NOTICE OF MEETING



BYRON SHIRE FLOODPLAIN RISK MANAGEMENT COMMITTEE MEETING

A Byron Shire Floodplain Risk Management Committee Meeting of Byron Shire Council will be held as follows:

Venue	**Conference Room, Station Street, Mullumbimby**
Date	**Thursday, 29 October 2020**
Time	**9.00am**

Phillip Holloway
Director Infrastructure Services

I2020/1648
Distributed 22/10/20

CONFLICT OF INTERESTS

What is a "Conflict of Interests" - A conflict of interests can be of two types:
Pecuniary - an interest that a person has in a matter because of a reasonable likelihood or expectation of appreciable financial gain or loss to the person or another person with whom the person is associated.
Non-pecuniary – a private or personal interest that a Council official has that does not amount to a pecuniary interest as defined in the Code of Conduct for Councillors (eg. A friendship, membership of an association, society or trade union or involvement or interest in an activity and may include an interest of a financial nature).
Remoteness – a person does not have a pecuniary interest in a matter if the interest is so remote or insignificant that it could not reasonably be regarded as likely to influence any decision the person might make in relation to a matter or if the interest is of a kind specified in the Code of Conduct for Councillors.
Who has a Pecuniary Interest? - a person has a pecuniary interest in a matter if the pecuniary interest is the interest of the person, or another person with whom the person is associated (see below).
Relatives, Partners - a person is taken to have a pecuniary interest in a matter if:

- The person's spouse or de facto partner or a relative of the person has a pecuniary interest in the matter, or
- The person, or a nominee, partners or employer of the person, is a member of a company or other body that has a pecuniary interest in the matter.

N.B. "Relative", in relation to a person means any of the following:
(a) the parent, grandparent, brother, sister, uncle, aunt, nephew, niece, lineal descends or adopted child of the person or of the person's spouse;
(b) the spouse or de facto partners of the person or of a person referred to in paragraph (a)
No Interest in the Matter - however, a person is not taken to have a pecuniary interest in a matter:

- If the person is unaware of the relevant pecuniary interest of the spouse, de facto partner, relative or company or other body, or
- Just because the person is a member of, or is employed by, the Council.
- Just because the person is a member of, or a delegate of the Council to, a company or other body that has a pecuniary interest in the matter provided that the person has no beneficial interest in any shares of the company or body.

Disclosure and participation in meetings

- A Councillor or a member of a Council Committee who has a pecuniary interest in any matter with which the Council is concerned and who is present at a meeting of the Council or Committee at which the matter is being considered must disclose the nature of the interest to the meeting as soon as practicable.
- The Councillor or member must not be present at, or in sight of, the meeting of the Council or Committee:
  (a) at any time during which the matter is being considered or discussed by the Council or Committee, or
  (b) at any time during which the Council or Committee is voting on any question in relation to the matter.

No Knowledge - a person does not breach this Clause if the person did not know and could not reasonably be expected to have known that the matter under consideration at the meeting was a matter in which he or she had a pecuniary interest.
Non-pecuniary Interests - Must be disclosed in meetings.
There are a broad range of options available for managing conflicts & the option chosen will depend on an assessment of the circumstances of the matter, the nature of the interest and the significance of the issue being dealt with. Non-pecuniary conflicts of interests must be dealt with in at least one of the following ways:

- It may be appropriate that no action be taken where the potential for conflict is minimal. However, Councillors should consider providing an explanation of why they consider a conflict does not exist.
- Limit involvement if practical (eg. Participate in discussion but not in decision making or vice-versa). Care needs to be taken when exercising this option.
- Remove the source of the conflict (eg. Relinquishing or divesting the personal interest that creates the conflict)
- Have no involvement by absenting yourself from and not taking part in any debate or voting on the issue as of the provisions in the Code of Conduct (particularly if you have a significant non-pecuniary interest)

RECORDING OF VOTING ON PLANNING MATTERS

Clause 375A of the Local Government Act 1993 – Recording of voting on planning matters
(1) In this section, **planning decision** means a decision made in the exercise of a function of a council under the Environmental Planning and Assessment Act 1979:
  (a) including a decision relating to a development application, an environmental planning instrument, a development control plan or a development contribution plan under that Act, but
  (b) not including the making of an order under that Act.
(2) The general manager is required to keep a register containing, for each planning decision made at a meeting of the council or a council committee, the names of the councillors who supported the decision and the names of any councillors who opposed (or are taken to have opposed) the decision.
(3) For the purpose of maintaining the register, a division is required to be called whenever a motion for a planning decision is put at a meeting of the council or a council committee.
(4) Each decision recorded in the register is to be described in the register or identified in a manner that enables the description to be obtained from another publicly available document, and is to include the information required by the regulations.
(5) This section extends to a meeting that is closed to the public.

BUSINESS OF MEETING

1. APOLOGIES

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ADOPTION OF MINUTES FROM PREVIOUS MEETINGS

Report No. 3.1 **Adoption of Minutes from previous Floodplain Risk Management Committee Meeting**
Directorate: Infrastructure Services
Report Author: Shelley Flower, Infrastructure Planning Support Officer, IS - Assets & Major Projects
File No: I2020/1629

RECOMMENDATION:

That the minutes of the Byron Shire Floodplain Risk Management Committee Meeting held on 20 August 2020 be confirmed.

Attachments:

1 Minutes 20/08/2020 Byron Shire Floodplain Risk Management Committee, I2020/1204 , page 7⇩

Report

The attachment to this report provides the minutes of the Byron Shire Floodplain Risk Management Committee Meeting of 20 August 2020 .

Report to Council

The minutes were reported to Council on 24 September 2020.

Comments

In accordance with the Committee Recommendations, Council resolved the following:

20-499 **Resolved** that Council adopts the following Committee Recommendations:

Report No. 3.1 Minutes of Byron Shire Floodplain Risk Management Advisory Committee Meeting of 24 March 2020
File No: I2020/1199

1. That the minutes of the Byron Shire Floodplain Risk Management Committee Meeting held on 24 March 2020 be confirmed.

2. The minutes of the meeting held on 24 March 2020 were noted, and the Committee Recommendations adopted by Council, at the Ordinary Meeting held on 23 April 2020 without changes.

20-500 **Resolved** that Council adopts the following Committee Recommendations:

Report No. 4.1 North Byron Flood Risk Management Study and Plan Public Exhibition
File No: I2020/1154

Committee Recommendation 4.1.1

That Council:

1. Support the preparation of a further stand alone technical memorandum (with reference to the Study) to support the North Byron Floodplain Risk Management Study and Plan, detailing:
   a) four dune opening scenarios;
   b) rock wall modification scenarios;
   c) training wall removal scenario;
   d) dredging scenarios; and
   e) bund modifications.

2. Support the addition of a reference to the technical memorandum in the North Byron Floodplain Risk Management Study document prior to adoption.

3. Endorse the amendment of the North Byron Floodplain Risk Management Study and Plan to include modifications recommended in Attachment 2 in this committee agenda except for the following modifications, prior to adoption: -
   a) Comment 3 (MLRA) – that original wording be retained
   b) Comment 6 (Gray's lane) - no action

4. Adopt the North Byron Floodplain Risk Management Study and Plan following completion of the amendments within points 1 to 3 and with the removal of section 8.1.2.2

5. Create a new Operational Plan action to commence development of internal maintenance plans for Council's drainage network within Councils maintenance management software Reflect.

6. Create a new Operational Plan action to commence development of waterway management policies for waterways with relevant state agencies and the Byron Shire Floodplain Risk Management Committee.

MINUTES OF MEETING

BYRON SHIRE FLOODPLAIN RISK MANAGEMENT COMMITTEE MEETING

Venue	Conference Room, Station Street, Mullumbimby
Date	Thursday, 20 August 2020
Time	9.00am

Minutes of the Byron Shire Floodplain Risk Management Committee Meeting held on Thursday, 20 August 2020
File No: I2020/1204

PRESENT: Cr A Hunter and Cr M Lyon

Staff: Evan Elford (Manager Works)
Scott Moffett (Flood and Drainage Engineer)
Chloe Dowsett (Coastal and Biodiversity Coordinator)
Shelley Flower (Infrastructure Planning support Officer)
Dominika Tomanek (Minute Taker)

Invited Members: Andrew Page (Cape Byron Marine Park), Peter Mair (SES), Martin Rose (Environment and Heritage), Karl Allen

Community: Robyn Bolden, Rebecca Brewin, Duncan Dey and Matthew Lambourne

Consultant: Ella Harrison (WMA)

Cr Lyon (Chair) opened the meeting at 9:02 am and acknowledged that the meeting was being held on Bundjalung Country.

APOLOGIES:

Phil Holloway (Director Infrastructure Services)
James Flockton
Steve Keefe

ABSENT:
Cr J Hackett
Toong Chin (Environment and Heritage)
Chad Ellis
Susan Skyvington

DECLARATIONS OF INTEREST – PECUNIARY AND NON-PECUNIARY

There were no declarations of interest.

ADOPTION OF MINUTES FROM PREVIOUS MEETINGS

Committee Recommendation:

1. That the minutes of the Byron Shire Floodplain Risk Management Committee Meeting held on 24 March 2020 be confirmed.

2. The minutes of the meeting held on 24 March 2020 were noted, and the Committee Recommendations adopted by Council, at the Ordinary Meeting held on 23 April 2020 without changes.

(Brewin/Mair)

The recommendation was put to the vote and declared carried.

BUSINESS ARISING FROM PREVIOUS MINUTES

There was no business arising from previous minutes.

STAFF REPORTS - INFRASTRUCTURE SERVICES

Report No. 4.1 **North Byron Flood Risk Management Study and Plan Public Exhibition**
File No: I2020/1154

Committee Recommendation:

That Council:-

1. Support the preparation of a further stand alone technical memorandum (with reference to the Study) to support the North Byron Floodplain Risk Management Study and Plan, detailing:-

   a) four dune opening scenarios;
   b) rock wall modification scenarios;
   c) training wall removal scenario;
   d) dredging scenarios; and
   e) bund modifications.

2. Support the addition of a reference to the technical memorandum in the North Byron Floodplain Risk Management Study document prior to adoption.

3. *Endorse the amendment of the North Byron Floodplain Risk Management Study and Plan to include modifications recommended in Attachment 2 in this committee agenda except for the following modifications, prior to adoption:* -

   a) Comment 3 (MLRA) – that original wording be retained
   b) Comment 6 (Gray's lane) - no action

4. Adopt the North Byron Floodplain Risk Management Study and Plan following completion of the amendments within points 1 to 3.

5. Create a new Operational Plan action to commence development of internal maintenance plans for Council's drainage network within Councils maintenance management software Reflect.

6. Create a new Operational Plan action to commence development of waterway management policies for waterways with relevant state agencies and the Byron Shire Floodplain Risk Management Committee.

(Lyon/Lambourne)

The recommendation was put to the vote and declared carried.

No. 4.2 **Additional Recommendation - Mullumbimby Land Release Areas Flood Impact Assessment and Concept Surface Water Management Plan**
File No: I2020/1154

Committee Recommendation:

That Council share its Mullumbimby Land Release Areas Flood Impact Assessment and Concept Surface Water Management Plan for lot 22 in south Mullumbimby and surrounding land with the Committee and refer to committee for review, comment and advice prior to adoption.

(Dey/Bolden)

The recommendation was put to the vote and declared carried.

There being no further business the meeting concluded at 10:32 am.

STAFF REPORTS - INFRASTRUCTURE SERVICES

Report No. 4.1 **Mullumbimby Land Release Areas (MLRA) Flood and Stormwater Assessment**
Directorate: Infrastructure Services
Report Author: Scott Moffett, Drainage & Flood Engineer, IS - Works - Infrastructure Planning
Alex Caras, Land Use Plannning Coordinator
File No: I2020/1589

Summary:

The North Byron Flood Risk Management Study and Plan has now been adopted by Council.

Infrastructure Planning will now work closely with various internal departments to populate all internal data bases with the new study data to ensure future land use, strategic planning and future development occurring in the North Byron catchments consider this current and new body of work.

Infrastructure Planning will use the plan to inform future flood mitigation studies and capital works.

Council's Strategic Land Use Planning Coordinator is the project manager for the Mullumbimby Land Release Areas (MLRA) project and has developed a **DRAFT** Flood Impact Assessment to assess potential flood impacts from its potential development. This will be presented at the meeting.

RECOMMENDATION:

1. **That the Committee acknowledges the adoption of the North Byron Flood Risk Management Study and Plan.**

2. **That the Committee note the presentation on the Mullumbimby Land Release Areas DRAFT Flood Impact Assessment and Stormwater Management Plan (Attachment 1 – E2020/43608).**

Attachments:

1 Mullumbimby Land Release Areas - Flood Impact Assessment and SWMP Final_Aug2020, E2020/43608 , page 14⇩
2 Floodplain Risk Management Committee Presentation - Mullumbimby Release Areas Flood and Stormwater Assessment_29Oct2020, E2020/84777 , page 196⇩

REPORT

Council is preparing a draft Residential Strategy to set a clear vision and policy framework for the Shire's current and future urban residential lands. Housing affordability has been identified as a priority issue to address ahead of completing the Strategy.

Council, through an expression of interest process, invited land owners to submit affordable housing proposals for land in the Shire to be considered as part of an early implementation initiative. This resulted in five (5) potentially suitable sites being identified, four (4) of which are located along the southern fringe of the Mullumbimby urban area.

Future planning, development and servicing of these sites must be undertaken in a holistic manner to ensure integration with the adjoining Mullumbimby urban area. This is articulated in the draft Residential Strategy with flood and stormwater management among the priority issues to be addressed.

Council engaged consultants WMAwater to assess the flood impacts due to potential regional catchment flooding and to assess and mitigate the flood impacts caused by potential development of the MLRA. The MLRA Flood Impact Assessment is the outcome of this work.

WMAwater have also developed a concept level stormwater management plan for the MLRA to inform the stormwater infrastructure that may be required to service potential development.

A copy of the MLRA Flood Impact Assessment and Stormwater Management Plan is provided at Attachment 1. These will be presented by staff at the meeting.

Key issues
The key issues will be discussed during the presentation at Committee meeting. Refer to Attachment 2 for further detail.

Options
Stormwater management options will be presented and discussed during the presentation at committee meeting. Refer to Attachment 2 for further detail.

Next steps
The next steps are currently being developed internally and will be discussed at the Committee meeting.

STRATEGIC CONSIDERATIONS

Legal/Statutory/Policy Considerations
The flood impact assessment modelling is consistent with the recently adopted North Byron Flood Risk Management Study and Plan.

Financial Considerations
At this time there are no relevant financial considerations.

Consultation and Engagement
Internal consultation regarding the MLRA has been ongoing between Council departments throughout the development of the flood impact assessment.

BYRON SHIRE COUNCIL

MULLUMBIMBY LAND RELEASE AREAS FLOOD IMPACT ASSESSMENT AND CONCEPT SWMP

DRAFT FINAL REPORT



wma water

JULY 2020

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Front Image Source: Google Earth

MULLUMBIMBY LAND RELEASE AREAS FLOOD IMPACT ASSESSMENT AND CONCEPT SWMP

DRAFT FINAL REPORT

MAY 2020

Project Mullumbimby land release areas flood impact assessment and concept SWMP	**Project Number** **119066**
Client Byron Shire Council	**Client's Representative** Alex Caras
Project Manager Daniel Wood	

Revision History

Revision	Description	Distribution	Authors	Reviewed by	Verified by	Date
1	DRAFT	Byron Shire Council	Zahra Abed/Daniel Wood	Zahra Abed	Daniel Wood	MMM YY
2	DRAFT FINAL	Byron Shire Council	Daniel Wood	Bronte Board	Daniel Wood	Apr 20
3	FINAL	Byron Shire Council	Bronte Board	Daniel Wood	Daniel Wood	May 20

MULLUMBIMBY LAND RELEASE AREAS FLOOD IMPACT ASSESSMENT AND CONCEPT SWMP

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1. BACKGROUND

1.1. Introduction

Byron Shire Council (Council) is preparing a draft Residential Strategy (the 'Strategy') to set a clear vision and policy framework for the Shire's urban residential lands. Housing affordability has been identified as a priority issue to address ahead of completing the Strategy. Council, through an expression of interest process, invited land owners to submit affordable housing proposals for land in the Shire to be considered as part of an early implementation initiative. This resulted in five potentially suitable sites (referred to forthwith as the site) being identified, four of which are located along the southern fringe of the Mullumbimby urban area.

The four sites are shown on Plate 1.

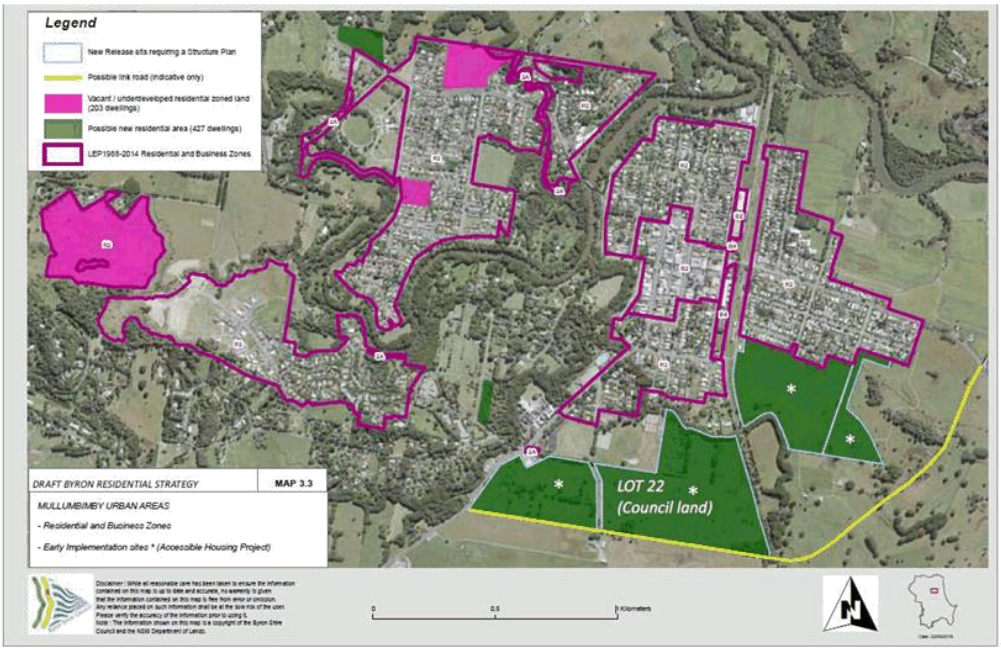


Plate 1 – Potential Urban Housing Supply – Mullumbimby (Provided by Council)

Future planning, development and servicing of these sites must be undertaken in a holistic manner and ensure integration with the adjoining Mullumbimby urban area. This is articulated in the draft Strategy with flood and stormwater management among the priority issues to be addressed.

Council has engaged WMAwater to assess the flood risk due to regional catchment flooding and to assess and mitigate the flood impacts caused by the proposed development. WMAwater has also been engaged to develop a concept level stormwater management plan for the area to inform the stormwater infrastructure that may be required to service the development.

1.2. Overview of Proposed Development Area

The development areas that have been selected for this project are located to the south and south east of Mullumbimby. The locations were selected based on their locality to the township and amongst other things the hazard posed to the site due to flooding.

The development in its existing condition is classified as rural land and consists primarily of land used for grazing purposes. The site is bounded by Mullumbimby Road to the east and Jubilee Avenue to the west. In the middle of the development is the existing (unused) rail corridor. To the north of the western lots, along Jubilee Avenue, are the Mullumbimby High School Fields and the Mullumbimby Rural Co-Op. To the north of the eastern lots is what is referred to as the New City Road section of Mullumbimby. To the south is agricultural land. Plate 2 shows the site and its surrounds.



Plate 2 – Study Area

1.3. Overview of Flooding

1.3.1. Regional Catchment Flooding

The existing site is subject to regional catchment flood affectation from the Brunswick River catchment. Saltwater Creek and Kings Creek run through the development area. Based on discussions with landowners Kings Creek has a historical choke point present at the rail crossing. This has caused flooding in the past as the crossing has insufficient capacity.

The sites are impacted by events greater than a 10% AEP from flooding from the Brunswick River. The river reaches a level which prevents Kings Creek and its associated catchment from effectively discharging downstream of Mullumbimby Road into the river. This action backs up Kings Creek and inundates the site. The site acts as a flood storage area for this event. The site is also impacted by flooding from Kings Creek, Saltwater Creek and by flows that overtop Jubilee Avenue from Mullumbimby Creek.

Through the middle of the sites runs a historic railway line. This line acts as a hydraulic control in the area. As the rail line has been present in the area for a significant period of time, the impact of the rail line on flood levels is deemed to be the base flood condition. While alteration to the rail line and drainage structures through it may improve flood levels west of the railway it would also potentially result in increases east. As such, no change to the current drainage regime through the rail line is proposed to prevent adverse impacts downstream.

1.3.2. New City Road Drainage Issues

During the course of the project, it was identified that in addition to regional catchment flood affection, in local storm events there is a significant ponding issue present on lot DP 1032298, which is located to the south east of New City Road. A previous study, undertaken by Ardill Payne and Partners (AP&P) on behalf of Council, the *Drainage Assessment and Mitigation Options Report, New City Road Mullumbimby* (AP&P, 2018) reviewed this issue and developed solutions to manage the ponding and storage of water. This report is provided in Appendix A.

The assessment identified that the primary issue causing ponding of water onsite is the presence of blockages to the waterway downstream of the site including a blockage of the channel at its discharge point into Kings Creek. A solution involving the removal of blockages, upgrades to existing culverts and the incorporation of flap gates at the channel discharge point into Kings Creek was identified as a potential solution.

It was noted in the report that the solutions developed only result in minor water level improvements, with the primary benefit being a reduced time of ponding. This is due to the low hydraulic gradient in the area.

The current assessment undertaken has not revised this local drainage assessment with the outcomes presented in the previous report logical and in alignment with WMAwater's understanding of the issue.

The options proposed in the drainage assessment would need to be incorporated into the future development, if it was to occur. The local drainage issue, unmanaged, would result in frequent and long-lasting ponding on the future development area which would significantly reduce the amenity of the development and also jeopardise the function of the local stormwater system.

2. AVAILABLE DATA

The following data sources were utilised in the establishment of the overland catchment flood model.

2.1. Existing Adopted Flood Model

Council adopted the North Byron Flood Study in June 2016, as a precursor to preparing the North Byron Floodplain Risk Management Study and Plan (FRMS&P). The Study investigates and quantifies the existing flood risk within the Brunswick River catchment (which includes the Mullumbimby subcatchment) by development and use of computer-based flood models. The supporting flood model has been recently reviewed and updated to provide more accurate calibration for the Mullumbimby subcatchment. Further details of this flood model are provided in the North Byron Flood Study (BMT, 2016).
This model has been utilised for this study, with updates undertaken to capture local features.

2.1.1. March 2017 Calibration

On the 31 March 2017, ex-Tropical Cyclone Debbie crossed into the Northern Rivers region in New South Wales subjecting the Brunswick River catchment to heavy rainfall. As a result of this, Mullumbimby, Ocean Shores, Billinudgel, Brunswick Heads and Main Arm experienced severe flooding. This flood event saw homes inundated, residents forced to evacuate, roads closed and thousands of people without power.

As part of the FRMS&P the hydraulic model was utilised to assess the March 2017 Flood Event. The FRMS&P process reviewed the previous modelling undertaken for the flood study and undertook several improvements to enable a better replication of the event.

2.2. New City Road Assessment Flood Model

A previous study, undertaken by Ardill Payne and Partners on behalf of Council, the *Drainage Assessment and Mitigation Options Report, New City Road Mullumbimby* (AP&P, 2018) developed a small TUFLOW model which focussed on the eastern lots of the site.

This model contained more up to date topography for the area and also included local drainage features through the site. This information was extracted and utilised within the hydraulic model developed for this site.

2.3. Existing Drainage

Details of the existing pit and pipe drainage system covering all upstream areas draining to the site was provided by Council.

3. ENVIRONMENTAL ASSESSMENT

A desktop level environmental assessment was undertaken based on available data and information provided by Council. A larger study area rather than four sites was considered for this assessment (
Figure 1). The purpose of the assessment was to determine if there were any specific environmental constraints that should be accounted for during the project when considering the potential developable area.

