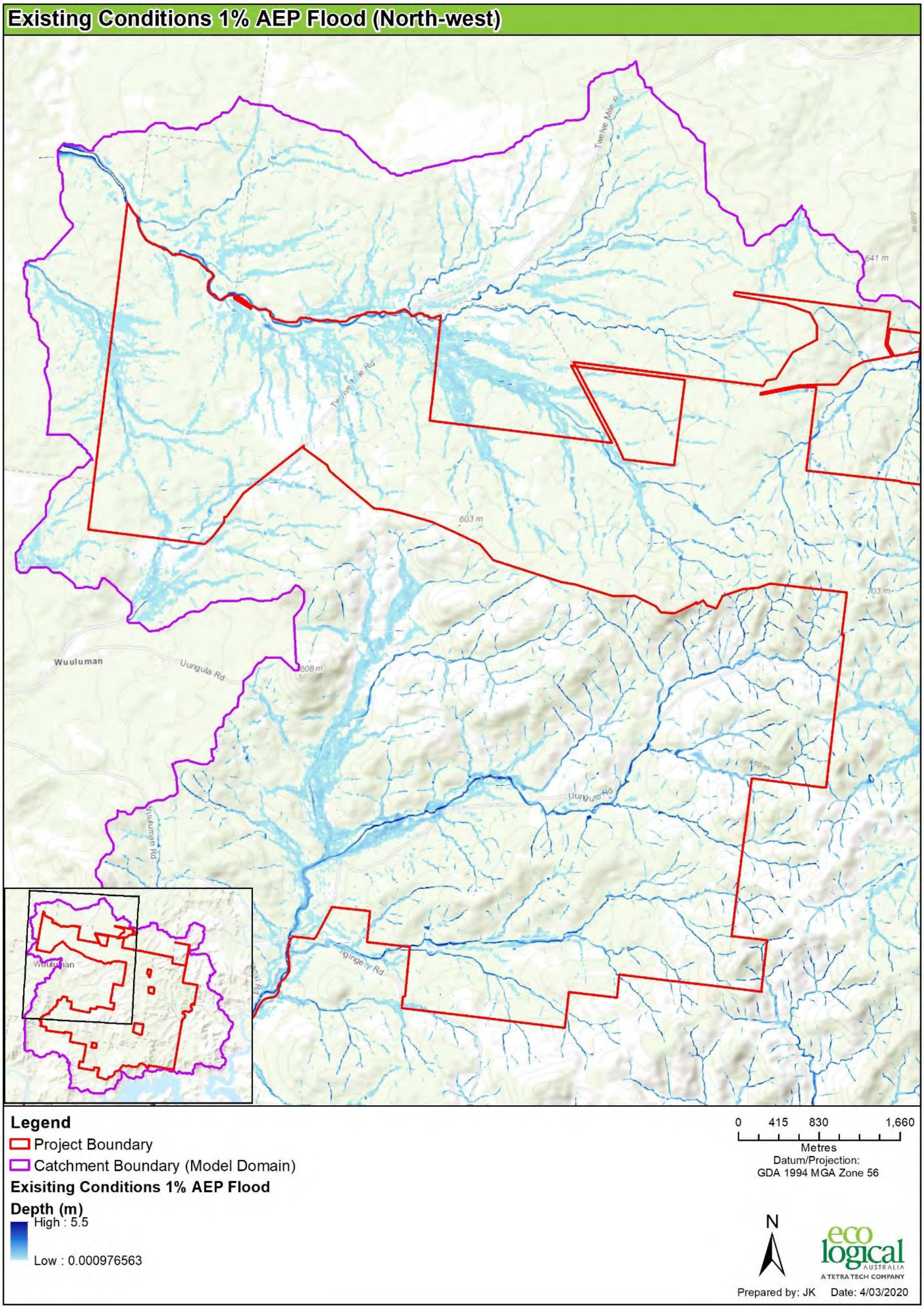

Figure 6-7 1% AEP Existing Conditions Flood Depths - North West

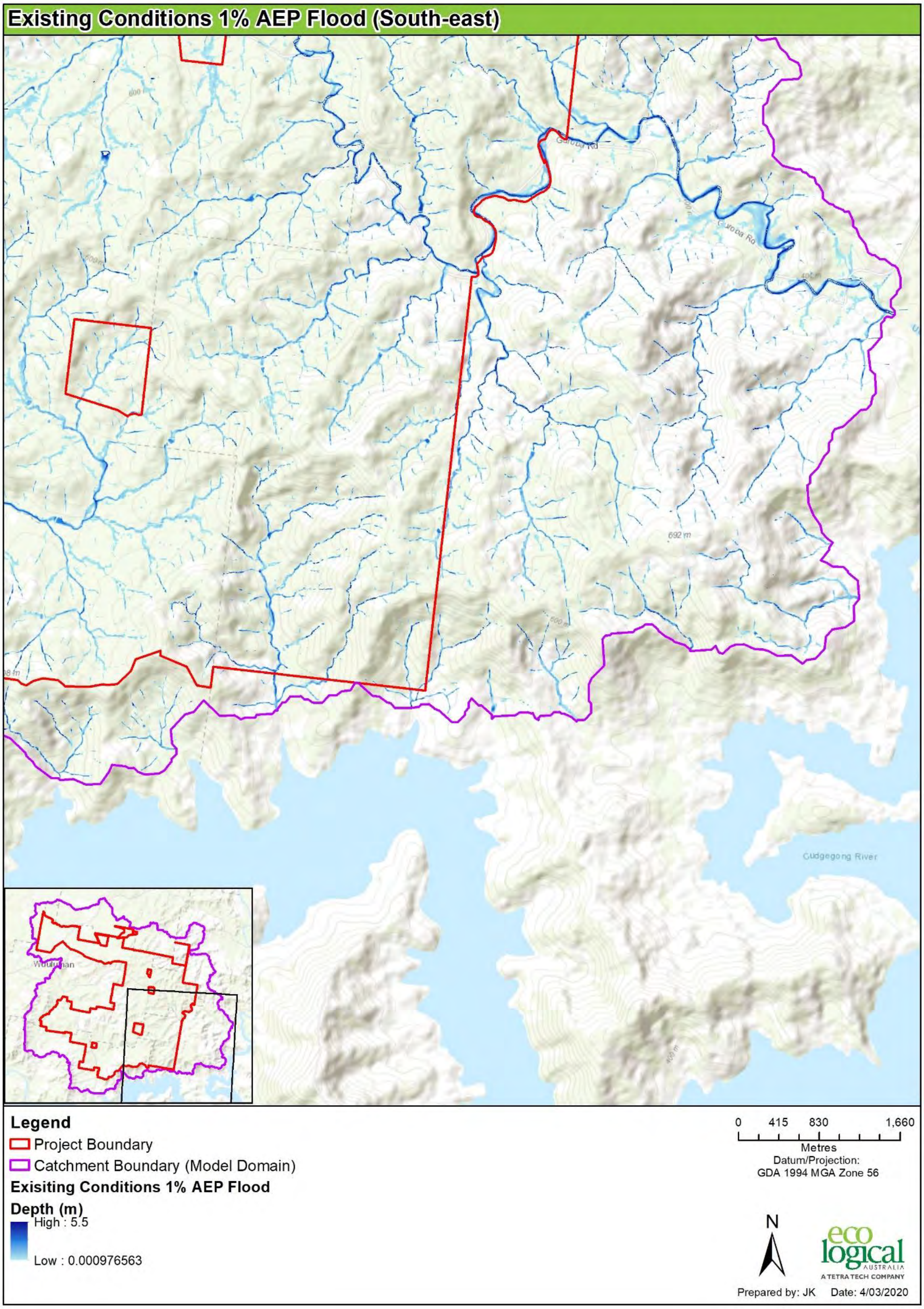

Figure 6-8 1% AEP Existing Conditions Flood Depths - South East

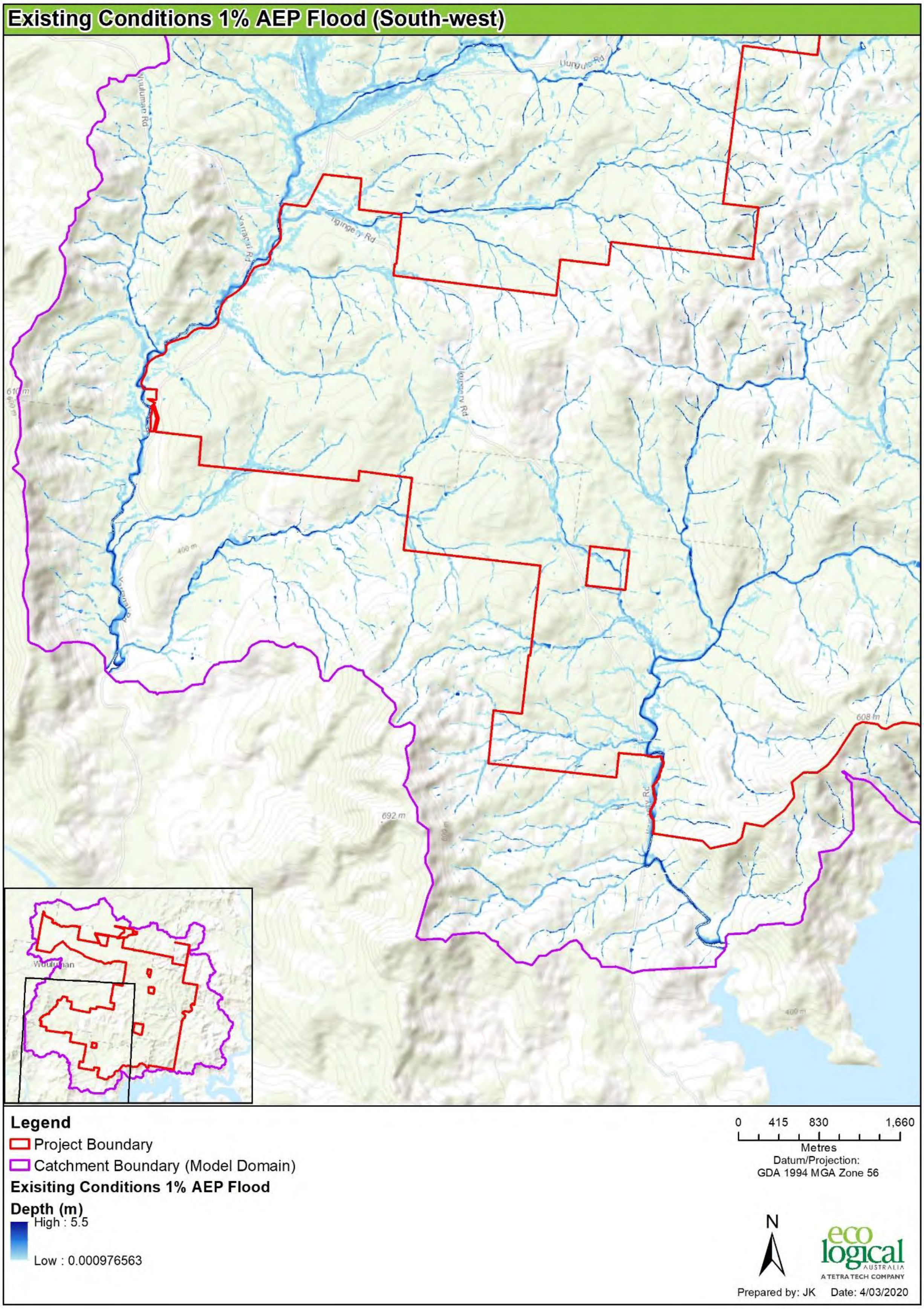

Figure 6-9 1% AEP Existing Conditions Flood Depths - South West

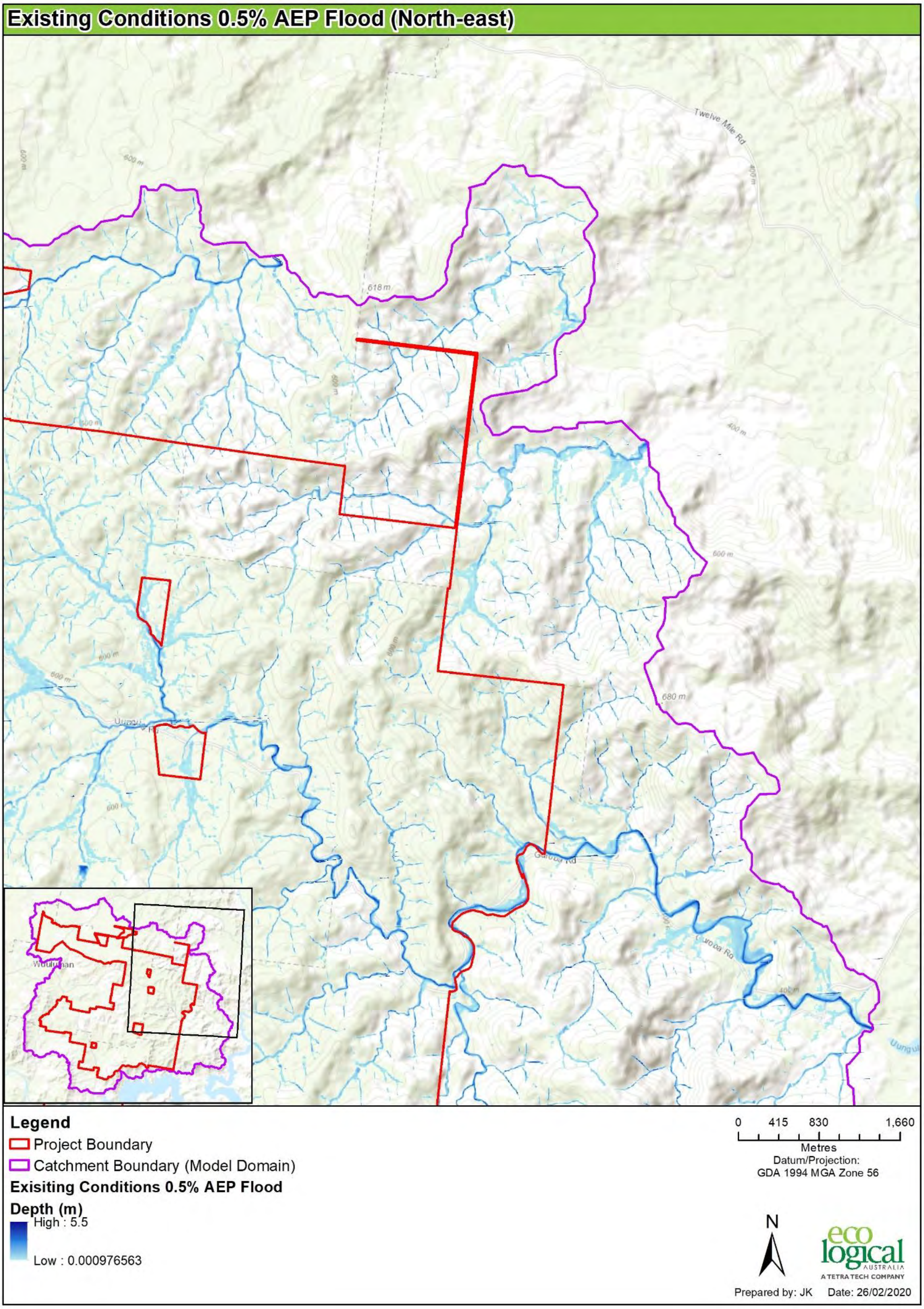

Figure 6-10 0.5% AEP Existing Conditions Flood Depths - North East

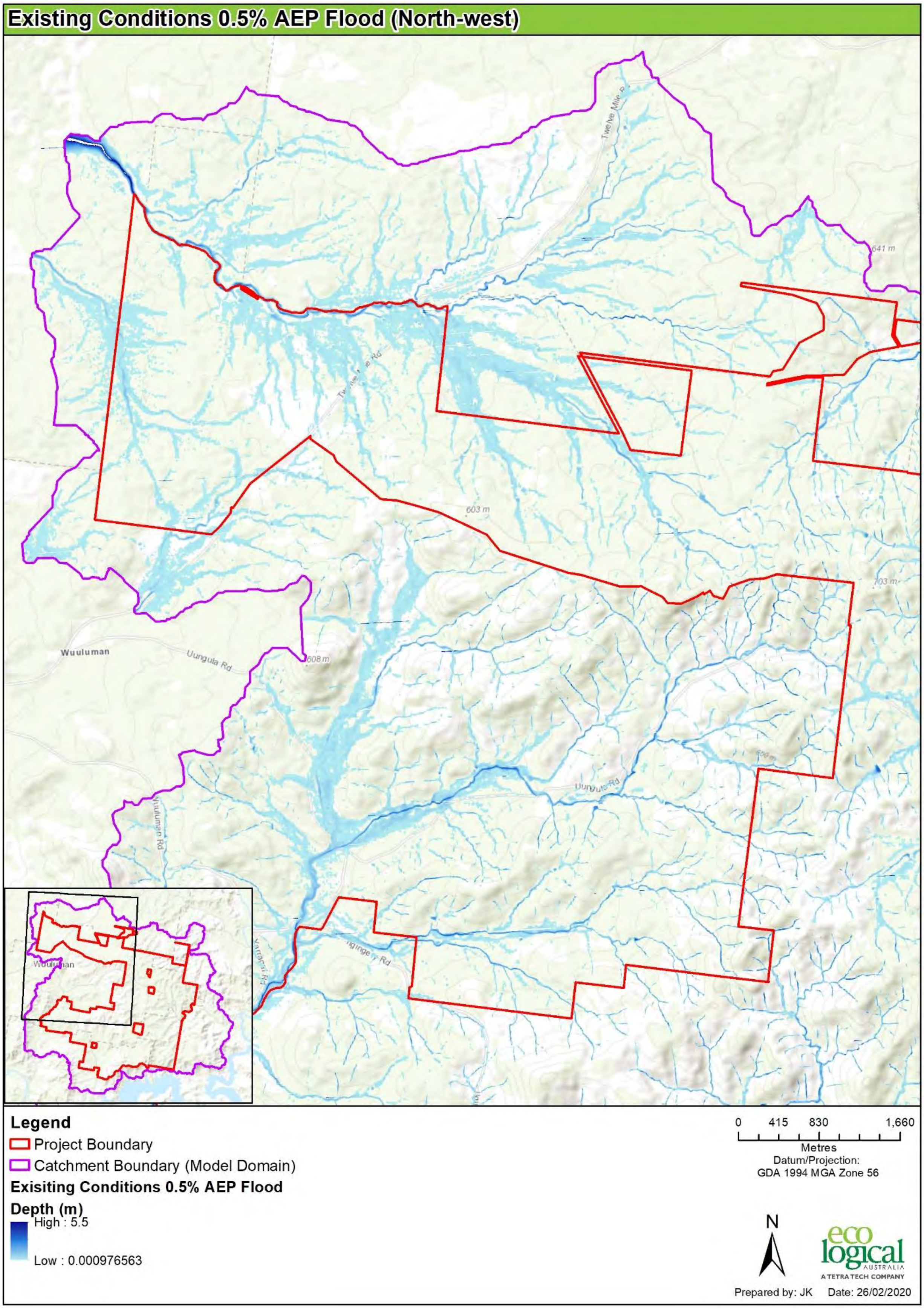

Figure 6-11 0.5% AEP Existing Conditions Flood Depths - North West

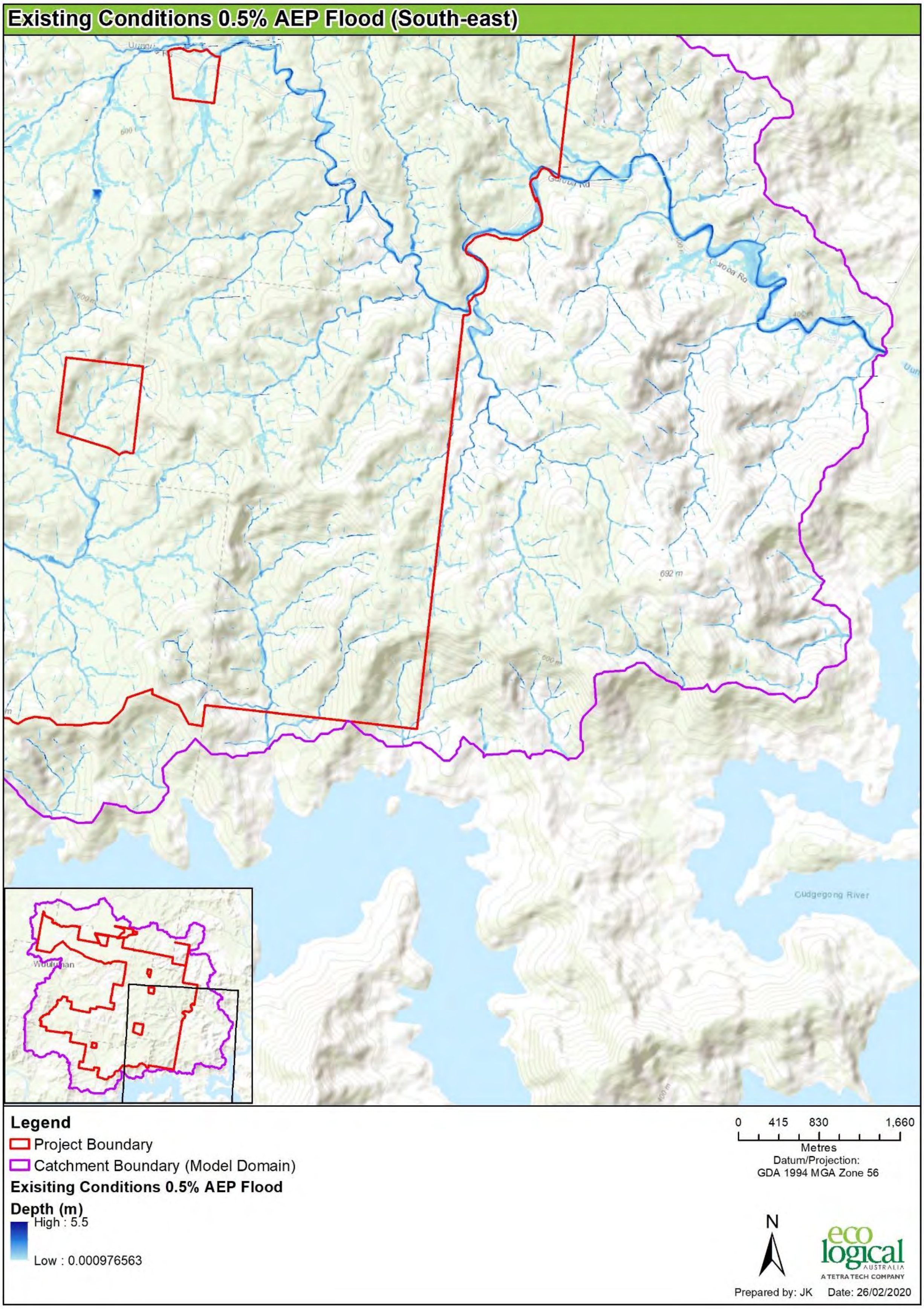

Figure 6-12 0.5% AEP Existing Conditions Flood Depths - South East

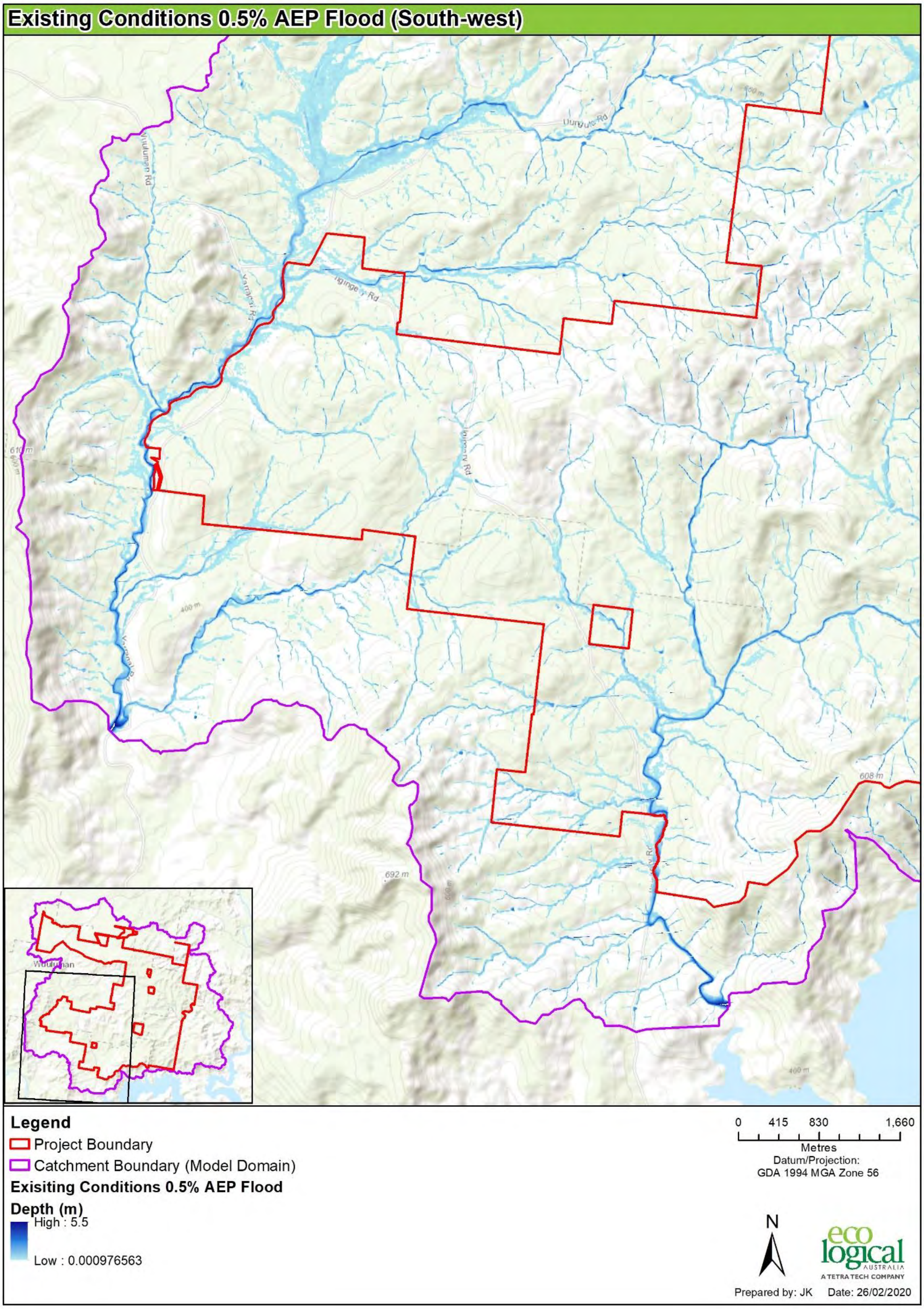

Figure 6-13 0.5% AEP Existing Conditions Flood Depths - South West

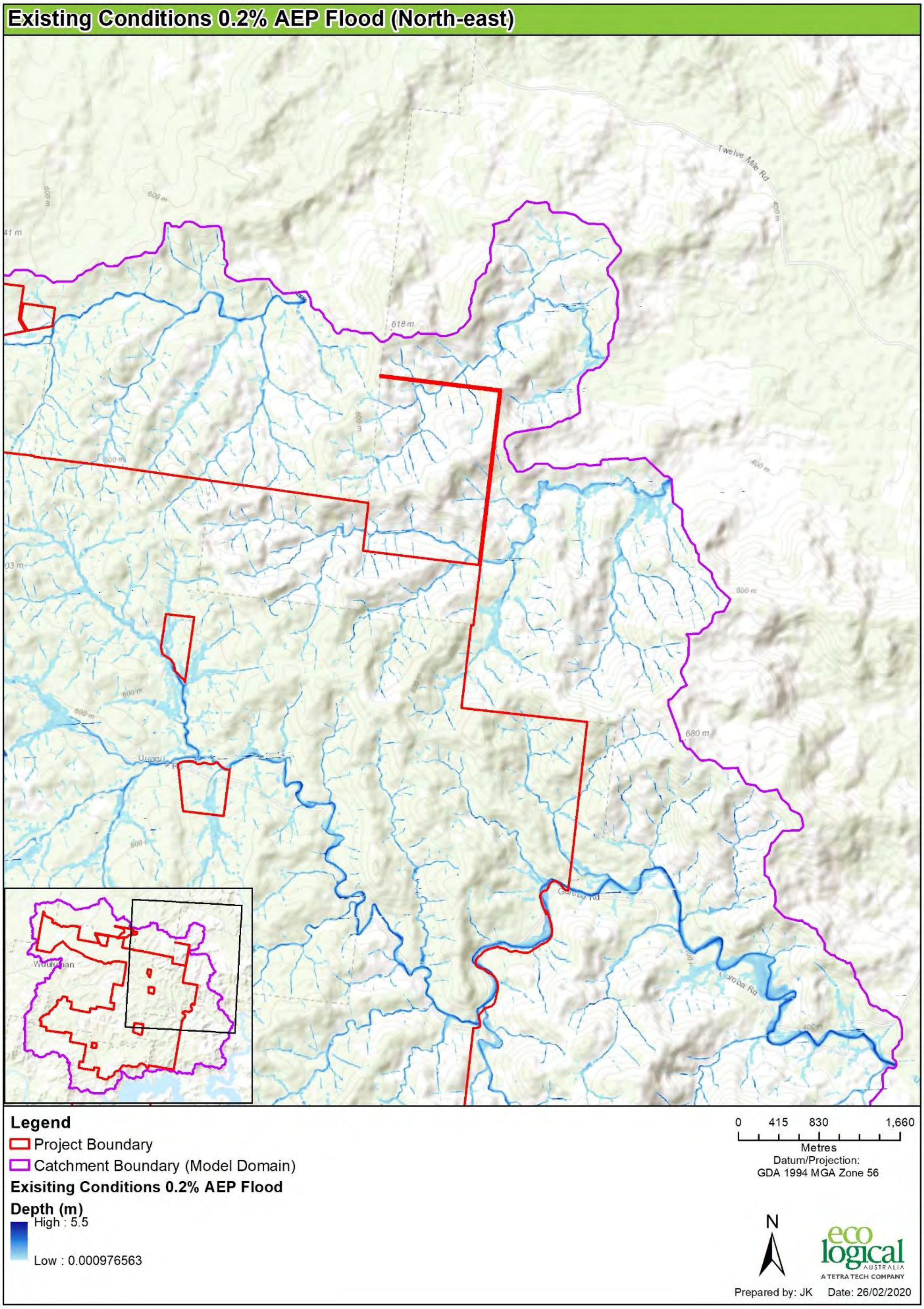

Figure 6-14 0.2% AEP Existing Conditions Flood Depths - North East

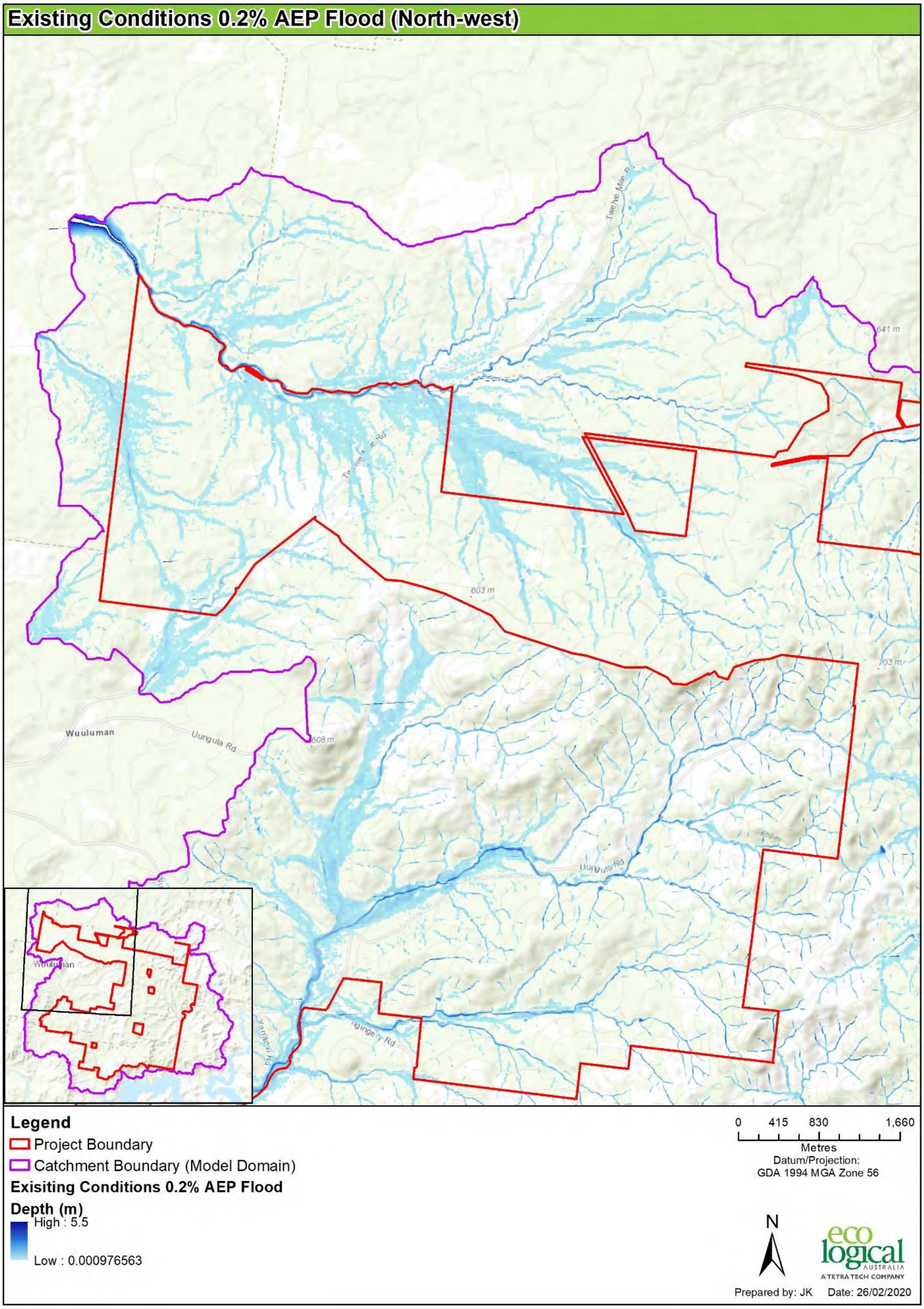

Figure 6-15 0.2% AEP Existing Conditions Flood Depths - North West

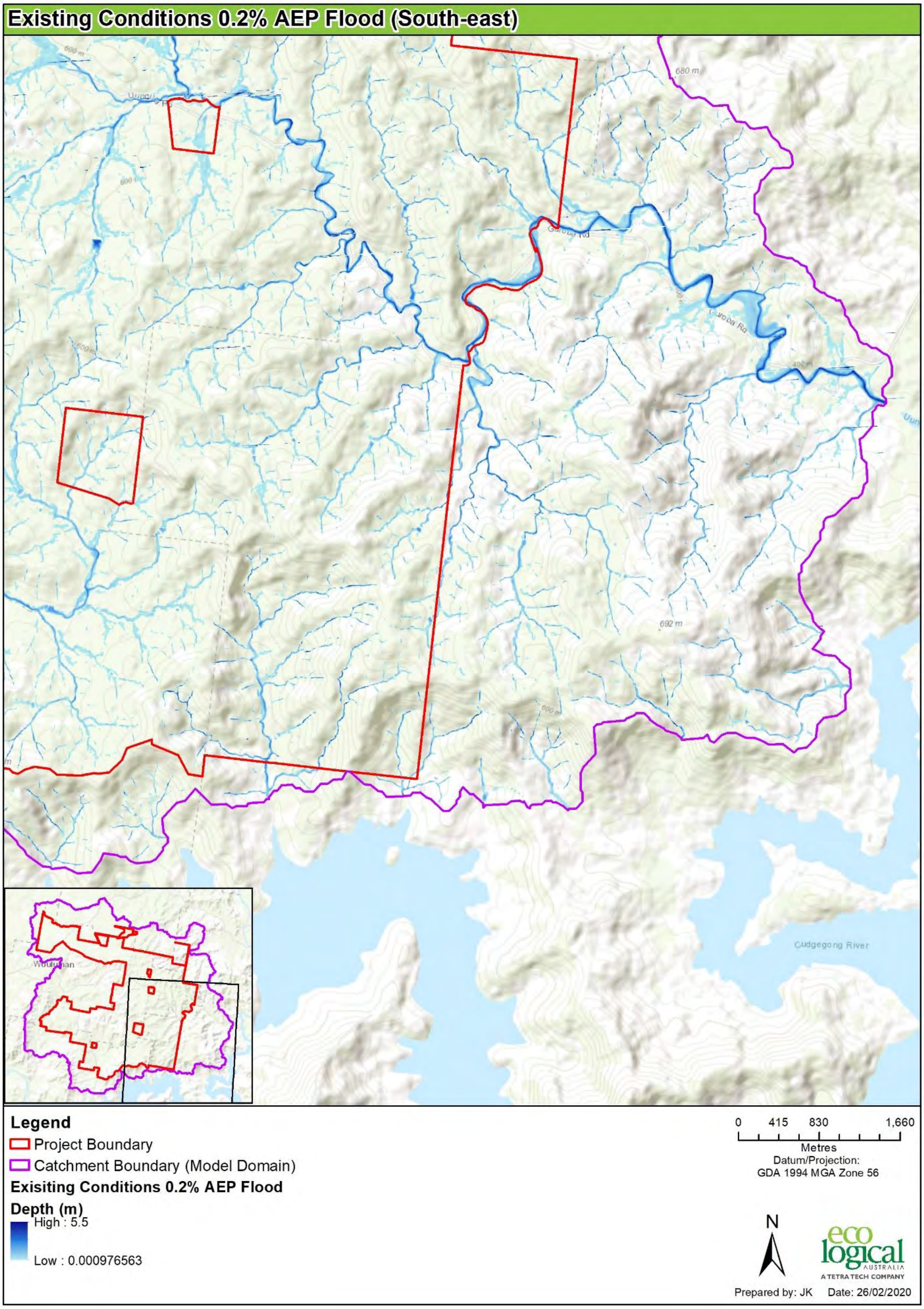