Investigation into the environmental assessment identified a species of kola with scientific name of *Phascolarctos cinercus* as threatened Fauna. Table 1 presents the details of this threatened koala species.

Table 1 - Threatened Fauna Details

Species Code	Family Name	Scientific	Common Name
1162	Phascolarctidae	Phascolarctos cinercus	Koala

Three koala tertiary habitats with a total area of 31,779 square metres were recognized in the assessment area.
Figure 1 shows the locations of these three tertiary habitats. Table 2 indicates the area of each habitat.

Table 2 – Koala Habitat Details

Label	Habitat Type	Area (m2)
1	Tertiary Habitat	10302.23
2	Tertiary Habitat	15466.84
3	Tertiary Habitat	6009.67

A review of the available high environmental value vegetation information layer identifies the presence of key habitat 4 and 5 in the assessment area. The high value vegetation has been identified in forms of forested wetlands and rainforests and into class of coastal swamp forests, camphor laurel 51-80%, and subtropical rainforests. Table 3 is summarized the details of high value vegetation for study area.

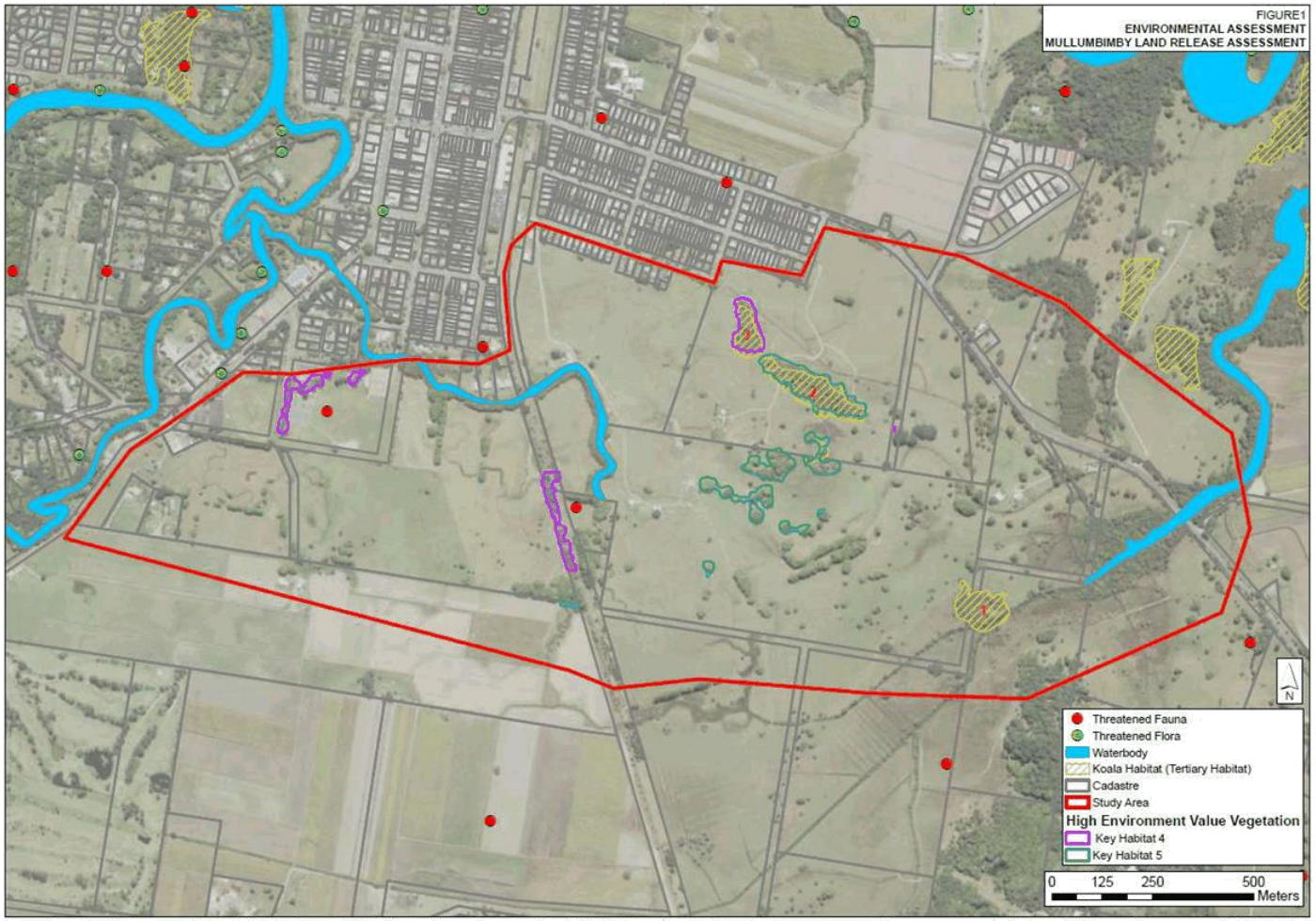

FIGURE1
ENVIRONMENTAL ASSESSMENT
MULLUMBIMBY LAND RELEASE ASSESSMENT
N
Threatened Fauna
Threatened Flora
Waterbody
Koala Habitat (Tertiary Habitat)
Cadastre
Study Area
High Environment Value Vegetation
Key Habitat 4
Key Habitat 5
0 125 250 500
Meters

Table 3 – High Value Vegetation Details

Vegetation Type	Key Habitat	LOCALITY	PCT form	PCT class	PCT comm
Paperbark-Rainforest	5	Mullumbimby Rd	Forested Wetlands	Coastal Swamp Forests	Broad-leaved Paperbark swamp sclerophyll forest with rainforest elements on coastal floodplains
Camphor Laurel 51-80%	4	Mullumbimby	Rainforests (Derived)	Camphor Laurel 51-80%	Derived Camphor Laurel Rainforest Wet Sclerophyll Forest
Rainforest	5	Mullumbimby Rd	Rainforests	Subtropical Rainforests	unassigned
Paperbark	5	Mullumbimby Rd	Forested Wetlands	Coastal Swamp Forests	Broad-leaved Paperbark-Brush Box-Swamp Box swamp sclerophyll forest zone clays of coastal plains
Rainforest	5	Mullumbimby Rd	Rainforests	Subtropical Rainforests	Bangalow Palm-Umbrella Cheese Tree-Brown Kurrajong-Broad-leaved Paperbark floodplain rainforest
Paperbark	4	Mullumbimby Rd	Forested Wetlands	Coastal Swamp Forests	Broad-leaved Paperbark swamp sclerophyll forest with rainforest elements on coastal floodplains
Wattle	4	Saltwater Creek	Rainforests	Subtropical Rainforests	Wattle
Rainforest	5			Rainforests	Subtropical Rainforests

The desktop ecological assessment highlighted some locations where there is potentially high value habitats and vegetation, but did confirm that in general the area does not have significant environmental value that needs to be maintained.

4. FLOOD IMPACT ASSESSMENT

The purpose of this study was to undertake a concept level analysis of the potential developable areas within the site. To do this it is required to first understand the base flood conditions and then assess a range of development footprints to determine a viable development footprint.

The following section provides a summary of the process that was undertaken to achieve this goal. In general, the process involved the following:

- Base hydraulic model update;
- Base hydraulic model results;
- Development footprint optimisation; and,
- Impact assessment.

Note that no hydrologic model updates were completed as part of the regional flood analysis. It was considered that the base hydrology component of the North Byron Flood Study Model was sufficiently accurate to assess the regional flood impacts of this development.

4.1.1. Base Hydraulic Model Update

The TUFLOW 2D hydraulic model developed as part of the North Byron Flood Study was used as the base point of this flood assessment. This model consists of several nested grids with a coarse grid overlaying areas outside the key areas of interest.

The site in the base model was located at an area where the coarse grid and a fine grid representing the Mullumbimby town centre overlapped. The area contained several 1-dimensional channels due to the use of the coarse grid which could potentially impact the results of a local analysis in the area. In order to better define the flood risk and the potential flood impacts onsite the hydraulic model had several updates including the following:

- Extension of the high-resolution nested grid to full encompass the study area and surrounds;
- Removal of the 1d network in the area now covered by the high-resolution nested grid;
- Minor update of the inflow locations in the model to ensure the correct flows were placed in logical positions in the floodplain;
- Review and update of 1d structures in the area of interest to ensure reasonable representation of hydraulic controls;
- Incorporation of local drainage features as surveyed in the New City Road Drainage Assessment (AP&P, 2018); and
- Incorporation of detailed ground survey undertaken as part of the New City Road Drainage Assessment (AP&P, 2018).

Figure 2 shows the revised hydraulic model setup for the site.

4.1.2. Revised Base Conditions Results

Figure 3 through to Figure 18 show the revised flood results. Results for the Water Surface Elevation, Depth, Velocity and Hazard for the 20%, 5%, 1% and 0.2% AEP existing conditions model are presented.

The differences to the flood results achieved in the North Byron Flood Study (BMT, 2016) are minor with the flood conditions present onsite generally unchanged. The revised model does however result in a higher resolution of flood results being presented and the high hazard corridors, especially in the areas where the 1d channel was removed, being more defined.

The 1% AEP was also run for a range of Climate Change Events in accordance with Council's climate change policy:

1. 1% AEP + 2.9 mAHD tailwater enveloped with 5% AEP and 3.1 mAHD tailwater
2. 1% AEP + 10% rainfall increase + 2.4 mAHD tailwater enveloped with 5% AEP + 10% rainfall increase and 2.6 mAHD tailwater
3. 1% AEP + 30% rainfall increase + 2.9 mAHD tailwater enveloped with 5% AEP + 30% rainfall increase and 3.1 mAHD tailwater
4. 1% AEP + 30% rainfall increase + 3.1 mAHD tailwater

The results of this assessment are provided in Appendix B. Note a review of the initial flood model results confirmed the site did not have any areas that were dominated by the 5% AEP with higher tailwater and thus to save modelling time these were omitted. The results presented are only relevant for the site of interest. Areas outside the site of interest should utilise the results presented in the North Byron Flood Study (BMT, 2016).

In addition to the sensitivity runs set out in Councils climate change policy, the Draft North Byron Floodplain Risk Management Study and Draft Plan (FRMS&P 2020), provides a recommendation that the Flood Planning Level (FPL) should be based upon a climate change scenario of 1% AEP + 20% rainfall increase + 2.9 mAHD tailwater enveloped with 5% AEP + 20% rainfall increase and 3.1 mAHD tailwater. The scenario been used to set Draft Flood Planning Levels for the site.

Following the confirmation of the base flood conditions for the site, the flood model was updated to incorporate concept development footprints.

4.1.3. Development Footprint Optimisation

Once the base model was updated and the revised flood levels obtained a concept level development layout for the site was developed. The footprint was based on the constraints present on the site, noting that within the Council's Development Control Plan (DCP 2014) New Release Areas are not considered suitable in areas of High Flood Hazard in the 1% AEP. As such areas within the high hazard zone have not been considered suitable for development as part of this assessment. The assessment also aimed to consider the viability of the footprint with regards to the land incorporated into the model being of viable size and its serviceability with regards to roads and services connections.

4.1.3.1. Consultation

Throughout the course of the project several consultations were undertaken. At each consultation various development footprints, including fully filled and optimised footprints were provided to the group for discussion. The following key findings and discussions with regards to development footprints and flood impacts were present throughout these meetings:

- The landowners, while understanding of the limitations of the development constraints provided by the high hazard areas were interested in understanding if any area inside the high hazard zone could potentially be developed without causing impact;
- Landowners were concerned that indicative roadways presented on some maps for visualisation purposes were inappropriate and may cause issues in the future; and,
- In some locations existing preliminary works and proposed fill areas did not align.

Based on the feedback from these meetings, the following resolutions were proposed:

- An additional model run, provided as an addendum (Appendix D) to this report summarises the additional area that, when ignoring the DCP requirements, has the potential to be filled without causing impact to surrounding properties;
- Roadways that were provided on the consultation material have been removed within this report. The purpose of the roadways was to ensure a corridor was considered on the footprints developed not specifically to define the road corridor. As such the roadways serve no other purpose in this analysis and can be removed. Potential road access points are however presented on Figure 19; and,
- A masterplan for the western lots was provided following the last consultation. This masterplan was reviewed and where changes could be implemented into the development footprint without causing offsite flood impacts these were undertaken. The results of this have been incorporated into the development footprint utilised.

4.1.4. Fill Pad Arrangement

Figure 19 shows the final development footprint used for this assessment. The numbers presented on the map are the numbers to be used as a reference for each fill pad when reviewing the results of the assessment.

Each fill pad has been set to meet the requirements of Council's DCP (2014), which is the 1% AEP + climate change. Based on the North Byron Floodplain Risk Management Study and Draft Plan (FRMS&P 2020), the climate change consideration is to be a 20% increase in rainfall intensity and a 0.9 m sea level rise.

A review of the viability of the option to lower the fill pads was undertaken as part of the process, with the concept that lowering the fill pads would reduce the overall cost of the development. A review of the current Council design guidelines indicates that the new roadways are to be built at the 1% AEP + climate change levels, with an allowance of a maximum of 300 mm of water to be present on the roadway in this event. Based on this control level, to enable grading of the sites to

the roadway there is limited opportunity to reduce the fill pad levels as they would be unable to drain to the roadway.

In addition to the fill pads presented, there are some areas (around sites 1-5) through the site which may require the drainage corridor to be modified as part of the potential cut fill balance approach used for this area however these are not specifically required in the hydraulic model to achieve a local non-worsening outcome. The areas where drainage corridor modifications are required to offset regional flood impacts are presented on Plate 3. The dimensions of the drainage corridor upgrades required have not been included in this report the as these systems will likely undergo significant revision once additional constraints are considered at the development application stage. The channels within the analysis have been developed to a concept level and designed to tie into existing ground levels offsite with a maximum of 1:4 bank slopes.



Plate 3 – Potential Drainage Corridor Works Locations

4.1.5. Flood Storage

As part of the footprint optimisation process a review of available flood storage within the development area when compared to the potential developable area was undertaken. The footprints proposed result in close to a cut to fill balance for the development as a whole. However, this does assume that the individual landowners will provide additional spoil to other landowners where there is a deficit.

The hydraulic model has been run assuming no balance of floodplain storage is present. This is done to provide a level of conservativeness to the assessment. Figure 20 shows the preliminary cut to fill balance that has been undertake for the purposes of confirming that no loss of flood storage is achievable onsite.

5. ASSESSMENT RESULTS

5.1. Impacts of Proposed Development on Regional Catchment Flooding

Future development will involve different subdivision layouts, housing designs and earthwork grading. Figure 20 shows the peak flood level impacts on mainstream flooding caused by the proposed works in the 1% AEP event. In general, the impacts are limited to less than 0.02 m offsite; however, some local impacts are present north of the co-op in the sport fields and on the community garden. Impacts greater than 0.01 m are limited to open space areas. Appendix C shows the results of flooding for the development footprint for all modelled events.

Figure C37 shows the impact of development under the Draft Flood Planning Level (FPL) Event (1% AEP, 20% Rainfall Increase and 0.9 m Sea Level Rise to account for climate change). The impacts in the event are slightly greater than in the 1% AEP current climate conditions assessment. This is due to the loss of flood storage being proportionately greater in this event. The results of this assessment highlight the need to ensure that there is no net flood storage loss due to the development of the site.

5.2. Estimated Fill Pad Levels and Volumes

Based on the Draft FRMS&P the minimum floor level for a New Release area is the 2100 FPL Event (1% AEP, 20% Rainfall Increase and 0.9 m Sea Level Rise to account for climate change + 500 mm). Table 4 shows the estimated FPL for each lot as noted on Figure 19. Note that some lots have a varying water level based on the results generated and as such a variable level is presented. These levels were used to estimate the fill required for each lot.

During the community consultation it was discussed and agreed that the fill estimation will be based on the design flood level rather than the flood planning level, with the ultimate flood planning level to be achieved through appropriate construction techniques.

Following a presentation to Council, a query regarding the potential to further lower development fill levels with alternative building products (such as buildings on stumps) was raised. This is was based on aligning with the Draft FRMS&P direction of not allowing slab on ground development (to enable future house raising to occur more easily if required) while also potentially lowering the cost of developing the area.

While this may have merit, the potential reduction in fill is limited by several other considerations:

- The lot must have pedestrian and vehicular access to a readily accessible refuge at a level equal to or higher than the lowest habitable floor level of a dwelling house;
- Vehicular access to a dwelling house will not be inundated by a water level to a level of more than 0.3 m during a 1% AEP flood event;
- The lots in general should be able to freely drain to the roadway and as such lot will need to be at a level greater than the 1% AEP flood level minus 300 mm at minimum; and
- The road design of the land release area must be in alignment with both Council and SES Flood Evacuation Strategies.

Based on these considerations, there is a potential that some sections of the lot parcels may be lowered to below the Draft Flood Planning Level Event (1% AEP, 20% Rainfall Increase and 0.9 m Sea Level Rise to account for climate change). As the lots still must be free draining to the roadway however and cannot be lower than 1% AEP flood level minus 300 mm, the reductions in fill requirements are unlikely to be substantial.

Table 4 – Flood Levels and Flood Planning Levels

Lot ID	Flood Level (mAHD)	Flood Planning Level (mAHD)
1	4.5	5.0
2	4.3-4.0	4.8-4.5
3	4.6-4.0	5.1-4.5
4	4.4-3.9	4.9-4.4
5	3.9-3.8	4.4-4.3
6	3.7-3.6	4.2-4.1
7	4.1-3.6	4.6-4.1
8	3.6	4.1
9	3.6	4.1

Table 5 presents the estimated cut and fill required to meet the flood level as discussed above for each lot. The rows titled as cut from surrounds are the estimated cut available from the land adjacent to the development footprints assuming a landform that aligns with the intent of the stormwater management option described in Section 6.5. It is likely that through refinement of the development fill pads and the stormwater design in subsequent phases of the project that this outcome could be optimised to achieve a cut to fill balance for the entire development footprint.

Table 5 – Estimated Volume Balance

Lot ID	Development Area (m^2)	Estimated Fill Volume (m^3)	Estimated Cut Volume (m^3)	Balance (m^3)
1*	19,000	1,600	-	-1,600
2	30,000	11,050	150	-10,900
3	11,000	4,700	50	-4,650
Cut from Surrounds			32,000	**14,650**
4	55,000	19,250	100	19,150
5	48,000	46,200	0	46,200
Cut from Surrounds			49,000	**-16,350**
6	7,000	2,550	50	2,500
7	89,000	30,450	12,700	17,750
8	38,000	40,450	0	40,450
9	4,350	6,750	0	6,750
Cut from Surrounds			60,000	**-7,450**
Total Balance		163,000	154,050	**-9,150**

*This site was assumed to have no cut as it is understood the existing residence is to remain – therefore for conservatism it is assumed only fill will occur onsite.

5.3. Impacts of Proposed Development on Local Overland Flow Flooding

The proposed development footprint impact results show some minor impacts offsite in specific areas. A review of the model results indicates this is due to the local runoff mechanisms of the area to the north of the site not being fully captured in the regional model. Additionally, some small areas of the model were removed to accommodate local flows. These locations are shown on Figure 21 as the additional potential development area. These areas can likely be developed without causing impact if the local drainage system is augmented to ensure the upstream areas can drain appropriately.

It is a requirement of any future development approval to ensure these local impacts (as well as regional impacts) are appropriately managed.

6. CONCEPT STORMWATER MANAGEMENT PLAN

Following the finalisation of the development footprint, a concept level stormwater management assessment was undertaken. The purpose of this process was to provide a preliminary sizing of water quantity and quality systems for the area, including indicative trunk stormwater pipe sizes.

The methodology for the assessment is as follows:

- Determination and validation of pre-development flows;
- Determination of post development stormwater flows;
- Development of appropriate stormwater quantity management systems; and,
- Estimation of stormwater quality treatment system sizes and locations.

The stormwater quantity analysis has been undertaken utilising Australian Rainfall and Runoff (ARR 2019) methodology. The hydrologic model XP-RAFTS has been used to inform the peak flow rates and estimate the detention volumes required to offset the increased runoff generated by the development.

Note that at this stage in the assessment of the site it has been assumed that runoff from the site will need to be managed back to pre-development flow rates. Given the location of the development area relative to the location of the creek it may be identified in future assessments that detention storage is not required.

6.1. Pre-Development Stormwater Quantity

In order to understand the post-development stormwater management requirements, it is necessary to establish the pre-development flow rates for the area. Currently the area consists of low-lying land which has limited grade. There are three main discharge locations: Kings Creek and Saltwater Creek west of the railway, and the New City Road drainage system east of the railway.

As previously discussed, there are significant drainage issues present within the New City Road drainage system. For the purposes of this assessment it has been assumed the issues have been resolved as part of the development of the land. An allowance for these works has been provided in the costing section of this report.

6.1.1. Catchment Delineation

The study area was divided into thirteen subcatchments based on the proposed development locations and the topography of the site. Figure 22 shows the pre-development stormwater catchment delineation. Table 6 outlines the pre-development subcatchment details. A Manning's 'n' of 0.03 was utilised for the pre-development conditions roughness. This is slightly lower than the recommended value of 0.04 for pre-development however results in a good validation to the estimated Rational Method flow rates. A 0% effective fraction impervious was considered for all pre-development catchments.

Table 6 – Subcatchment details

Catchment Name	Subcatchment Area (ha)	Slope (%)
E_11	3.68	3.5
E_12	4.83	0.6
E_21	4.04	0.9
E_22	5.60	0.5
E_3	2.73	1.3
K_1	2.83	0.35
K_21	3.24	1.0
K_22	3.23	1.8
K_3	9.91	0.45
K_4	9.37	0.65
F_11	2.71	0.55
F_12	5.43	0.5
F_2	7.17	0.4

6.1.2. Design Flow Assessment

Design flow estimates were undertaken using parameters developed in accordance with current best practice guidance (ARR2019). The following is a summary of the design flow assessment approach:

- The IL and CL values selected for pervious area were extracted from Data Hub and were applied as 25 millimetres and 1.0 millimetre per hour, respectively;
- Rainfall Intensity Frequency Duration (IFD) data and temporal pattern data from ARR was also extracted from the ARR (2019) Data Hub. The 1% AEP event was adopted for modelling and assessment of the pre-development scenario;
- Manning's n was set as 0.03 for pervious catchments and 0.025 for impervious catchments;
- Storm durations ranging from 10 minutes to 30 hours, each with an ensemble of 10 different temporal patterns, were assessed to determine the critical storm for each subcatchment; and,
- The critical duration was deemed to be the duration which resulted in the highest median peak flow rate over the 10 temporal patterns that were assessed.

The pre-development peak flow rates and critical durations, for each subcatchment, are shown in Table 7.

Table 7 – Pre-development flow rates for 1% AEP event

Catchment Name	Pre-development flow (m^3/s)	Critical duration and temporal pattern
E_11	1.30	ECS_1pct_45min_8
E_12	1.12	ECS_1pct_2hr_9
E_21	1.07	ECS_1pct_2hr_2
E_22	1.19	ECS_1pct_2hr_9
E_3	0.78	ECS_1pct_2hr_10
K_1	0.59	ECS_1pct_2hr_2
K_21	0.88	ECS_1pct_2hr_10
K_22	0.99	ECS_1pct_2hr_10
K_3	1.90	ECS_1pct_6hr_3
K_4	2.01	ECS_1pct_2hr_9
F_11	0.67	ECS_1pct_2hr_4
F_12	1.16	ECS_1pct_2hr_9

6.1.3. Validation of Flows

In order to ensure that pre-development flow rates for the site were generally in the order of other empirical methods a Rational Method check for each subcatchment was undertaken.

Application of the Rational Method is based on a simple formula.

$$Q = CIA/360$$

Where:
Q = design discharge (m^3/s)
C = runoff coefficient (dimensionless)
I = design rainfall intensity (mm/hour)
A = subcatchment area (ha)

For the study area, *I* was extracted from Data Hub (ARR 2016) and for the time concentration for each subcatchment. *A* was obtained through GIS interrogation and 0.56 was adopted as the runoff coefficient, *C*.

The time of concentration of each subcatchment in the pre-development condition was estimated using the stream velocity method. The travel velocity for each subcatchment was assumed to be 0.3 m/s consistent with a flat terrain (QUDM 2016). Table 8 presents flow rates generated by each subcatchment produced via the Rational Method.

Table 8 – Rational Method flow rates for 1% AEP event

Subcatchment	Longest path (m)	Time of concentration (min)	I (mm/hour)	Area (ha)	C (-)	Q (m3/s)
E_11	328	18	174	3.68	0.56	1.0
E_12	339	19	169	4.83	0.56	1.3
E_21	320	18	174	4.04	0.56	1.1
E_22	360	20	164	5.60	0.56	1.4
E_3	449	25	147	2.73	0.56	0.6
K_1	388	22	157	2.83	0.56	0.7
K_21	311	17	178	3.24	0.56	0.9
K_22	305	17	178	3.54	0.56	0.9
K_3	602	33	129	9.9	0.56	2.0
K_4	560	31	132	9.34	0.56	1.9
F_11	294	16	183	2.7	0.56	0.8
F_12	431	24	15	5.43	0.56	1.3

6.1.4. Comparison to Pre-Development Flows

Table 9 outlines a comparison between the pre-development flow rates and Rational Method flow rates for 1% AEP event. The results of the hydrologic model are generally consistent with the Rational Method estimates.

Table 9 – Validation of hydrologic model flows to Rational Method flows for the 1% AEP event

Subcatchment	Pre-development flow (m^3/s)	Rational Method flow (m^3/s)
E_11	1.3	1.0
E_12	1.1	1.3
E_21	1.1	1.1
E_22	1.2	1.4
E_3	0.8	0.6
K_1	0.6	0.7
K_21	0.9	0.9
K_22	1.0	0.9
K_3	1.9	2.0
K_4	2.0	1.9
F_11	0.7	0.8
F_12	1.2	1.3

6.2. Post-Development Assessment without Stormwater Treatment Measures

The post-development scenario was modelled by updating the pre-development model to incorporate the estimated development footprint. The footprint was developed based on land which was shown to be free from flooding impacts. Each subcatchment was further divided into undeveloped (pervious) and developed (impervious) areas. Figure 23 shows the post development subcatchments.

The developed area in each subcatchment was considered to have an effective impervious area of approximately 60%. It is noted that this value is representative of medium density residential development and was thus deemed a conservative value for this assessment.

The following parameters were used to define the post-development model:

- The IL and CL values selected for pervious area were extracted from Data Hub and were applied as 25 millimetres and 1.0 millimetre per hour, respectively;
- The Manning's n value was set as 0.025 for impervious areas;
- Vectored slope of the impervious subareas was set as 0.5% to be consistent with AUS-SPEC's Development Design Specification (D5) Stormwater Drainage (2008) handbook (AUS-SPEC 2008); and,
- The same temporal pattern and critical duration used in the pre-development case was used to assess the post development increase in runoff.

Table 10 presents the development areas, impervious and pervious subareas as well as the post-development flow rates generated by each subcatchment.

Table 10 – Comparison of pre- and post-development flows – 1% AEP event

Catchment Name	Assumed developable area (ha)	Pre-development flow (m^3/s)	Post-development flow (m^3/s)	Increase in flow (%)
E_11	1.9	1.3	1.3	1
E_12	3.0	1.1	1.6	42
E_21	2.1	1.1	1.6	54
E_22	3.4	1.2	1.4	14
E_3	1.1	0.8	0.9	14
K_1	0.7	0.6	0.7	19
K_21	2.8	0.9	1.1	26
K_22	2.7	1.0	1.1	12
K_3	2.1	1.9	2.1	13
K_4	5.1	2.0	2.8	41
F_11	1.7	0.7	1.1	61
F_12	3.2	1.2	1.7	48

6.3. Stormwater Quantity Management Plan

A Stormwater Quantity Management Plan for the study area was developed in accordance with AUS-SPEC's Stormwater Drainage Design (2008) guidance. The aim of the Stormwater Quantity Management Plan is to restrict outflow rates from the subcatchments post-development outflows to pre-development conditions. To achieve this several detention storages have been incorporated into the developed conditions model to allow required storage volumes to be estimated.

6.3.1. Stormwater Detention Basin Sizing

The XP-RAFTS model was utilised to identify the storage volume needed for each subcatchment to restrict post-development flow rates to pre-development conditions. The post-development landscape was considered to identify appropriate detention basin locations for each subcatchment, Figure 24 presents a potential detention basin arrangement. To identify the approximate surface area required for detention basins, it was assumed that the detention basins will be one metre deep. This was applied to ensure a conservative footprint and because having the basins sitting low in the floodplain reduces the likelihood of them impacting on a regional flood event. Table 11 presents the detention basin storage capacities for the subcatchments.

Table 11 – Detention Basin Details

Catchment Name	Assumed developable area (ha)	Required detention basin volume (m^3)
E_11	1.9	100
E_12	3.0	1000
E_21	2.1	1300
K_22	3.4	100
E_3	1.1	400
K_1	0.7	700
K_21	2.8	950
E_22	3.4	650
F_11	1.7	
K_3	2.1	700
K_4	5.1	
F_12	3.1	1900

The reductions in peak flow due to the addition of the detention basins are presented in Table 12. Table 13 presents a comparison of the water surface elevations pre-development and post-development assuming offsite runoff is managed to pre-development conditions. Figures 2 and 21 provide the reference locations of these points.

Table 12 – Reduction in peak flows due to addition of detention basins for the 1% AEP event

Catchment Name	Pre-development flow (m^3/s)	Post-development flow (m^3/s)
E_11	1.33	1.26
E_12	1.12	1.10
E_21	1.07	1.07
K_22	0.99	0.97
E_3	0.78	0.77
K_1	0.59	0.59
K_21	0.88	0.88
E_22	1.19	1.85
F_11	0.67	
K_3	1.90	3.90
K_4	2.01	
F_12	1.16	1.15

Table 13 – Comparison of pre- and post-development water surface elevation – 1% AEP event

Point ID	Pre-development WSE (mAHD)	Post-development WSE (mAHD)	Difference(m)
1	4.66	4.67	0.01
2	4.93	4.93	0
3	4.46	4.51	0.05
4	4.42	4.45	0.03
5	3.77	3.77	0
6	3.81	3.71	-0.1
7	3.63	3.63	0
8	3.58	3.59	0.01
10	3.94	3.95	0.01
11	3.55	3.56	0.01
12	3.54	3.55	0.01
13	3.49	3.49	0
14	3.52	3.52	0
15	3.65	3.65	0
16	3.55	3.63	0.08
17	3.84	3.88	0.04
18	4.29	4.3	0.01
19	4.38	4.4	0.02
20	4.43	4.45	0.02
21	4.77	4.77	0
22	4.84	4.84	0
23	4.41	4.41	0
24	4.02	4.03	0.01
25	3.37	3.38	0.01
26	3.32	3.32	0
27	3.32	3.32	0
28	3.31	3.31	0
29	3.3	3.3	0
30	3.32	3.32	0
31	3.32	3.33	0.01
32	3.33	3.33	0
34	3.32	3.33	0.01
36	3.33	3.35	0.02
38	3.33	3.34	0.01

39	3.33	3.34	0.01
40	3.33	3.34	0.01
41	3.48	3.49	0.01
42	3.45	3.45	0
43	3.39	3.39	0
44	3.31	3.32	0.01
45	3.31	3.31	0
46	3.32	3.33	0.01
47	3.19	3.2	0.01
48	4.42	4.42	0
49	4.5	4.51	0.01

At this stage outlet pipes have been estimated to optimise the detention basin sizes and for indicative pricing purposes. As the final arrangement and overall designs of the basins is incomplete however, the proposed outlet systems have not been stipulated in the report. It is considered that each basin outlet design will need to accommodate for a low flow outlet pipe and a high flow spillway which will ensure controlled flow in all events.

6.3.2. Trunk Stormwater Pipe Size Estimation

In addition to sizing of the detention basin systems, indicative trunk stormwater pipe sizes were determined using AUS-SPEC's Stormwater Drainage Design handbook (2008). This guideline provides the following advice:

- A minimum conduit size of 375 mm diameter for circle pipes;
- The minimum pipe capacity required is considered to be equivalent to the minor storm event (assumed to be 20% AEP capacity in this instance); and,
- An acceptable gutter flow width in the minor design storm is a maximum of 2.5 metres.

For achieving pipe sizing based on the above criteria, the Rational Method was applied to estimate the 20% AEP discharge for the developed areas of each subcatchment. Time of concentration estimates were based on a standard inlet time of 10 minutes. It was assumed that the road surface has an inlet time of 5 minutes, and that the residential areas have an inlet time between 10-15 minutes. Therefore, an average of 10 minutes was deemed appropriate. An average pipe velocity of 2.5 m/s was assumed.

The required pipe diameters to service the peak flows for each subcatchment were then estimated, adopting the minimum longitudinal grade of 0.5%. These are shown in Table 14.

It has been assumed that the pipe will be required to be utilised for a nominal length within each subcatchment, equivalent to roughly 50% of the length of the catchment in the projected direction of flow Figure 24 shows the concept level trunk drainage assumed.

It is noted that the pipe size will ultimately reduce as the catchment area upstream of the pipe reduces; however, for concept design and costing purposes this assumption is considered conservative. Once indicative lot and road arrangements are developed, the stormwater system assumptions should be revisited to ensure appropriate setup.

No assessment of inter-allotment drainage or drains upstream of the trunk stormwater line has been undertaken at this time.

Table 14 – Pipe sizing and Capacity Details

Catchment Name	20% AEP Peak Flow (m^3/s)	Pipe Capacity (m^3/s)	Pipe Velocity (m/s)	Pipe Diameter (m)	Pipe Length (m)
E_11	0.5	0.6	1.7	0.675	90
E_12	0.9	1.0	1.9	0.825	145
E_21	0.9	1.0	1.9	0.825	195
E_22	1.0	1.3	2.0	0.9	70
E_3	0.3	0.4	1.5	0.6	71
K_1	0.2	0.2	1.3	0.45	103
K_21	0.8	0.8	1.8	0.75	121
K_22	1.2	1.3	2.0	0.9	130
K_3	0.6	0.6	1.7	0.675	118
K_4	1.3	1.9	2.2	1.05	139
F_11	0.5	0.6	1.7	0.675	85
F_12	0.9	0.8	1.8	0.75	175

6.3.3. Road Capacity

For events greater than a 20% AEP event, it has been assumed the remaining stormwater will be conveyed in the roadway.

Utilising the Northern Rivers Local Government Typical Urban Road cross-section (refer Plate 4), the capacity of the roadway has been estimated to ensure the 1% AEP event can be carried within the road reserve. It has been assumed that the road will be at 0.75% longitudinal grade and will be seven metres wide, with a 3.5 m verge on each side and no allowance for parking.

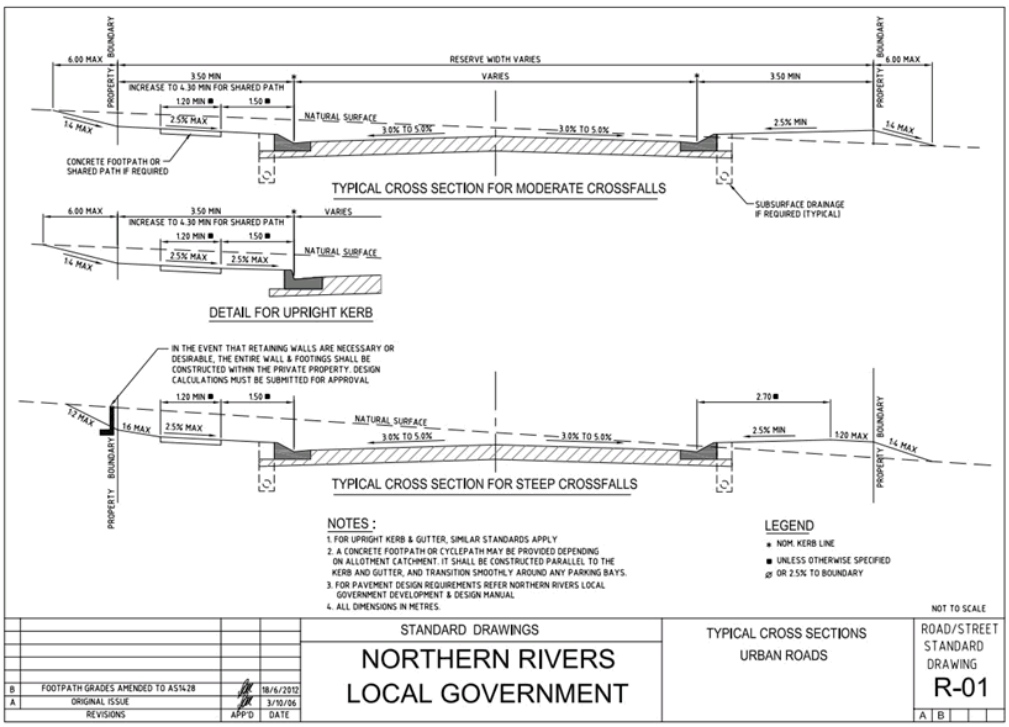


Plate 4 – Typical road cross section (Northern Rivers Local Government, Standard Drawings, 2012)

The requirement of the roadway is to ensure the depth of flooding in the major event does not exceed 0.2 m and a velocity-depth product of < 0.4 m^2/s is present. Table 15 shows the results of the analysis.

Table 15 - Estimated Road Flows

Catchment Name	1% Flow (m^3/s)	1% + CC Flow (m^3/s)	Pipe Capacity (m^3/s)	Road Capacity Required (m^3/s)	Climate Change Road Capacity Required (m^3/s)
E_11	1.1	1.4	0.6	0.5	0.9
E_12	1.8	2.4	1.0	0.8	1.3
E_21	1.8	2.4	1.0	0.8	1.3
E_22	1.3	1.7	1.3	0.0	0.4
E_3	0.7	0.9	0.4	0.3	0.5
K_1	0.4	0.6	0.2	0.2	0.4
K_21	1.6	2.1	0.8	0.8	1.3
K_22	1.6	2.0	1.3	0.3	0.7
K_3	1.3	1.6	0.6	0.7	1.0
K_4	2.9	3.7	1.9	0.9	1.8
F_11	1.0	1.2	0.6	0.4	0.7
F_12	1.8	2.4	0.8	1.0	1.6

Based on the assumed cross section and design requirements it was confirmed the road has a capacity of 1.36 m^3/s and a velocity-depth product of 0.26 m^2/s at 0.2 m deep. This confirms the standard road design has capacity to carry the 1% AEP event safely.

A review of the road capacity when considering climate change indicates that the roadway has insufficient capacity to carry the 1% AEP + CC peak flow estimates. In these events a maximum depth of 0.22 m was present with a velocity-depth product of 0.33 m^2/s. This is still carried within the road corridor and verge. As such, whilst this does not meet the design standard of the roadways, it still ensures that in a climate change scenario the road has sufficient capacity to carry the 1% AEP event plus climate change flows.

6.4. Stormwater Quality Management

In addition to managing stormwater quantity, it is important to ensure that all new developments take into consideration their impact on water quality. A concept level stormwater quality review has been undertaken for the area to estimate the required water quality treatment systems that would ensure that the water discharging from the site meets current best practice guidance.

The application of stormwater quality management includes an approach to urban planning and design that provides a sustainable solution for integrating land development with a view of providing water treatment that will prevent the stormwater pollutants from entering natural waterways. For the study area, bioretention and wetland systems were considered as initial options to ensure that runoff generated by the proposed development areas was treated. Bioretention basins are preferred in areas that are space constrained while wetlands require more land to achieve the same water quality outcomes.

Figure 24 presents the footprint of the proposed Stormwater Quality Management Plan. A wetland has been proposed between saltwater creek and the railway as this location has been identified as a historical wetland which requires remediation. All other areas utilise bio basins as the land take is significantly lower, and the system, with appropriate engineering, can be placed inside the detention basin footprint.

The assessment at this stage is high level, utilising rule of thumb approaches as set out in Water by Design's Deemed to Comply Solutions – Stormwater Quality Management (South East Queensland) (2010). This document provides the following land take size requirements (relative to the development area):

- 1-2% for a bio retention basin; and,
- 4-8% for a wetland.

A 10-metre buffer was considered to determine the total area footprint for the Stormwater Management Plan to allow for maintenance tracks around the systems. Table 16 outlines details of treatment options for each subcatchment.

Table 16 – Stormwater Quality Management Details

Catchment Name	Stormwater Treatment Option	Required Detention Basin Surface (m2)	Treatment Area (m^2)	Total Area Footprint (m^2)
E_11	Bioretention System	100	386	1630
E_12	Bioretention System	1000	606	2880
E_21	Bioretention System	1300	648	3310
E_22	Bioretention System	650	1008	2580
F_11				
E_3	Bioretention System	400	230	1470
K_1	Bioretention System	700	144	2170
K_21	Bioretention System	950	556	2700
K_22	Wetland	100	1614	3920
K_3	Bioretention System	700	1442	3860
K_4				
F_12	Bioretention System	1900	630	4450

6.5. Alternative Stormwater Management Approach

The management approach discussed in this report is based on managing and treating of stormwater runoff in an engineered fashion. This has been done primarily to assist in quantifying the cost associated with such a management technique.

For this site there are also opportunities to improve the amenity and water quality not just for the area under consideration, but for areas upstream of the site. One such approach to achieve this is to begin the process of creek restoration and improvement for the three primary drainage systems in the development area. Figure 25 shows proposed locations where these works could occur.

Some potential benefits of this alternative approach are as follows:

- Improvement of stream water quality for both areas upstream of the site and around the development area;
- Reconnecting people to the natural environment through urban regeneration;
- Reduced likelihood of negative impacts caused by climate change through increased ecosystem resilience;
- Natural stream beds generally have slower moving flow than designed channels;
- Enhanced habitats for wildlife;
- Potential to integrate social and cultural experiences into the rejuvenated corridors; and,
- Detention storage can be incorporated into the overall design of the stream restoration (i.e. less hard engineering required).

Plate 5 provides an example cross-section of the creek corridor that may be achieved and its potential interaction with surrounding residential areas. Plate 6 shows a before and after outcome for a system where this approach was implemented after development had occurred.

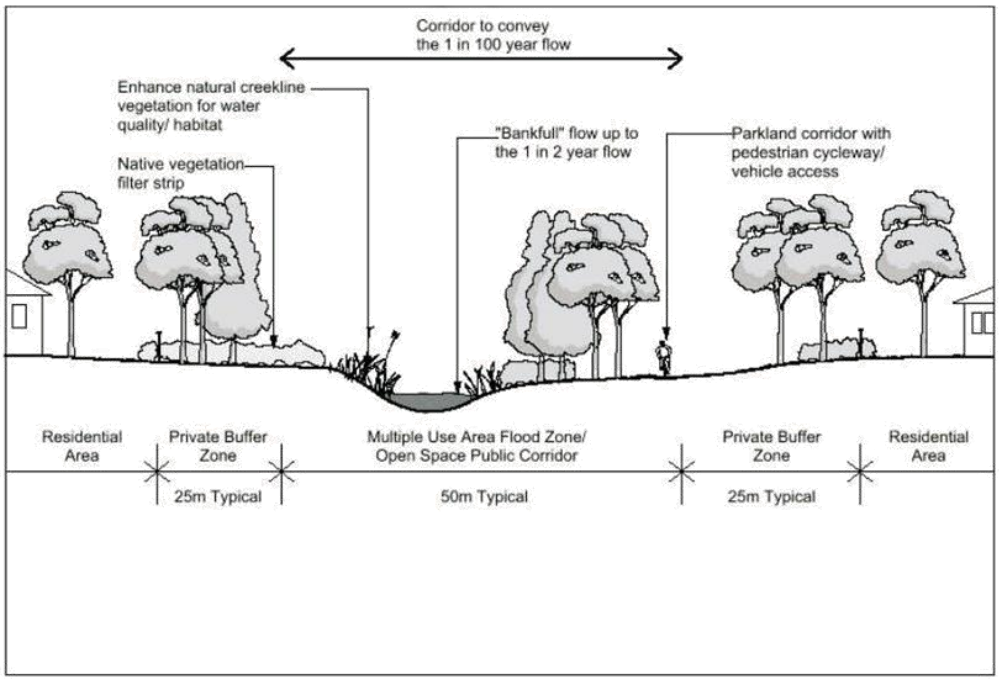


Plate 5 – Typical creek cross-section (Warriewood Valley Urban Land Release Water Management Specification – Revised Version, Pittwater Council, 2001)



Plate 6 - Example of implemented approach (University of WA, CRC for Water Sensitive Cities, 2013)

6.5.1. Catchment Delineation

To assess this alternative stormwater management option, the additional contributing catchment area within the study area was modelled. The eastern study area and local catchments adopted are based on the works completed by AP&P (2018). The study area and catchments adopted by AP&P are shown in Figure 1 of Attachment 1.
Figure 25 shows the additional catchment areas adopted in this study which contribute towards the three primary drainage systems modelled, and Table 17 shows the details of these additional subcatchments.

Table 17 – Additional subcatchment details

Subcatchment	Subcatchment Area (ha)	Slope (%)
N_1	2.33	0.45
N_2	2.58	0.45
N_3	4.45	0.50
UOD	6.58	0.40
UC_1	14.87	0.45
UC_2	2.49	0.55
C1_1	6.02	0.30
C2_2	3.76	0.35
LC_1	5.49	1.55
LC_2	5.40	0.70
C2_3	5.73	0.70
C2_1	5.11	0.80

6.5.2. Design Flow Assessment

In a similar fashion to the previous options examined, design flow estimates were undertaken using parameters developed in accordance with current best practice guidance (ARR2019). The following is a summary of the design flow assessment approach:

- The IL and CL values selected for pervious area were extracted from Data Hub and were applied as 25 millimetres and 1.0 millimetre per hour, respectively (and as applied in the previous options assessed);
- The additional subcatchments detailed in Table 17 and Figure 25 were added into the hydrologic models;
- Subcatchment routing was added to the system to better estimate the peak flow at each of the three channel systems. Routing was estimated through the application of the Modified Stream Velocity method (refer QUDM 2017, Table 4.6.6);
- Storm durations ranging from 10 minutes to 30 hours, each with an ensemble of 10 different rainfall temporal patterns, were assessed to determine the critical storm for each subcatchment (as completed in the previous options); and,
- The critical duration was deemed to be the duration which resulted in the highest median peak flow rate over the 10 temporal patterns that were assessed.

As this assessment pertains to the peak flow at the outlet of each drain rather than the local

subcatchment flows, the pre-development peak flow rates and critical durations at the outlet of each drain were investigated and are shown in Table 7. The location of each channel (Drain ID) is displayed in Figure 25.

Table 18 – Pre-development flow rates for 1% AEP event

Drain ID	Pre-development flow rate (m^3/s)	Critical storm combinations
D1	4.61	ECS_63pct_2hr_6 ECS_1pct_2hr_2
D2	2.70	ECS_63pct_3hr_8 ECS_1pct_2hr_2
D3	15.08	ECS_63pct_6hr_5 ECS_1pct_2hr_4

6.5.3. Creek Restoration Assessment

The XP-RAFTS model was utilised to identify the storage volume and spillway arrangement needed for each subcatchment to restrict post-development flow rates to pre-development conditions. The post-development landscape was considered to identify any geometric constraints such as available fall across the site and corridor width available for creek restoration.

Figure 25 shows the creek restoration arrangement assessed. In this assessment, each subcatchment was assigned to contribute to one of the three channels for sizing purposes based on its natural fall. The subcatchments assigned to each drain are shown in Table 19. Note that subcatchments F_2 and F_12 are assumed to drain to the north into the proposed wetland, and then ultimately into Saltwater Creek rather than contributing to one of the three areas designated for creek restoration.

Table 19 – Subcatchments routed to the proposed channels

Drain ID	Contributing subcatchments
D1	E_11, E_12, N_1, N_2, E_21
D2	N_3, E_22, F_11
D3	UOD, K_1, K_21, K_22, UC_1, K_3, K_4, C2_1, C2_3, UC_2, C1_1, C2_2, LC_1, LC_2

At a conceptual level, each of the restored drains is to act in similar fashion to a detention system whereby frequent events are discharged via a low flow outlet and larger events are controlled by a high flow spillway. For the purposes of this assessment (pricing and design optimisation), the low flow outlets were sized to pass a 63.2% AEP event and the spillway was designed to hold up to 1% AEP post-development flows back to pre-development flows.