Figure 6-16 0.2% AEP Existing Conditions Flood Depths - South East

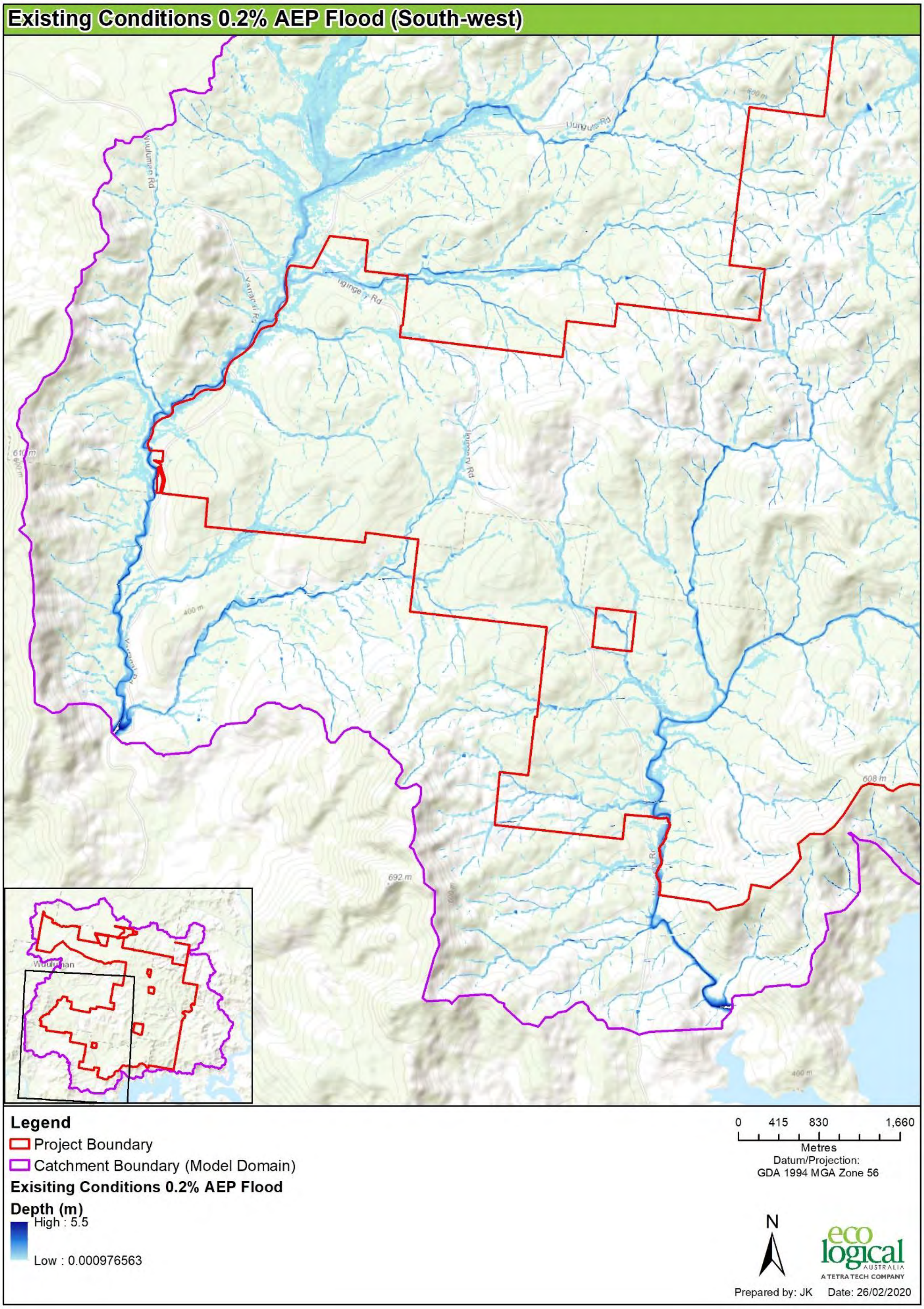

Figure 6-17 0.2% AEP Existing Conditions Flood Depths - South West

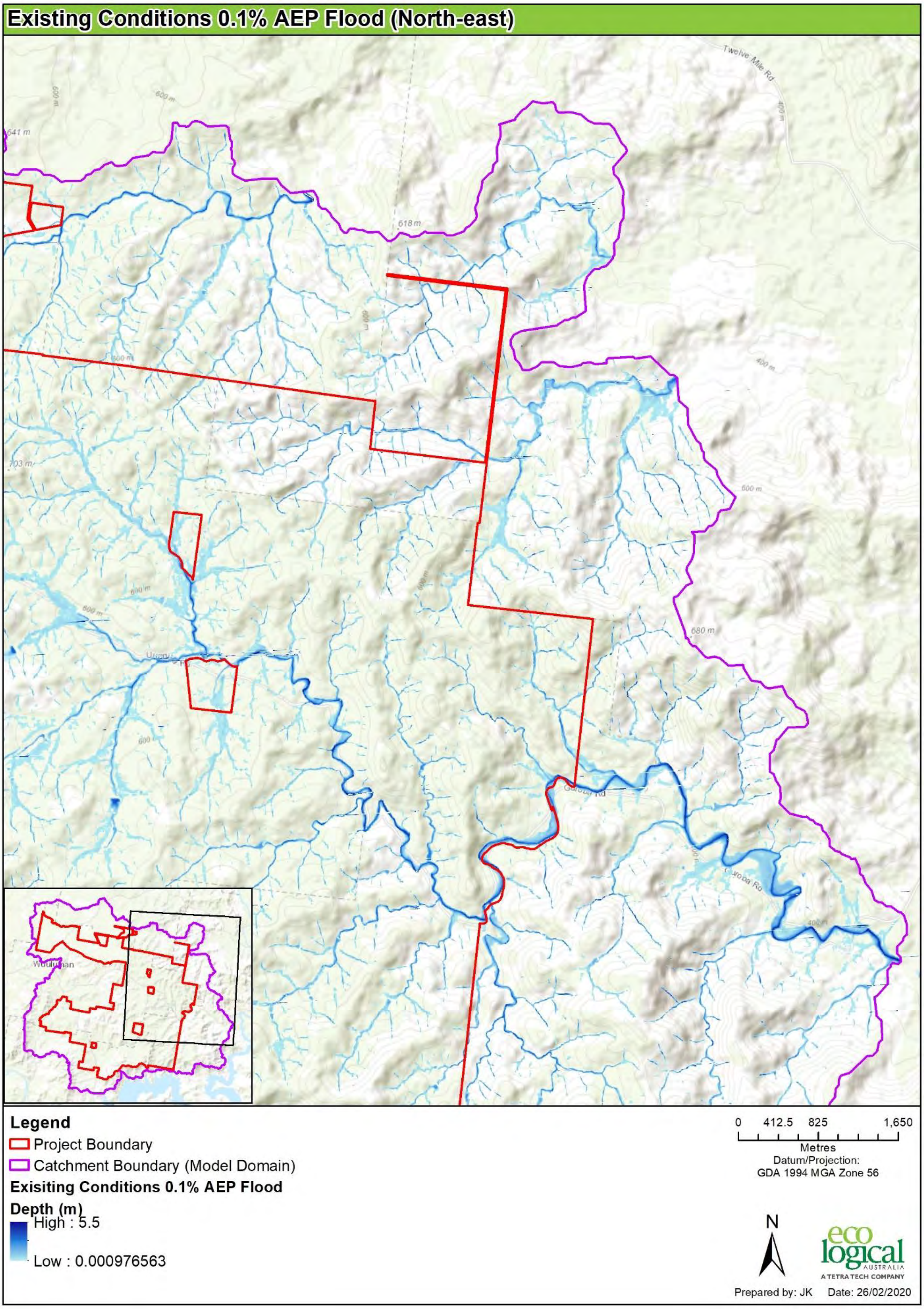

Figure 6-18 0.1% AEP Existing Conditions Flood Depths - North East

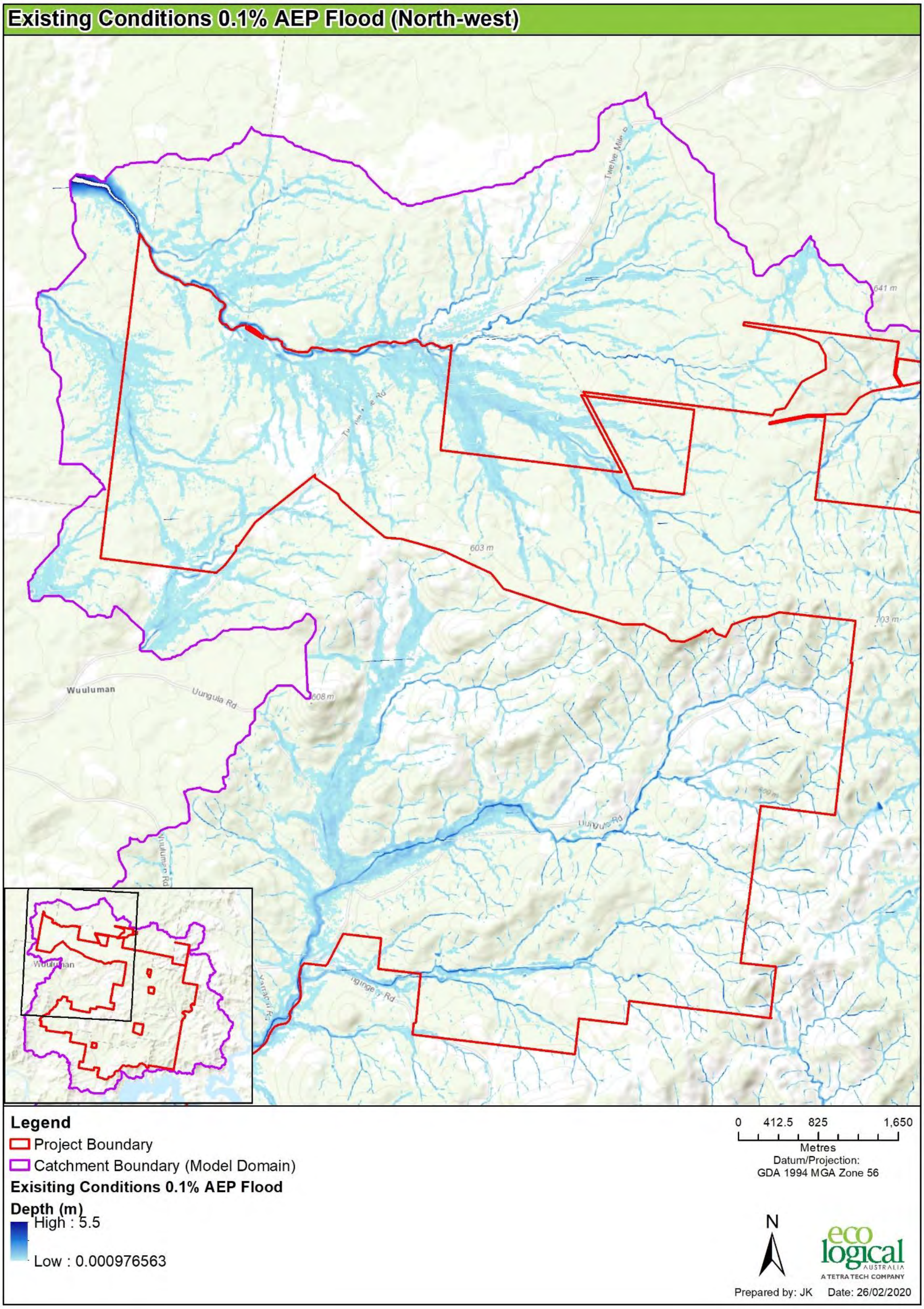

Figure 6-19 0.1% AEP Existing Conditions Flood Depths - North West

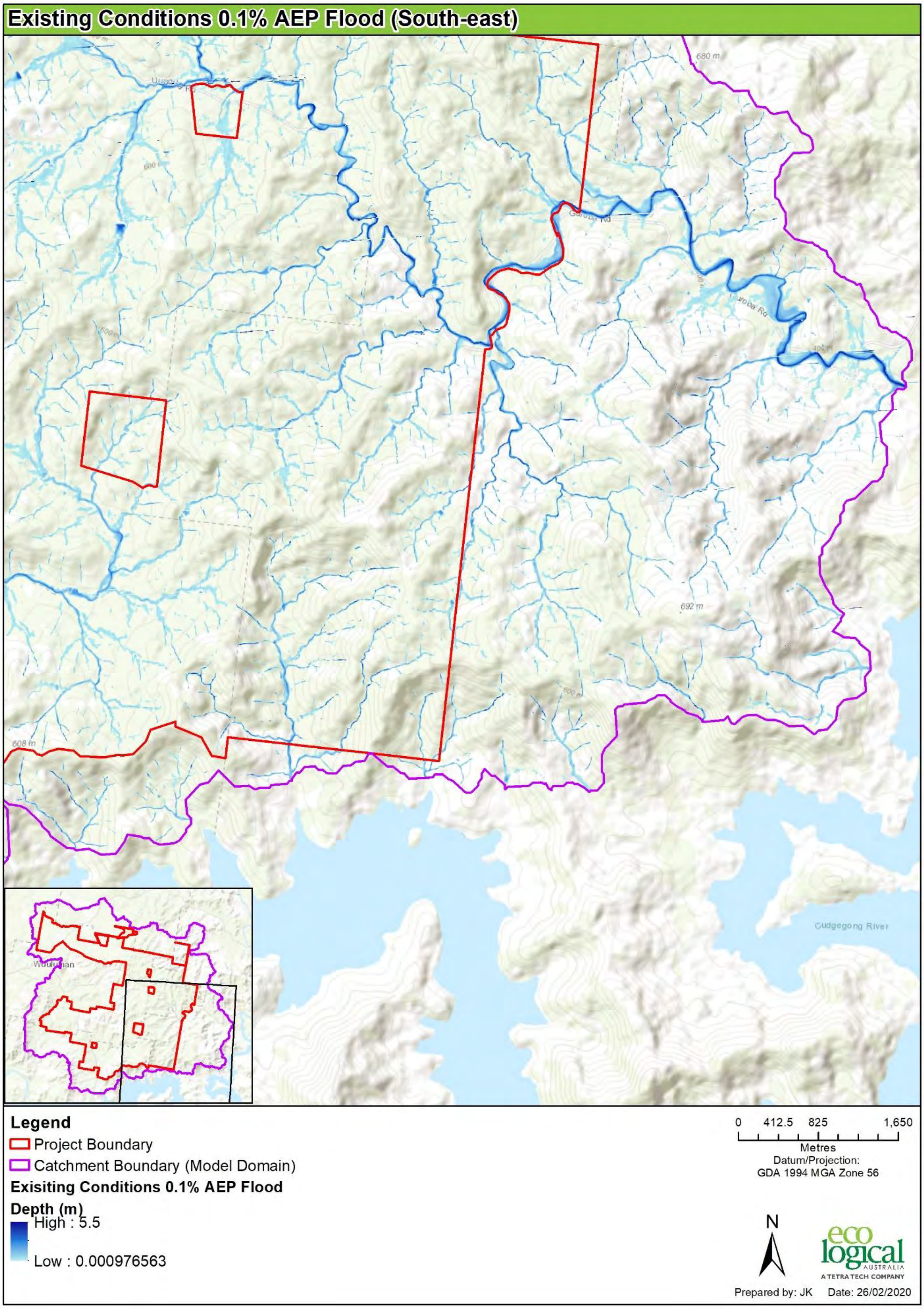

Figure 6-20 0.1% AEP Existing Conditions Flood Depths - South East

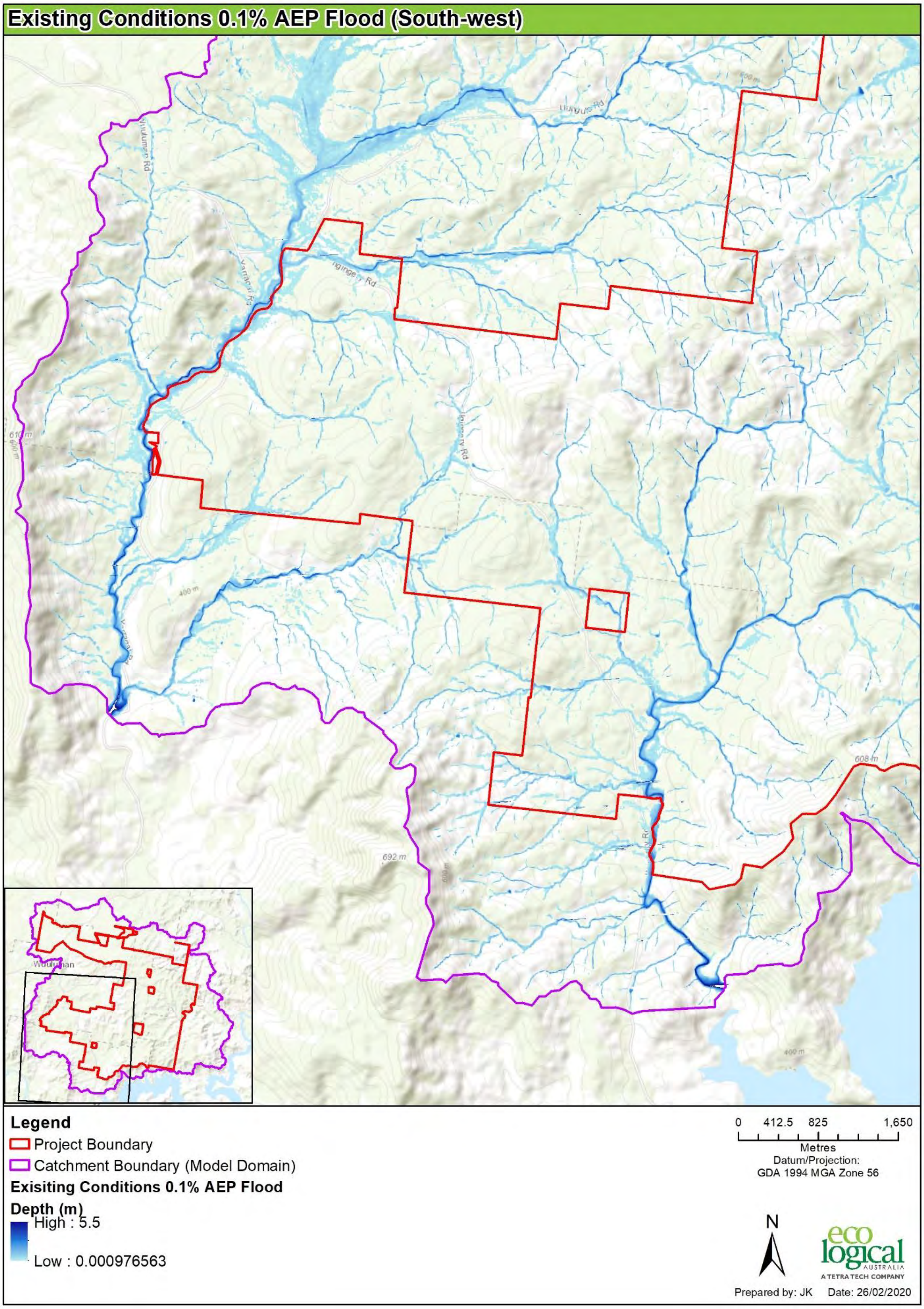

Figure 6-21 0.1% AEP Existing Conditions Flood Depths - South West

E2 Velocities

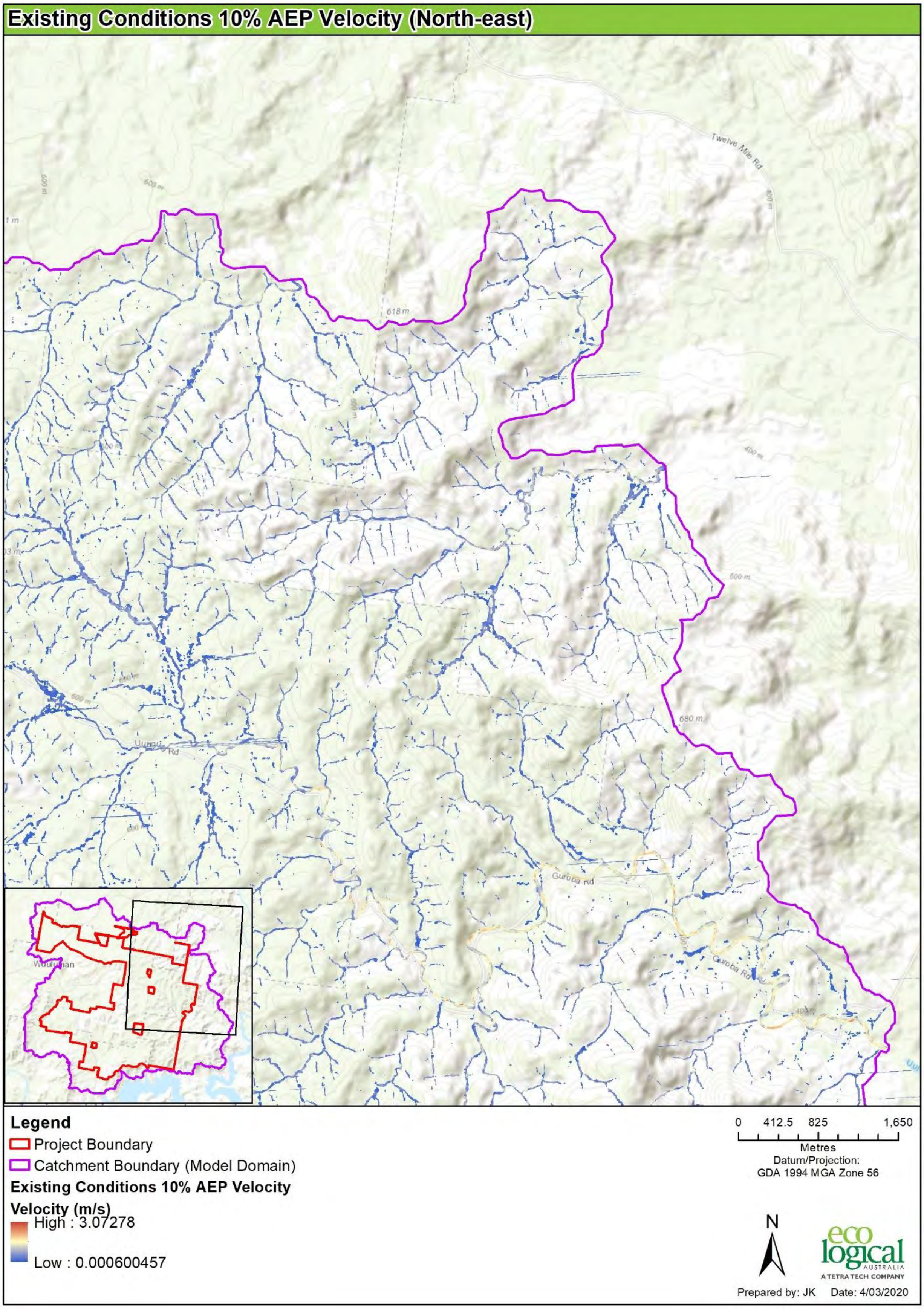

Figure 6-22 10% AEP Existing Conditions Velocities - North East

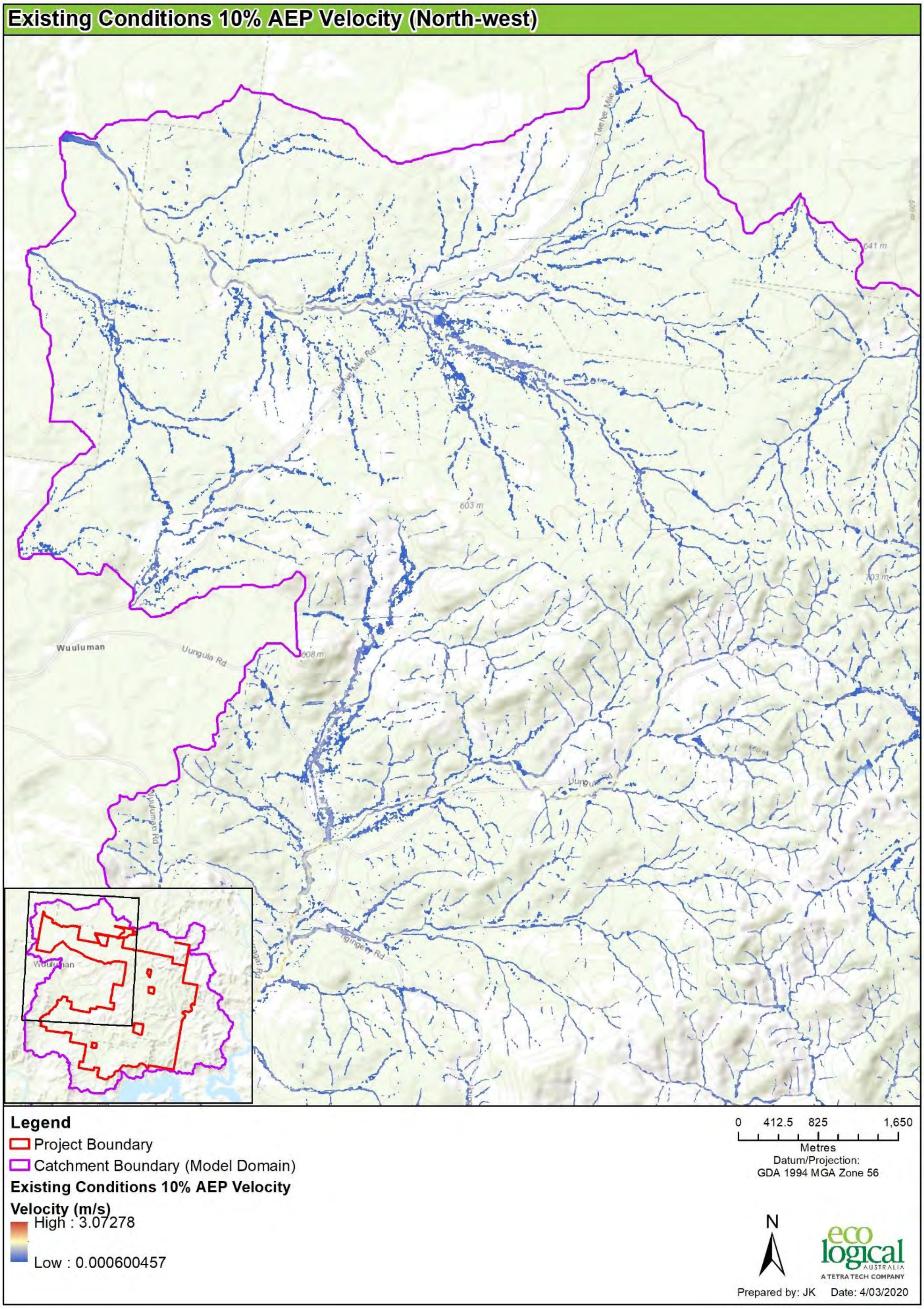

Figure 6-23 10% AEP Existing Conditions Velocities - North West

Figure 6-24 10% AEP Existing Conditions Velocities - South East

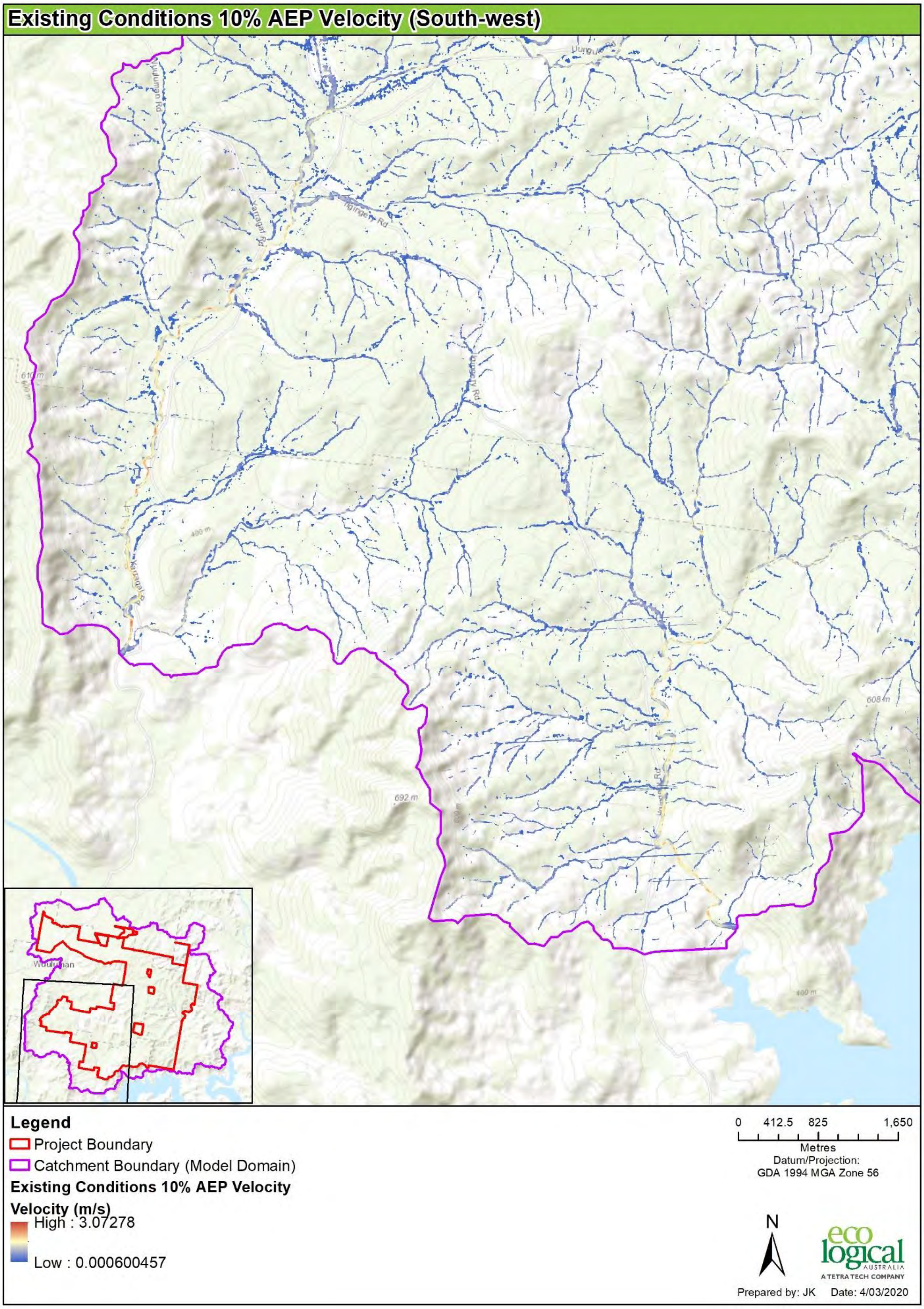

Figure 6-25 10% AEP Existing Conditions Velocities - South West