Table 20 shows the low flow outlet configurations and spillway configurations for each channel modelled in the assessment. The estimated available cut volume available was calculated using a conceptual cut/fill balance in 12d. The results show that the site has more than adequate capacity for the construction of the proposed channels and wetlands.

Table 20 – Proposed channel structural details

Drain ID	Low flow outlet configuration (m)	Estimated available cut volume (m^3)	Estimated basin storage required (m^3)	Spillway invert level (m)
D1	5/0.9x0.3 RCBC	32,000	1700	2
D2	3/0.6x0.3 RCBC	49,000	850	0.8
D3	8/1.2x0.3 RCBC	60,000	19,100	0.6

Average channel geometry for each drain was adopted at this conceptual phase of design to develop estimated drain extents and available cut volume. Typical values used in the preliminary assessment of each channel are shown in Table 21.

Table 21 – Estimated channel geometric details

Drain ID	Average longitudinal slope (%)	Channel length (m)	Average depth (m)	Average top width (m)	Average cross-sectional area (m^2)	Estimated batter slope (1 in x)
D1	0.2	850	1.6	45	38.6	10
D2	0.4	350	0.6	75	28	35
D3	0.2	1200	0.4	50	13.4	15

The pre-development and post-development (with detention) peak flows are presented in Table 22.

Table 22 – Reduction in peak flows due to addition of downstream controls for the 1% AEP event

Drain ID	1% AEP		63.2% AEP	
	Pre-development flow (m^3/s)	Post-development basin outflow (m^3/s)	Pre-development flow (m^3/s)	Post-development low flow (m^3/s)
D1	4.6	4.6	1.0	1.0
D2	2.7	2.7	0.5	0.5
D3	15.1	15.0	3.2	3.1

7. COST ESTIMATES

The costing incorporates the following contingencies:

- Contingency for unknowns (20%);
- Design Allowance ($20,000 per fill pad and per basin); and,
- Project Management Contingency (15%).

The cost presented has no allowance for development of road networks, sewer, water, or other infrastructure that will be required to develop the lots. The costing is based on the estimated cost to fill each development pad to the 1% AEP + CC flood level and the stormwater systems required to manage runoff from the site. No allowance for channel works is incorporated as this will likely be augmented with the stormwater management system in the final designs. It has been assumed that all fill will be imported as the quality of the soil is currently unknown.

A separate line item has been provided for the New City Road drainage upgrades that are required to ensure the local stormwater runoff from both the site and the existing New City Road area can discharge into Kings Creek.

It should be noted that for options where cut to fill balance is achieved it is necessary to undertake several lots at the same time so that fill can be appropriately apportioned and land remediation can be achieved. At a high level the lots to the west of the railway would need to be developed at the same time and the lots to the east of the railway line would need to be developed at the same time.

It has been assumed that fill would be shared freely throughout the development to achieve the cut to fill balance. Appendix E provides the rate assumptions and some example costings as undertaken for the assessment.

7.1. Traditional Stormwater Approach – Imported Fill

Provided in Table 23 is a high-level cost estimate for the works associated with the development of this site with regards to flooding and stormwater, assuming all fill is imported. This results in a loss of flood storage onsite, however negates the risk of unknown soil conditions on the site.

Table 23 – Concept Level Cost Estimate – Traditional Stormwater Management – 100% Imported Fill

Lot ID	Fill Pad (100% Import Fill)	Stormwater Quantity and Quality (Inc Trunk Drainage)	Total Cost	Cost Per m^2
1	$0.46 M	$0.42 M	$0.88 M	$46
2	$1.56 M	$0.66 M	$2.22 M	$74
3	$0.69 M	$0.34 M	$1.02 M	$93
4	$2.86 M	$1.36 M	$4.22 M	$77
5	$5.72 M	$0.12 M	$5.84 M	$122
6	$0.40 M	$0.26 M	$0.66 M	$94
7	$4.54 M	$1.16 M	$5.71 M	$64
8	$4.96 M	$1.81 M	$6.77 M	$178
9	$0.82 M	N/A	$0.82 M	$189
NCRDI	N/A	$0.27 M	$0.27 M	N/A

Based on the analysis undertaken, some lots are more cost effective to develop than others. This is primarily associated with the large cost of importing fill in low lying areas. It should be noted that efficiencies of scale have not been considered in this analysis. It has been assumed each lot would be developed independently.

7.2. Traditional Stormwater Approach – Cut Fill Balance

Table 24 provides an estimate of the cost to develop assuming that a cut/fill balance (based on the cut available) is achieved to negate the loss of flood storage on the site. This approach results in a slightly lower cost estimate and includes indicative costs associated with the reseeding and management of the exposed spoil areas. Note that no allowance for improvement of the excavated material (if acid sulphate soils are present) is provided in the cost estimate. It has been assumed the detention basins will be developed in conjunction with the cut/fill balance to reduce rework.

Note that the cost of land rehabilitation has been apportioned based on development fill requirements (as there is no other measure at this stage with regards to distribution of this cost) and as such may not be fully representative.

Table 24 – Concept Level Cost Estimate – Traditional Stormwater Management – Cut Fill Balance

Lot ID	Fill Pad (Cut/Fill Balance)	Stormwater Quantity and Quality (Inc Trunk Drainage)	Excavation Area Rehab	Total Cost	Cost Per m^2
1	$0.37 M	$0.27 M	$0.09 M	$0.73 M	$38
2	$0.97 M	$0.18 M	$0.60 M	$1.75 M	$58
3	$0.43 M	$0.28 M	$0.25 M	$0.97 M	$88
4	$1.83 M	$0.38 M	$0.45 M	$2.66 M	$48
5	$3.23 M	$0.41 M	$1.08 M	$4.71 M	$98
6	$0.26 M	$0.32 M	$0.06 M	$0.65 M	$92
7	$2.90 M	$0.82 M	$0.74 M	$4.46 M	$50
8	$2.78 M	$0.41 M	$0.98 M	$4.17 M	$110
9	$0.46 M	N/A	$0.16 M	$0.62 M	$143
NCRDI	N/A	$0.27 M		$0.27 M	N/A

The option of using onsite spoil in the development is slightly cheaper than using imported fill. As the process requires the use of the land surrounding the development footprint for winning the spoil, there is a cost associated with the management of this land that does not need consideration if imported fill is utilised. If any improvement of the soil is required it is likely that this would cost more than utilising imported fill.

This option does however result in the maintenance of flood storage for the development and as such is a desired outcome with regards to the regional impacts of the development.

7.3. Alternative Stormwater Management Approach

Table 25 provides an estimate of the cost to develop the site utilising the option of rehabilitation of the channel and surrounding areas for water quality and quantity management. This process involves the development of a naturalised channel system as discussed in Section 6.5. Note that the costs are extremely high level and do not consider any paths, infrastructure, tracks or public amenities. An allowance has been provided for planting and creek alignment and management. The revitalisation cost has been estimated at approximately $40/m^2$ of area to be improved.

Cost has been apportioned again based on development fill requirements (as there is no other measure at this stage with regards to distribution of this cost) and as such may not be fully representative.

Table 25 – Concept Level Cost Estimate – Alternative Stormwater Management

Lot ID	Fill Pad (Cut/Fill Balance)	Trunk Drainage	Channel Revitalisation	Total Cost	Cost Per m^2
1	$0.37 M	$0.12 M	$0.27 M	$0.76 M	$40
2	$0.97 M	$0.20 M	$1.83 M	$3.01 M	$100
3	$0.43 M	$0.10 M	$0.78 M	$1.31 M	$119
4	$1.83 M	$0.37 M	$0.91 M	$3.11 M	$56
5	$3.23 M	$0.12 M	$2.18 M	$5.52 M	$115
6	$0.26 M	$0.12 M	$0.23 M	$0.61 M	$87
7	$2.90 M	$0.36 M	$2.78 M	$6.04 M	$68
8	$2.78 M	$0.36 M	$3.69 M	$6.83 M	$180
9	$0.46 M	N/A	$0.62 M	$1.07 M	$247
NCRDI	N/A	$0.27 M		$0.27 M	N/A

As would be expected, the revitalisation of the channel is the costliest of all options. The difference is on average $19/m^2$ more than the cut fill balance option utilising stormwater treatment. This cost is ultimately due to the required planting and rock work associated with reforming a natural system.

8. MULTI-CRITERIA ASSESSMENT

Multi-criteria decision matrices are a tool to used guide the prioritisation and assessment of alternative design options. The matrices allow the consideration of a number of factors such as cost, community acceptance, environmental impacts, to be included to provide weight to non-quantitative benefits of options.

The criteria utilised in the matrix for the site are:

- Total Option Cost;
- Site Water Quality;
- Potential for Local drainage and Water Quality improvements;
- Ecology/Habitat Improvement;
- Maintenance Cost; and,
- Potential for Social Engagement and Improved Social Amenity.

The weighting system shown in Table 26 has been applied to the options. Note that only the options which achieve a cut to fill balance have been assessed. The imported fill option would result in a loss of flood storage and is more expensive than the cut to fill option and thus has been discounted at this stage until a greater understanding of soil conditions is available.

Table 26 –Multi-Criteria Scoring and Weighting Criteria

Assessment Criteria	Score and Definition			
	1	2	3	Weight (%)
Cost	High	Moderate	Low	**25**
Site Water Quality Improvement	Low	Moderate	High	**10**
Potential for local drainage and water quality improvements	Low	Moderate	High	**10**
Ecology /Habitat Improvement	Low	Moderate	High	**20**
Maintenance Cost	High	Moderate	Low	**25**
Potential for Social Engagement and Improved Social Amenity	Low	Moderate	High	**10**

Table 27 presents the results of the multi-criteria analysis. Each option was reviewed and scored relative to the benefit to each criterion that it provides.

Table 27 –Multi-Criteria Analysis Results

Assessment Criteria	Traditional WSUD (engineered basins and stormwater quality devices)	Natural Channel Rehabilitation	Mixed (both Engineered and channel rehab)
Cost	3 (0.75)	1 (0.25)	1 (0.25)
Site Water Quality Improvement	3 (0.3)	2 (0.2)	3 (0.3)
Potential for local drainage and water quality improvements	1 (0.1)	3 (0.3)	3 (0.3)
Ecology /Habitat Improvement	1 (0.2)	3 (0.6)	3 (0.6)
Maintenance Cost	1 (0.25)	3 (0.75)	1 (0.25)
Potential for Social Engagement and Improved Social Amenity	1 (0.1)	3 (0.3)	3 (0.3)
Weighted Score	**1.7**	**2.4**	**2.0**

Based on the assessment undertaken the natural channel rehabilitation option is identified as the preferred outcome the development. While this option is more expensive, it will provide greater environmental benefit to the area, potential for improved drainage and water quality for areas external to the development and also has a greater opportunity for social engagement and amenity. The rehabilitation option is also likely to have a lower ongoing maintenance cost when compared to engineered solutions, especially with regards to water quality. Engineered water quality solutions require constant maintenance to ensure function, which often does not occur, resulting in a poor urban design outcome.

9. CONCLUSIONS

Byron Shire Council is preparing a draft Residential Strategy (the 'Strategy') to set a clear vision and policy framework for Council's urban residential land. Housing affordability has been identified as a priority issue to address ahead of completing the Strategy. Council, through an expression of interest process, invited landowners to submit affordable housing proposals for land to be considered as part of an early implementation initiative. This resulted in five potentially suitable sites being identified, four of which are located along the southern fringe of the Mullumbimby urban area.

WMAwater was engaged by Council to assess the flood risk due to regional catchment flooding and to assess and mitigate the flood impacts caused by the proposed development of these four sites. WMAwater has also been engaged to develop a concept level stormwater management plan for the area to inform the stormwater infrastructure that may be required to service the development. WMAwater has also developed high level cost estimates and multi-criteria analysis (MCA) for the development to aid in decision making.

Based on the analysis undertaken, the following findings were obtained with regards to regional flood impacts:

- The sites all have a portion of area which is deemed developable when considering the impact to the regional flood levels and the development controls with regards to flooding on new land release areas;
- A cut to fill balance may be achievable however its viability is dependent on the soil quality onsite, which is currently unknown;
- Some channel works may be required to achieve the development footprint proposed – these have not been considered in the costing; and,
- Some local drainage corridors servicing existing areas may be impacted by the development. Future assessments should ensure that the proposed development does not cause local drainage issues or regional flooding impacts.

With regards to stormwater management, two potential management options were reviewed:

- A traditional engineered option which relies on bioretention and detention basins to treat runoff; and,
- An alternative approach which aims at improving the existing drainage corridor through a revitalisation process.

Based on the outcomes of the MCA, if development is to occur, the use of an alternative stormwater management approach is recommended, which aims at improving the amenity and function of the drainage reserves while also reducing long term maintenance requirements. This approach restores the existing channels into a more natural form, manages stormwater quality and quantity in the corridor and also provides opportunity for the community to engage with the space. The option also enables an efficient cut/fill balance to be achieved onsite which will help offset any potential regional cumulative impacts of the development.

The conceptual requirements of the preferred approach are summarised in the following tables.

Table 28 – Pipe sizing and Capacity Details (to convey drainage from the lots to the drainage corridor)

Catchment Name	20% AEP Peak Flow (m^3/s)	Pipe Capacity (m^3/s)	Pipe Velocity (m/s)	Pipe Diameter (m)	Pipe Length (m)
E_11	0.5	0.6	1.7	0.675	90
E_12	0.9	1.0	1.9	0.825	145
E_21	0.9	1.0	1.9	0.825	195
E_22	1.0	1.3	2.0	0.9	70
E_3	0.3	0.4	1.5	0.6	71
K_1	0.2	0.2	1.3	0.45	103
K_21	0.8	0.8	1.8	0.75	121
K_22	1.2	1.3	2.0	0.9	130
K_3	0.6	0.6	1.7	0.675	118
K_4	1.3	1.9	2.2	1.05	139
F_11	0.5	0.6	1.7	0.675	85
F_12	0.9	0.8	1.8	0.75	175

Table 29 – Estimated naturalised drainage channel geometric details

Drain ID	Average longitudinal slope (%)	Channel length (m)	Average depth (m)	Average top width (m)	Average cross-sectional area (m^2)	Estimated batter slope (1 in x)
D1	0.2	850	1.6	45	38.6	10
D2	0.4	350	0.6	75	28	35
D3	0.2	1200	0.4	50	13.4	15

A cost estimate to achieve this outcome is presented in the table below.

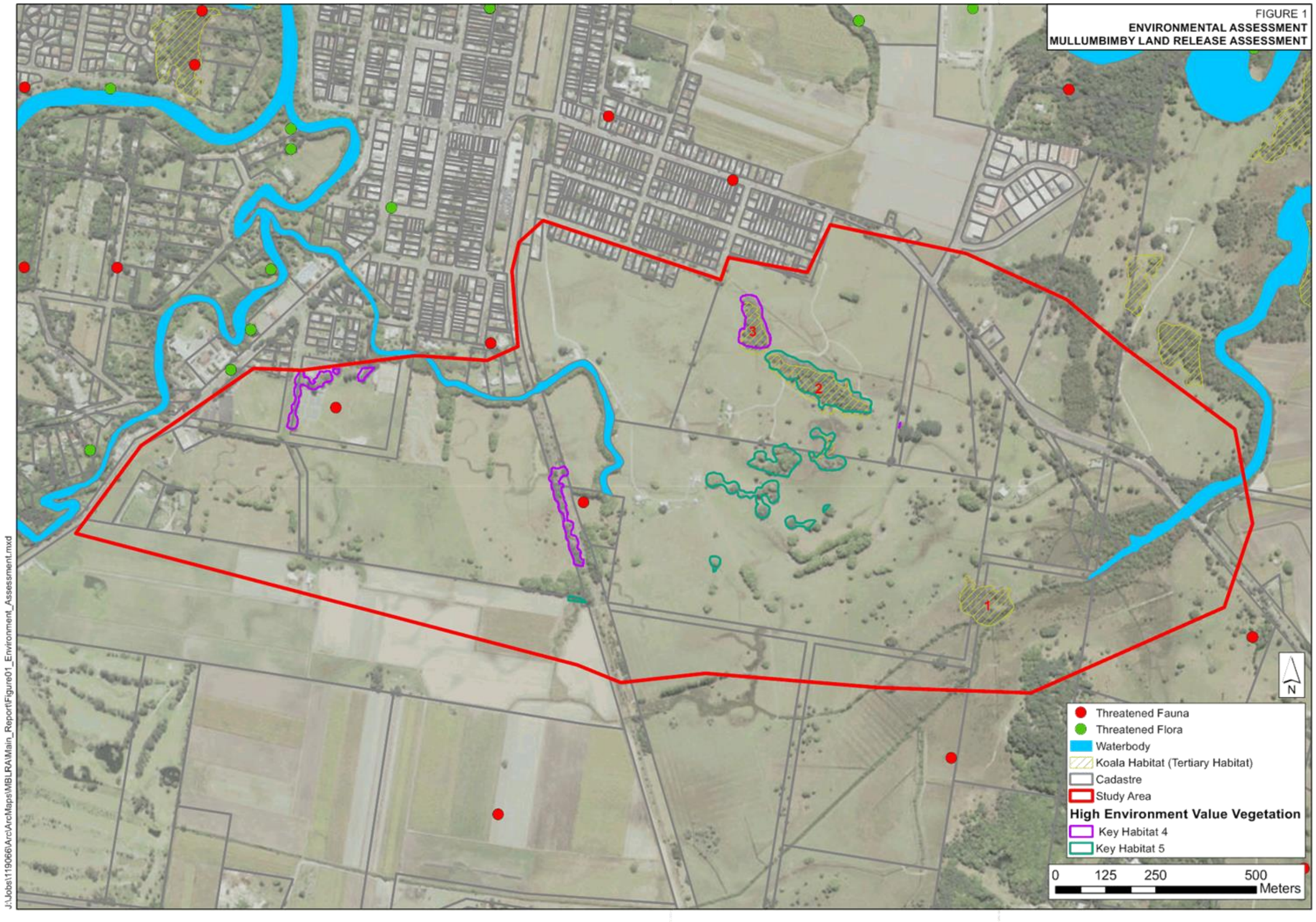
Lot ID	Fill Pad (Cut/Fill Balance)	Trunk Drainage	Channel Revitalisation	Total Cost	Cost Per m^2
1	$0.37 M	$0.12 M	$0.27 M	$0.76 M	$40
2	$0.97 M	$0.20 M	$1.83 M	$3.01 M	$100
3	$0.43 M	$0.10 M	$0.78 M	$1.31 M	$119
4	$1.83 M	$0.37 M	$0.91 M	$3.11 M	$56
5	$3.23 M	$0.12 M	$2.18 M	$5.52 M	$115
6	$0.26 M	$0.12 M	$0.23 M	$0.61 M	$87
7	$2.90 M	$0.36 M	$2.78 M	$6.04 M	$68
8	$2.78 M	$0.36 M	$3.69 M	$6.83 M	$180
9	$0.46 M	N/A	$0.62 M	$1.07 M	$247
NCRDI	N/A	$0.27 M		$0.27 M	N/A

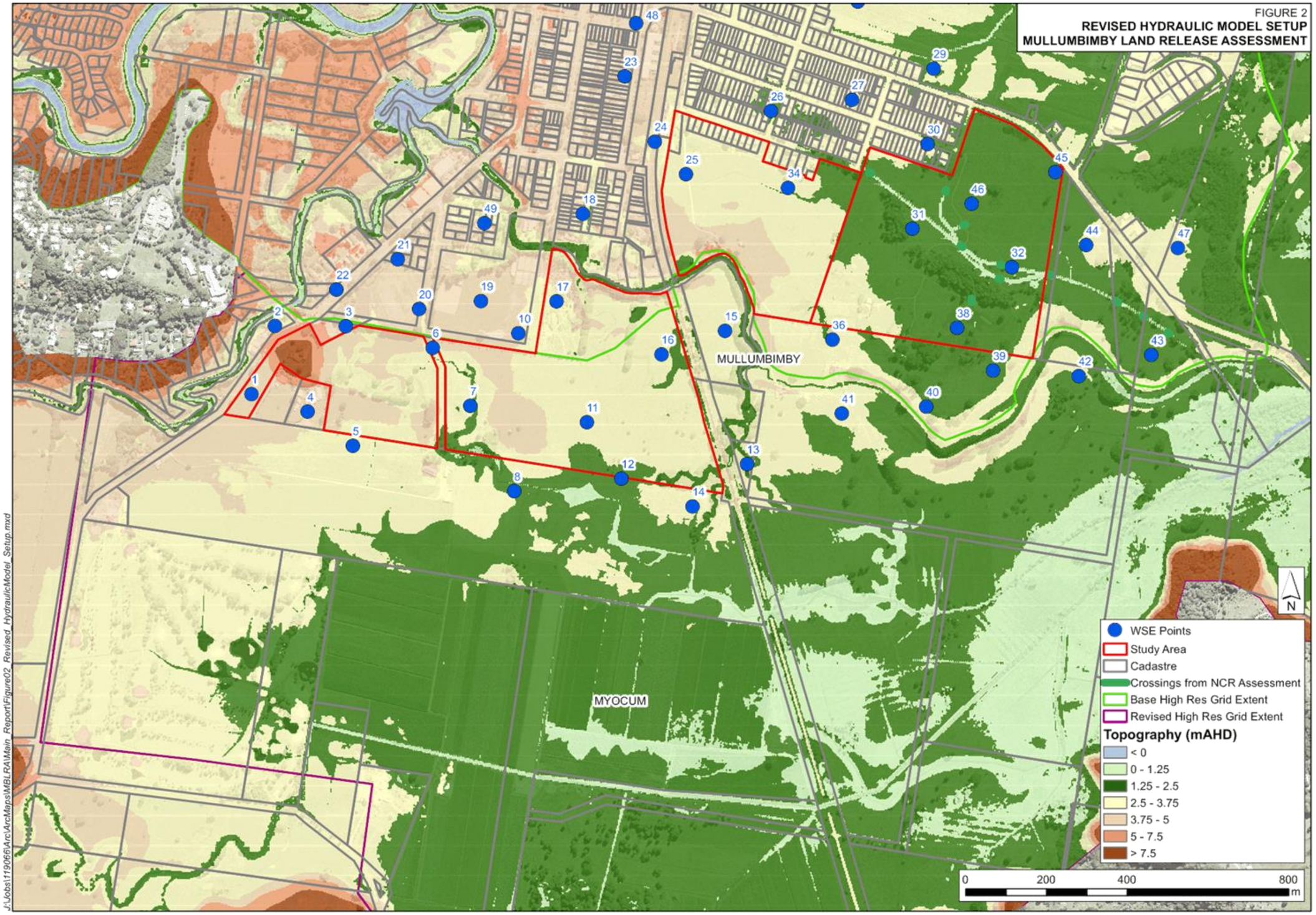
While the option is the most expensive of the assessed it is the highest ranked option in the multi-criteria assessment, which considers non qualitative benefits such as potential for local drainage and water quality improvements, ecology/habitat improvement, long term maintenance cost and the potential for social engagement. As such this option is recommended.

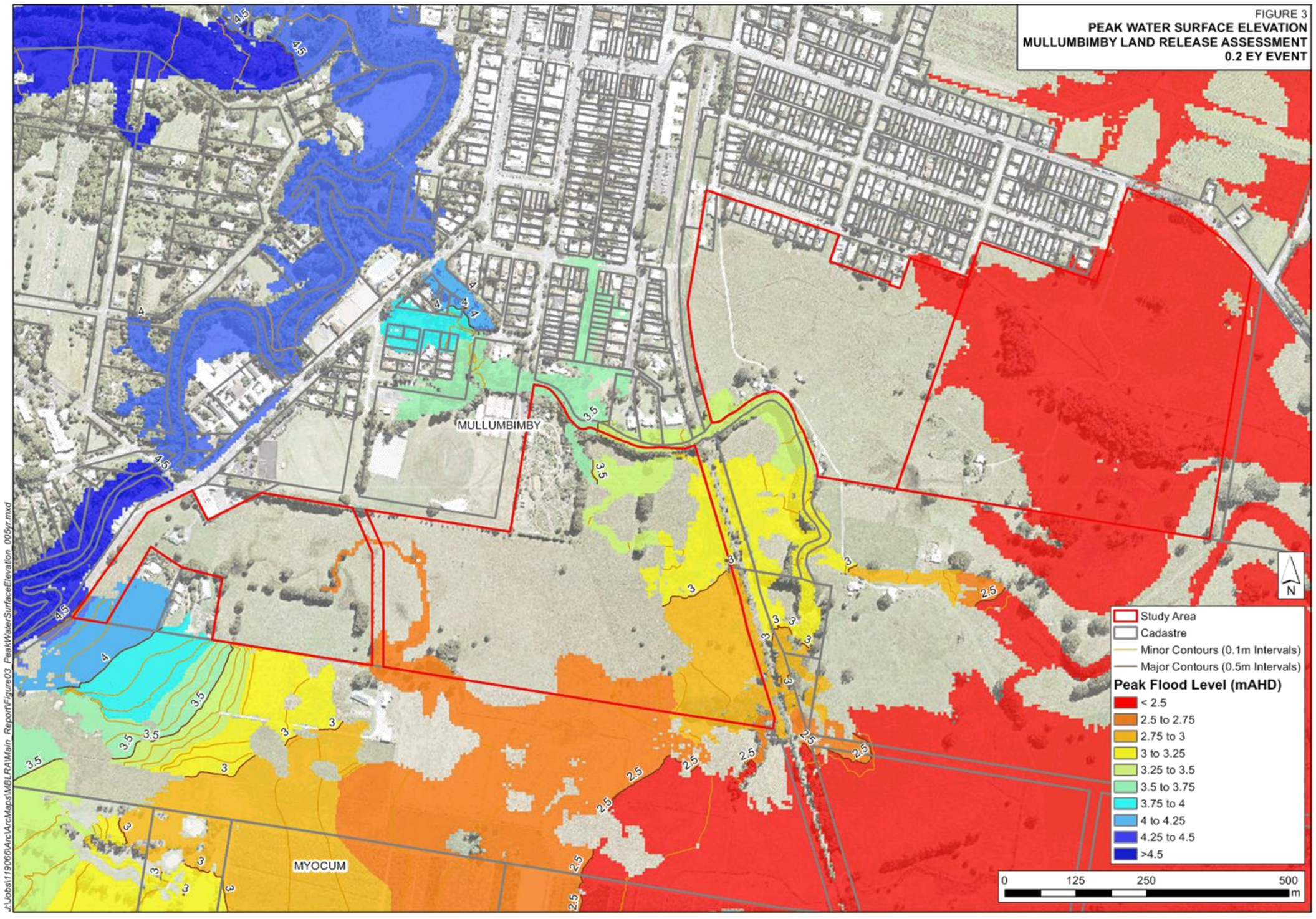
10. REFERENCES

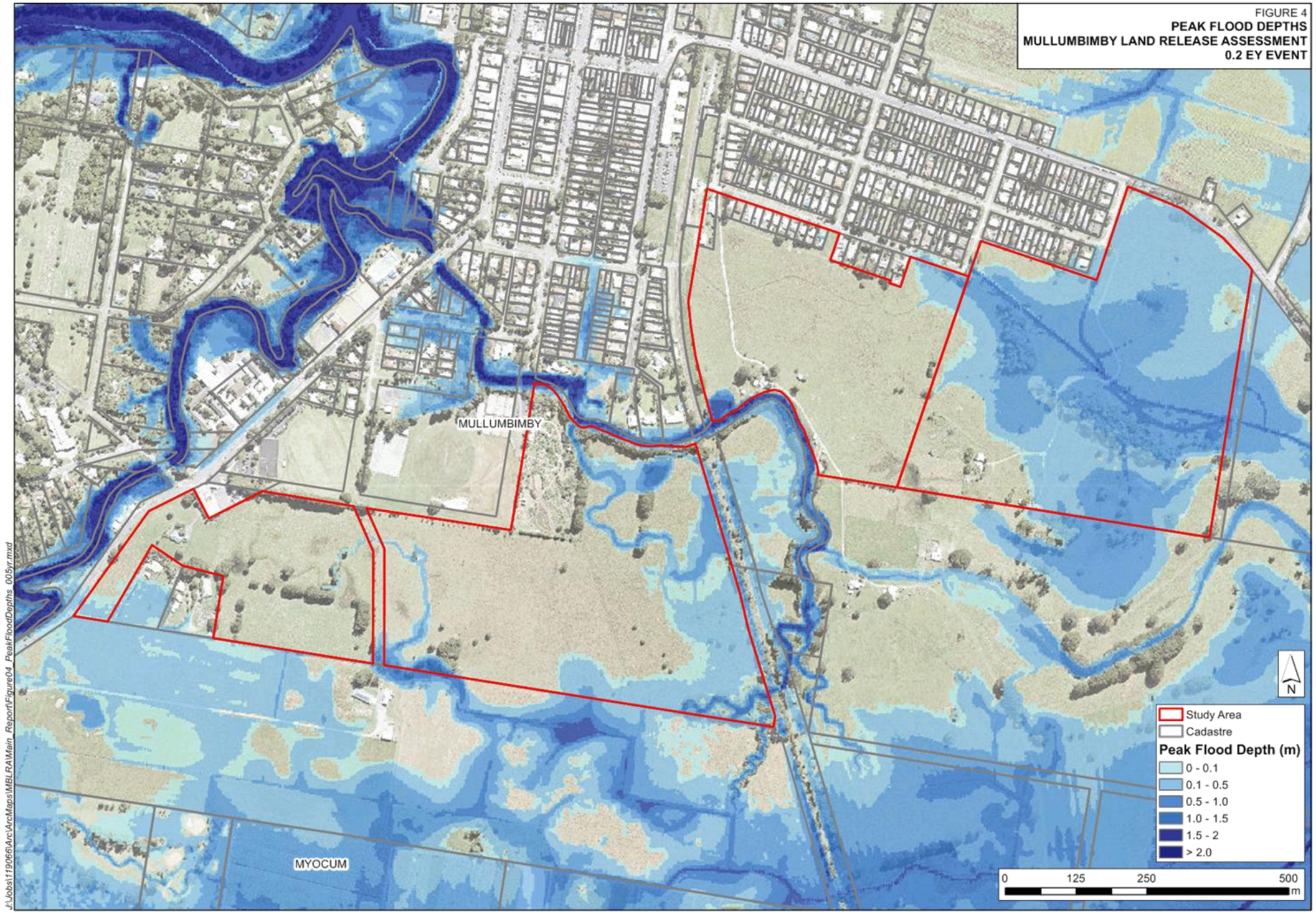
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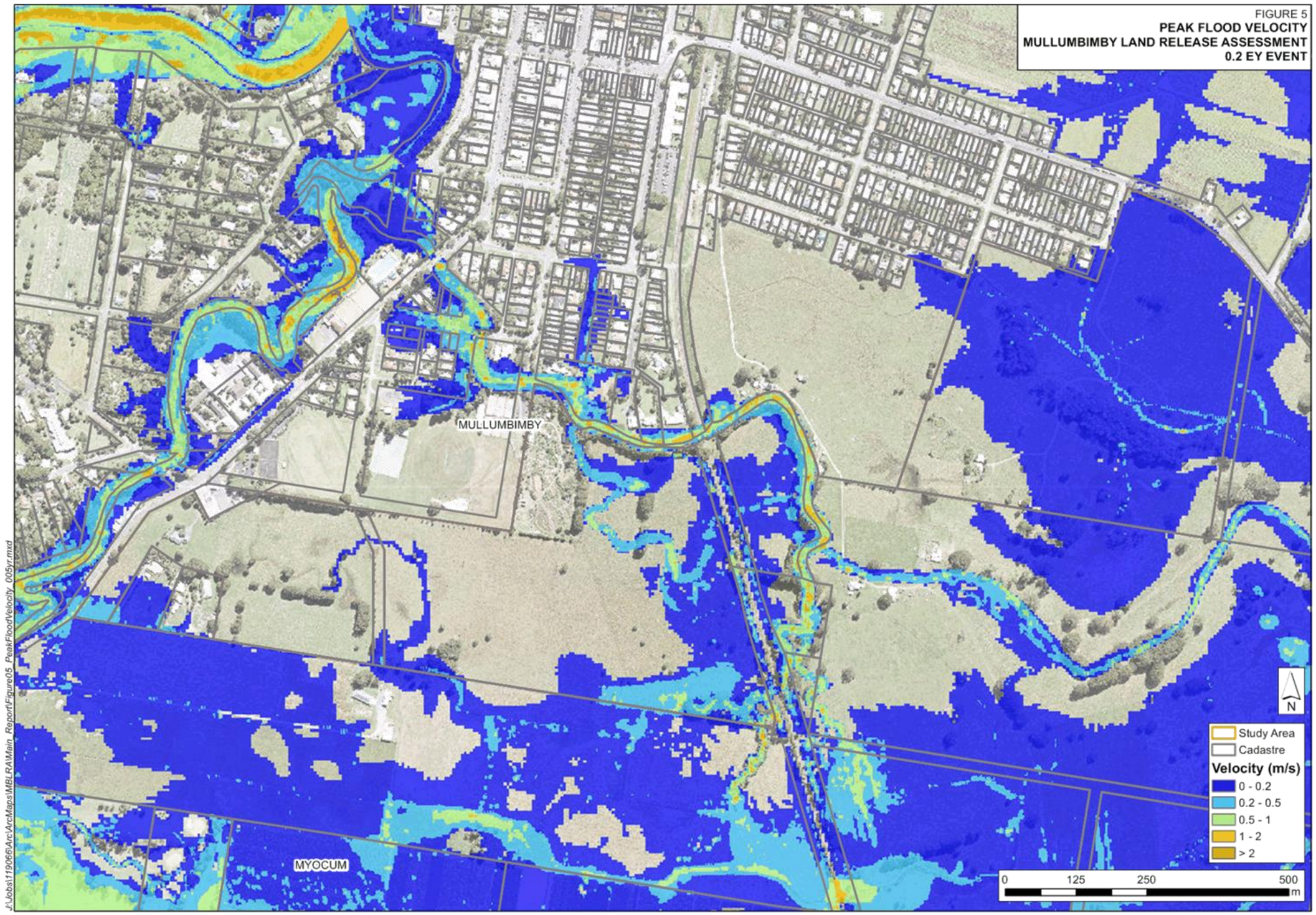

Figures

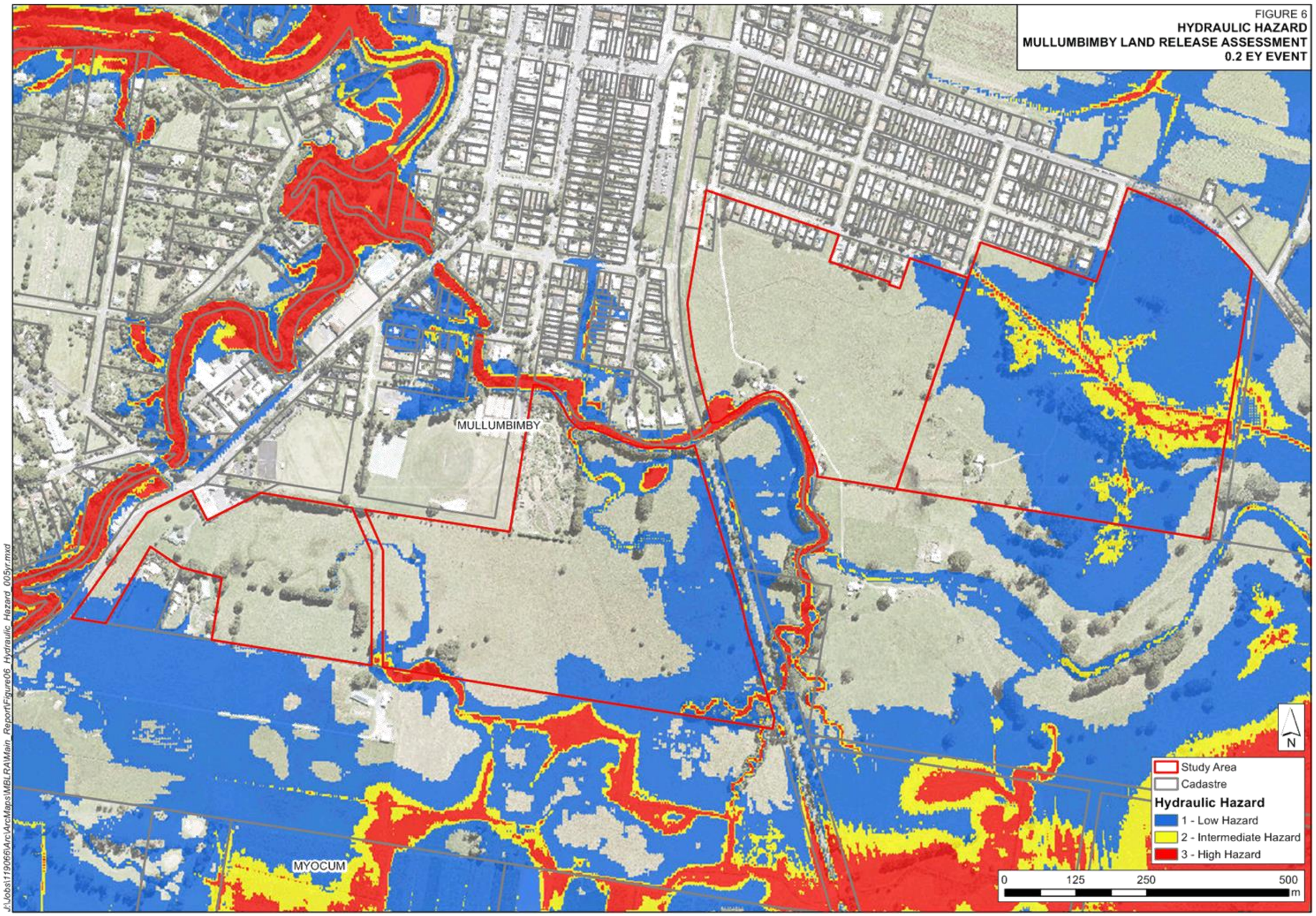

FIGURE 1
ENVIRONMENTAL ASSESSMENT
MULLUMBIMBY LAND RELEASE ASSESSMENT
1
2
3
N
Threatened Fauna
Threatened Flora
Waterbody
Koala Habitat (Tertiary Habitat)
Cadastre
Study Area
High Environment Value Vegetation
Key Habitat 4
Key Habitat 5
0 125 250 500
Meters
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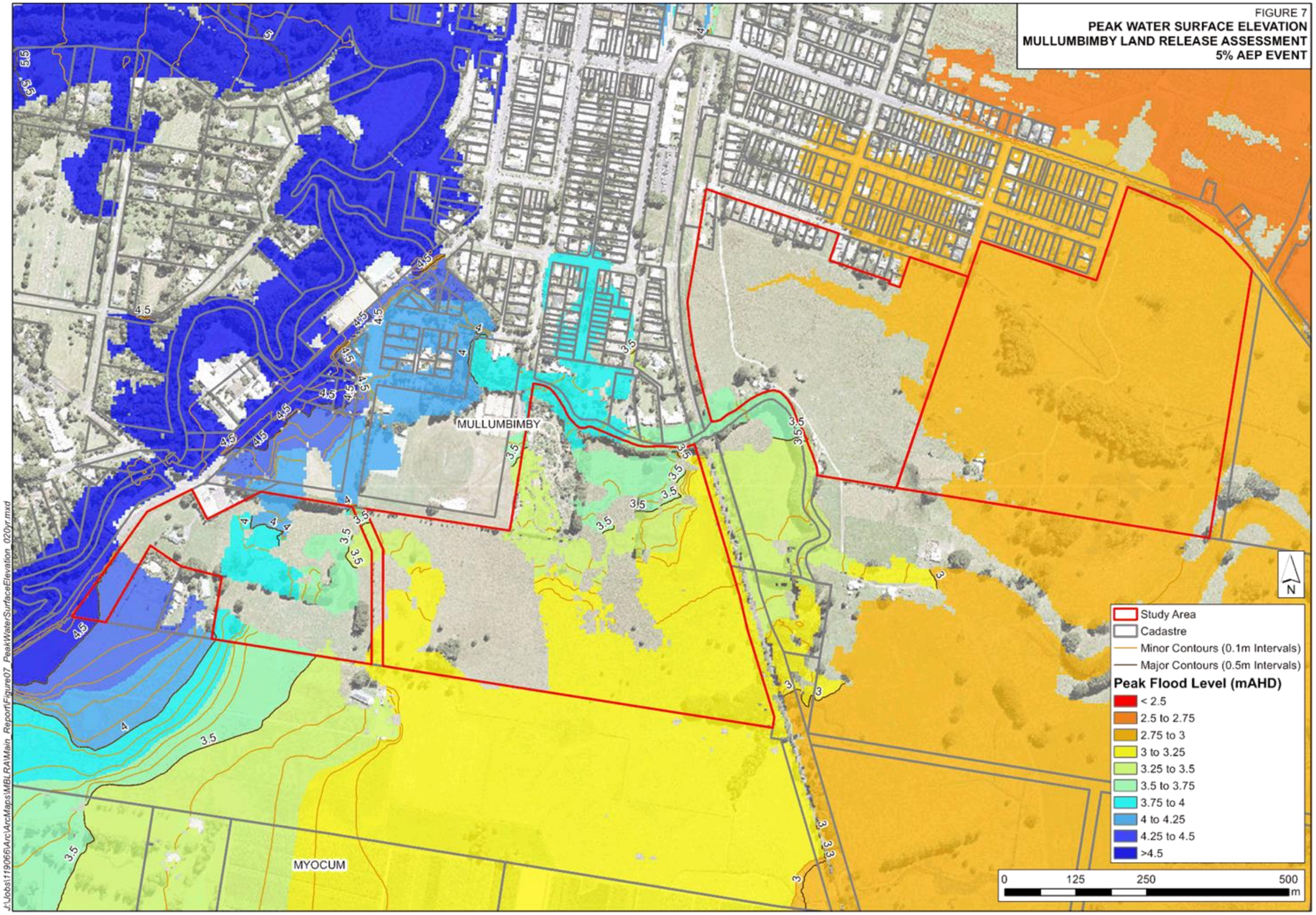

FIGURE 2
REVISED HYDRAULIC MODEL SETUP
MULLUMBIMBY LAND RELEASE ASSESSMENT
MULLUMBIMBY
MYOCUM
WSE Points
Study Area
Cadastre
Crossings from NCR Assessment
Base High Res Grid Extent
Revised High Res Grid Extent
Topography (mAHD)
< 0
0 - 1.25
1.25 - 2.5
2.5 - 3.75
3.75 - 5
5 - 7.5
> 7.5
0
200
400
800
m
N
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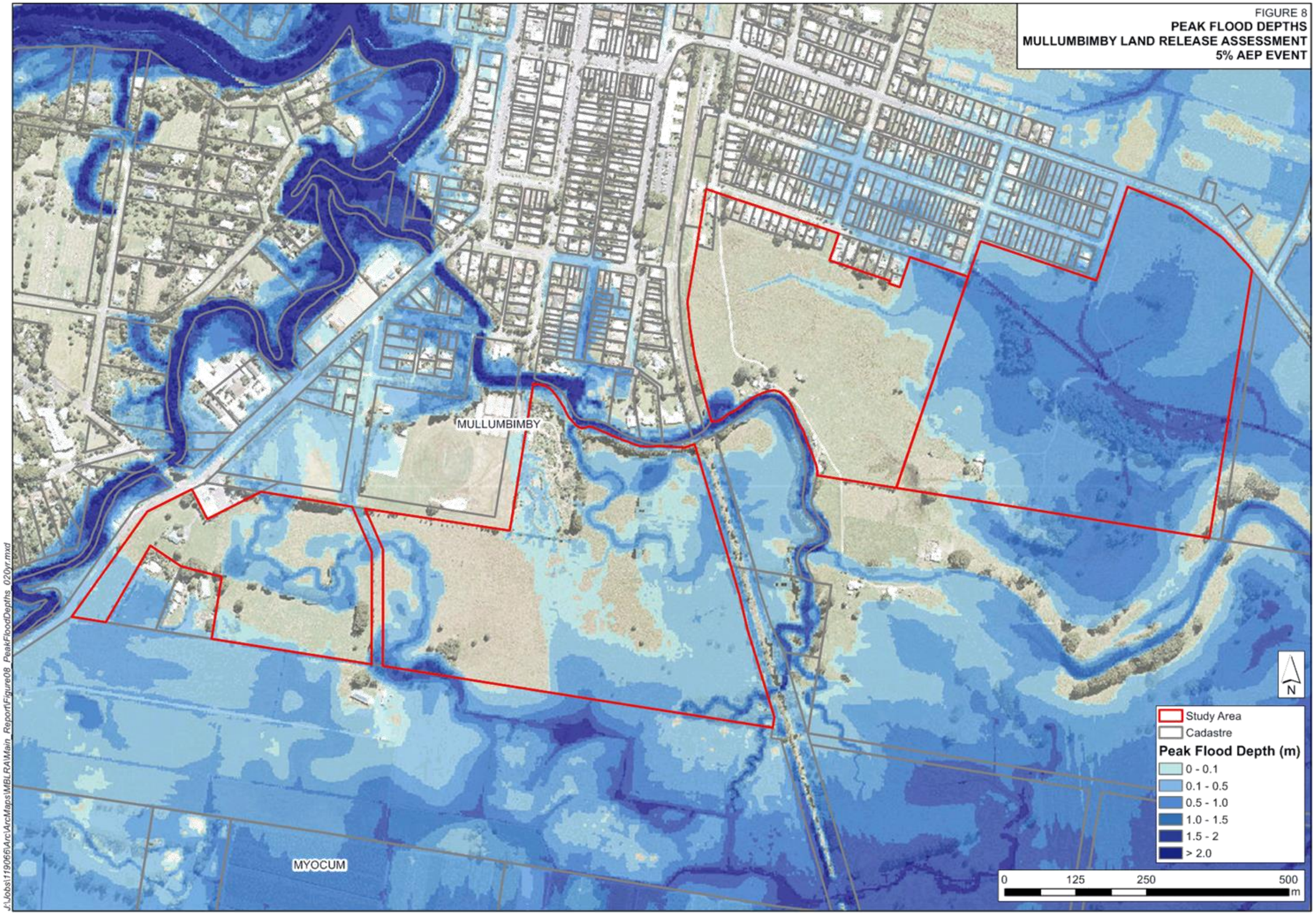

FIGURE 3
PEAK WATER SURFACE ELEVATION
MULLUMBIMBY LAND RELEASE ASSESSMENT
0.2 EY EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Minor Contours (0.1m Intervals)
Major Contours (0.5m Intervals)
Peak Flood Level (mAHD)
< 2.5
2.5 to 2.75
2.75 to 3
3 to 3.25
3.25 to 3.5
3.5 to 3.75
3.75 to 4
4 to 4.25
4.25 to 4.5
>4.5
0
125
250
500
m
J:\Jobs\119066\4Arc\ArcMaps\MBLRA\Main_Report\Figure03_PeakWaterSurfaceElevation_005yr.mxd