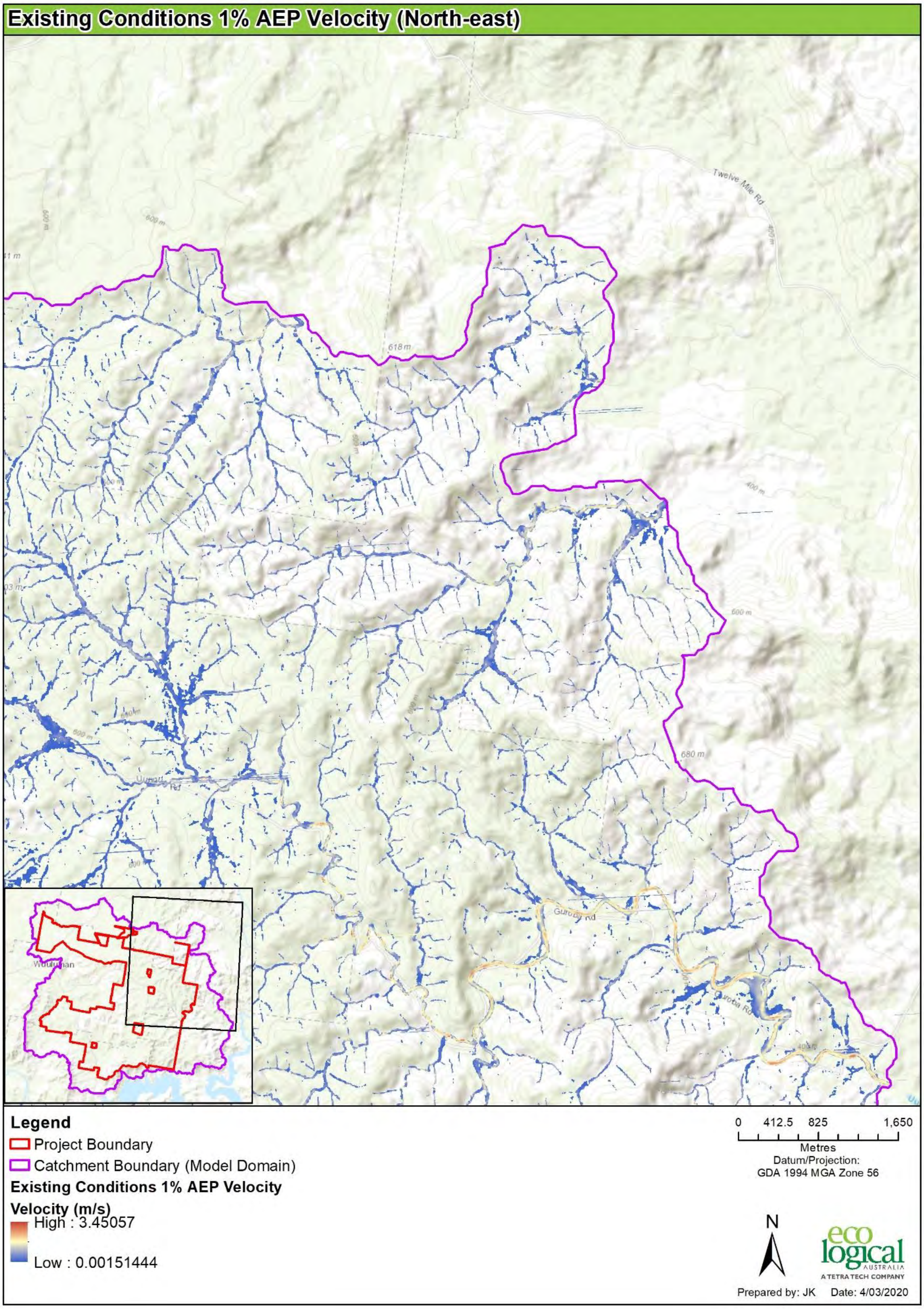

Figure 6-26 1% AEP Existing Conditions Velocities - North East

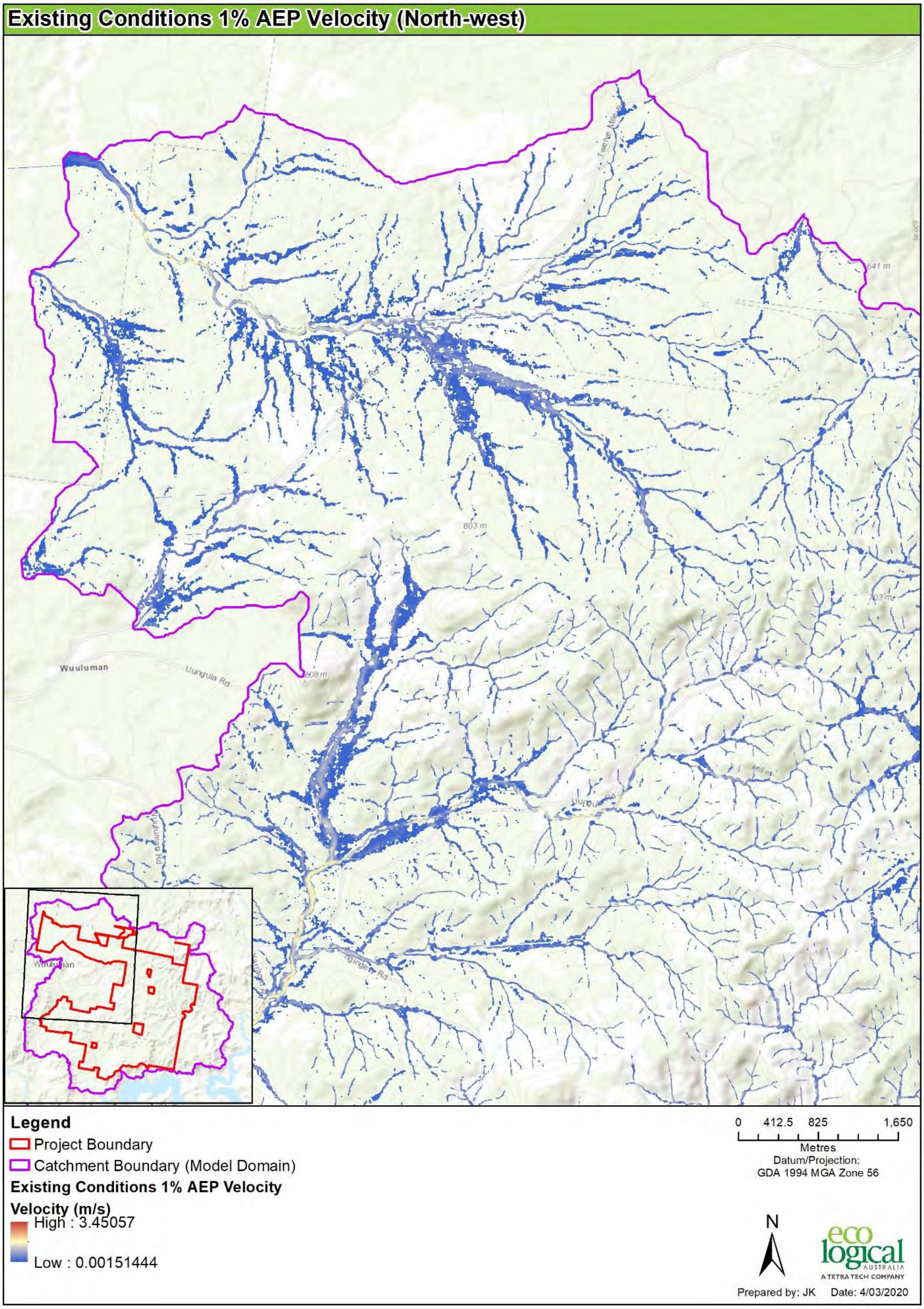

Figure 6-27 1% AEP Existing Conditions Velocities - North West

Figure 6-28 1% AEP Existing Conditions Velocities - South East

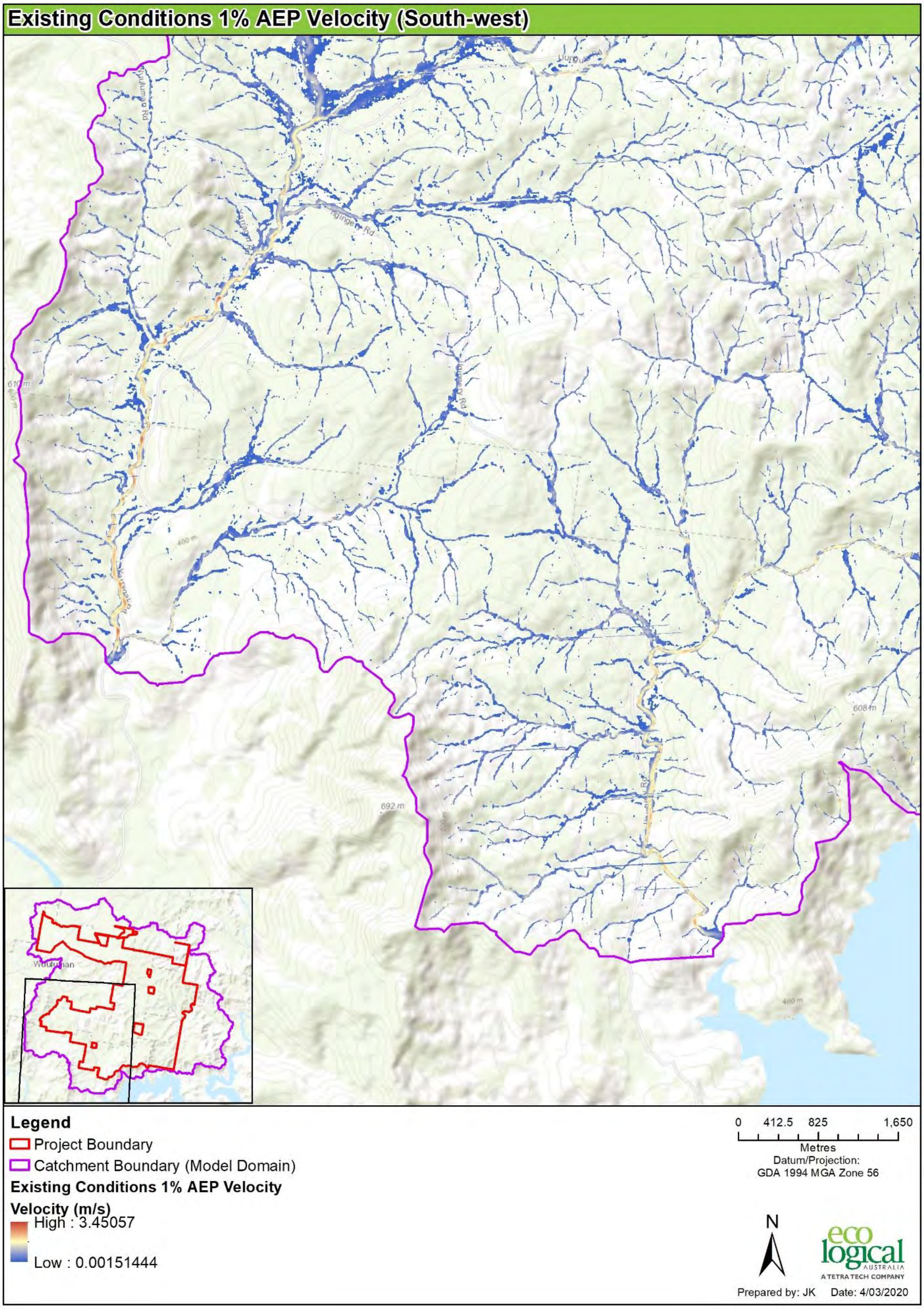

Figure 6-29 1% AEP Existing Conditions Velocities - South West

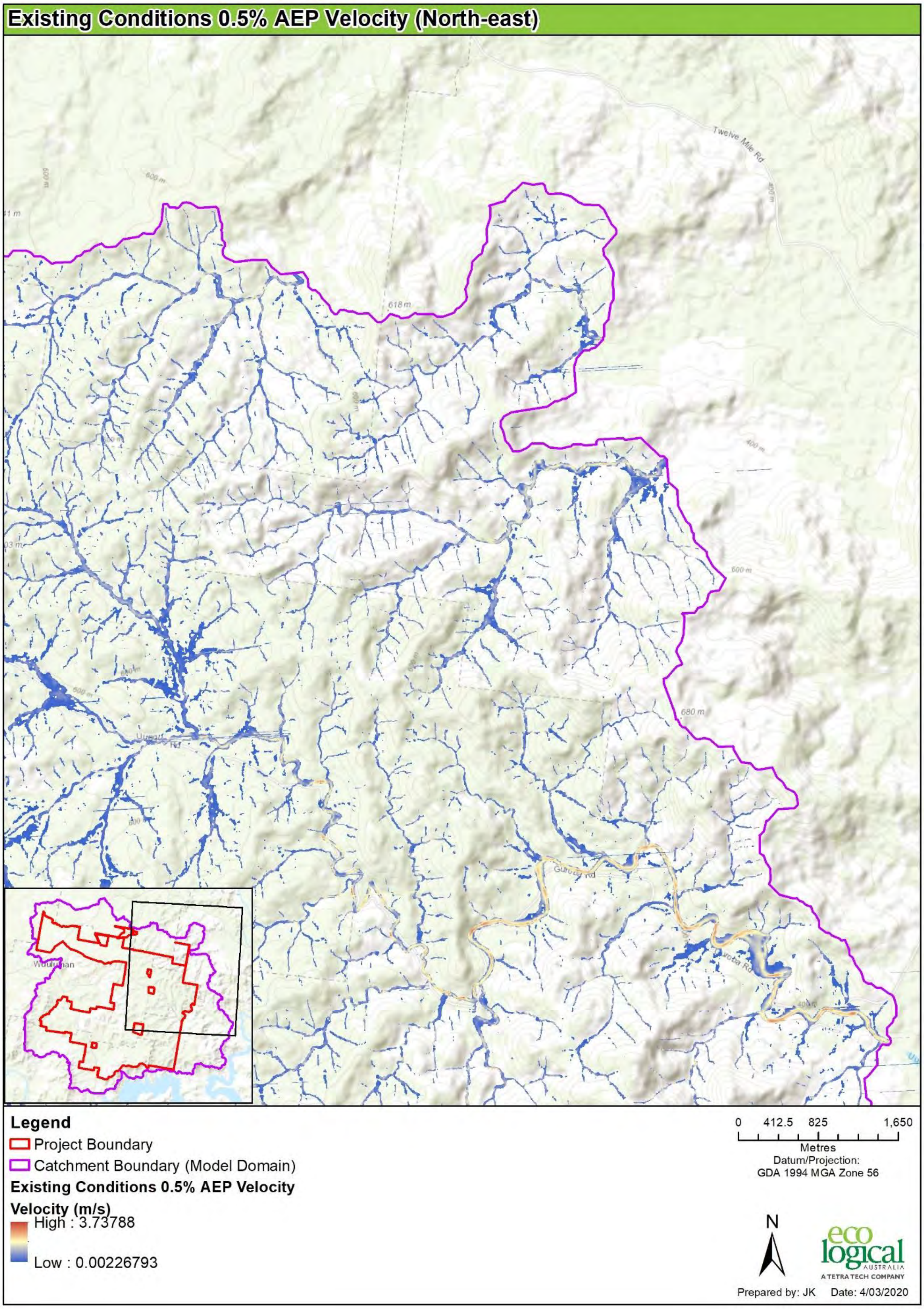

Figure 6-30 0.5% AEP Existing Conditions Velocities - North East

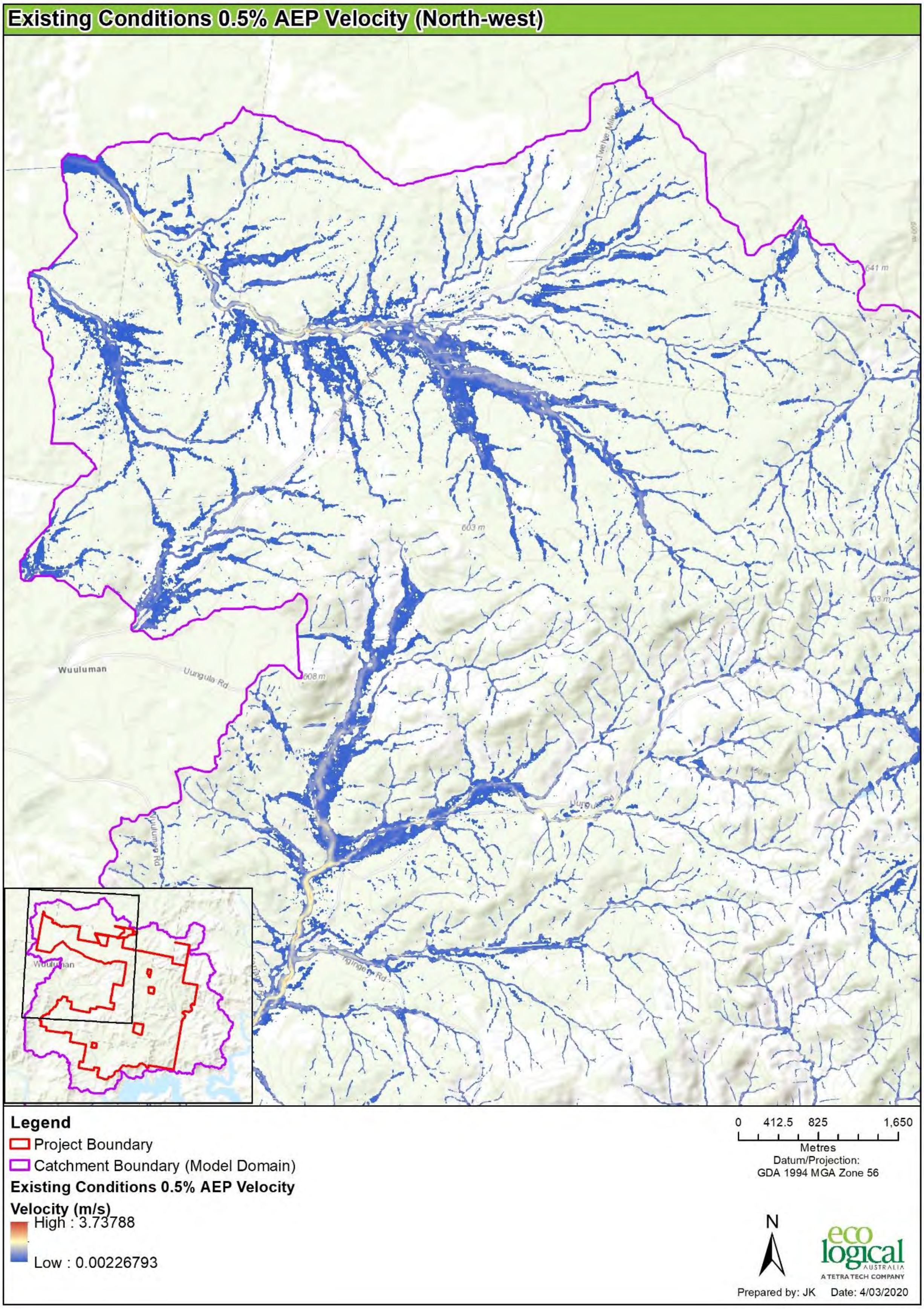

Figure 6-31 0.5% AEP Existing Conditions Velocities - North West

Figure 6-32 0.5% AEP Existing Conditions Velocities - South East

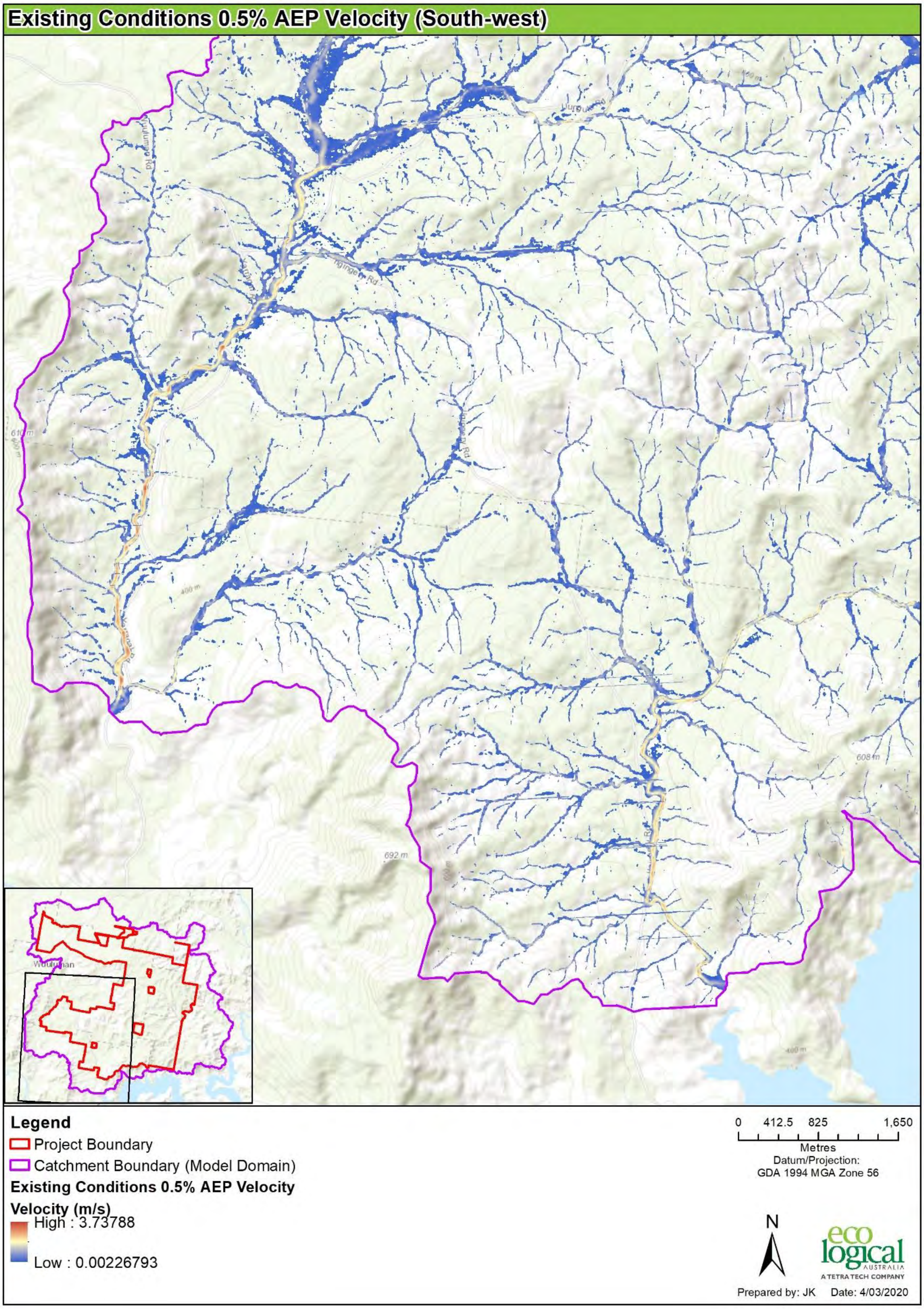

Figure 6-33 0.5% AEP Existing Conditions Velocities - South West

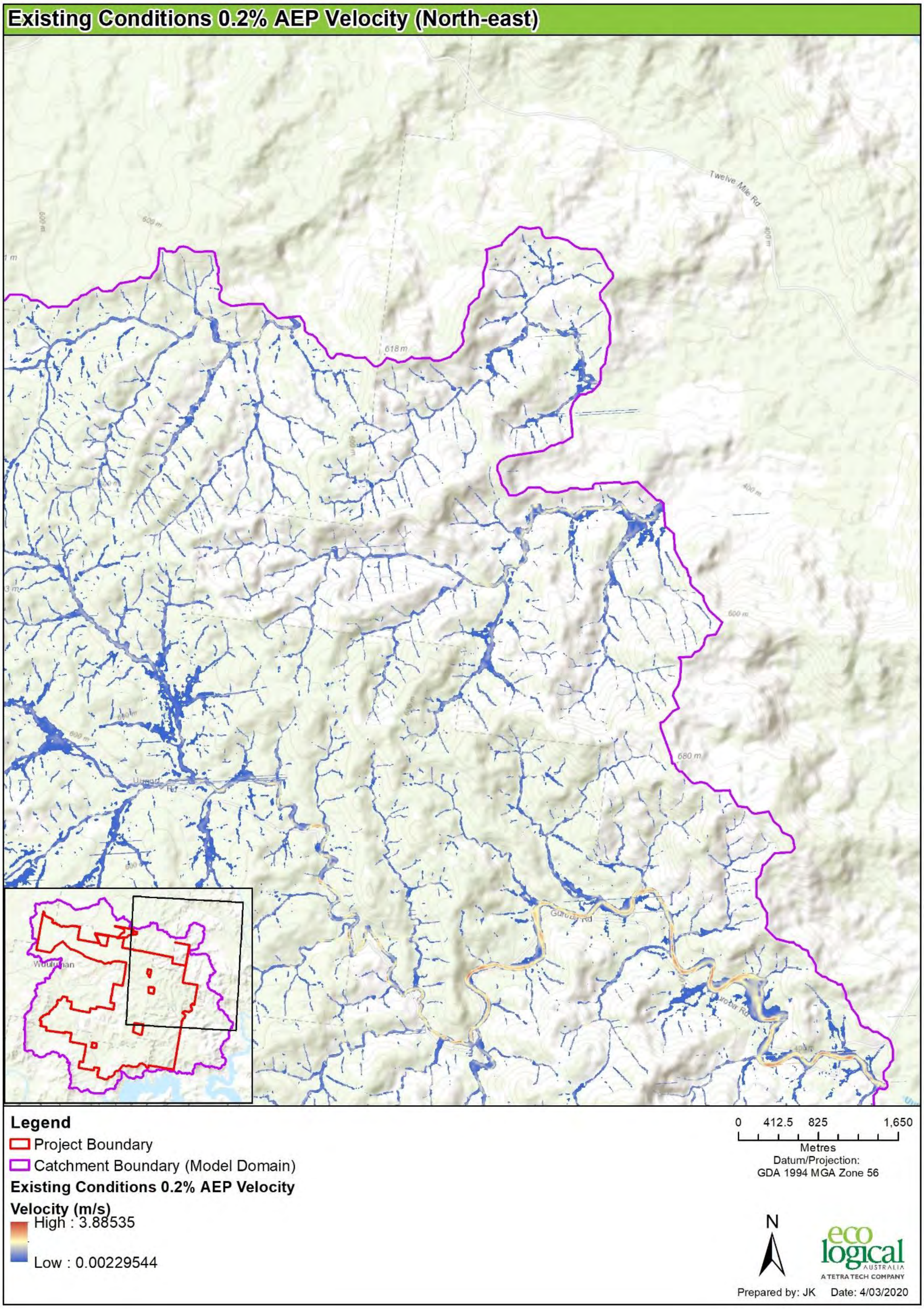

Figure 6-34 0.2% AEP Existing Conditions Velocities - North East

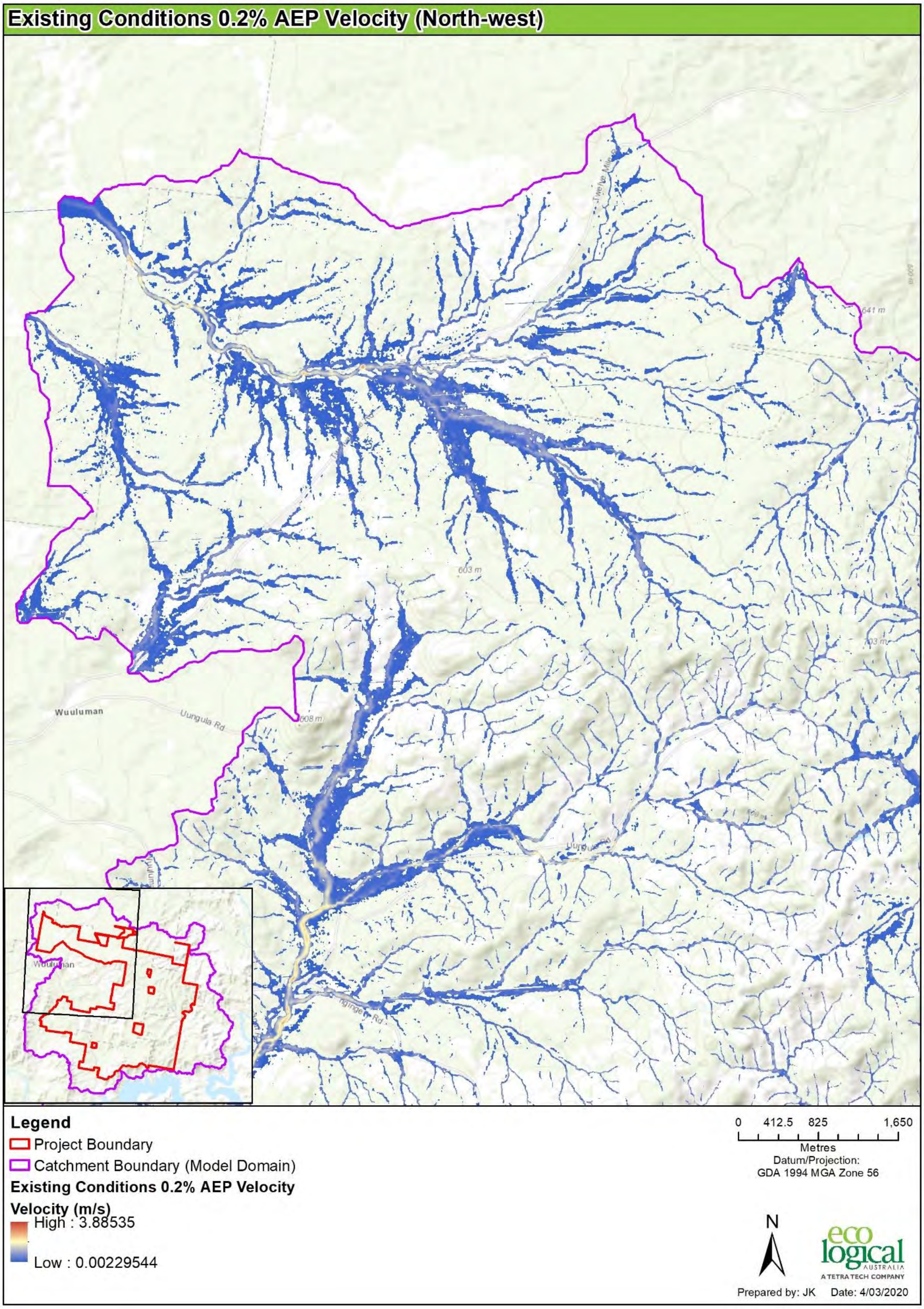

Figure 6-35 0.2% AEP Existing Conditions Velocities - North West