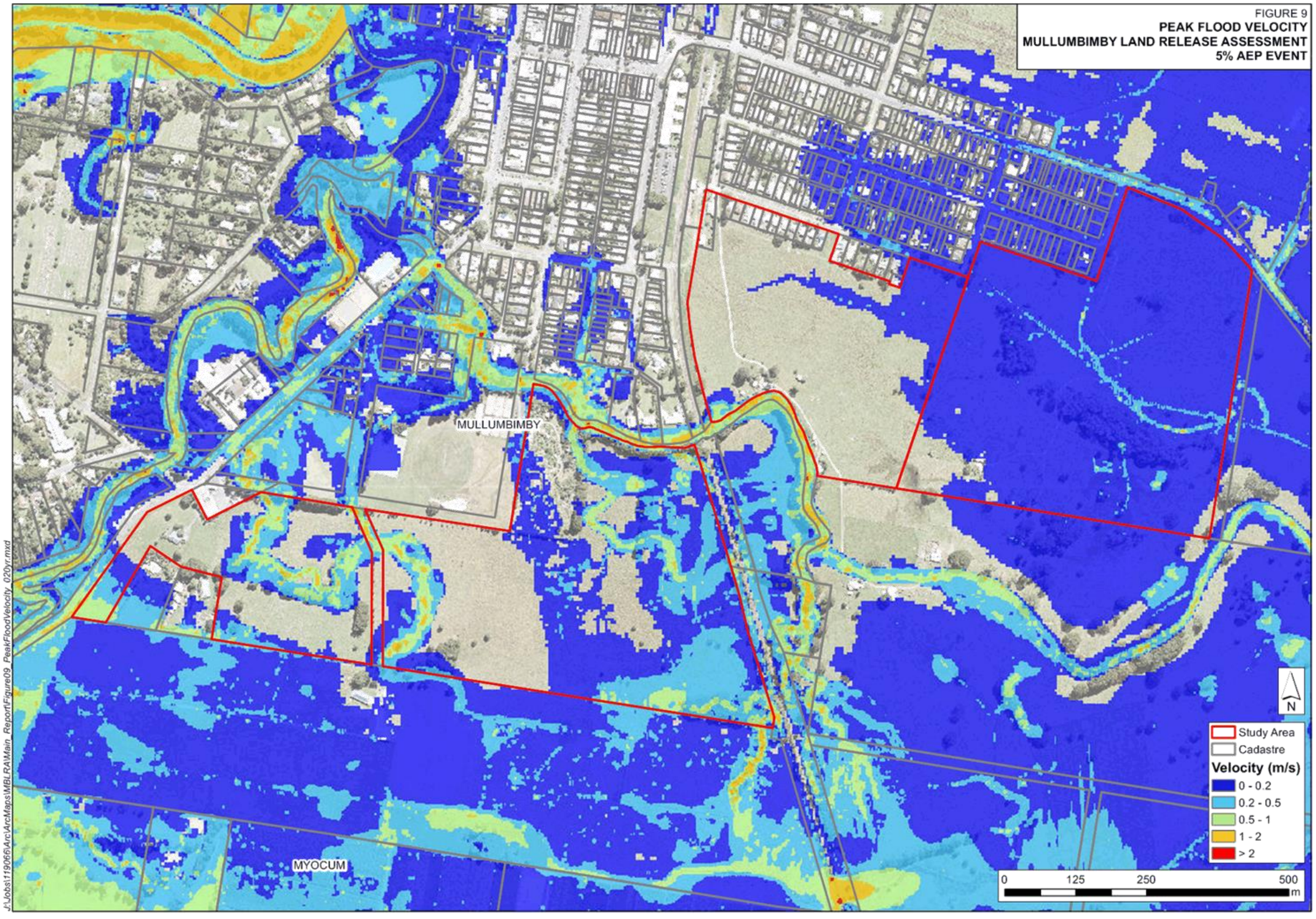

FIGURE 4
PEAK FLOOD DEPTHS
MULLUMBIMBY LAND RELEASE ASSESSMENT
0.2 EY EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Peak Flood Depth (m)
0 - 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2
> 2.0
0
125
250
500
m
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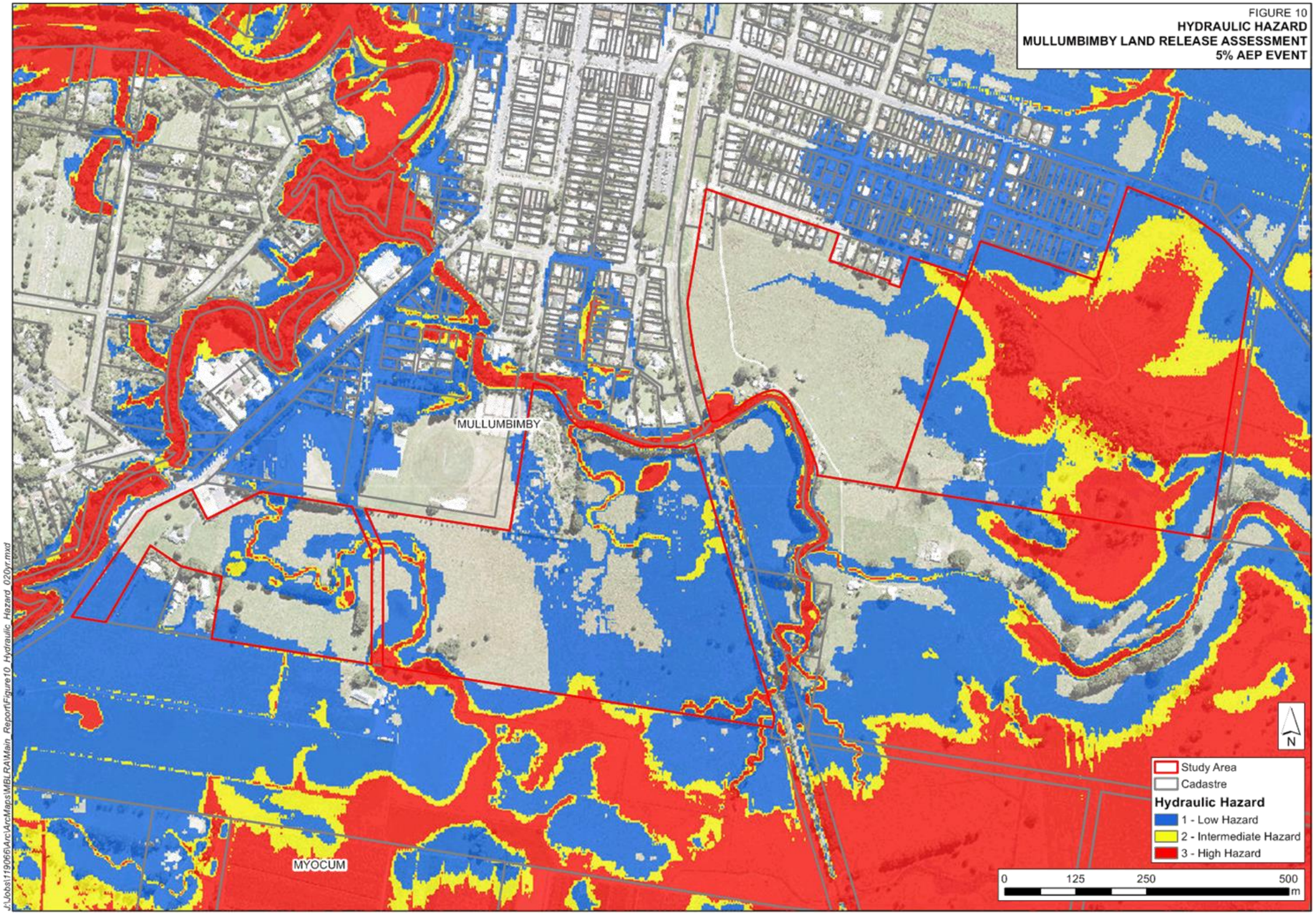

FIGURE 5
PEAK FLOOD VELOCITY
MULLUMBIMBY LAND RELEASE ASSESSMENT
0.2 EY EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Velocity (m/s)
0 - 0.2
0.2 - 0.5
0.5 - 1
1 - 2
> 2
0
125
250
500
m
J:\Jobs\119066\ArcMaps\MBLRA\Main_Report\Figure05_PeakFloodVelocity_005yr.mxd

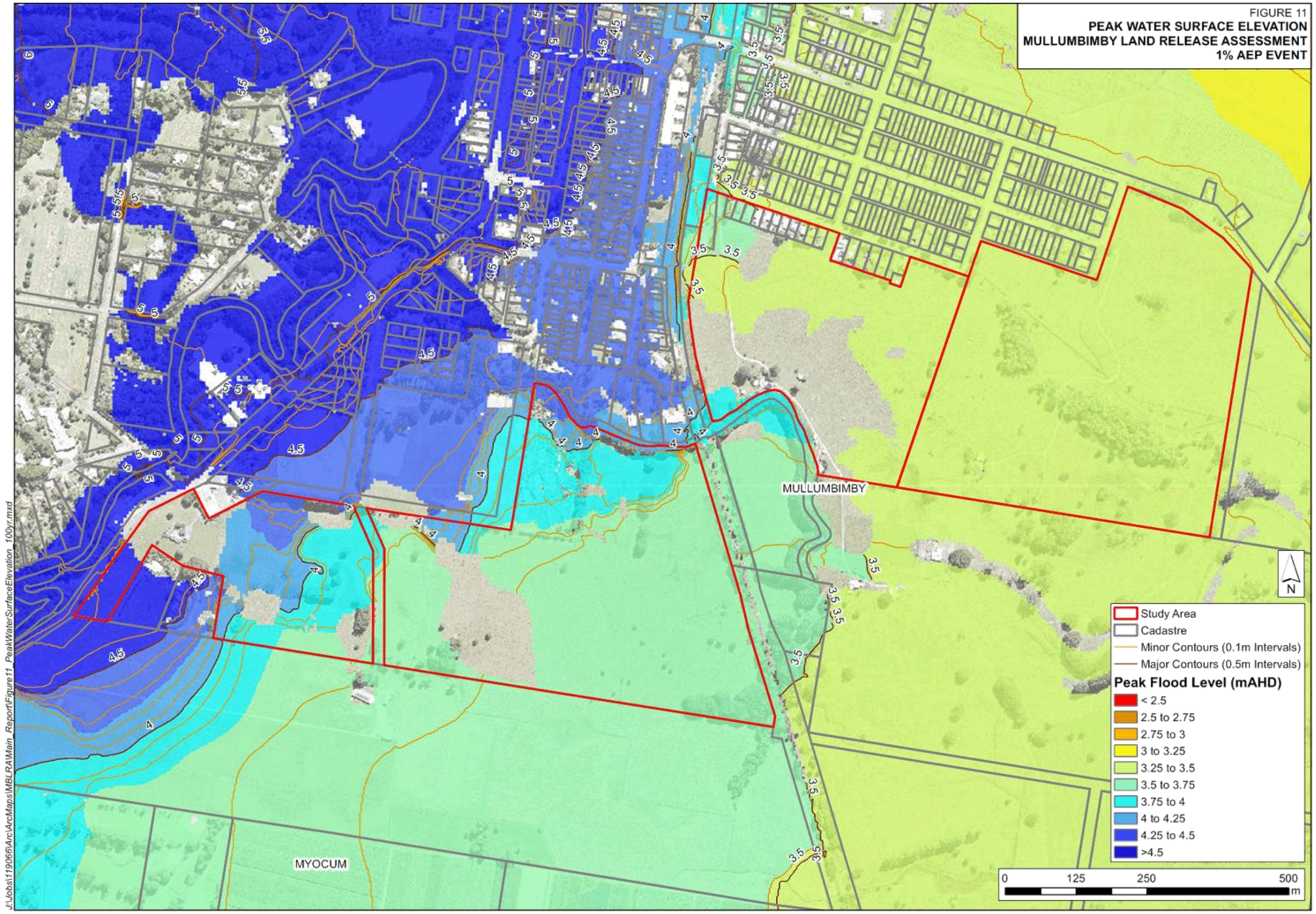

FIGURE 6
HYDRAULIC HAZARD
MULLUMBIMBY LAND RELEASE ASSESSMENT
0.2 EY EVENT
MULLUMBIMBY
MYOCUM
J:\Jobs\119066\ArcMaps\MBLRA\Main_Report\Figure06_Hydraulic_Hazard_005yr.mxd
N
Study Area
Cadastre
Hydraulic Hazard
1 - Low Hazard
2 - Intermediate Hazard
3 - High Hazard
0
125
250
500
m

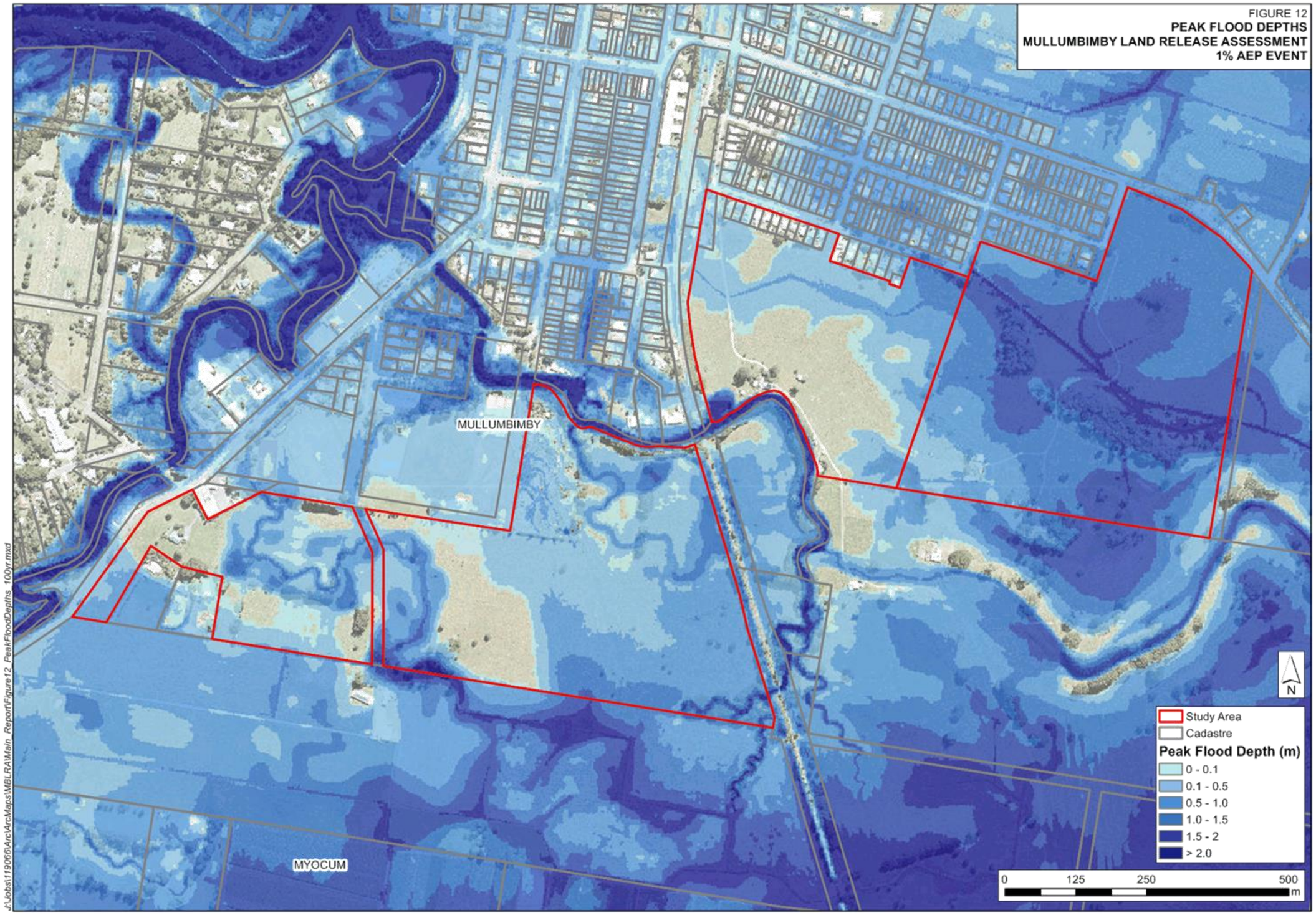

FIGURE 7
PEAK WATER SURFACE ELEVATION
MULLUMBIMBY LAND RELEASE ASSESSMENT
5% AEP EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Minor Contours (0.1m Intervals)
Major Contours (0.5m Intervals)
Peak Flood Level (mAHD)
< 2.5
2.5 to 2.75
2.75 to 3
3 to 3.25
3.25 to 3.5
3.5 to 3.75
3.75 to 4
4 to 4.25
4.25 to 4.5
>4.5
0
125
250
500
m
J:\Jobs\119066\ArcMaps\MBLRA\Main_Report\Figure07_PeakWaterSurfaceElevation_020yr.mxd

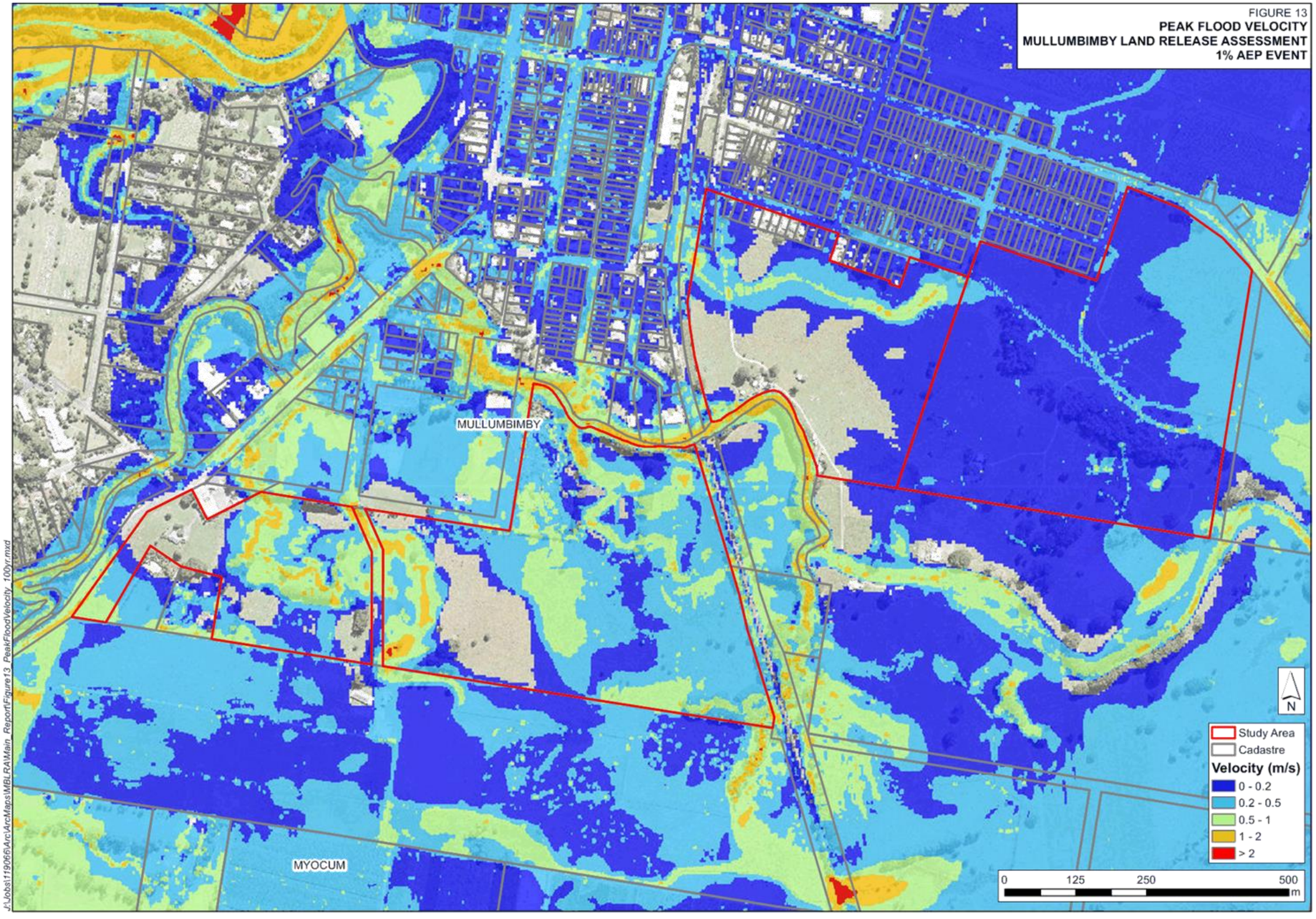

FIGURE 8
PEAK FLOOD DEPTHS
MULLUMBIMBY LAND RELEASE ASSESSMENT
5% AEP EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Peak Flood Depth (m)
0 - 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2
> 2.0
0
125
250
500
m
J:\Jobs\119066\Arc\ArcMaps\MBLRA\Main Report\Figure08_PeakFloodDepths_020yr.mxd

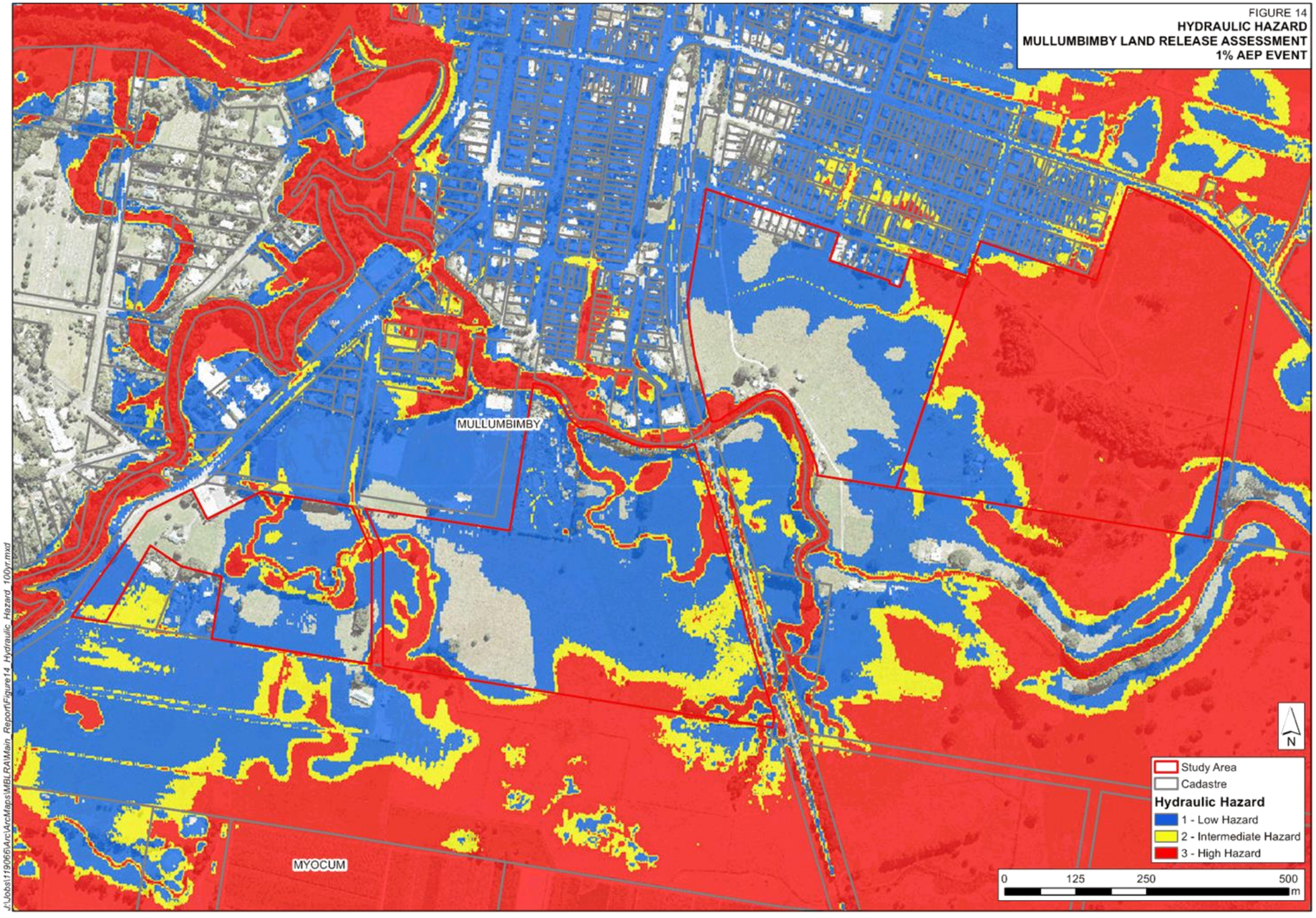

FIGURE 9
PEAK FLOOD VELOCITY
MULLUMBIMBY LAND RELEASE ASSESSMENT
5% AEP EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Velocity (m/s)
0 - 0.2
0.2 - 0.5
0.5 - 1
1 - 2
> 2
0
125
250
500
m
J:\Jobs\119065\ArcMaps\MBLRA\Main_Report\Figure09_PeakFloodVelocity_020yr.mxd

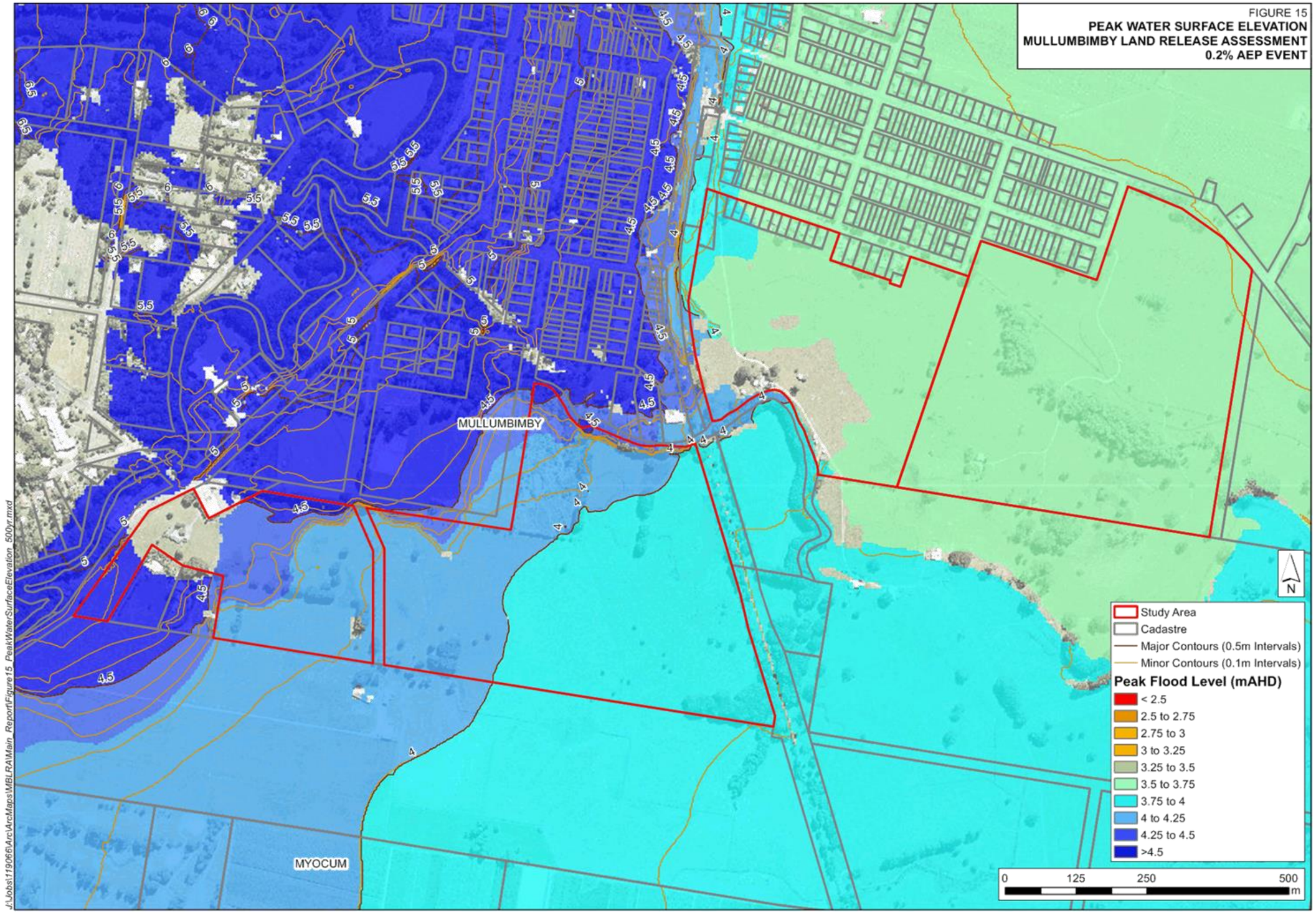

FIGURE 10
HYDRAULIC HAZARD
MULLUMBIMBY LAND RELEASE ASSESSMENT
5% AEP EVENT
MULLUMBIMBY
MYOCUM
J:\Jobs\119066\Arc\ArcMaps\MBLRA\Main Report\Figure10_Hydraulic_Hazard_020yr.mxd
N
Study Area
Cadastre
Hydraulic Hazard
1 - Low Hazard
2 - Intermediate Hazard
3 - High Hazard
0
125
250
500
m

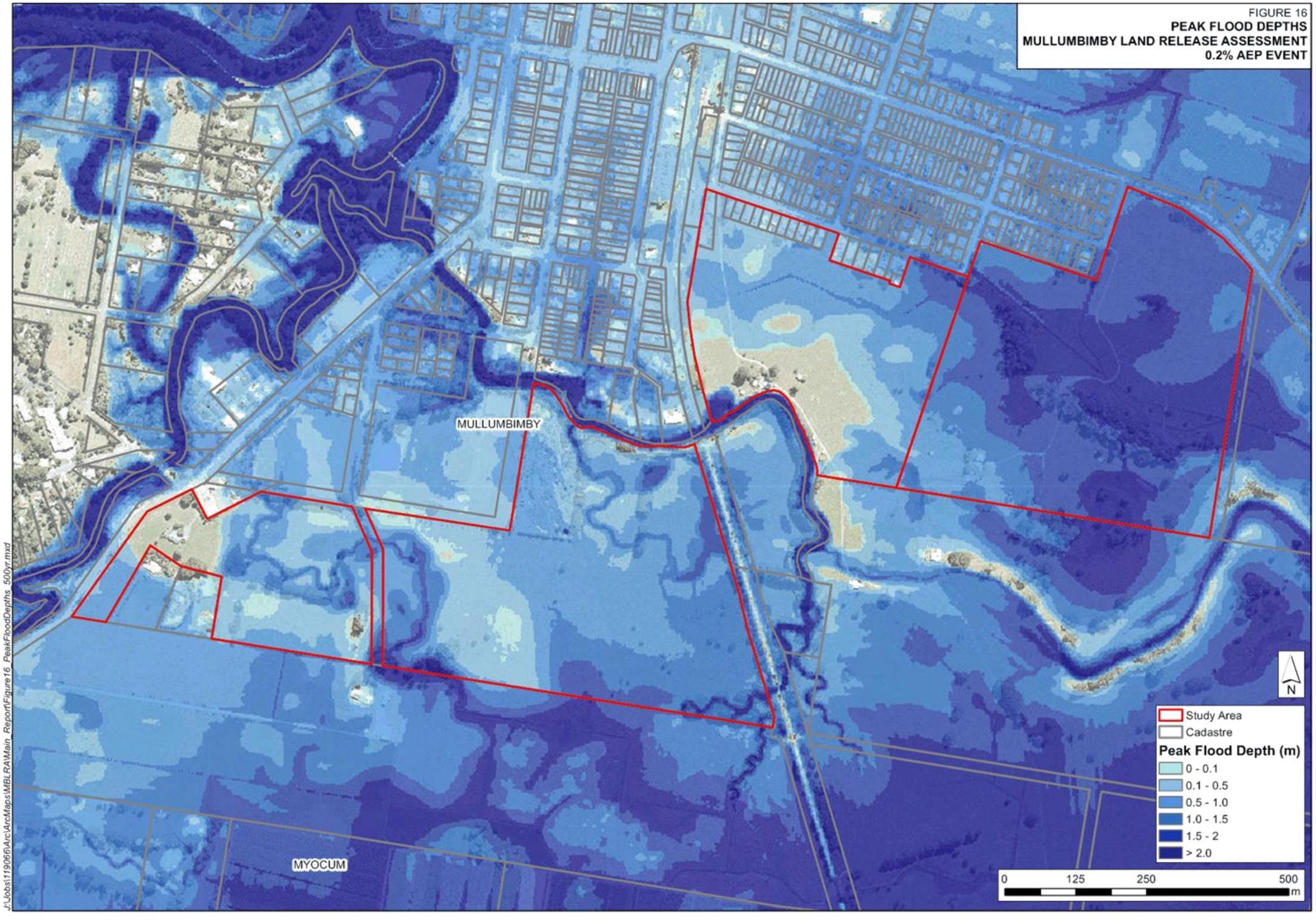

FIGURE 11
PEAK WATER SURFACE ELEVATION
MULLUMBIMBY LAND RELEASE ASSESSMENT
1% AEP EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Minor Contours (0.1m Intervals)
Major Contours (0.5m Intervals)
Peak Flood Level (mAHD)
< 2.5
2.5 to 2.75
2.75 to 3
3 to 3.25
3.25 to 3.5
3.5 to 3.75
3.75 to 4
4 to 4.25
4.25 to 4.5
>4.5
0
125
250
500
m
J:\Jobs\119066\4Arc\ArcMaps\MBLRAMain Report\Figure11 PeakWaterSurfaceElevation 100yr.mxd

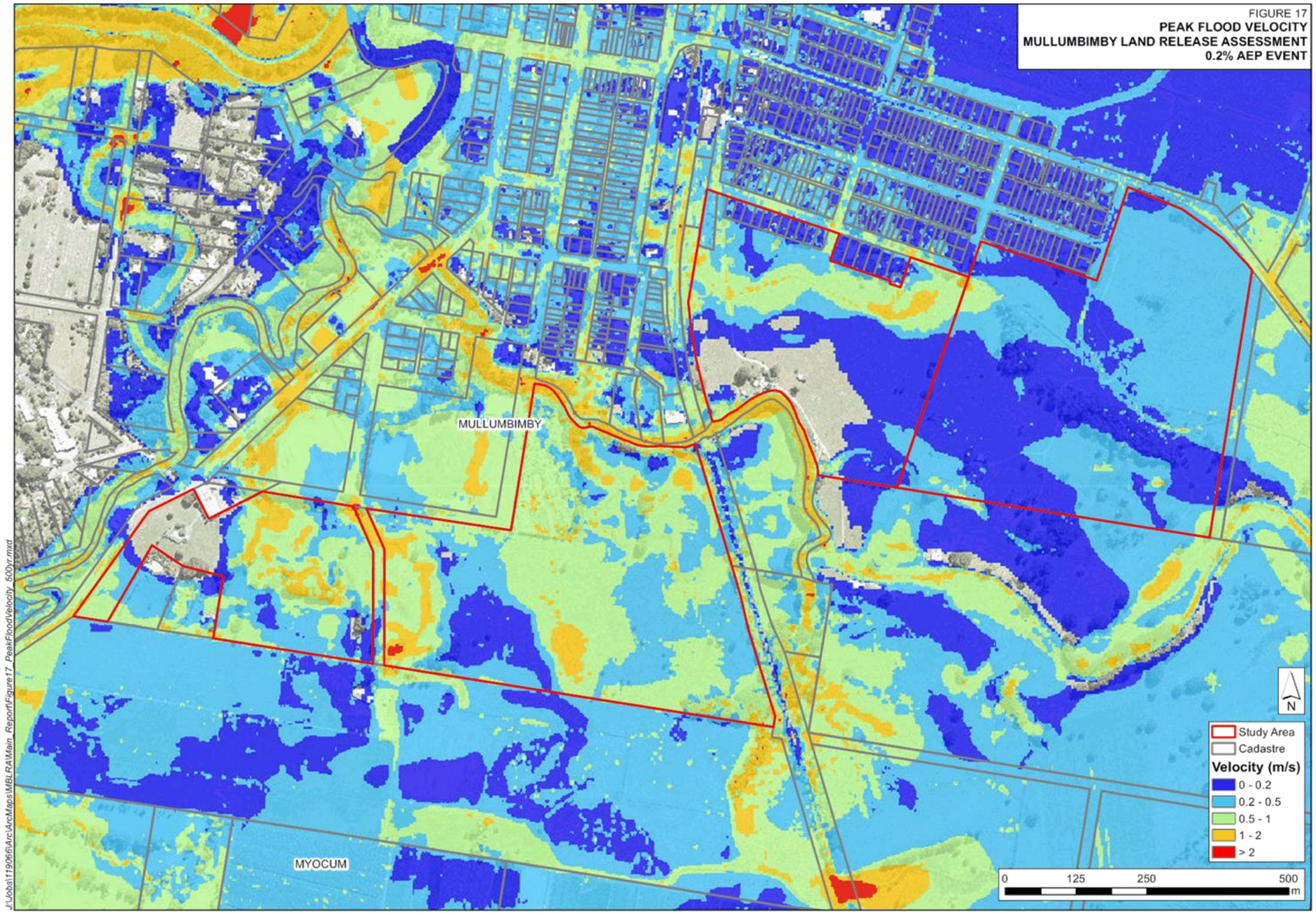

FIGURE 12
PEAK FLOOD DEPTHS
MULLUMBIMBY LAND RELEASE ASSESSMENT
1% AEP EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Peak Flood Depth (m)
0 - 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2
> 2.0
0
125
250
500
m
J:\Jobs\119066\ArcMaps\MBLRAMain_Report\Figure12_PeakFloodDepths_100yr.mxd

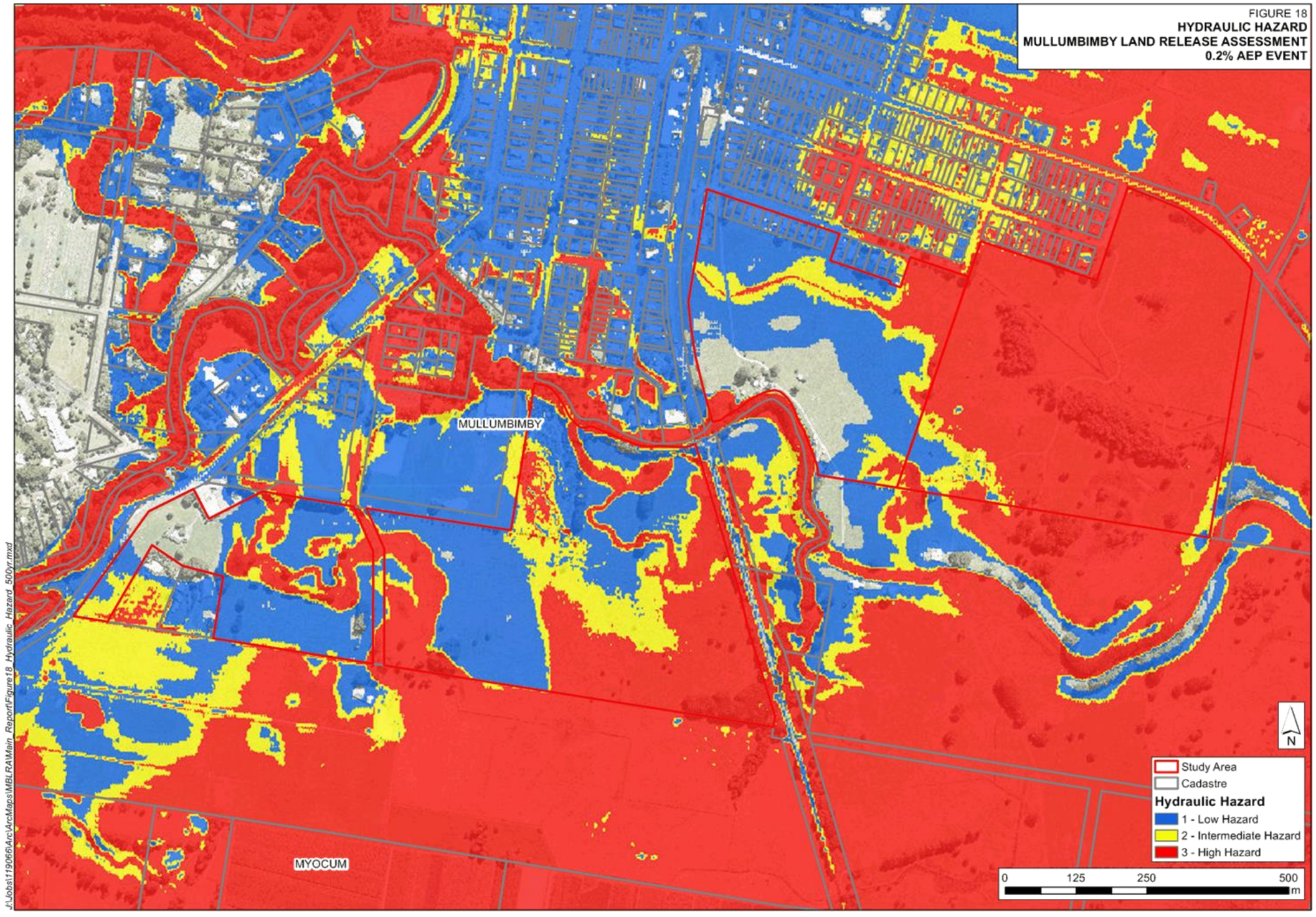

FIGURE 13
PEAK FLOOD VELOCITY
MULLUMBIMBY LAND RELEASE ASSESSMENT
1% AEP EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Velocity (m/s)
0 - 0.2
0.2 - 0.5
0.5 - 1
1 - 2
> 2
0
125
250
500
m
J:\Jobs\119066\ArcMaps\MBLRAIMain_Report\Figure13_PeakFloodVelocity_100yr.mxd


FIGURE 14
HYDRAULIC HAZARD
MULLUMBIMBY LAND RELEASE ASSESSMENT
1% AEP EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Hydraulic Hazard
1 - Low Hazard
2 - Intermediate Hazard
3 - High Hazard
0
125
250
500
m
J:\Jobs\119066\ArcMaps\MBLRA\Main Report\Figure14_Hydraulic_Hazard_100yr.mxd


FIGURE 15
PEAK WATER SURFACE ELEVATION
MULLUMBIMBY LAND RELEASE ASSESSMENT
0.2% AEP EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Major Contours (0.5m Intervals)
Minor Contours (0.1m Intervals)
Peak Flood Level (mAHD)
< 2.5
2.5 to 2.75
2.75 to 3
3 to 3.25
3.25 to 3.5
3.5 to 3.75
3.75 to 4
4 to 4.25
4.25 to 4.5
>4.5
0
125
250
500
m
J:\Jobs\119056\ArcArcMaps\MBLRA\Main_Report\Figure15_PeakWaterSurfaceElevation_500yr.mxd


FIGURE 16
PEAK FLOOD DEPTHS
MULLUMBIMBY LAND RELEASE ASSESSMENT
0.2% AEP EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Peak Flood Depth (m)
0 - 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2
> 2.0
0
125
250
500
m
J:\Jobs\119066\ArcIArcMaps\MBLRAIMain_Report\Figure16_PeakFloodDepths_500yr.mxd


FIGURE 17
PEAK FLOOD VELOCITY
MULLUMBIMBY LAND RELEASE ASSESSMENT
0.2% AEP EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Velocity (m/s)
0 - 0.2
0.2 - 0.5
0.5 - 1
1 - 2
> 2
0
125
250
500
m
J:\Jobs\119066\ArcMaps\MBLRA\Main Report\Figure17 PeakFloodVelocity 500yr.mxd


FIGURE 18
HYDRAULIC HAZARD
MULLUMBIMBY LAND RELEASE ASSESSMENT
0.2% AEP EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Hydraulic Hazard
1 - Low Hazard
2 - Intermediate Hazard
3 - High Hazard
0
125
250
500
m
J:\Jobs\119066\ArcMaps\MBLRA\Main_Report\Figure18_Hydraulic_Hazard_500yr.mxd

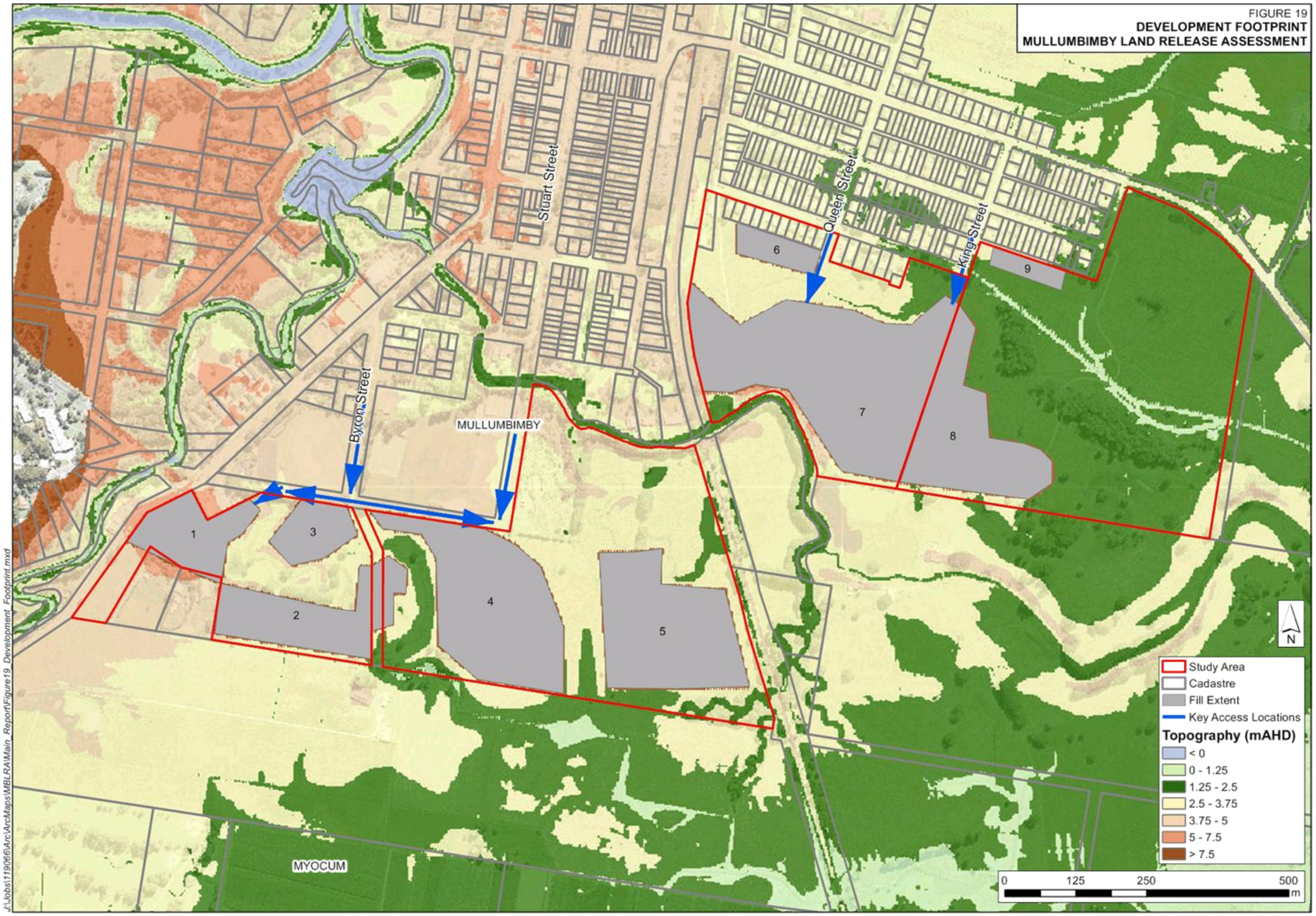
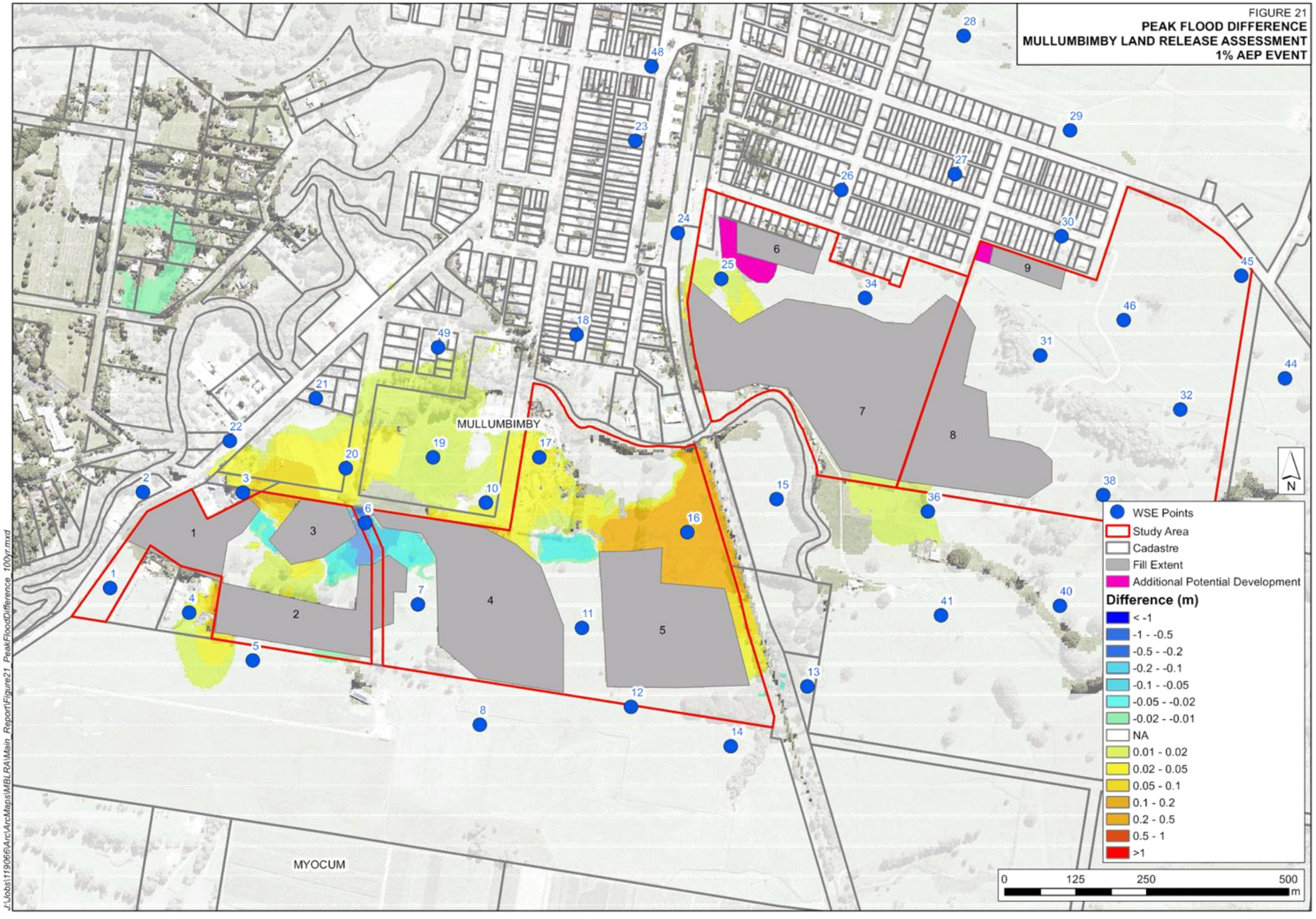