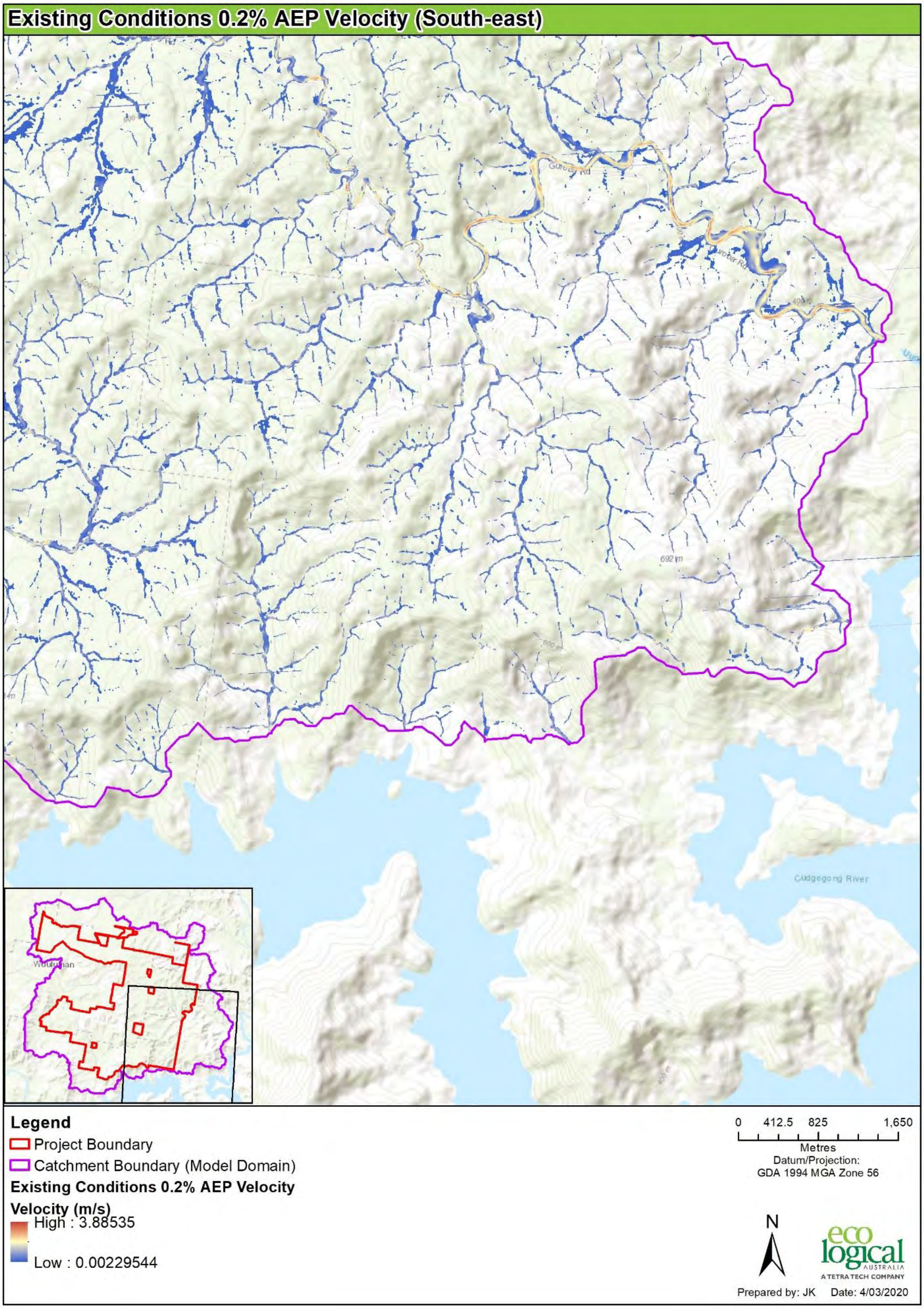

Figure 6-36 0.2% AEP Existing Conditions Velocities - South East

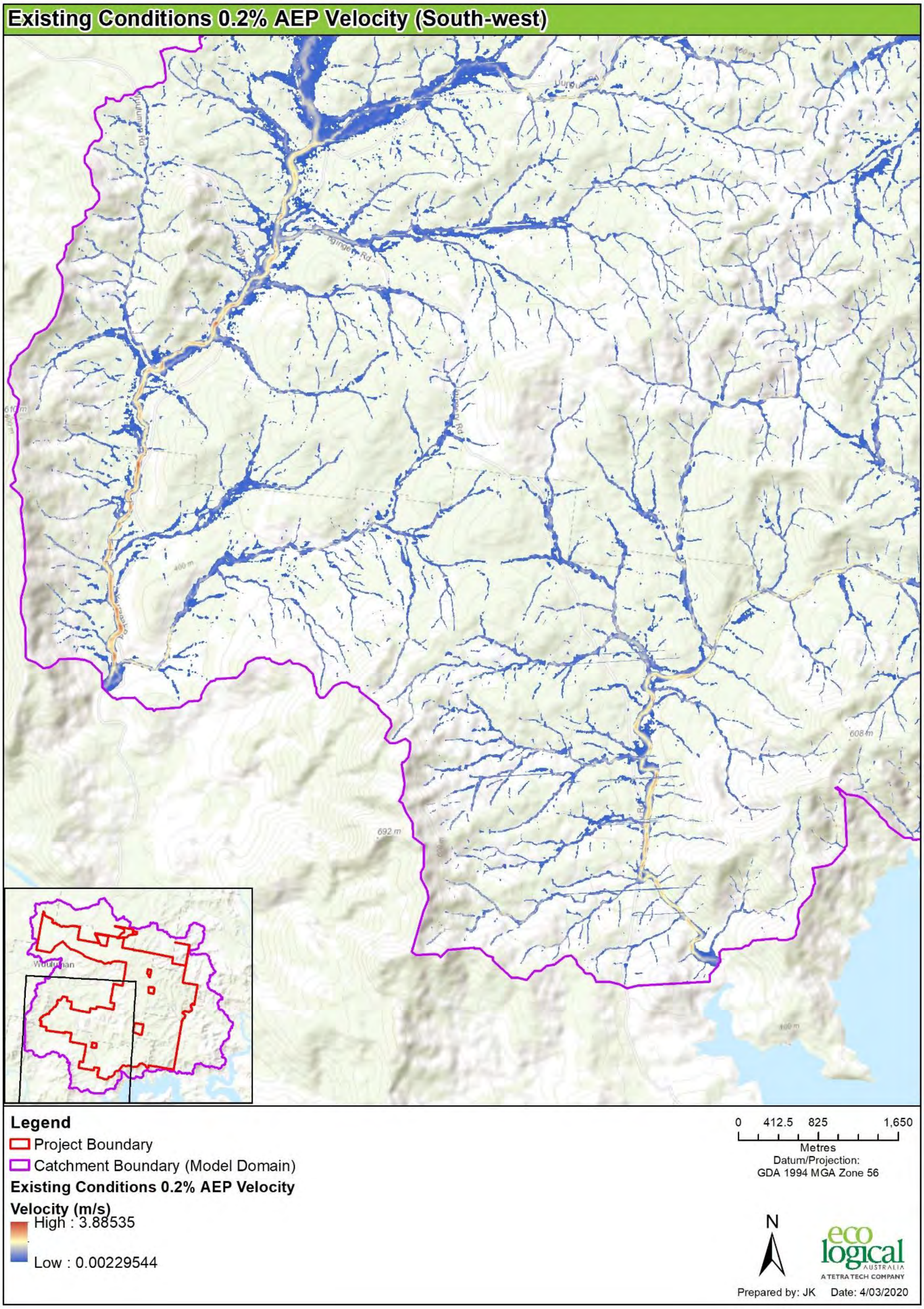

Figure 6-37 0.2% AEP Existing Conditions Velocities - South West

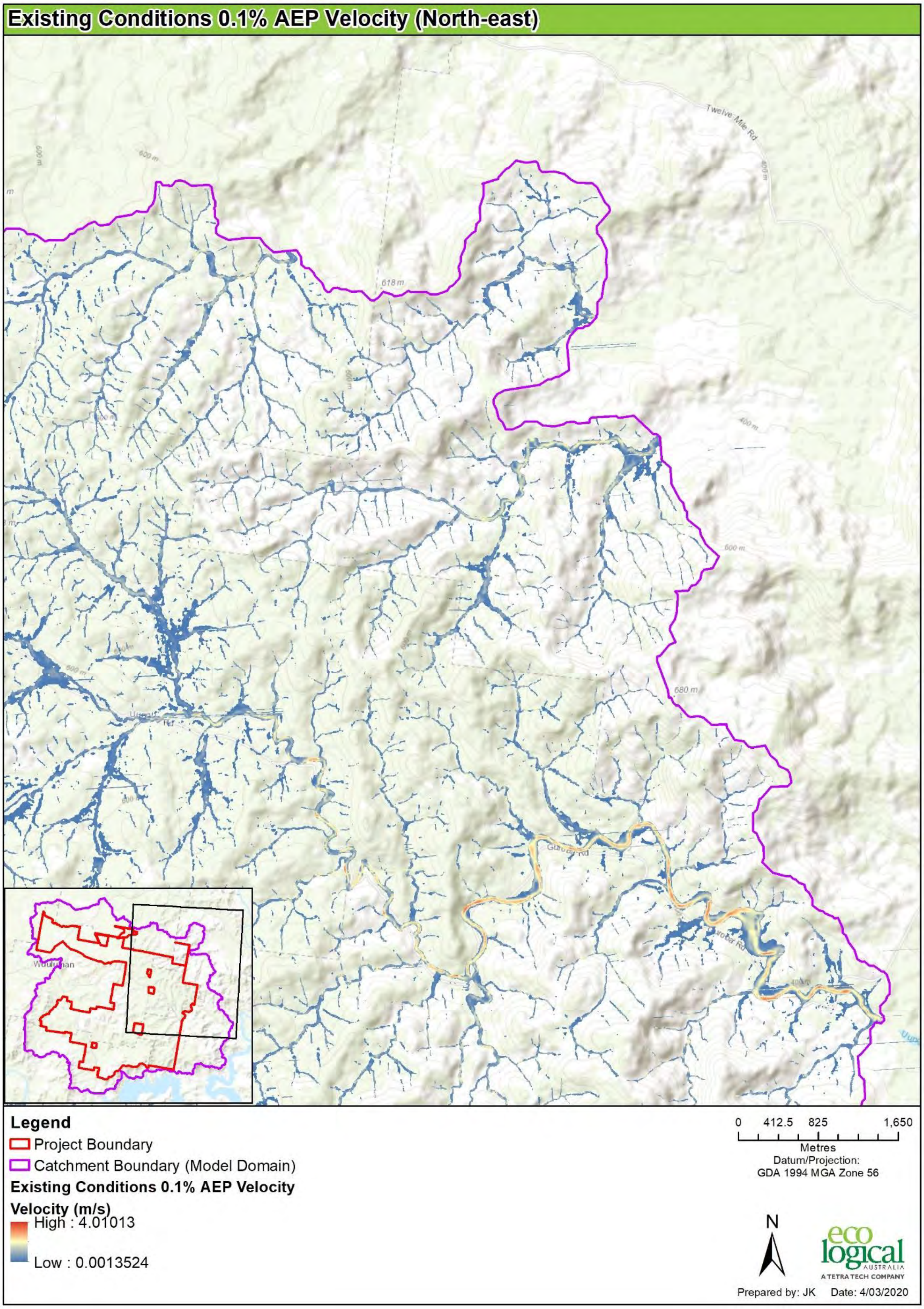

Figure 6-38 0.1% AEP Existing Conditions Velocities - North East

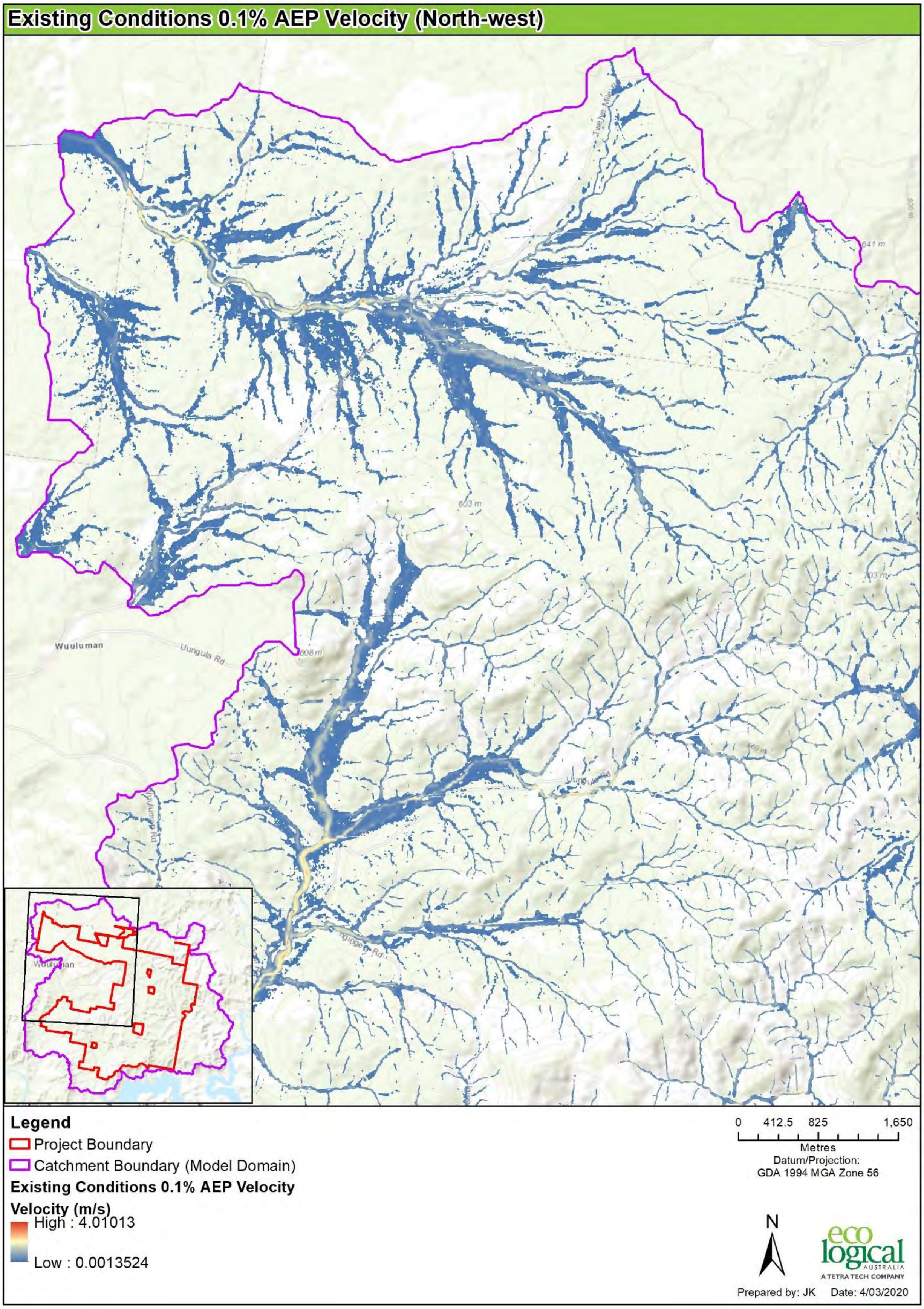

Figure 6-39 0.1% AEP Existing Conditions Velocities - North West

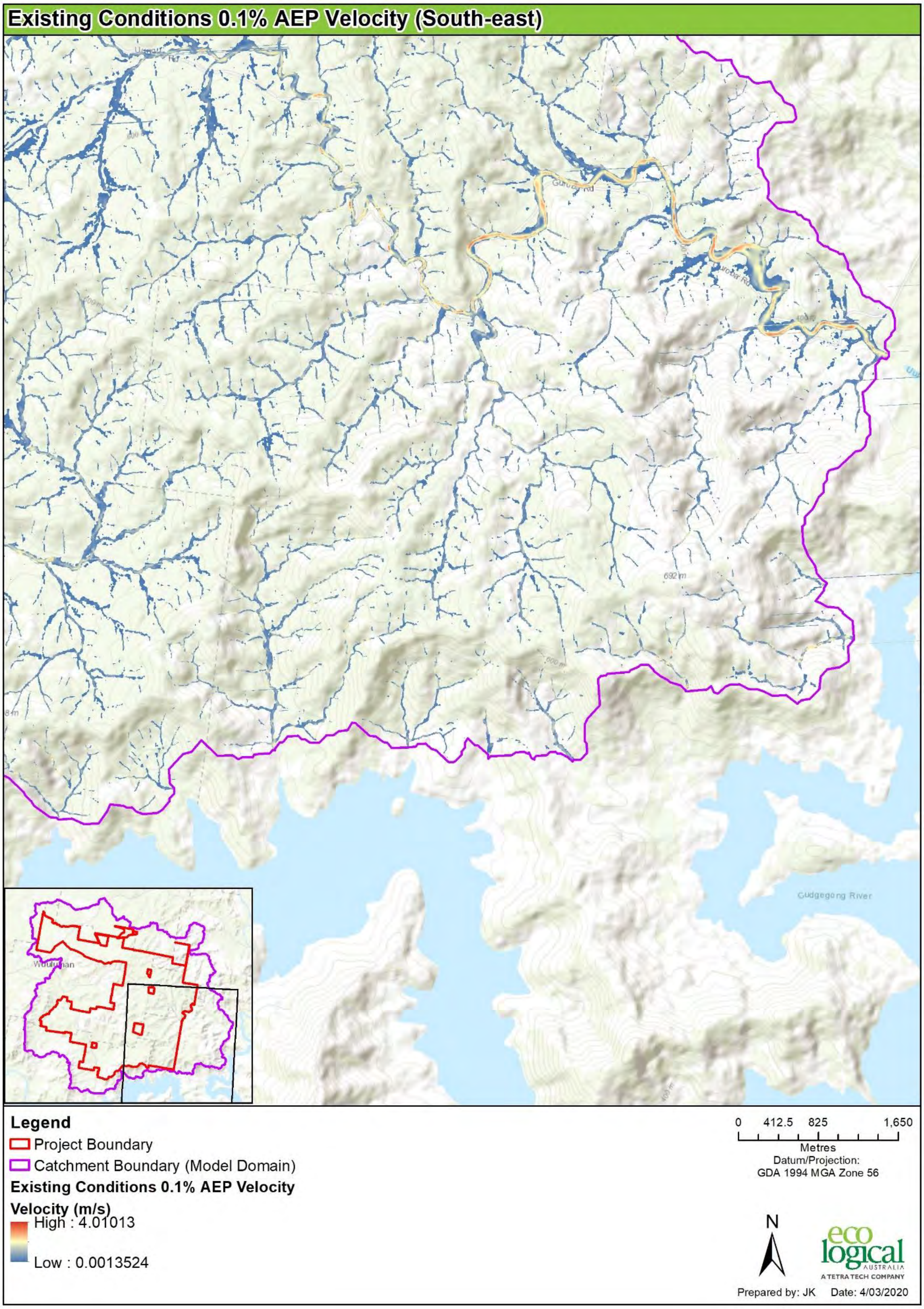

Figure 6-40 0.1% AEP Existing Conditions Velocities - South East

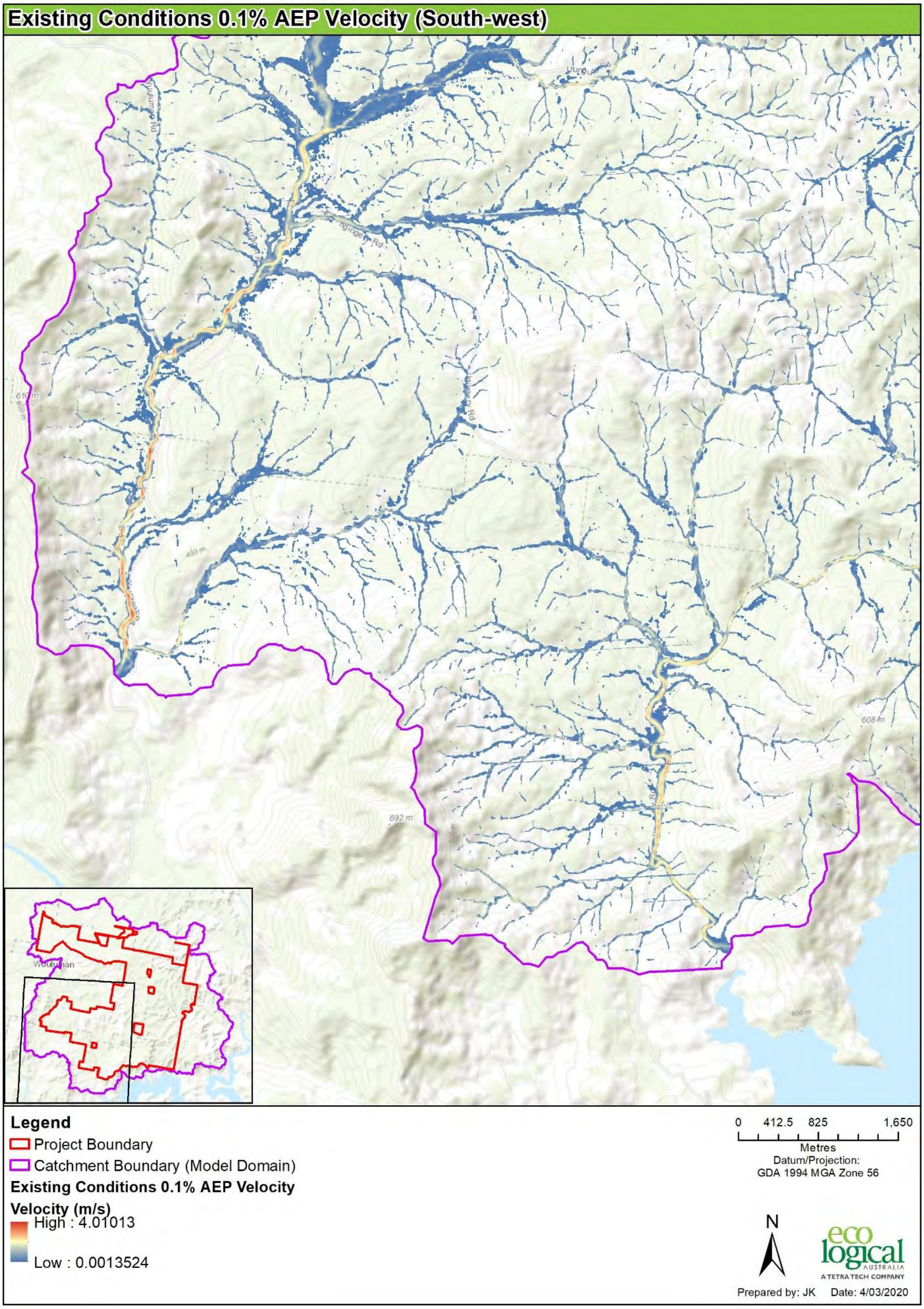

Figure 6-41 0.1% AEP Existing Conditions Velocities - South West

Appendix F Proposed Conditions HEC-RAS Results

F1 Flood depths

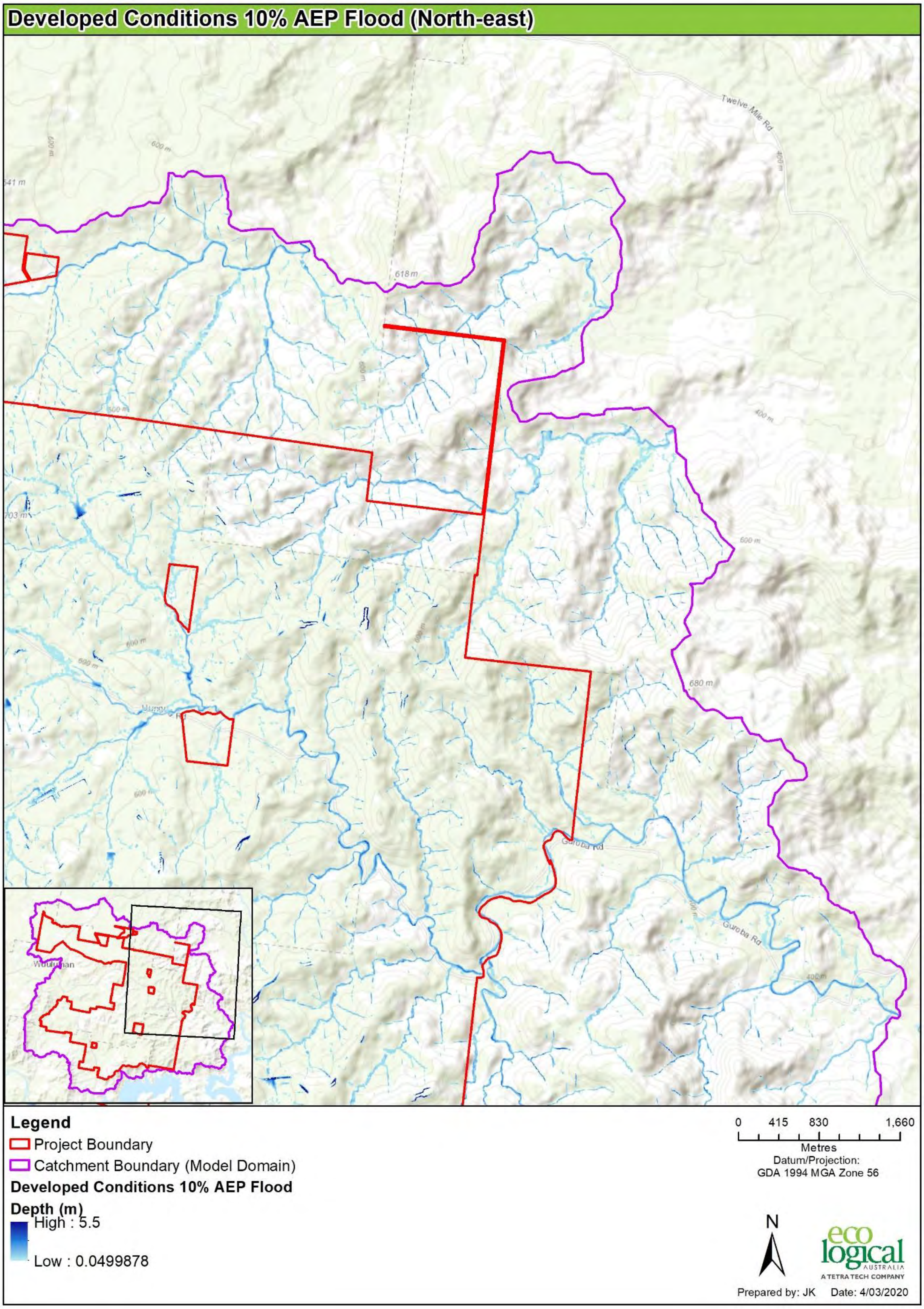

Figure 6-42 10% AEP Proposed Conditions Flood Depths - North East

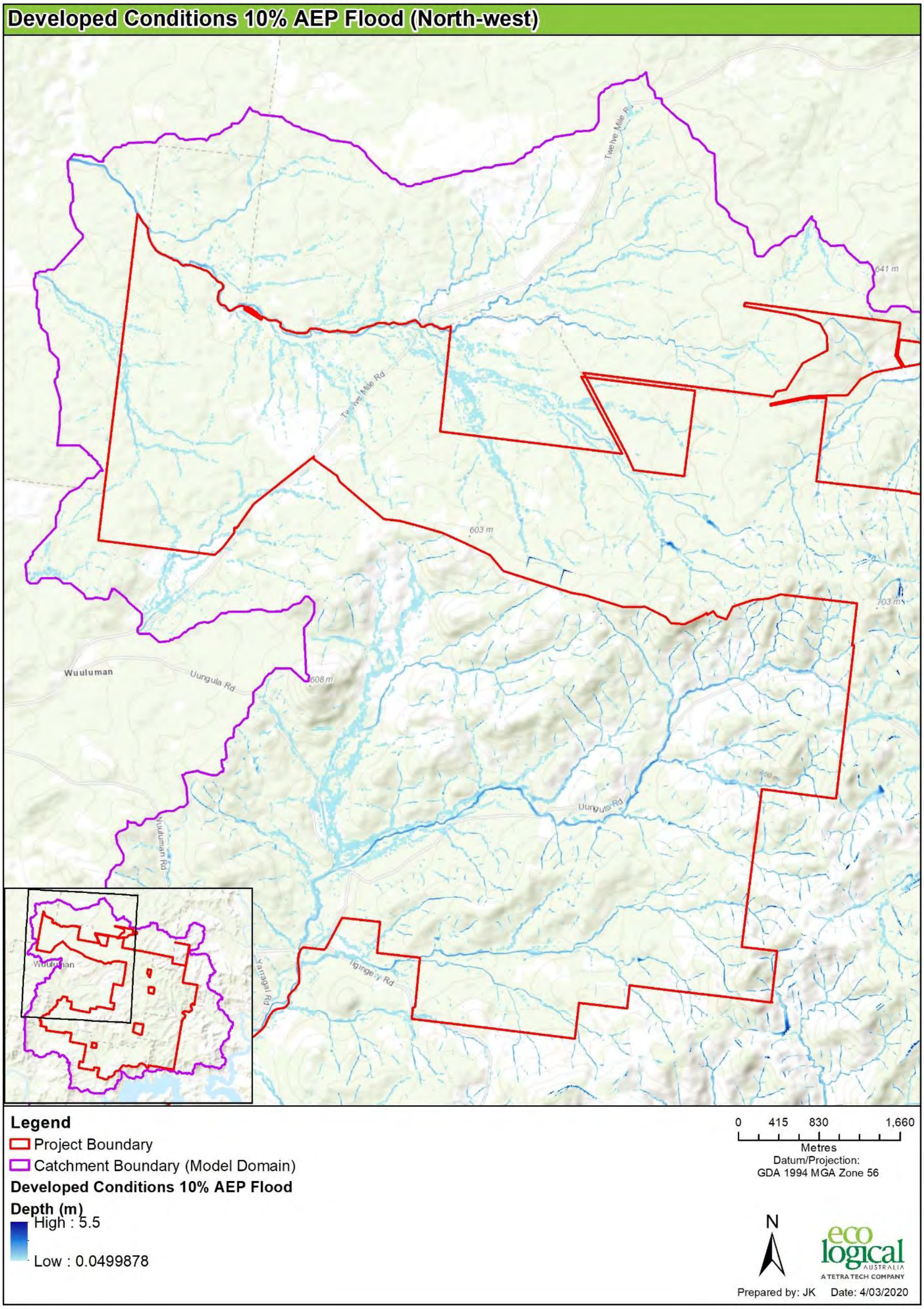

Figure 6-43 10% AEP Proposed Conditions Flood Depths - North West

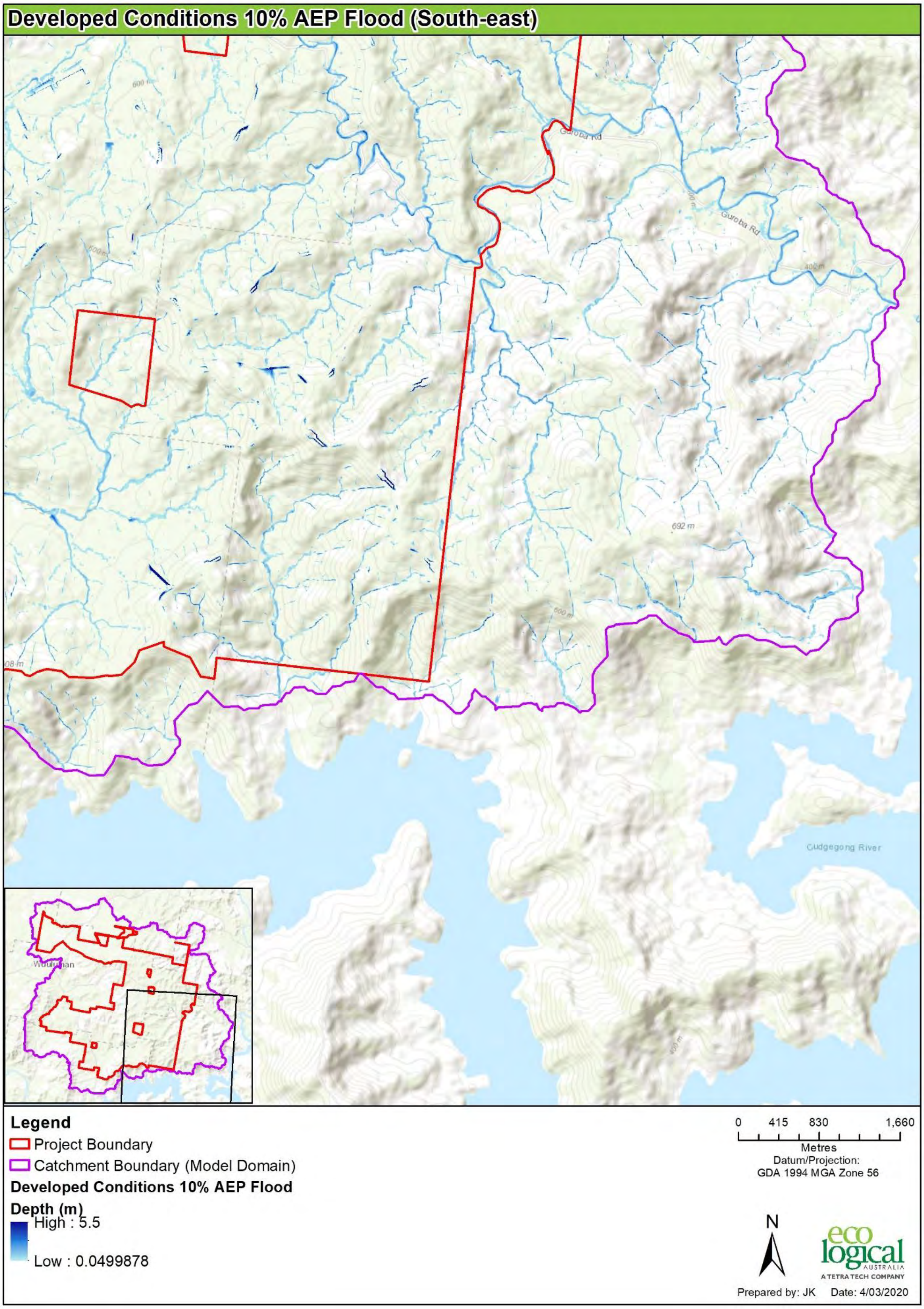

Figure 6-44 10% AEP Proposed Conditions Flood Depths - South East

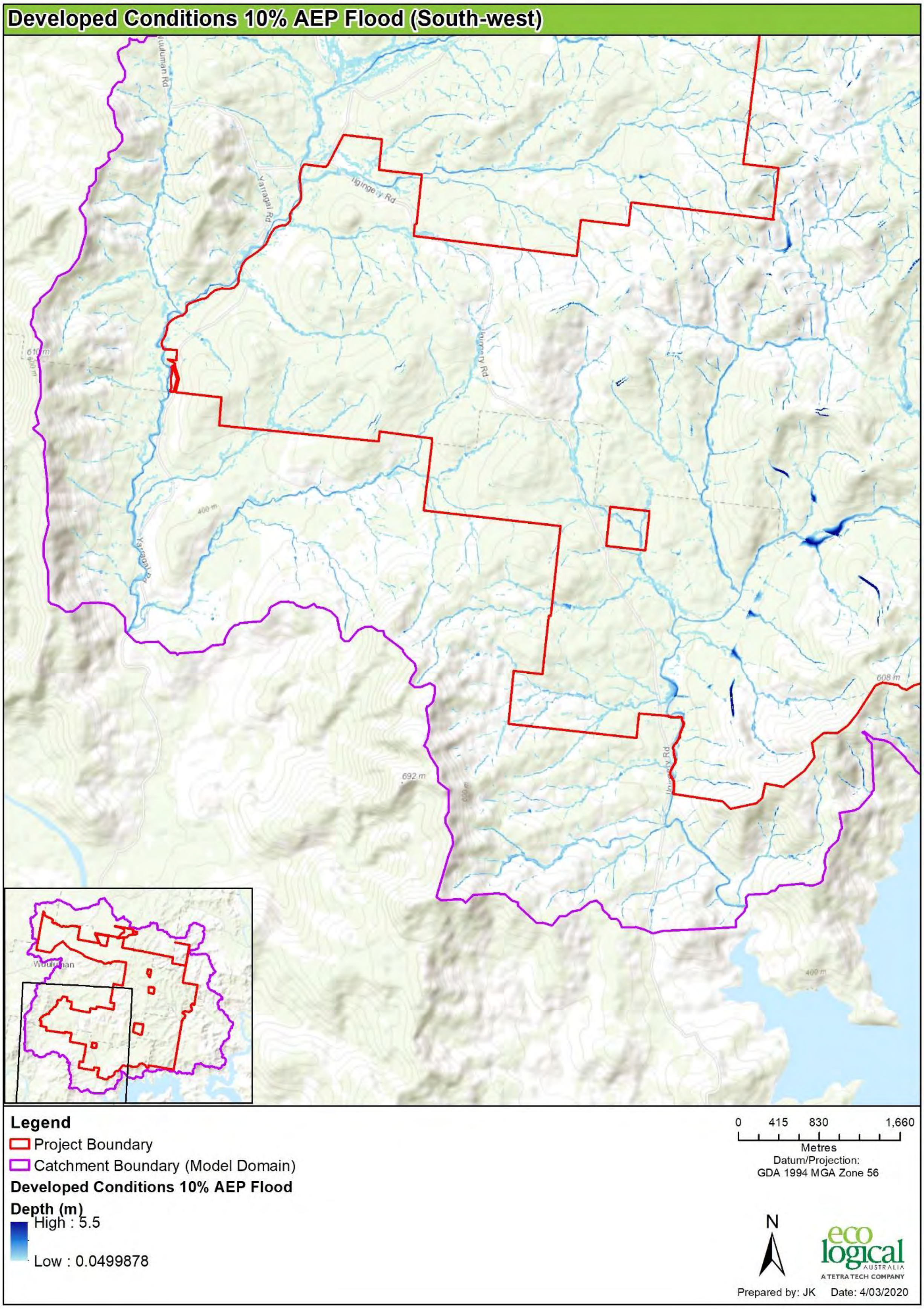

Figure 6-45 10% AEP Proposed Conditions Flood Depths - South West

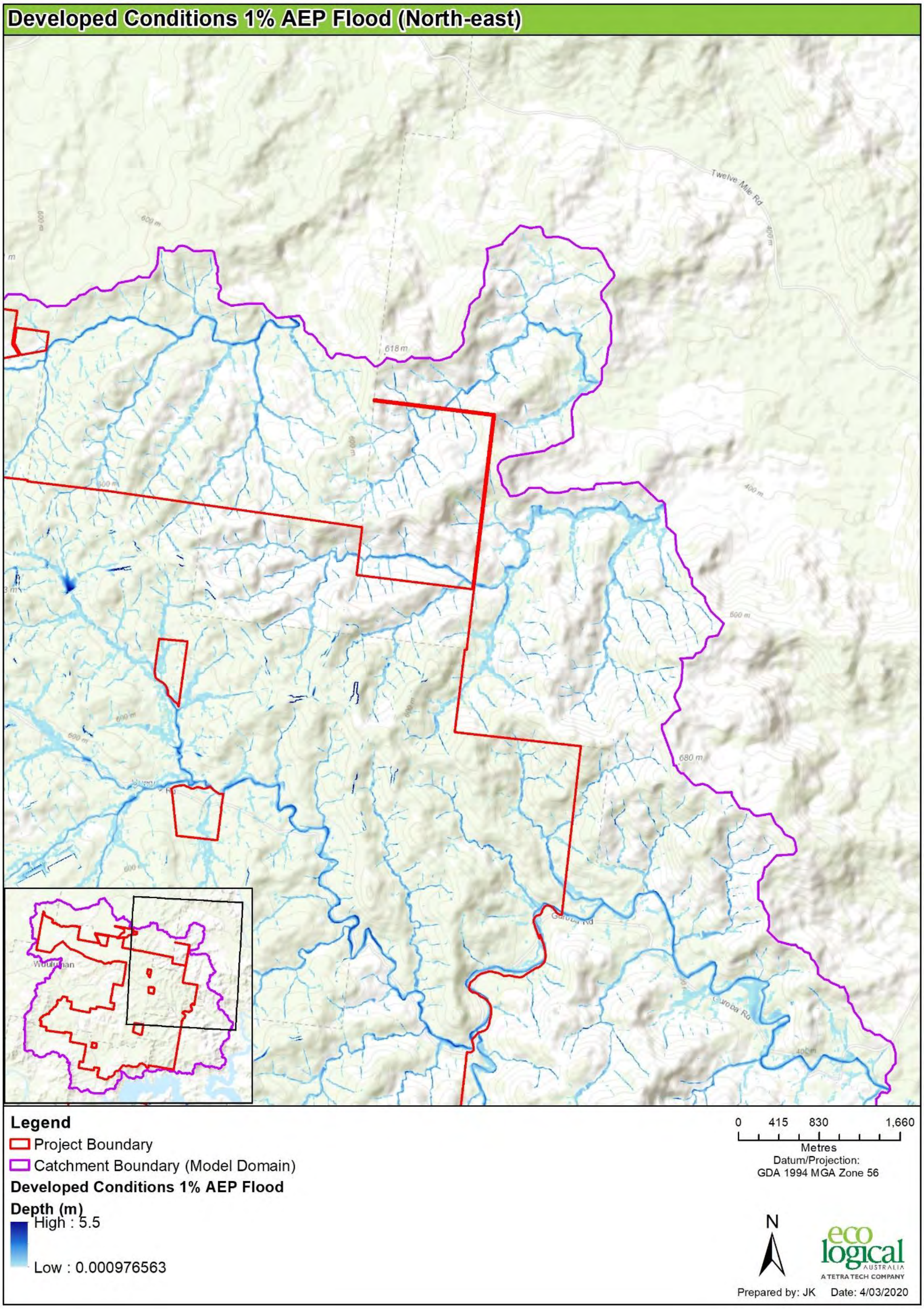

Figure 6-46 1% AEP Proposed Conditions Flood Depths - North East

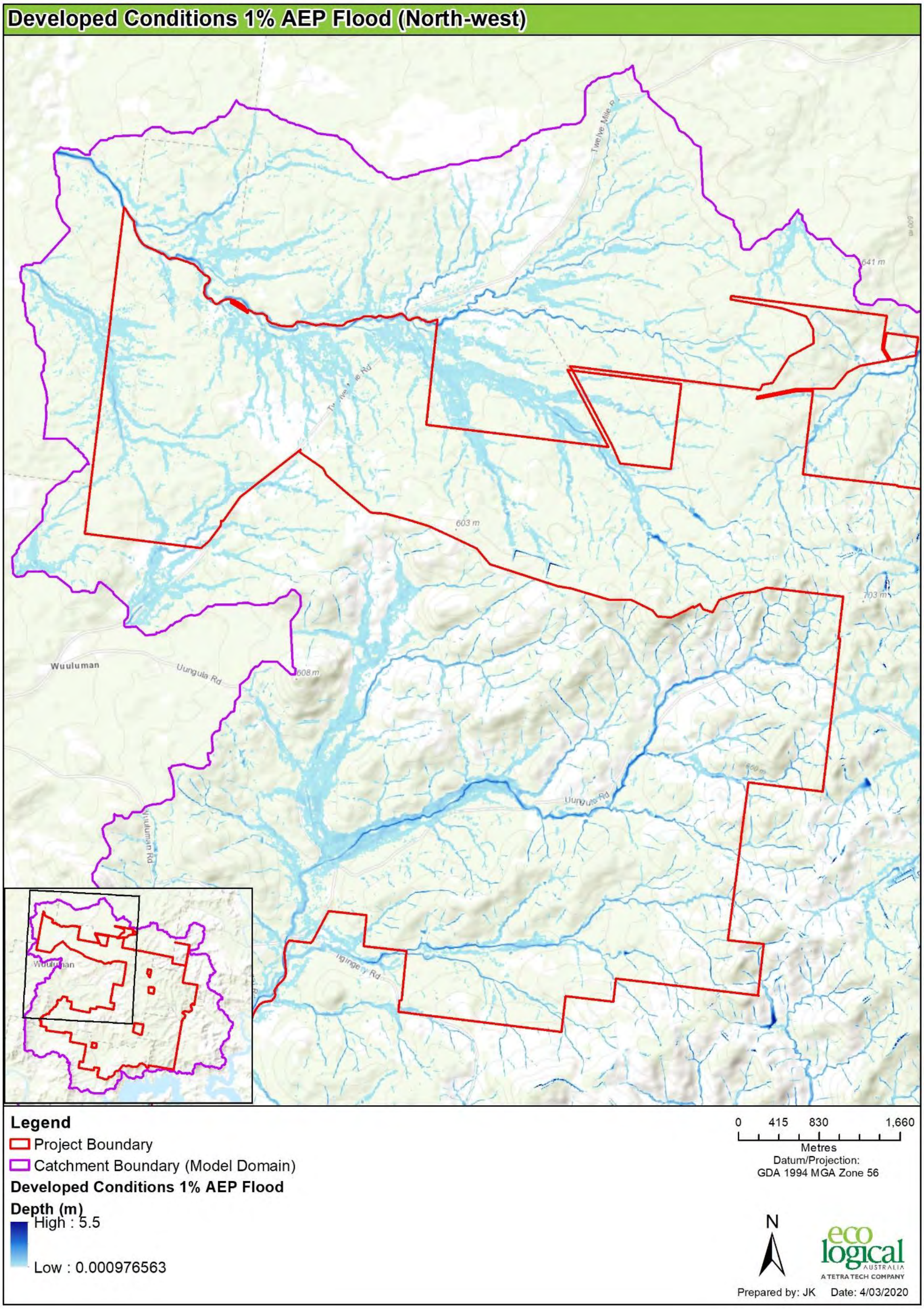

Figure 6-47 1% AEP Proposed Conditions Flood Depths - North West

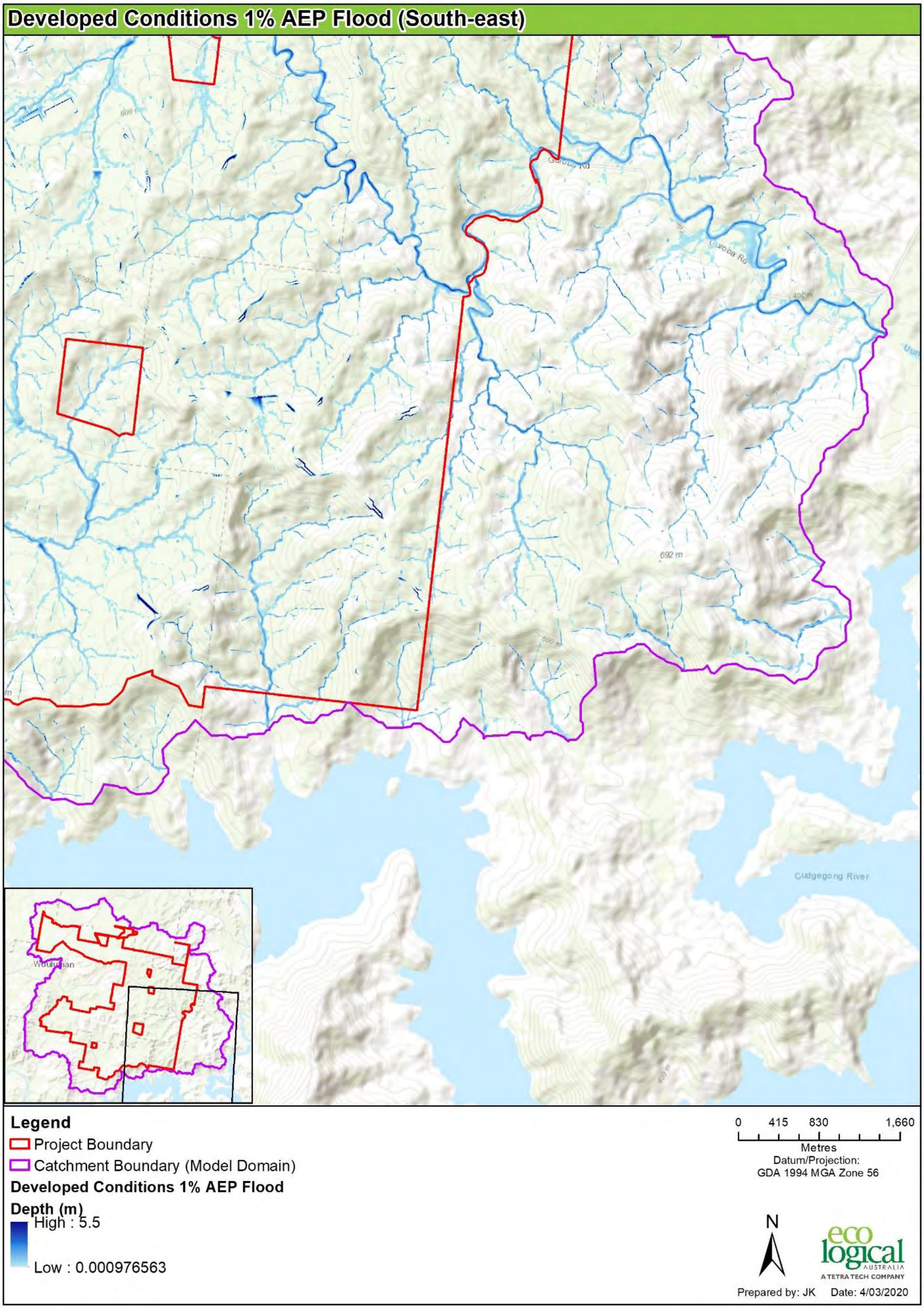

Figure 6-48 1% AEP Proposed Conditions Flood Depths - South East

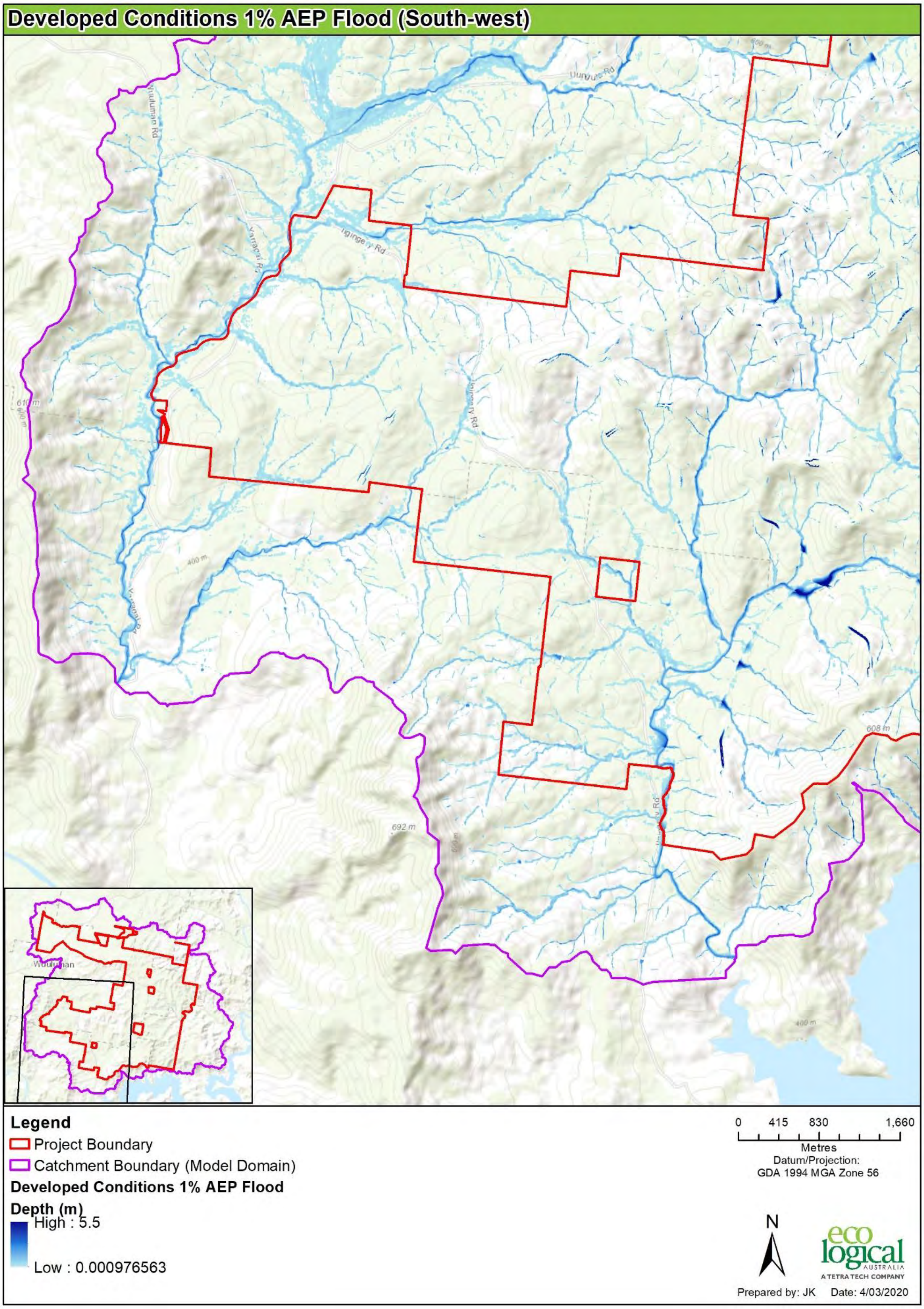

Figure 6-49 1% AEP Proposed Conditions Flood Depths - South West

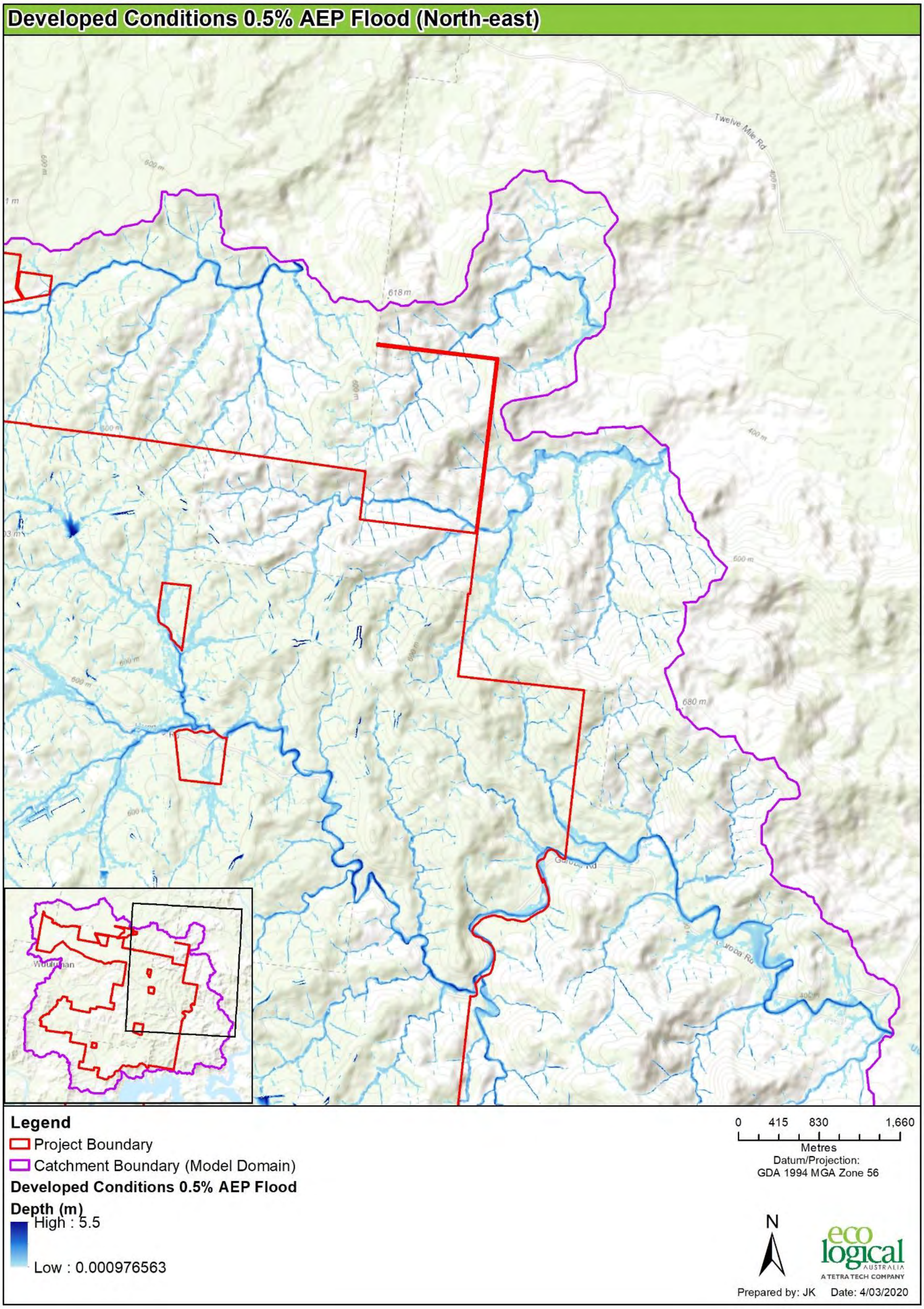

Figure 6-50 0.5% AEP Proposed Conditions Flood Depths - North East

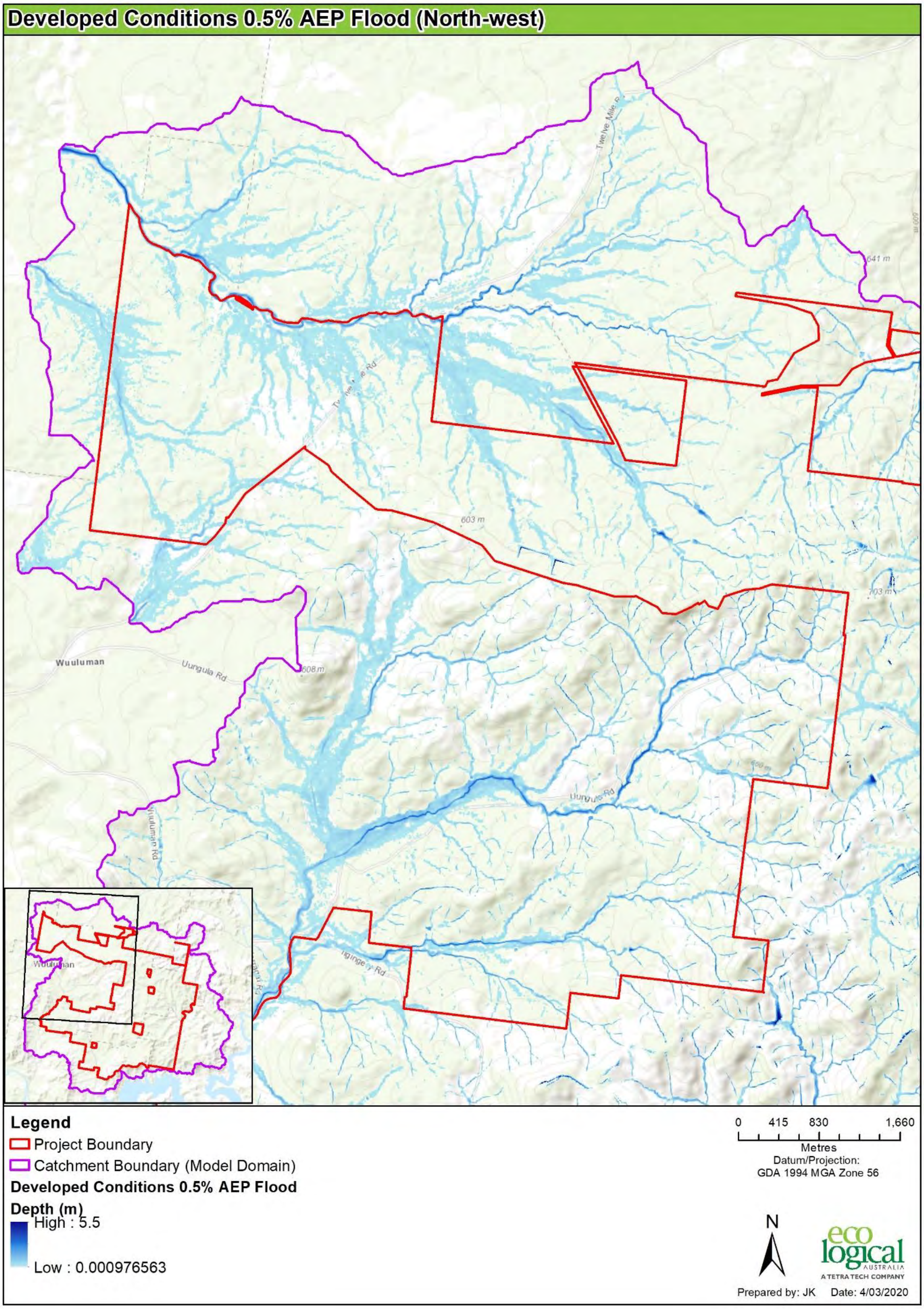

Figure 6-51 0.5% AEP Proposed Conditions Flood Depths - North West

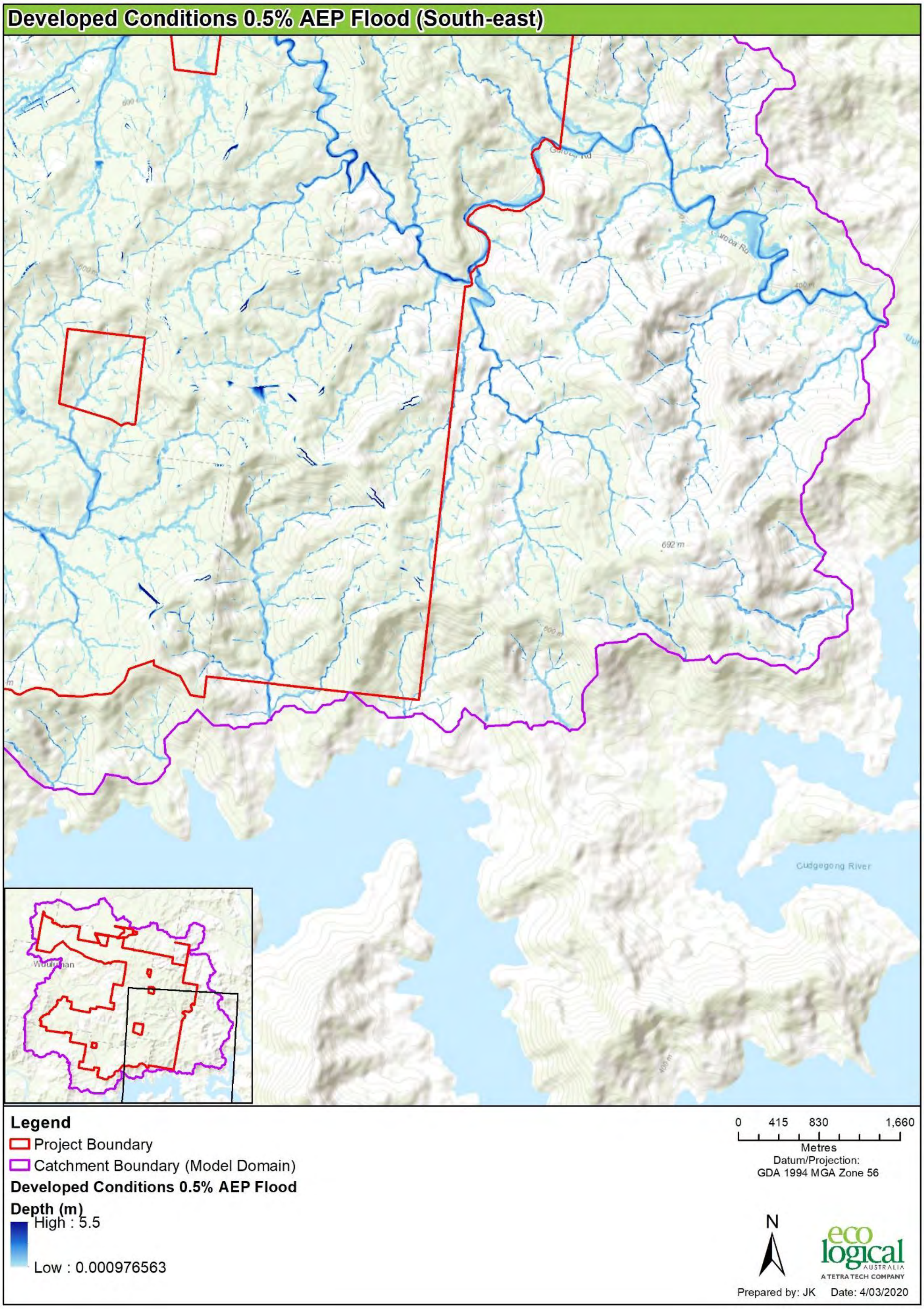

Figure 6-52 0.5% AEP Proposed Conditions Flood Depths - South East

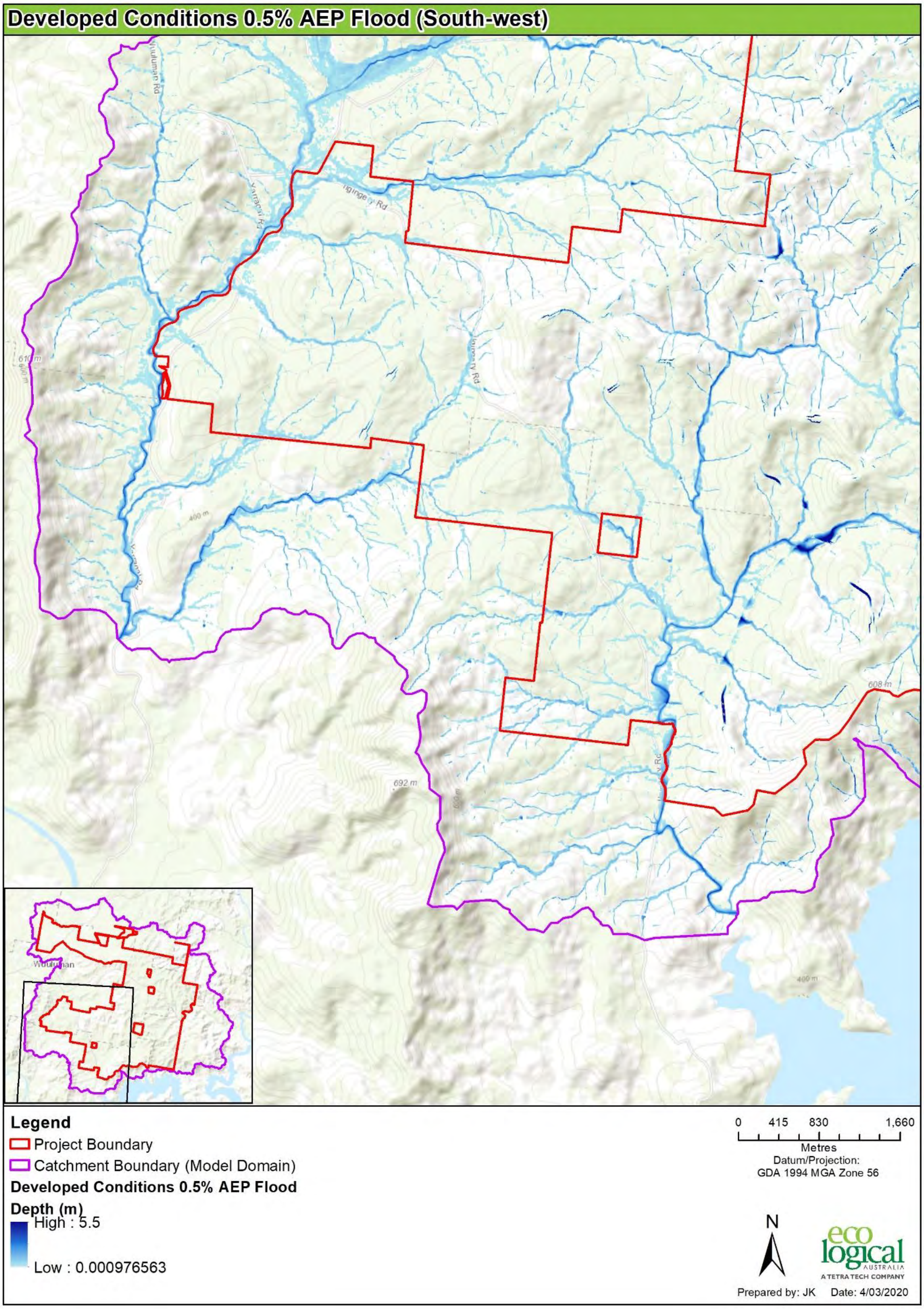

Figure 6-53 0.5% AEP Proposed Conditions Flood Depths - South West

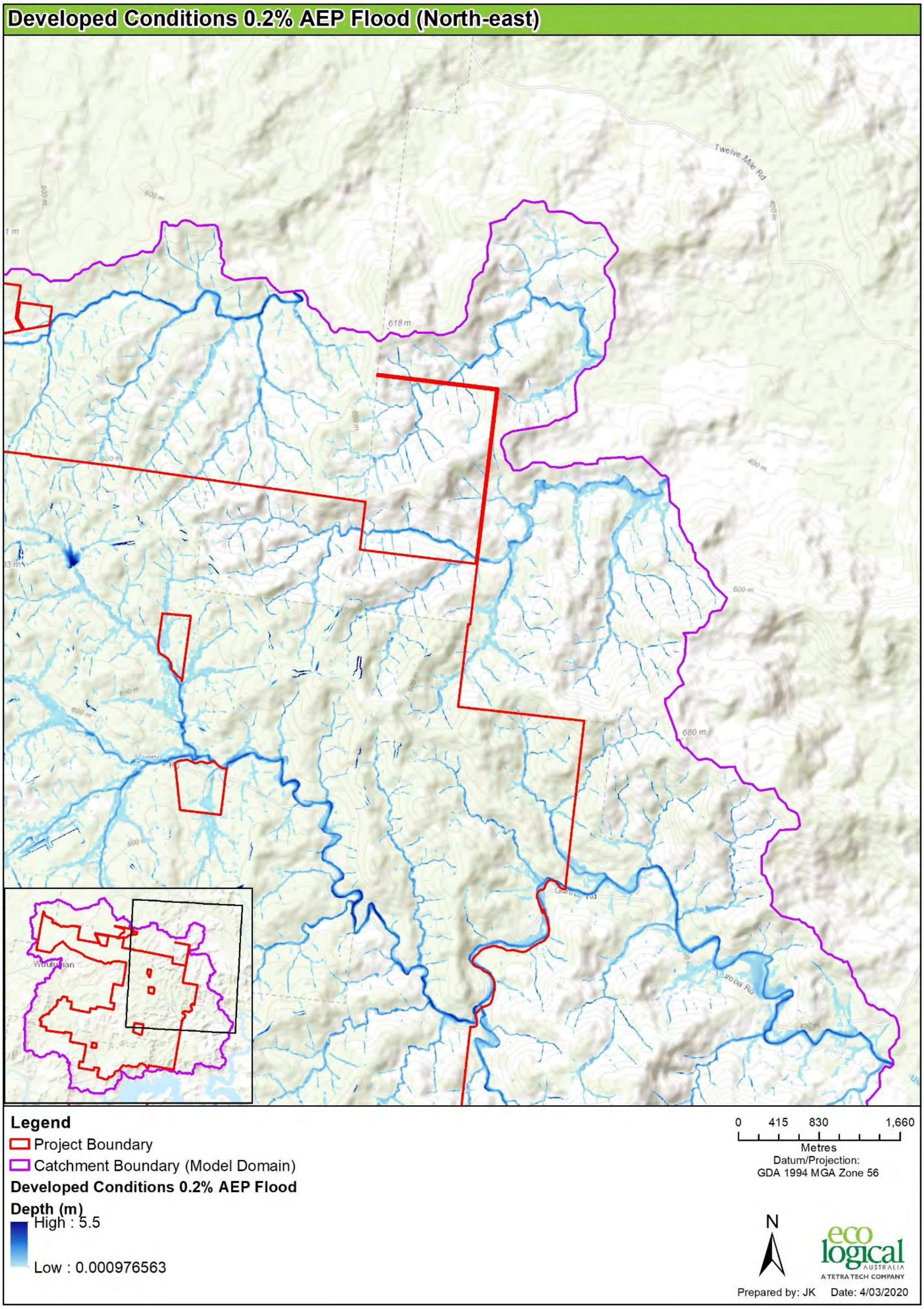

Figure 6-54 0.2% AEP Proposed Conditions Flood Depths - North East

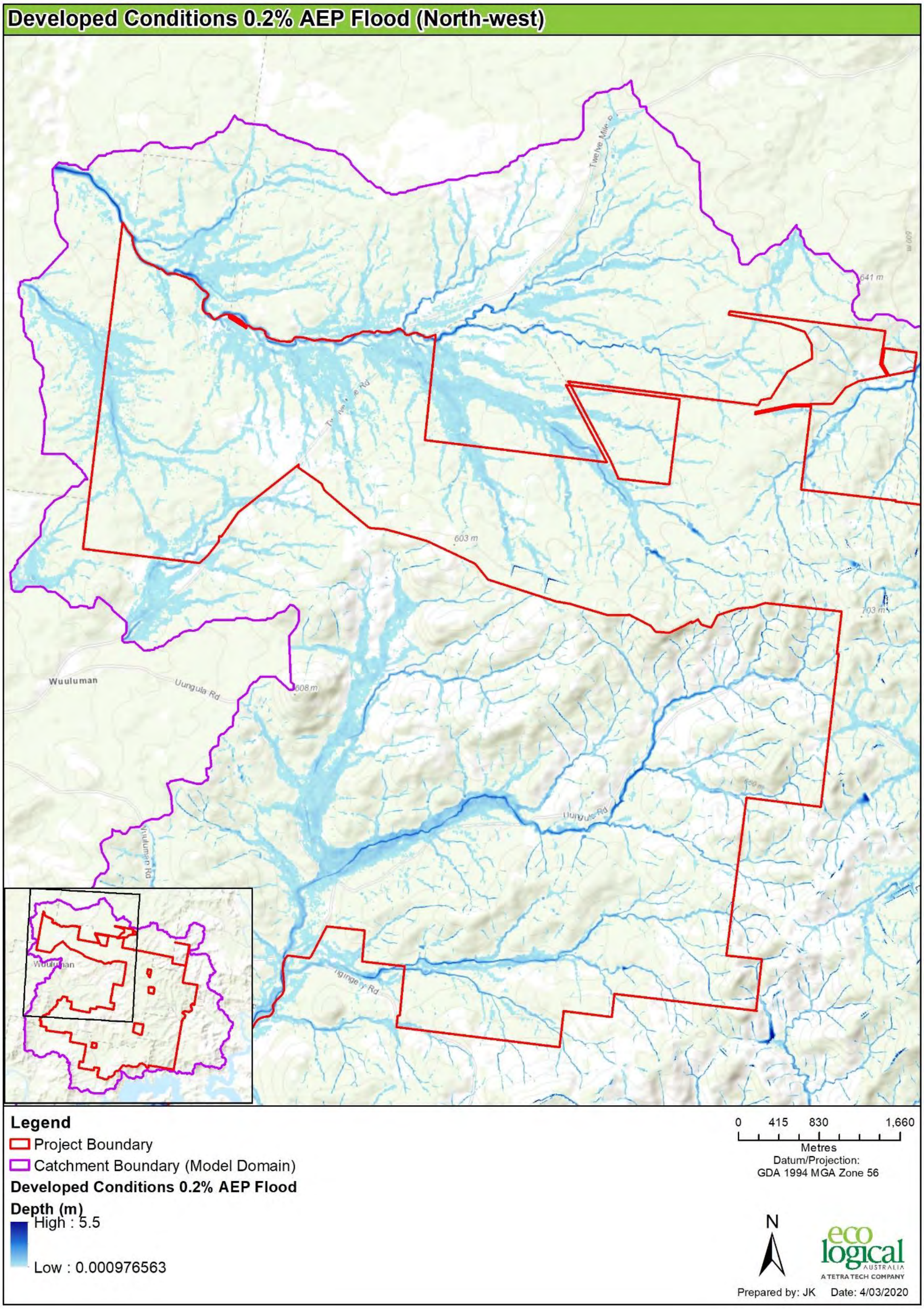

Figure 6-55 0.2% AEP Proposed Conditions Flood Depths - North West

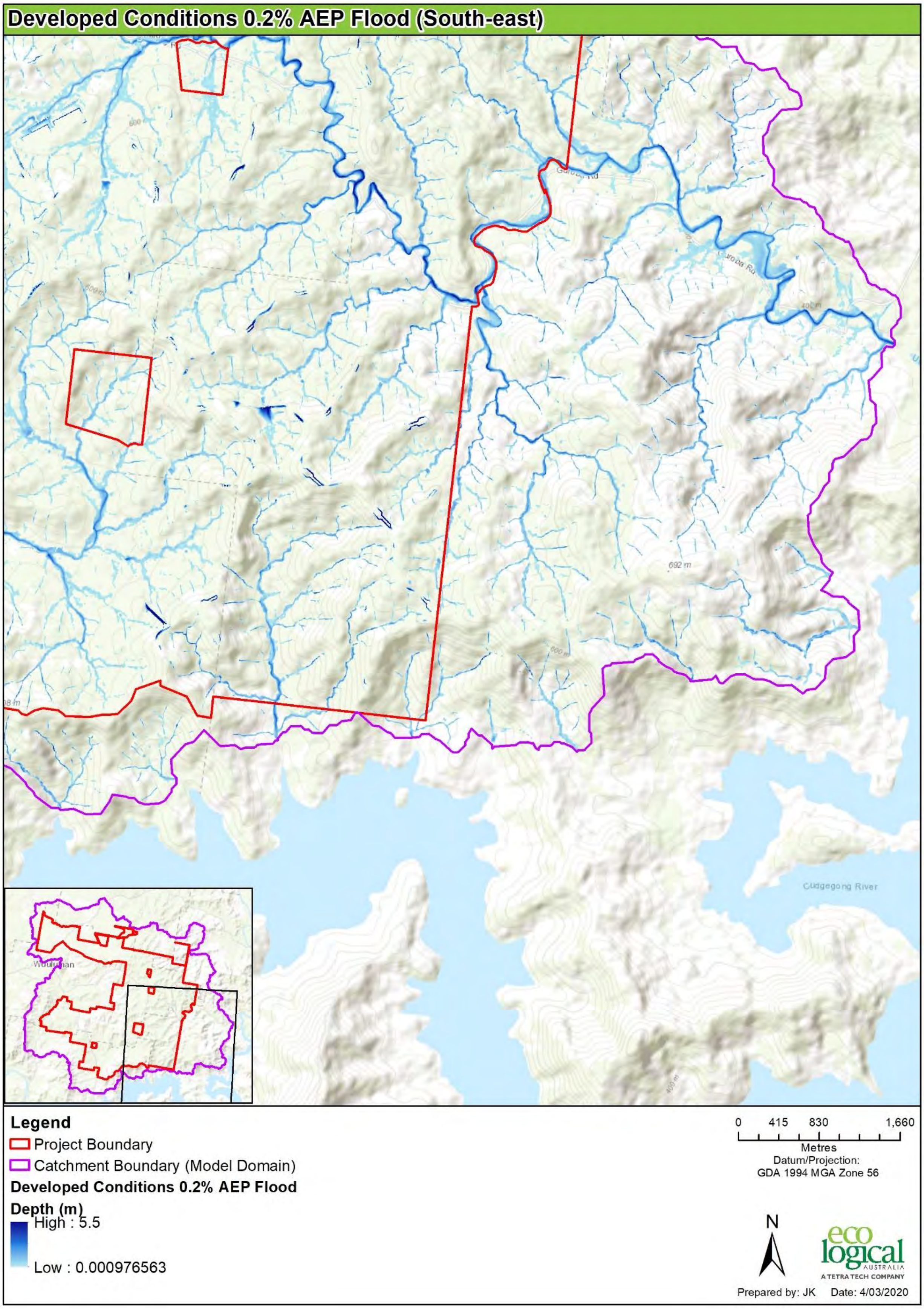

Figure 6-56 0.2% AEP Proposed Conditions Flood Depths - South East

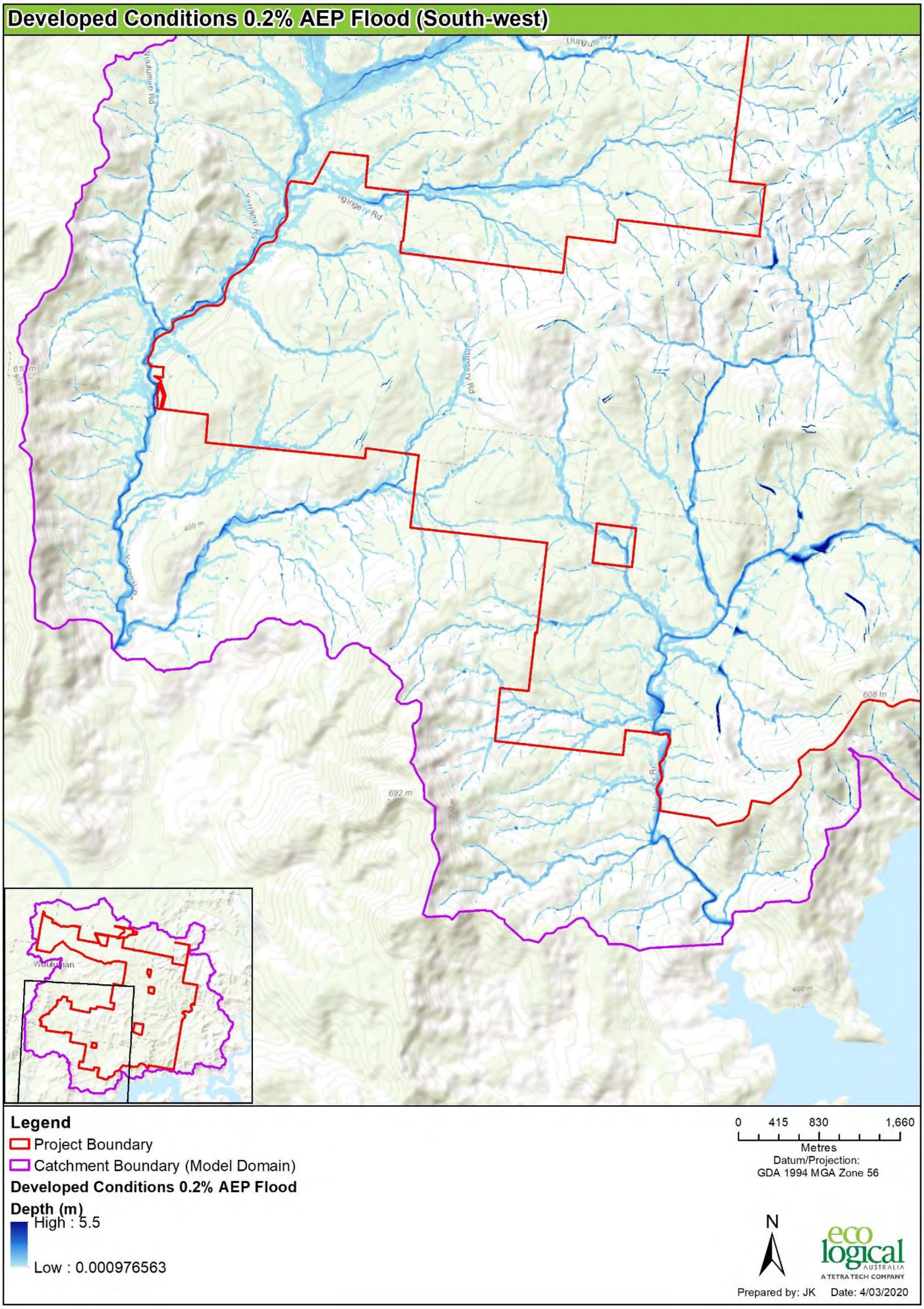

Figure 6-57 0.2% AEP Proposed Conditions Flood Depths - South West

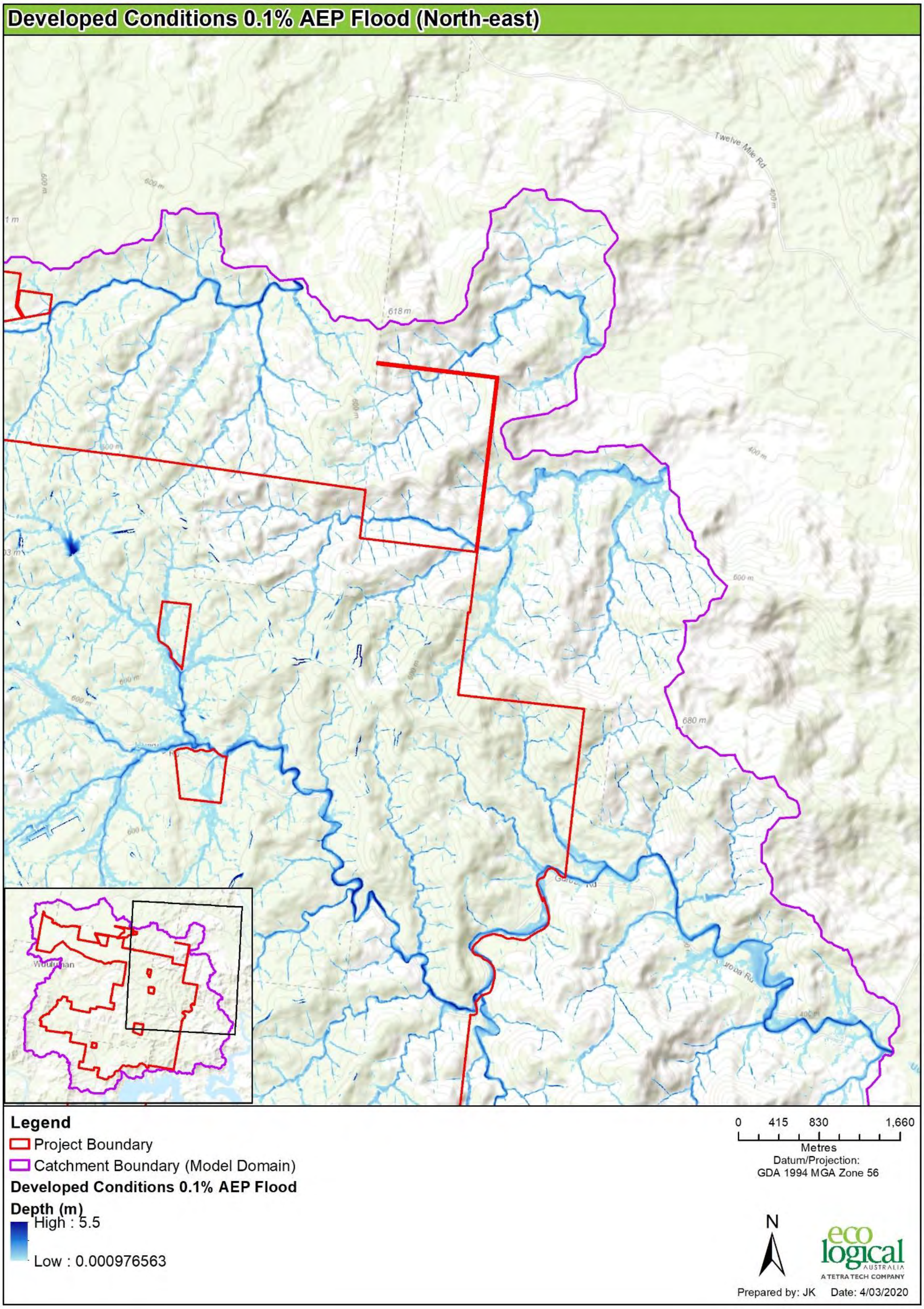

Figure 6-58 0.1% AEP Proposed Conditions Flood Depths - North East

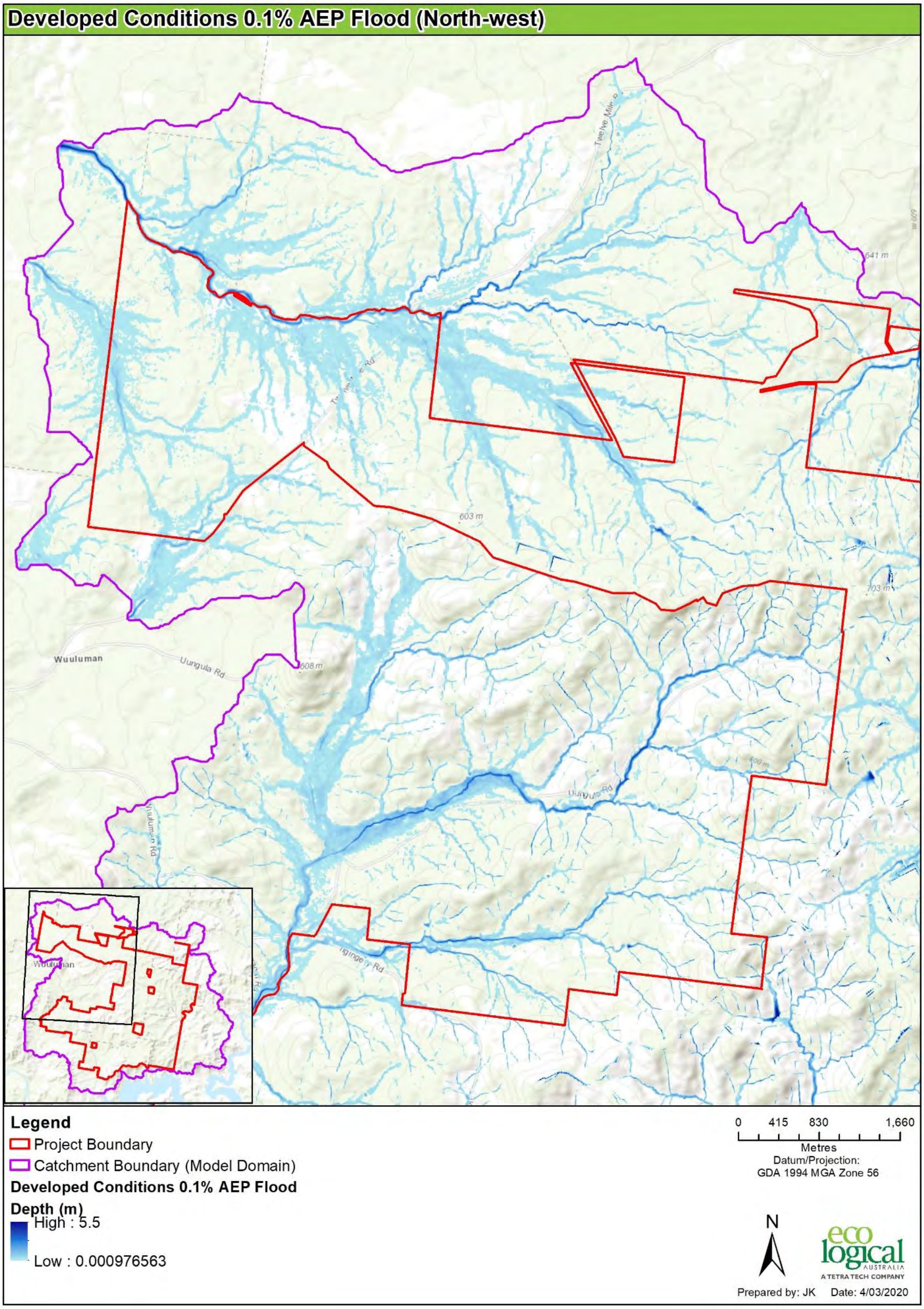

Figure 6-59 0.1% AEP Proposed Conditions Flood Depths - North West

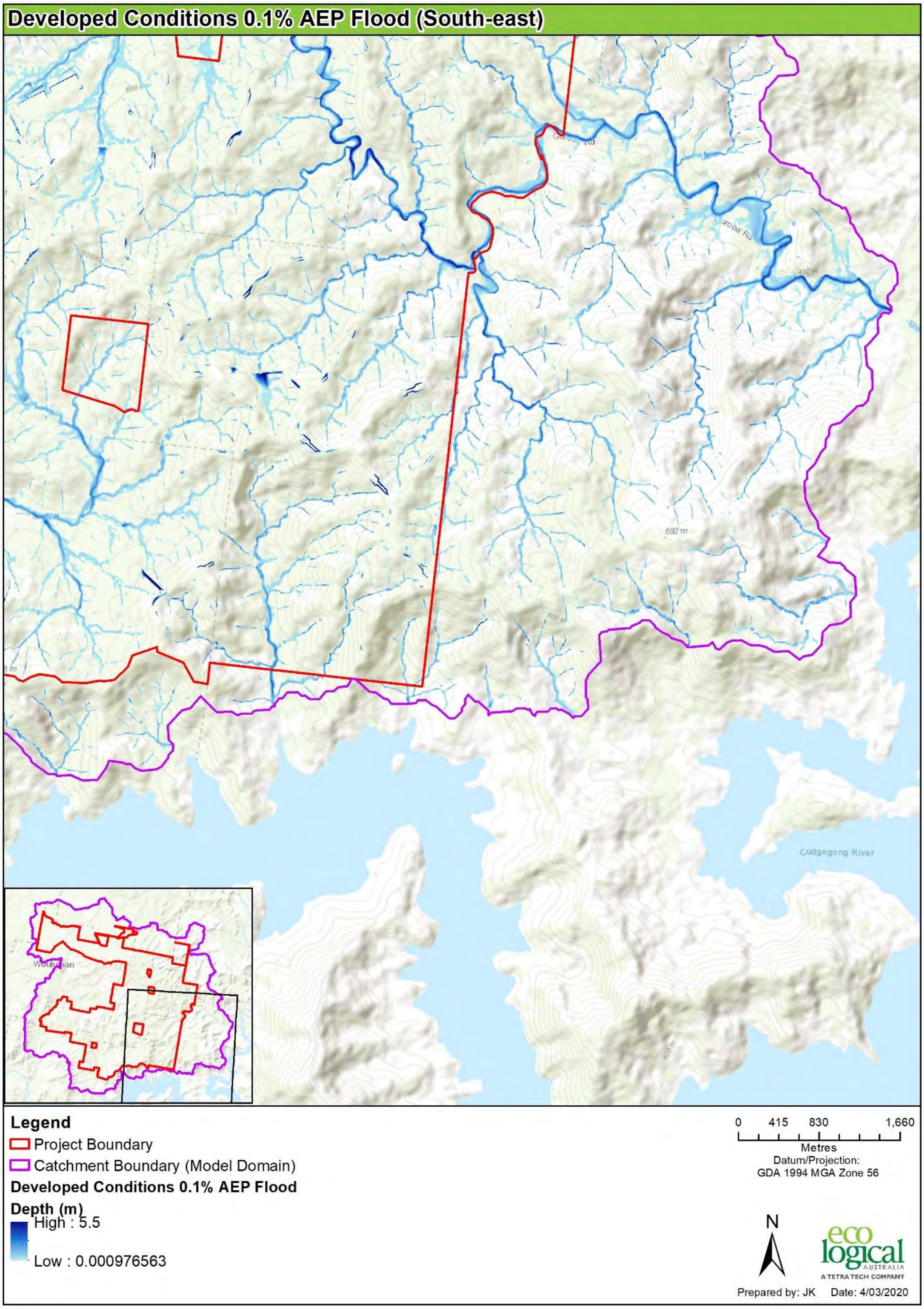

Figure 6-60 0.1% AEP Proposed Conditions Flood Depths - South East

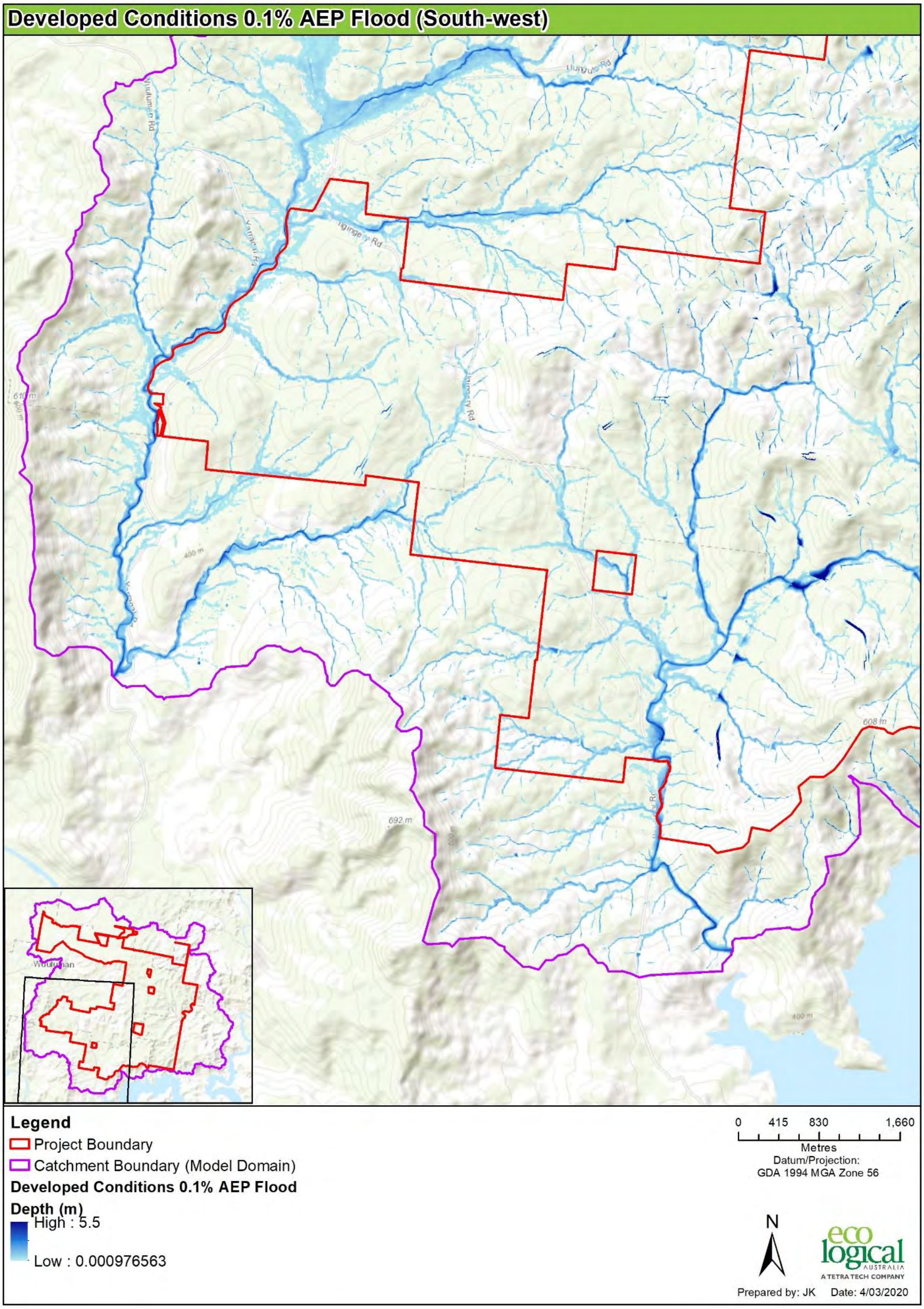

Figure 6-61 0.1% AEP Proposed Conditions Flood Depths - South West

F2 Velocities

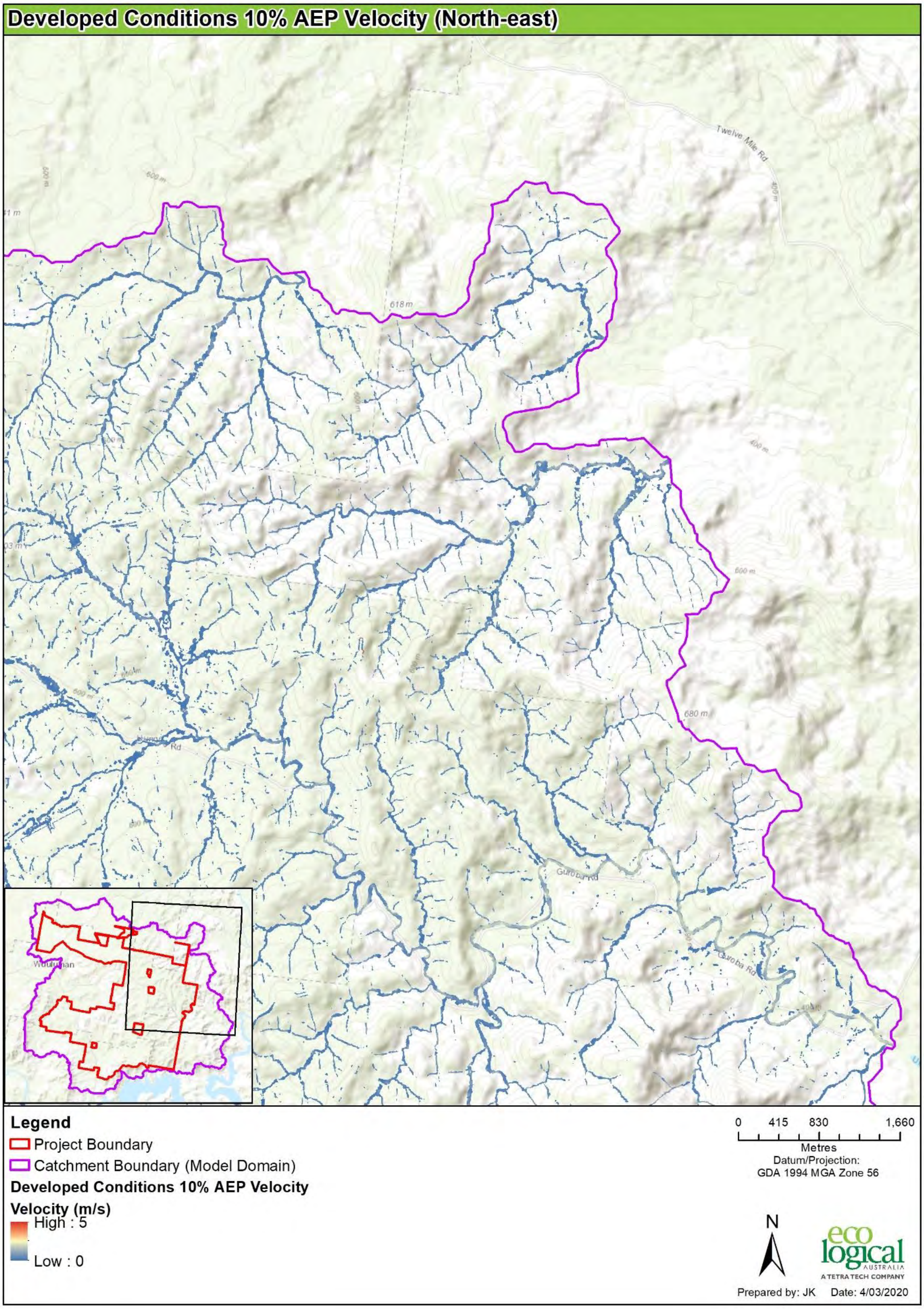

Figure 6-62 10% AEP Proposed Conditions Velocities - North East

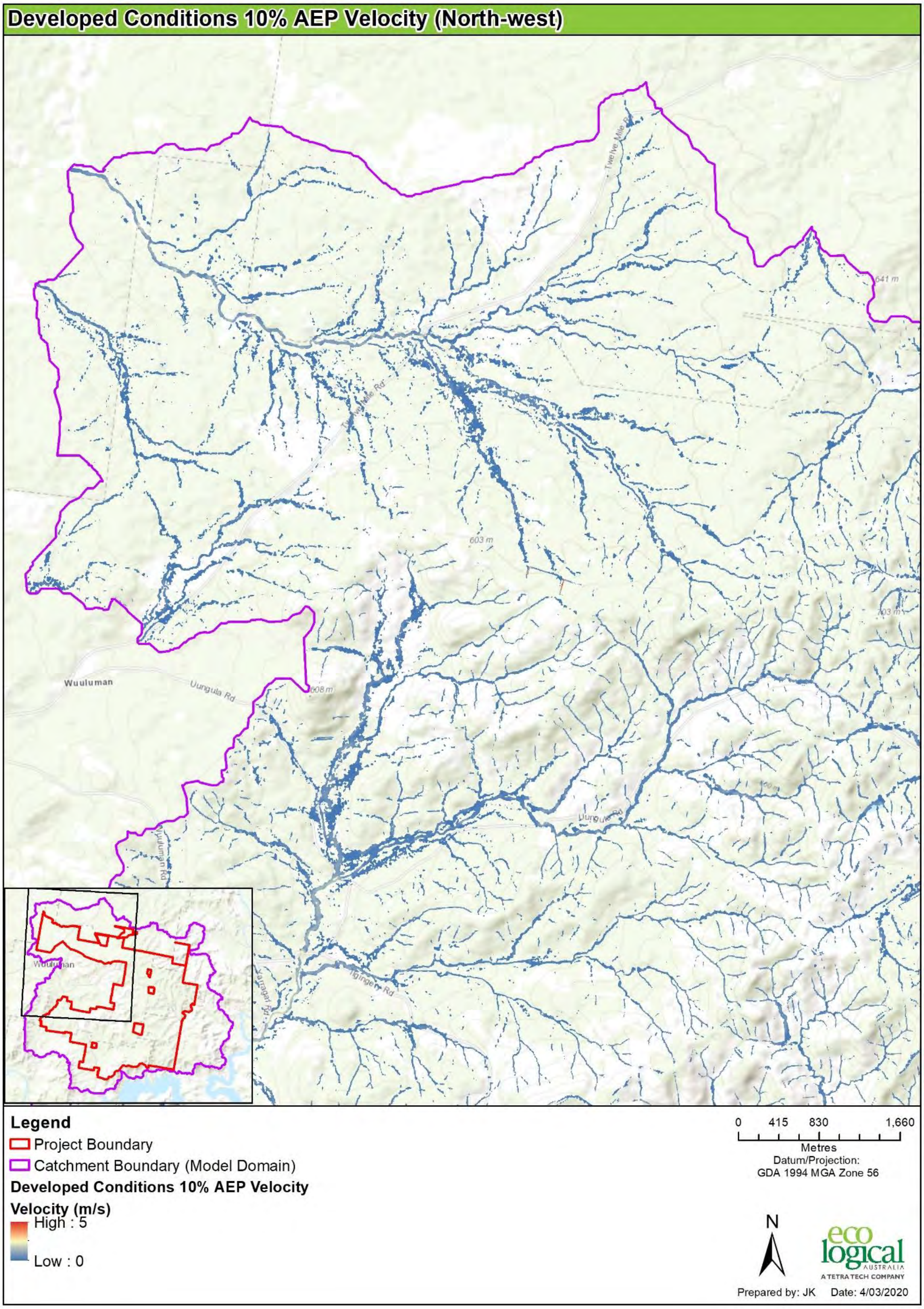

Figure 6-63 10% AEP Proposed Conditions Velocities - North West

Figure 6-64 10% AEP Proposed Conditions Velocities - South East

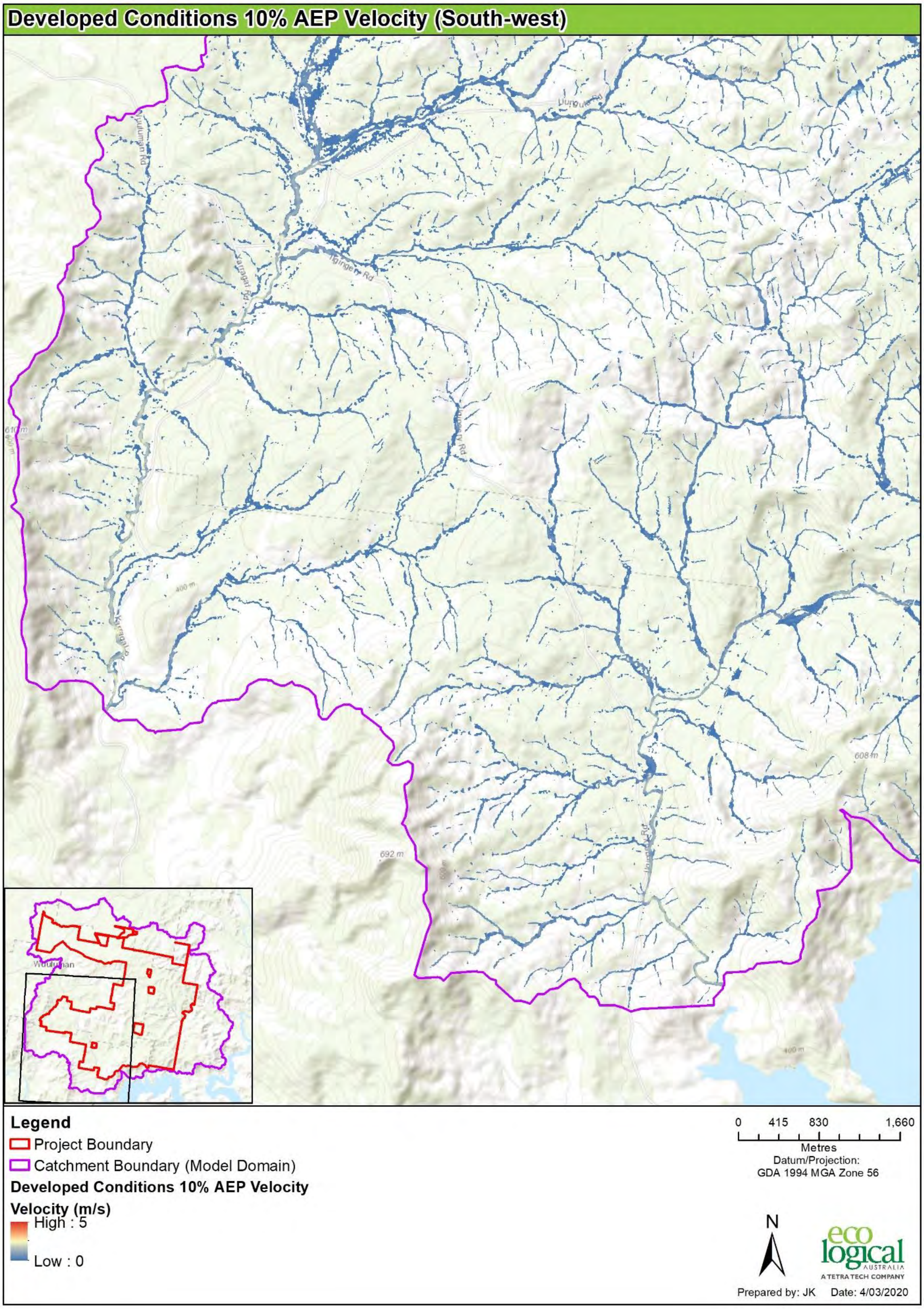

Figure 6-65 10% AEP Proposed Conditions Velocities - South West

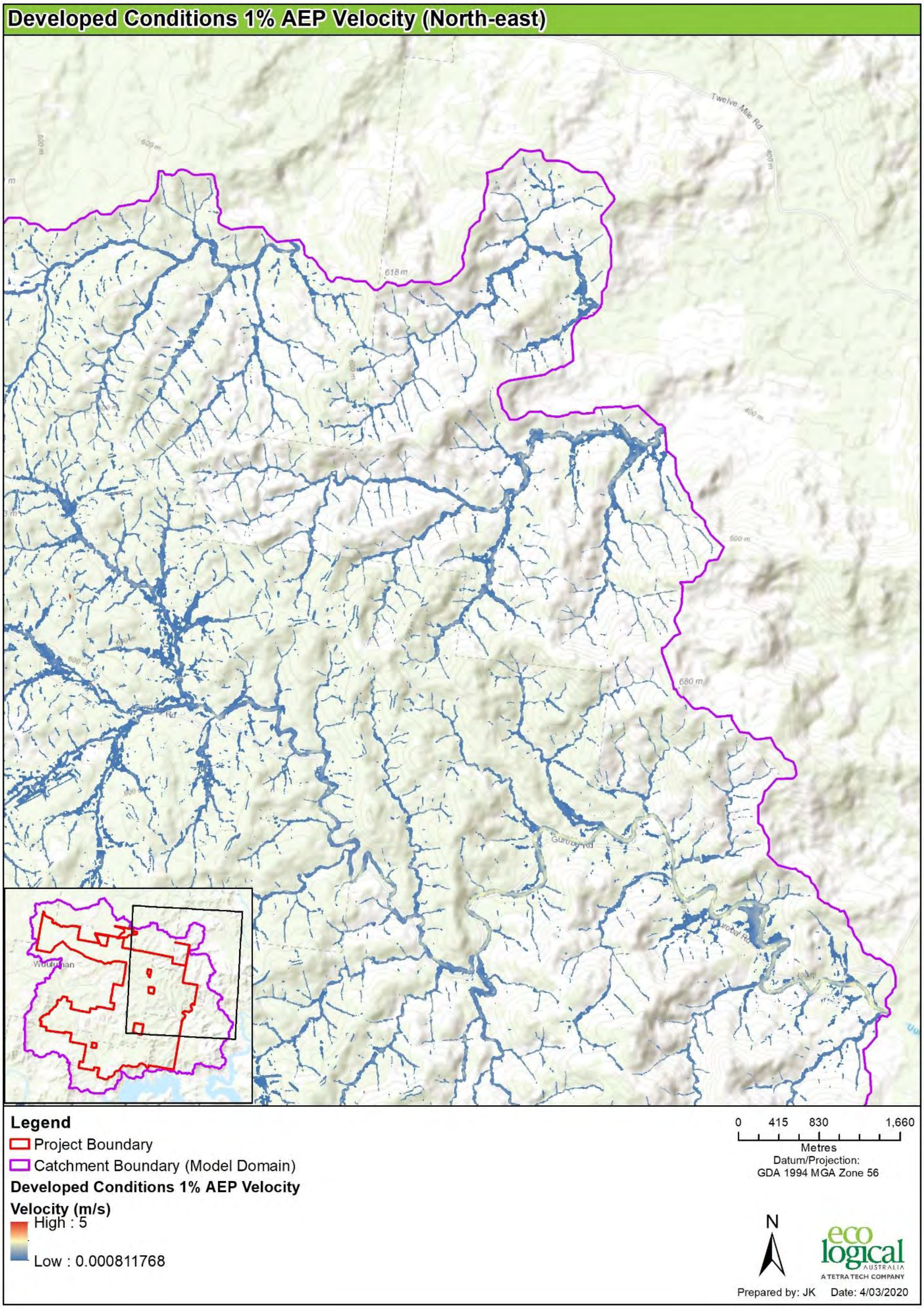

Figure 6-66 1% AEP Proposed Conditions Velocities - North East

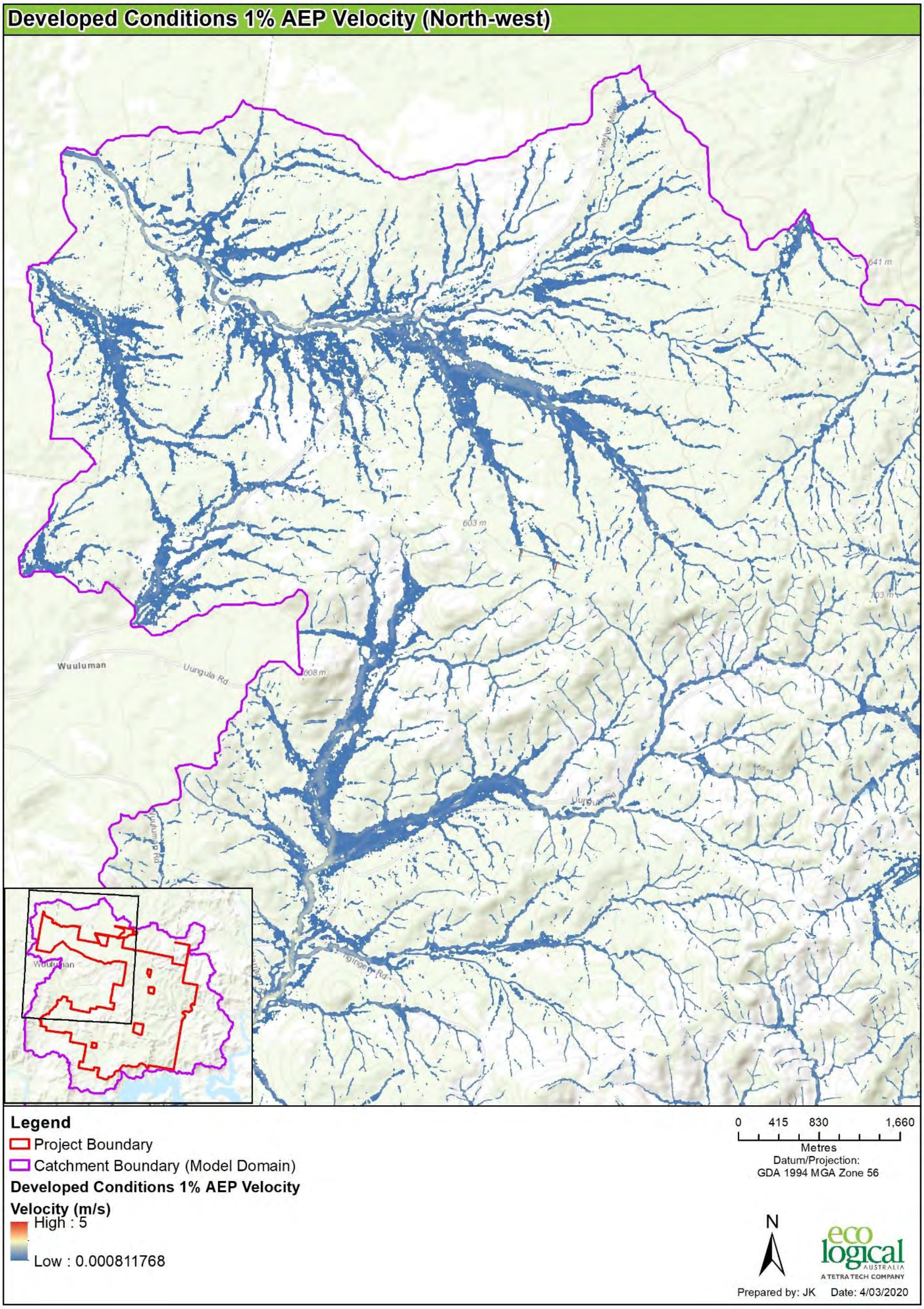

Figure 6-67 1% AEP Proposed Conditions Velocities - North West

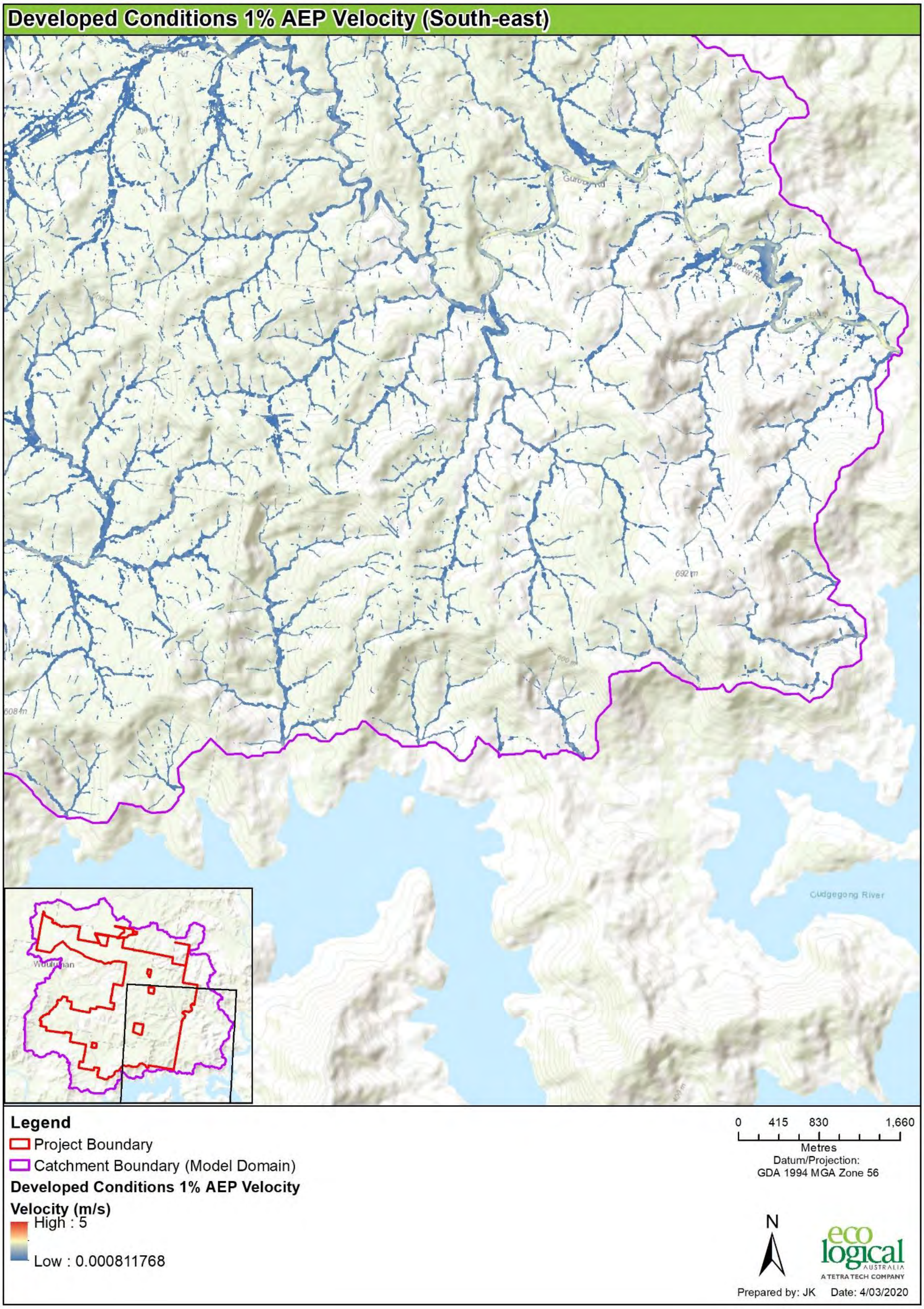

Figure 6-68 1% AEP Proposed Conditions Velocities - South East

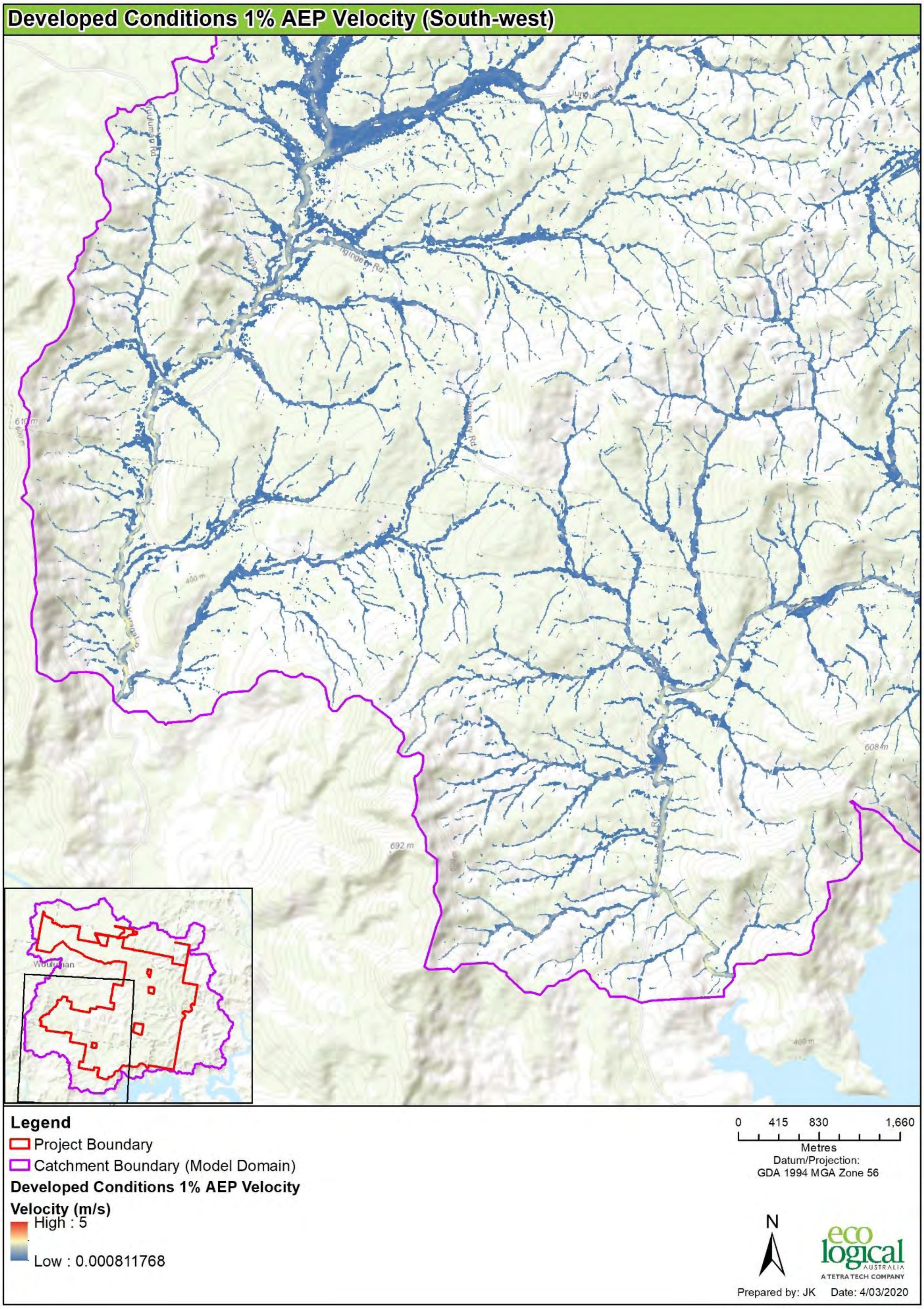

Figure 6-69 1% AEP Proposed Conditions Velocities - South West

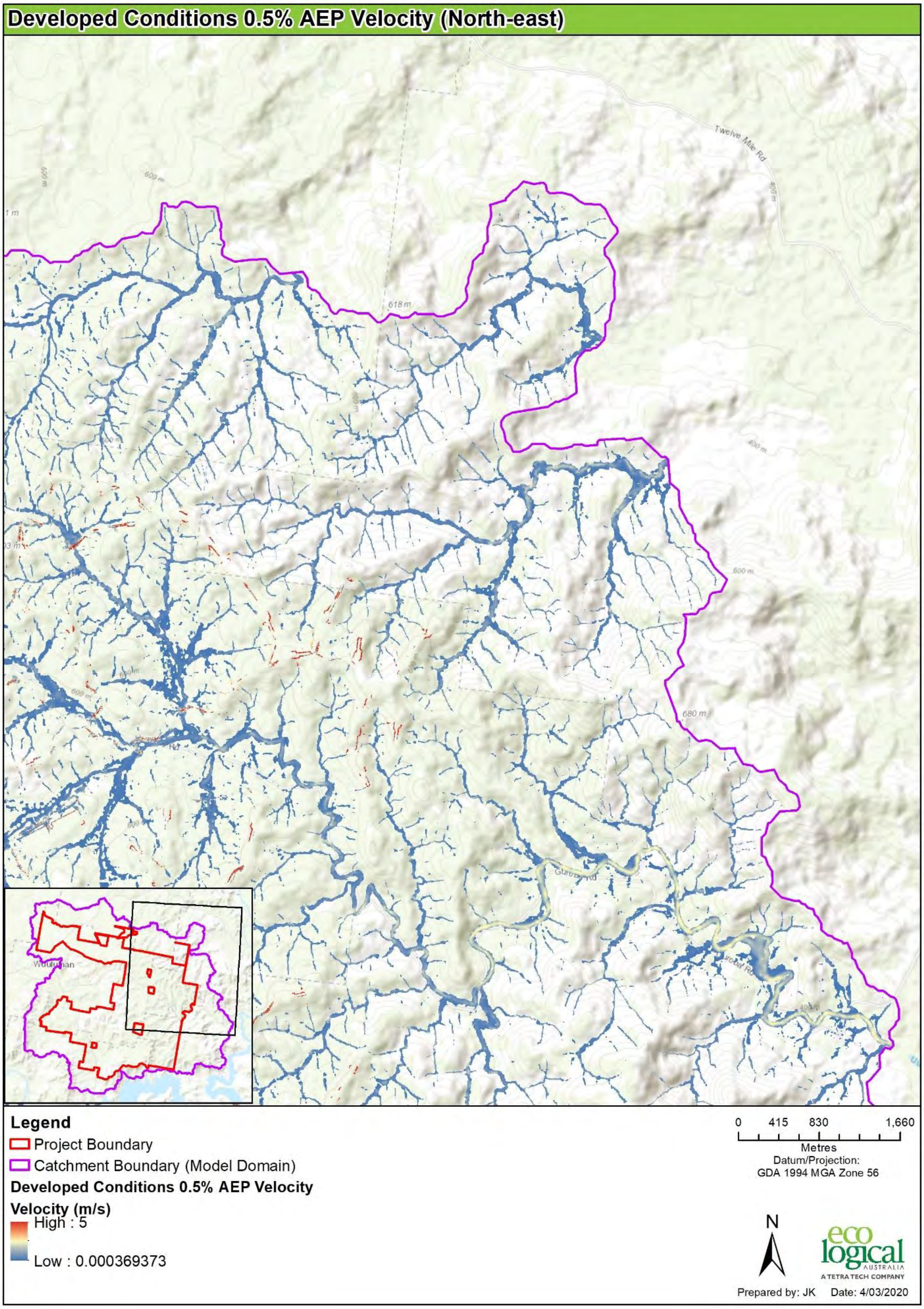

Figure 6-70 0.5% AEP Proposed Conditions Velocities - North East

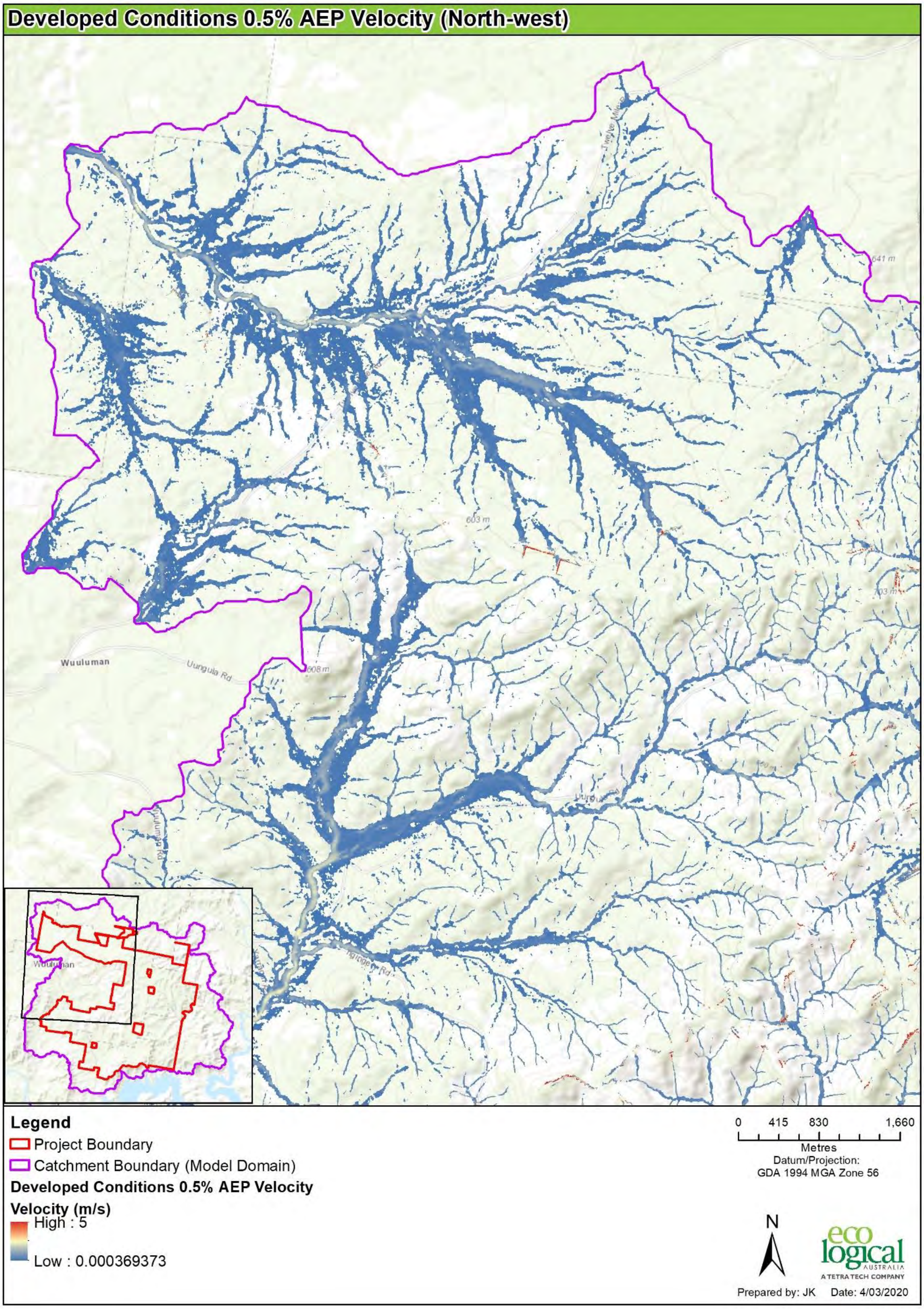

Figure 6-71 0.5% AEP Proposed Conditions Velocities - North West

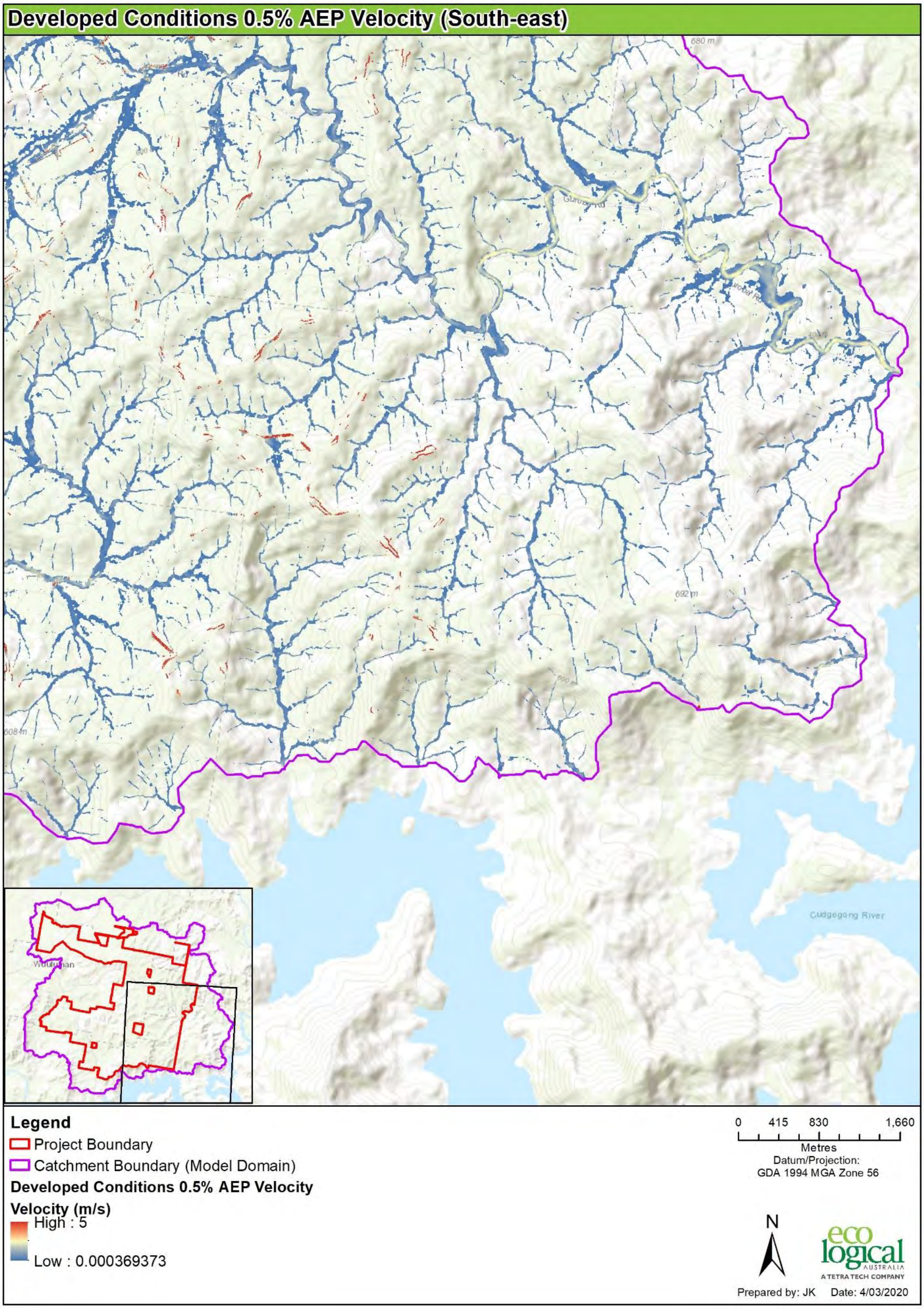

Figure 6-72 0.5% AEP Proposed Conditions Velocities - South East

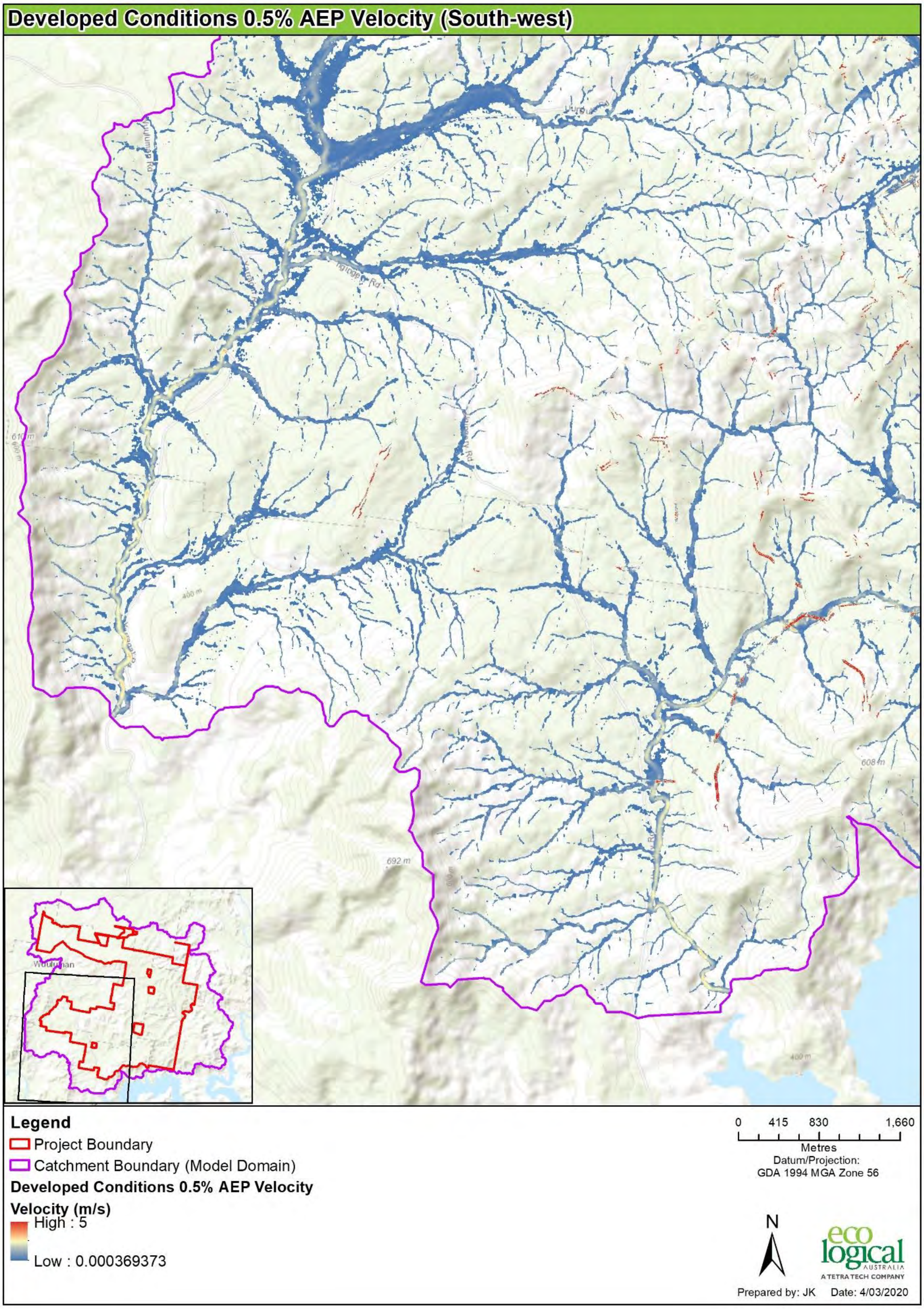

Figure 6-73 0.5% AEP Proposed Conditions Velocities - South West

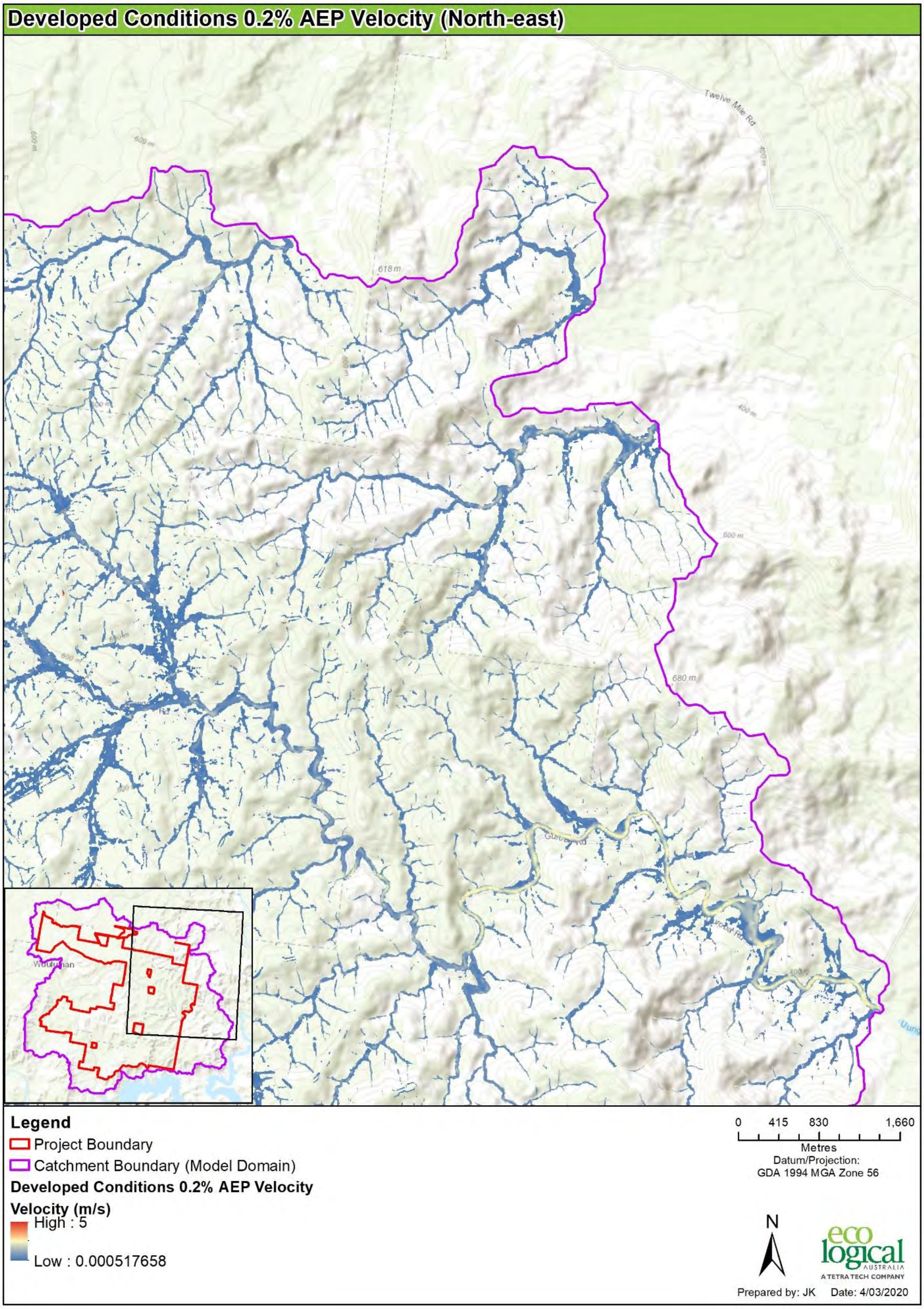

Figure 6-74 0.2% AEP Proposed Conditions Velocities - North East

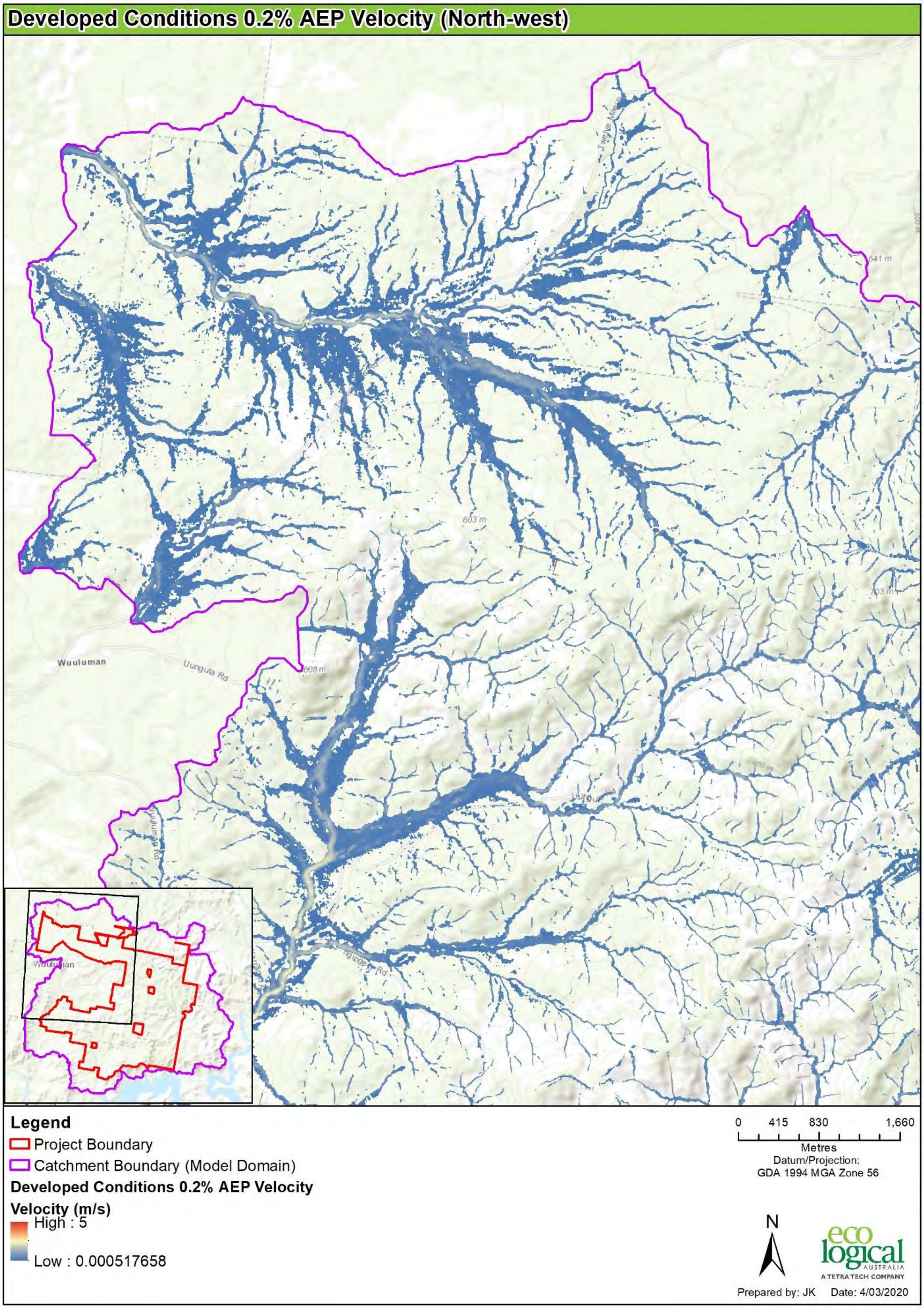

Figure 6-75 0.2% AEP Proposed Conditions Velocities - North West

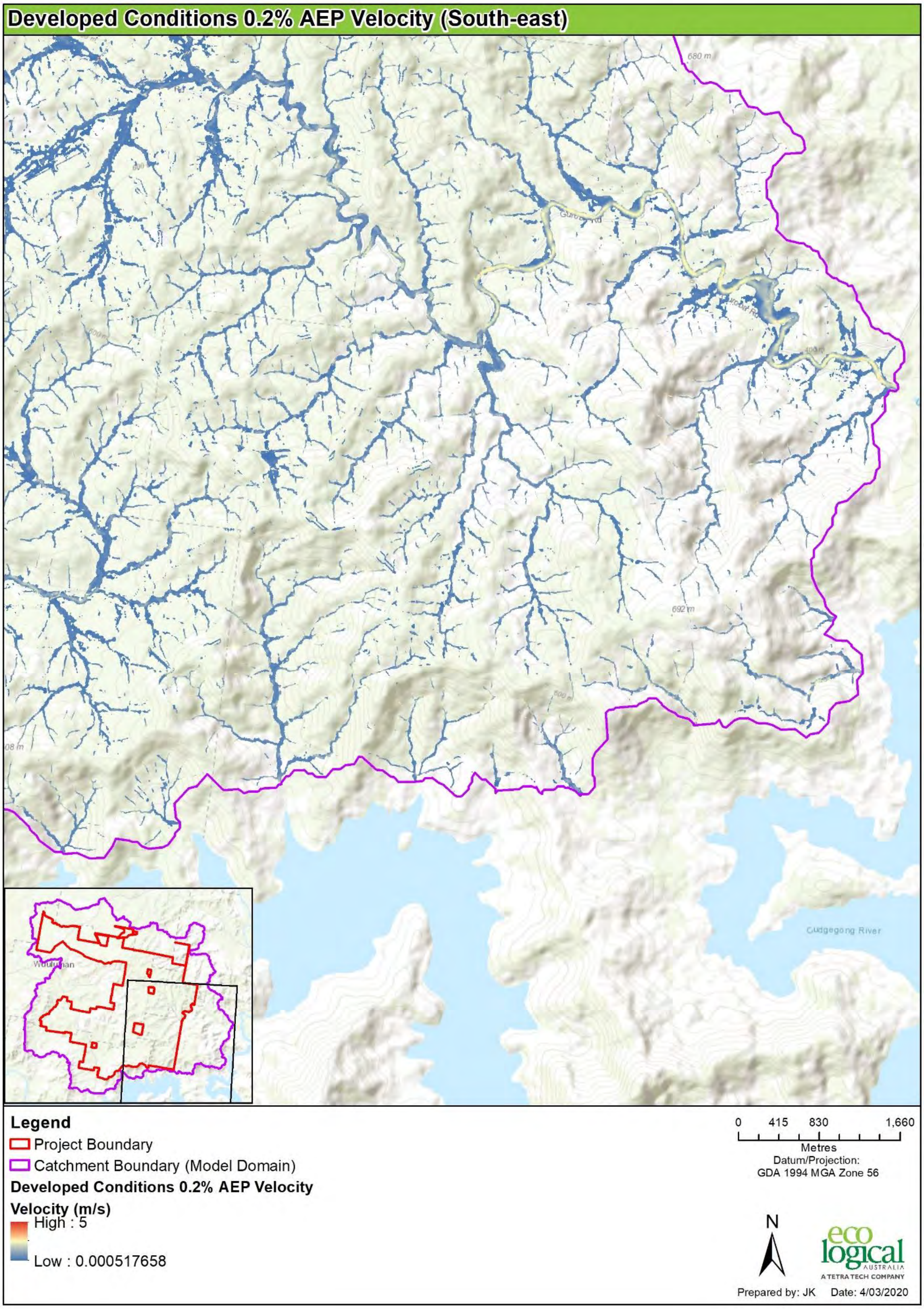

Figure 6-76 0.2% AEP Proposed Conditions Velocities - South East

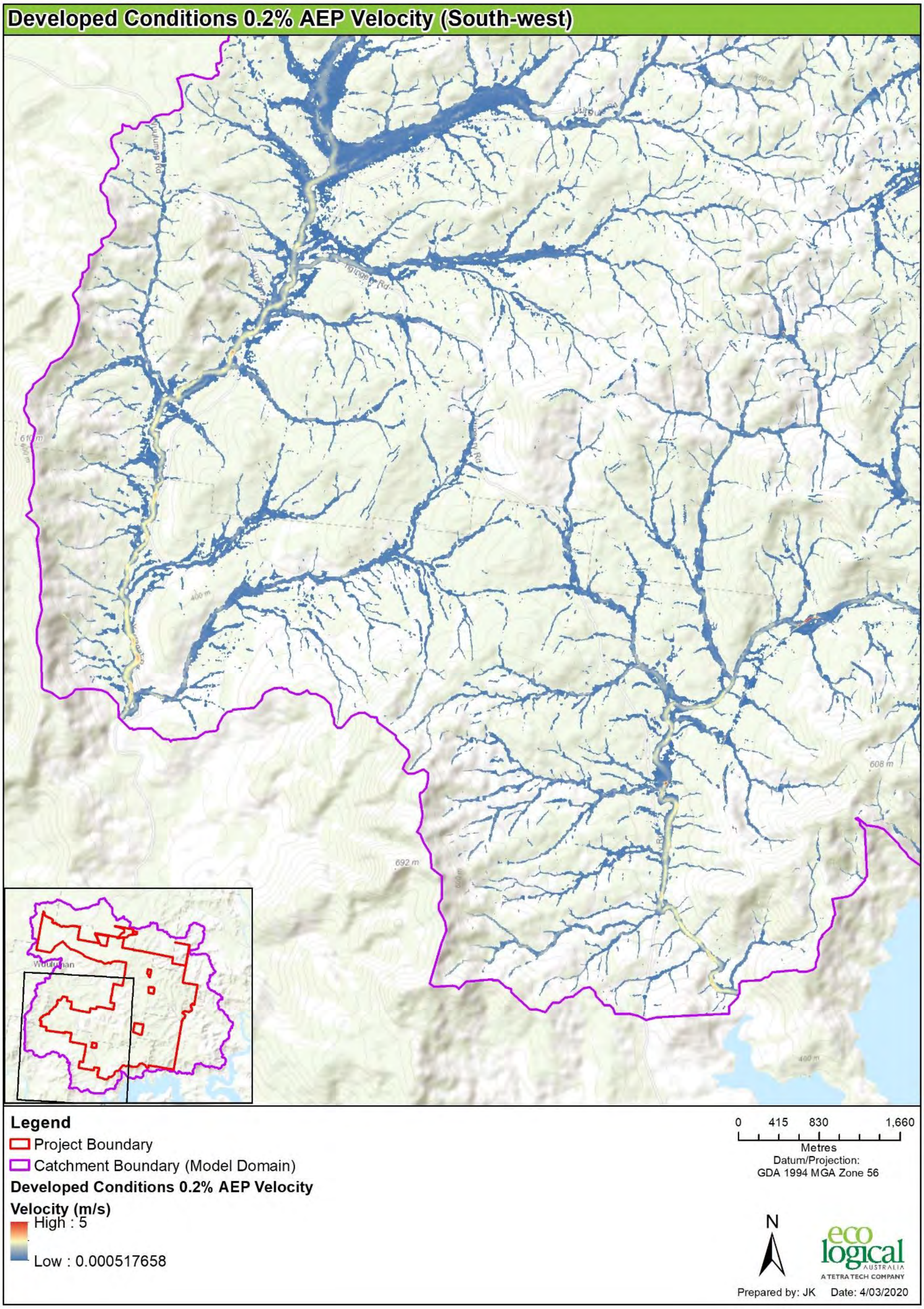

Figure 6-77 0.2% AEP Proposed Conditions Velocities - South West

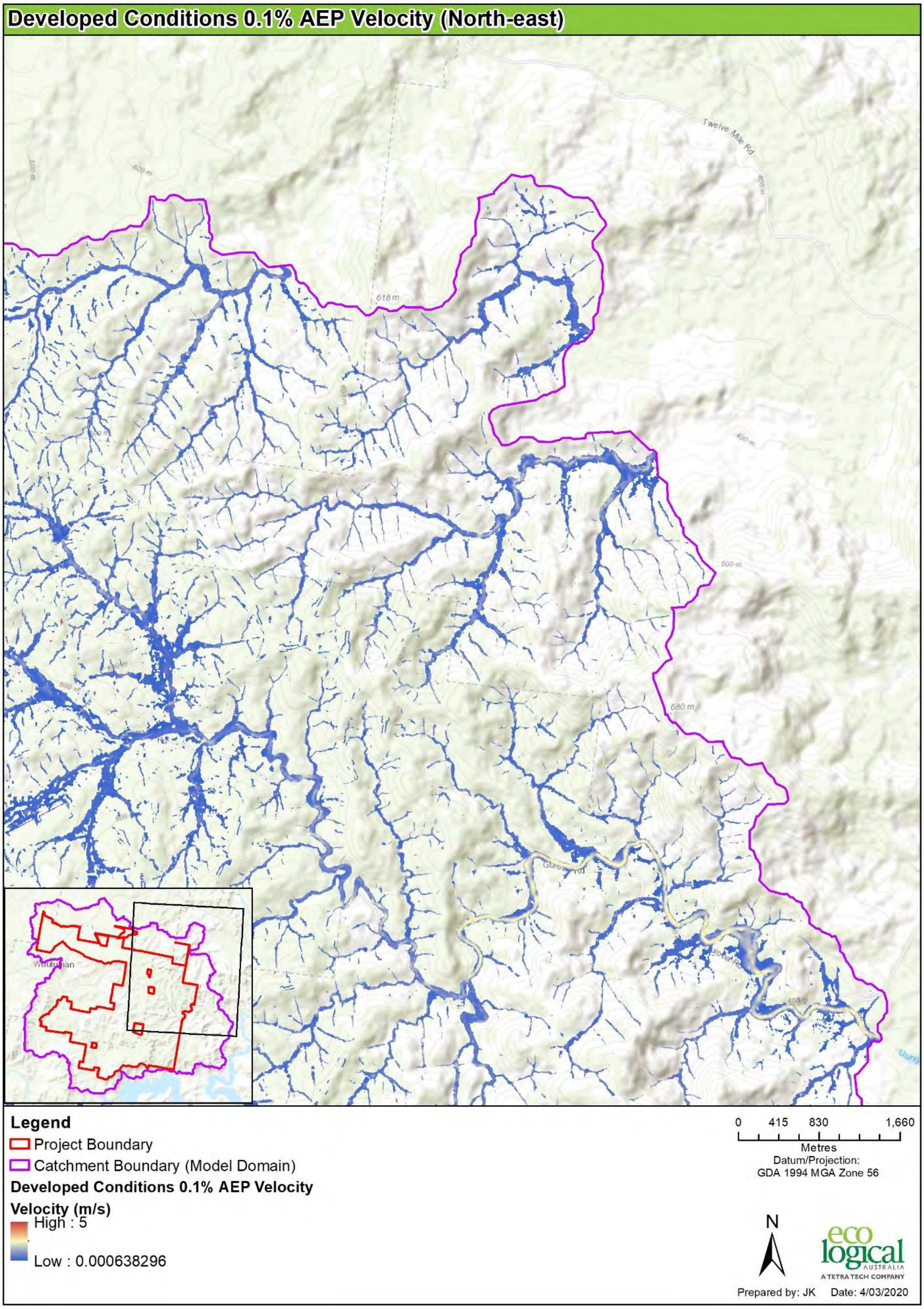

Figure 6-78 0.1% AEP Proposed Conditions Velocities - North East

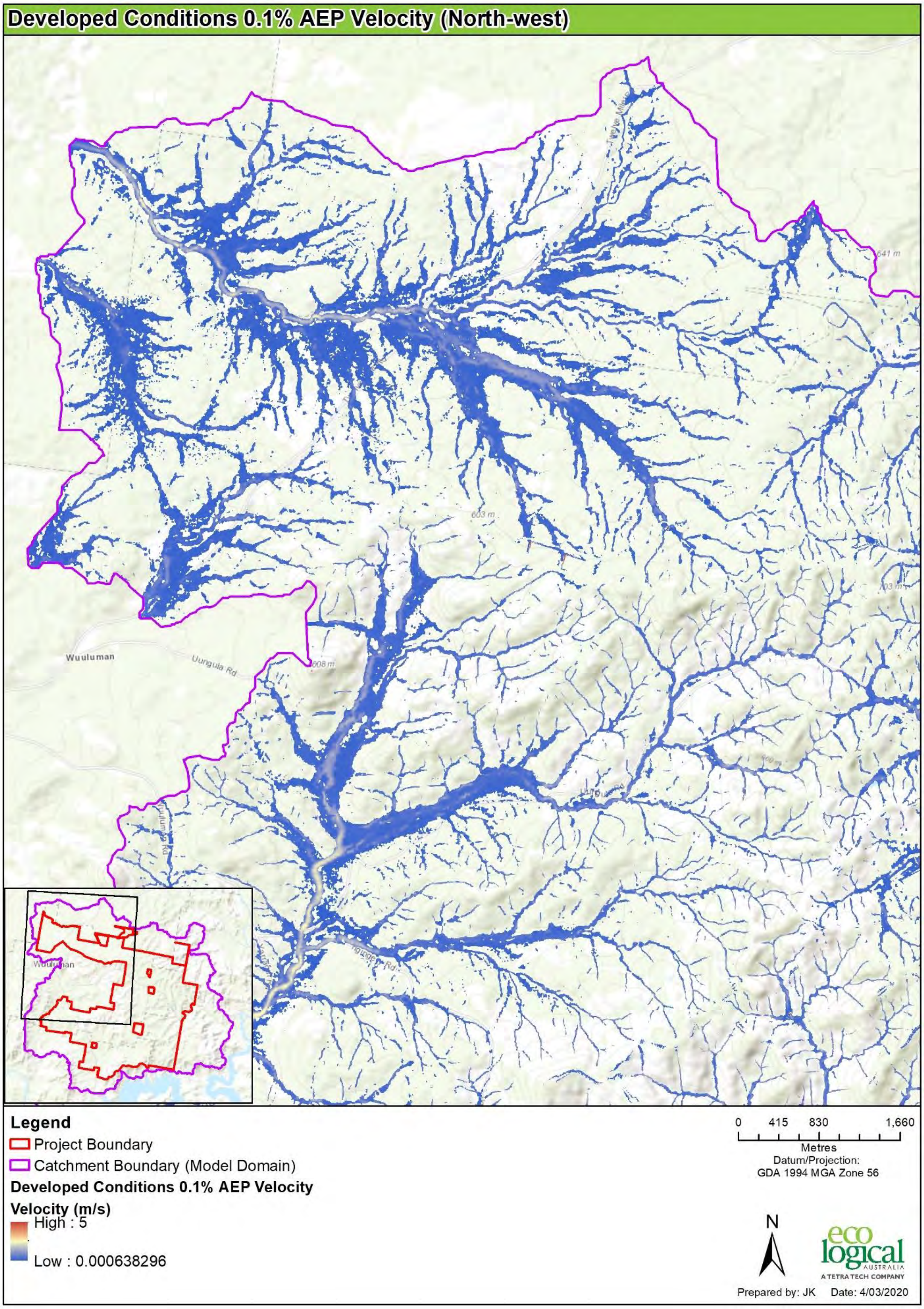

Figure 6-79 0.1% AEP Proposed Conditions Velocities - North West

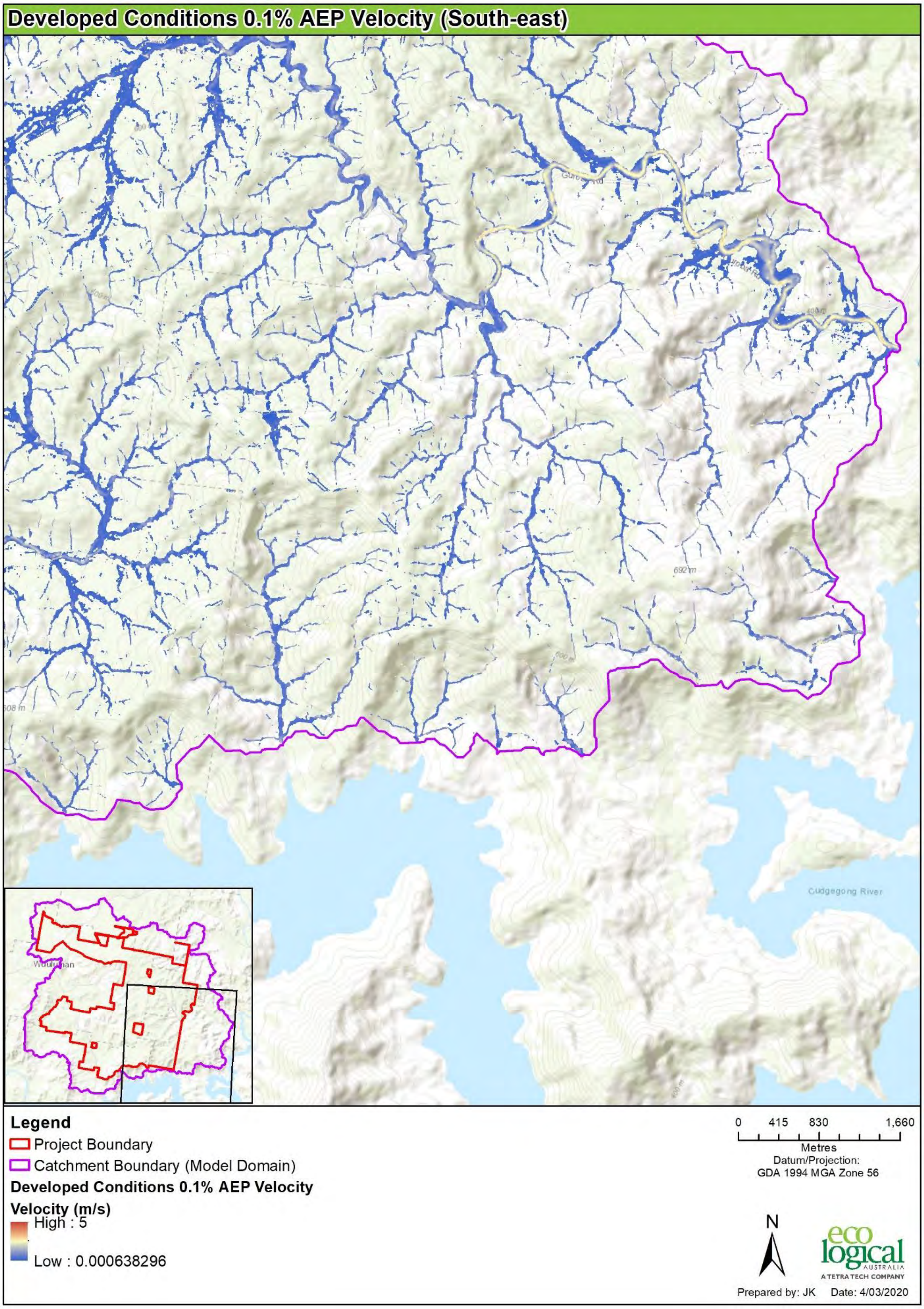

Figure 6-80 0.1% AEP Proposed Conditions Velocities - South East

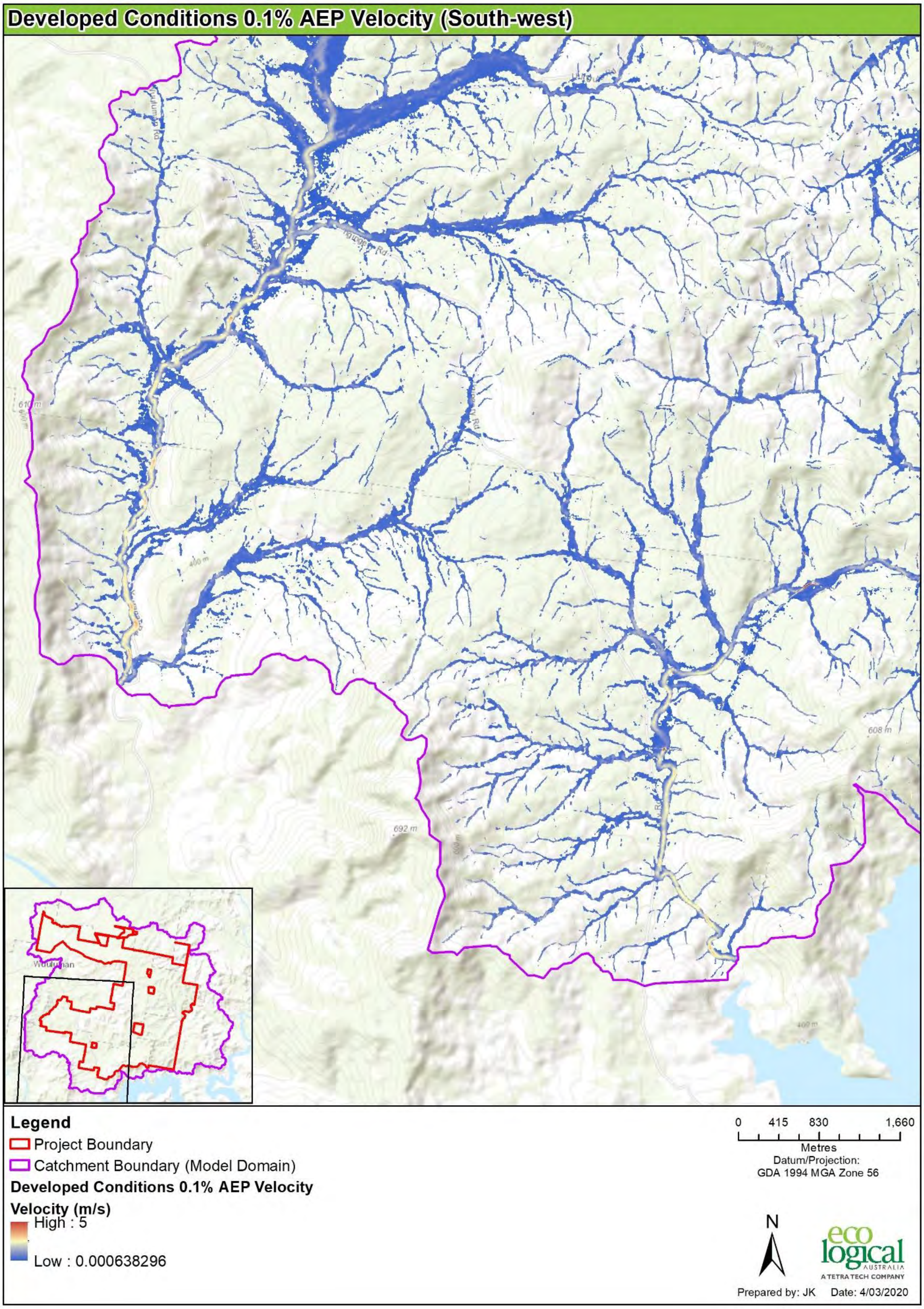

Figure 6-81 0.1% AEP Proposed Conditions Velocities - South West

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