FIGURE 19
DEVELOPMENT FOOTPRINT
MULLUMBIMBY LAND RELEASE ASSESSMENT
Stuart Street
Queen Street
King Street
Byron Street
MULLUMBIMBY
MYOCUM
1
2
3
4
5
6
7
8
9
N
Study Area
Cadastre
Fill Extent
Key Access Locations
Topography (mAHD)
< 0
0 - 1.25
1.25 - 2.5
2.5 - 3.75
3.75 - 5
5 - 7.5
> 7.5
0
125
250
500
m
J:\Jobs\119066\Arc\ArcMaps\MBLRA\Main_Report\Figure19_Development_Footprint.mxd


FIGURE 20
CUT TO FILL BALANCE
MULLUMBIMBY LAND RELEASE ASSESSMENT
N
Cadastre
Earthworks Contours (0.25m)
Depth of Cut and Fill (m)
< -1.5
-1.5 to -1.2
-1.2 to -0.9
-0.9 to -0.6
-0.6 to -0.3
-0.3 to 0
0 to 0.3
0.3 to 0.6
0.6 to 0.9
0.9 to 1.2
> 1.2
0
100
200
400
Meters
J:\Jobs\119066\Arc\ArcMaps\MBLRA\Main_Report\Figure20_Cut_to_fill_balance.mxd


FIGURE 21
PEAK FLOOD DIFFERENCE
MULLUMBIMBY LAND RELEASE ASSESSMENT
1% AEP EVENT
MULLUMBIMBY
MYOCUM
WSE Points
Study Area
Cadastre
Fill Extent
Additional Potential Development
Difference (m)
< -1
-1 - -0.5
-0.5 - -0.2
-0.2 - -0.1
-0.1 - -0.05
-0.05 - -0.02
-0.02 - -0.01
NA
0.01 - 0.02
0.02 - 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.5
0.5 - 1
>1
0
125
250
500
m
N
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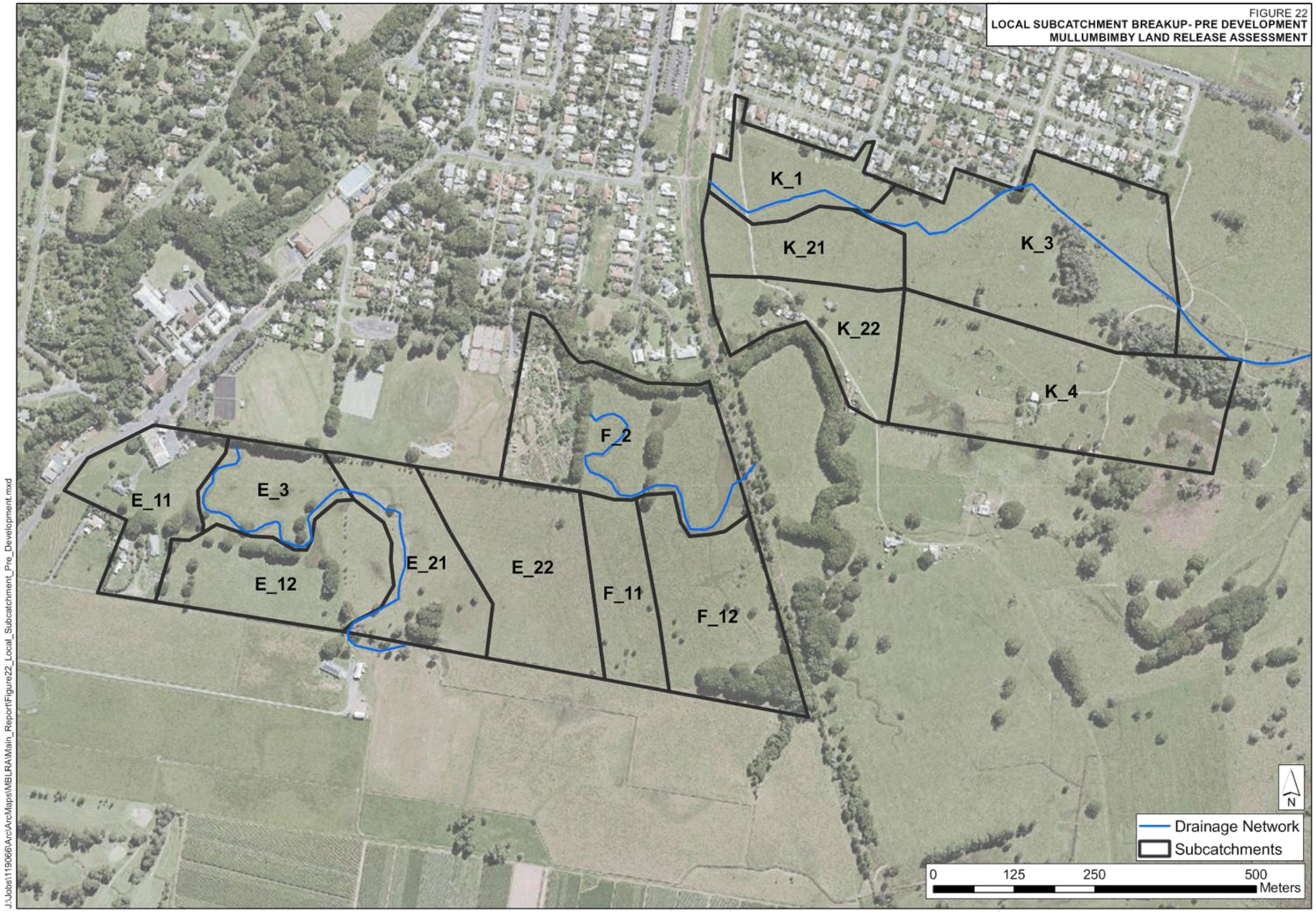

FIGURE 22
LOCAL SUBCATCHMENT BREAKUP- PRE DEVELOPMENT
MULLUMBIMBY LAND RELEASE ASSESSMENT
K_1
K_21
K_3
K_22
K_4
F_2
E_11
E_3
E_12
E_21
E_22
F_11
F_12
N
Drainage Network
Subcatchments
0
125
250
500
Meters
J:\Jobs\119066\ArcIArcMaps\MBLRA\Main_Report\Figure22_Local_Subcatchment_Pre_Development.mxd

FIGURE 23
LOCAL SUBCATCHMENT BREAKUP-POST DEVELOPMENT
MULLUMBIMBY LAND RELEASE ASSESSMENT




FIGURE 24
CONCEPT STORMWATER MANAGEMENT PLAN
MULLUMBIMBY LAND RELEASE ASSESSMENT
K_1
K_21
K_3
K_22
K_34
K_4
F_2
E_11
E_3
E_12
E_21
E_22
E22+F11
F_11
F_12
N
Trunk Stormwater Line
Development Area
Wetland
Detention /Bioretention
Footprint Area
Drainage Network
Inlet Pipe into Detetion Basin
Subcatchments
0
125
250
500
Meters
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FIGURE 25
ALTERNATIVE CONCEPT STORMWATER MANAGEMENT PLAN
MULLUMBIMBY LAND RELEASE ASSESSMENT




Appendix A

Ardill Payne & PARTNERS ENGINEERS PLANNERS SURVEYORS ENVIRONMENTAL PROJECT MANAGEMENT

DRAINAGE ASSESSMENT AND MITIGATION OPTIONS REPORT

NEW CITY ROAD, MULLUMBIMBY

Submission to

Byron Shire Council

for:
Byron Shire Council

March 2018

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Document Control Sheet

Filename:	New City Road Drainage Assessment and Mitigation Options Report.docx				
Job No.:	8550				
Job Captain:	Bill Payne				
Author:	Parham Ghasemzadeh; Bill Payne				
Client:	Byron Shire Council				
File/Pathname	S:\01 Jobs\8500-8599\8550 Stormwater and drainage assessments - New City Road\01 Administration\02 Reports\New City Road Drainage Assessment and Mitigation Options Report.docx				
Revision No:	Date:	Checked By		Issued By	
		Name	Signed	Name	Signed
0	7.2.18	B Payne		P Ghasemzadeh	
1	2.3.18	B Payne		P Ghasemzadeh	
2					

Ardill Payne & PARTNERS

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Executive Summary

The hydrologic and hydraulic modelling shows that for the adopted 5 year ARI event, flooding is caused by the lack of a discharge point through the constructed berm around the effected properties. The berm prevents larger back up floods from entering the property.

Drains and drain crossing across the site are undersized, have poor hydraulic gradient and require maintenance.

Two mitigation options were investigated. These were to:

1. Construct a culvert under the berm with a 5 year ARI capacity and flood gates to prevent inundation from back up flooding.
2. As for option 1 but improve the drain and drain crossings.

Results show that these mitigation options have a limited effect on reduction of the initial 5 year ARI flood height and extent. This is because in its current condition the drainage channel does not provide sufficient hydraulic capacity thus limiting the overall site drainage capacity. Mitigation to address short term flooding issues will only be possible if large scale cut and fill at the site and widening the channel is considered. This might be associated with further development or subdivision of the site. However, based on the tailwater conditions imposed by Kings Creek, the performance of the site drainage will remain under the influence of the tailwater conditions imposed by Kings Creek. In turn the Kings Creek tailwater condition will also be varied for different rainfall duration and pattern.

For longer term effects the study shows that the proposed mitigation options will have a more significant effect in accelerating the ponded water drawdown during and after the rainfall events. The study results for the 5 year ARI design event shows that after 12 hours both options significantly reduce the amount of ponded water at the site. That is, flood level and area covered by inundation are greatly reduced. Of the two options, option 2 has the greater effect. See Figure 11 in the attachments for comparative effects.

1. Introduction

1.1 Foreword

Ardill Payne and Partners (APP) has been commissioned by Byron Shire Council (Council) to undertake a drainage assessment for an area located in vicinity of New City Road at Mullumbimby, NSW. The works include identifying the drainage issues leading to the current stormwater ponding at the area and a hydraulic investigation into the requirements to reduce those issues. The 5 year ARI storm was defined as the reference design event for this assessment.

The previous version of this report was submitted to Council detailing the implemented hydrology and hydraulic studies, the identified issues and a qualitative evaluation of mitigation options. The report was reviewed by Council and the proposed mitigation options were discussed in a meeting. The limitations of the mitigation options imposed by the downstream ground elevation and flood level was also considered and deliberated in the meeting. That is, the creek outlet is higher than the lowest part of the inundated drainage gully. A gated culvert through the berm will reduce but not completely remove the inundation. The same can be said for keeping the drainage gully clean and increasing the conveyance capacity of the gully crossings.

An approach in terms of implementing short to long term solutions was agreed and it was decided that the study could be completed with quantification of the effects of the mitigation options in alleviating the existing issues.

1.2 Background

It is understood that this investigation has been arranged by Council following an appeal by the owner of lot DP 1032298 regarding frequent water ponding issues at their property. The problematic area is shown in Figure 1.1. Insufficient capacity of an existing channel traversing the area (Figure 1.2) was identified to be the potential cause of the current issues.



Figure 1.1: Study area locality plan

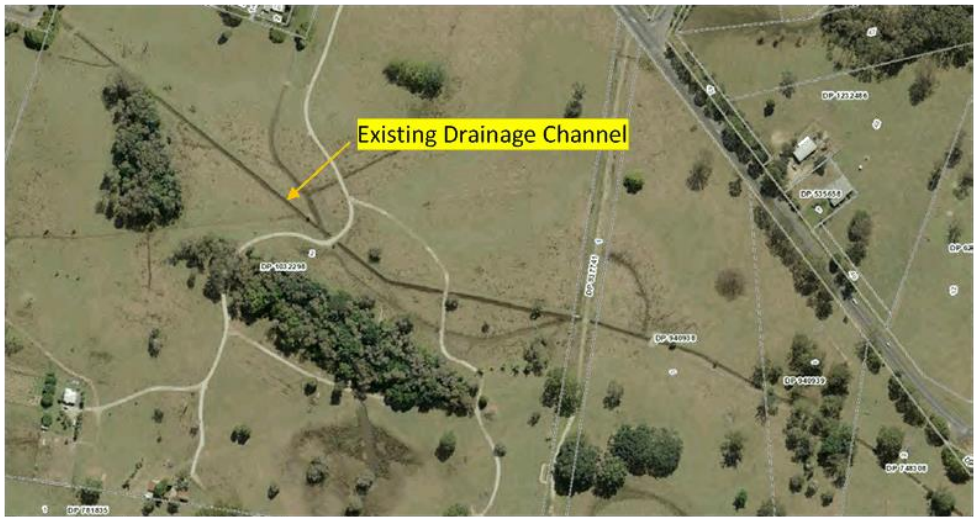


Figure 1.2: Reported problematic area

The site is located within the Kings Creek and Brunswick River flood plain. Council's 5 year ARI flood map at the study area is shown in Figure 1.3. In first instance it seems that flooding of the site may be river sourced. However, as can be seen in the figure, the ponded water at the site and the river flood plain are not joined and as such the site flows are rather from the local catchment. This has been further investigated in this study.

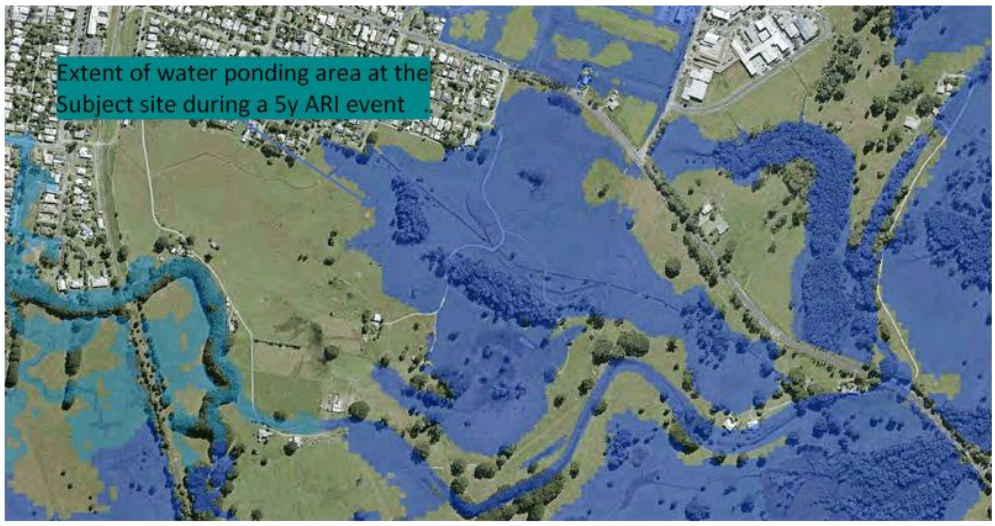


Figure 1.3: 5 year ARI flood plain at the study area

2. Hydrologic Assessment

The study area has a catchment of 83.4ha. The catchment extends to Prince Street from the west, Argyle Street from the north and the existing vegetated open area from the south and east. Regional scale hydrologic and hydraulic models have been setup by Council for the Brunswick River system. The study area is presented as one catchment in Council's XPRafts hydrology model. For this study, to undertake a more detailed hydraulic assessment to a stage enabling drainage upgrade designs, additional detail to the existing model was required. It was necessary to divide the catchment to sub-catchments and setup a separate hydrology model to enable flow allocations along the main drainage channel. Figure 2.1 provides a comparison between the scale of the Council regional model and the catchment of interest in this study. The site specific XPRafts hydrology model developed in this study is illustrated in Figure 2.2.



Figure 2.1: Location of the site in the existing Council regional model

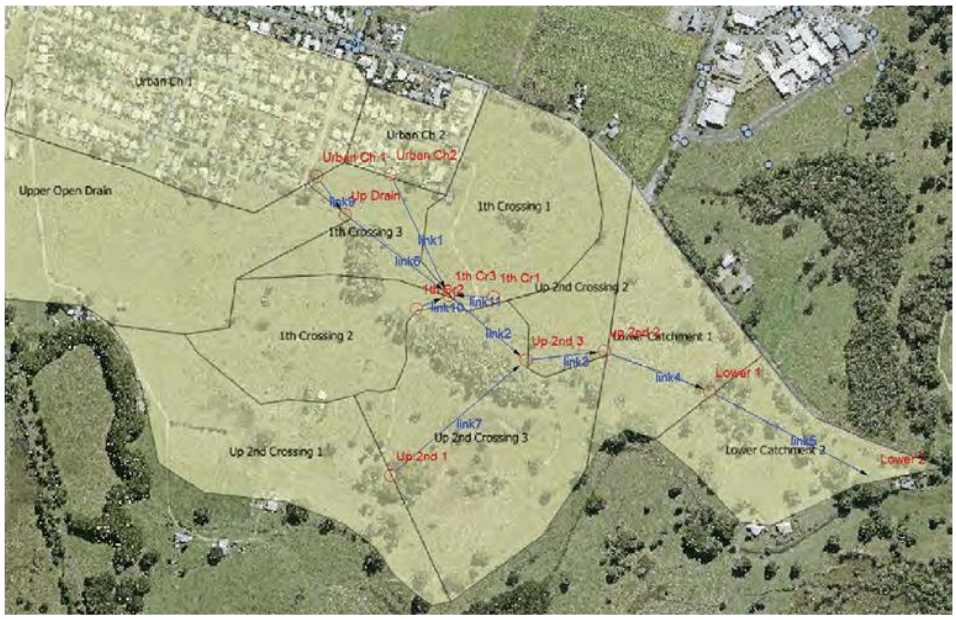


Figure 2.2: XPRafts model setup for the current study

To develop this model, the catchment was divided into 11 sub-catchments. The subcatchments are shown in Figure 1, Attachment 1. The subcatchment areas and computed 5 year ARI flows are presented in Table 2.1. Each subcatchment was modelled with loss parameters allocated based on the current site conditions ranging from fully vegetated to urban areas with light to dense settlements.

The quantity and temporal pattern of design 5 year ARI rainfall event was defined for the location of the catchment based on the Australian Rainfall and Runoff guideline. The hydrologic modelling of this event was undertaken for a range of rainfall durations. Running of the developed hydrologic and hydraulic models revealed that the 3hr rainfall would be the critical rainfall event for the catchment with 2hr rainfall duration creating very close peak discharges.

Table 2.1: Identified subcatchments and computed 5 year ARI peak discharges

No.	Catch Name	Area (ha)	5y ARI Peak Discharge (m^3/s)
1	Urban Ch 1	15.8	3.59
2	Upper Open Drain	16.6	1.62
3	Lower Catchment 2	5.3	0.56
4	Urban Ch 2	2.5	0.66
5	1th Crossing 1	6.8	0.66
6	1th Crossing 2	5.7	0.57
7	1th Crossing 3	3.1	0.34
8	Up 2nd Crossing 2	2.8	0.31
9	Lower Catchment 1	5.6	0.54
10	Up 2nd Crossing 1	8.2	0.78
11	Up 2nd Crossing 3	10.9	0.98
Total		**83.4**	**8.18**

Note: *Total flow is the total catchment peak discharge not the sum of subcatchments flows*

3. Hydraulic Modelling

3.1 Approach

In early planning of the study it was decided that the existing Council's Tuflow model be refined and used for the study. However, after further assessments, development of a separate model was preferred. This decision was based on that:

- It was illustrated that for the target 5 year ARI storm event the Brunswick River and/or Kings Creek floodplain do not extend to the site and as such no regional scale analysis was necessary.
- Based on its purpose, the regional model was too coarse with none of the site's existing culvert crossings being present in the model.

3.2 Model Setup

To assess flooding characteristics at and adjacent to the site of interest, a 2D hydrodynamic TUFLOW model was setup. TUFLOW is an industry accepted model in which flood water can be simulated in any direction within the surface. This gives a clear indication of distribution patterns of flows on the study area.

The modelling area extended to Kings Creek from the south and Mullumbimby Road from the north to encompass the full area of interest. In a 5 year ARI event the site is isolated from the Brunswick River flood plain by Mullumbimby Road. The Kings Creek maximum water levels in a 5 year ARI event was extracted from the Council regional model and included in the site specific hydraulic model as water level boundary condition in one of the modelling scenarios. Flows computed from the hydrologic model were also included in the model as flow boundary conditions. The hydraulic model extent and location of the boundary conditions are shown in Figure 2, Attachment 1.

The hydraulic model was setup to represent the existing condition of the site with the current drainage system and also to assess the drainage upgrade requirements. The existing channel within the site is the main drainage point of the catchment. Driveways to the existing properties are located within the site, many of which cross the channel with pipe and box culverts located at these crossings. A site visit and a land survey was undertaken to investigate the site condition and identify the culvert sizes and the channel specifications. The channel layout prepared from the site survey is shown in Attachment 3.

The surface digital elevation model (DEM) required for 2D hydraulic modelling was generated based on the Lidar data provided by Council. A 1m grid size DEM was generated from the data to best represent localised changes in the topography. The land survey data was overlaid on the Lidar base DEM and other necessary adjusts were made to ensure the hydraulic model represents the current channel depths and size.

The existing culverts were incorporated in the model with their exact number, size and levels provided from the land survey. The site DEM, contours and culvert crossings are shown in Figure 3, Attachment 1.

An overall Manning's n roughness value of 0.04 was used across the 2D model boundary as no significant spatial variation in roughness was detected and the channel was found to dominantly contain fully grown vegetation.

4. Current Issues

4.1 River Source Flooding

In this study the maximum water levels at Kings Creek were extracted from Council's regional model and implemented to the site specific model. The results shown in Figure 4, Attachment 1 illustrates that in a 5 year event the creek flows do not enter to the site. Further inspections showed that the existing earth bund along the creek is about 0.5m above the 5 year ARI maximum water level at the creek providing a high degree of flood immunity for the site from the creek sourced flows in frequent storm events.

4.2 Blockage of Channel Discharge Point

The site inspection and the following land survey showed that the natural discharge point of the existing drainage channel to Kings Creek as shown in Figure 4.1 has been cut off by the existing earth bund. With no discharge point, all the flows received from the upstream catchment build up on the site and remain there until gradually diminishing through infiltration and evaporation.

It should be noted that in the current condition a maximum water level of about 2m AHD would cover the site in a 5 year ARI design event, (Figure 4, Attachment 1). If the site was not isolated from the river by the earth bund a higher water level of at least 2.35m AHD in a 5 year ARI event could be expected.

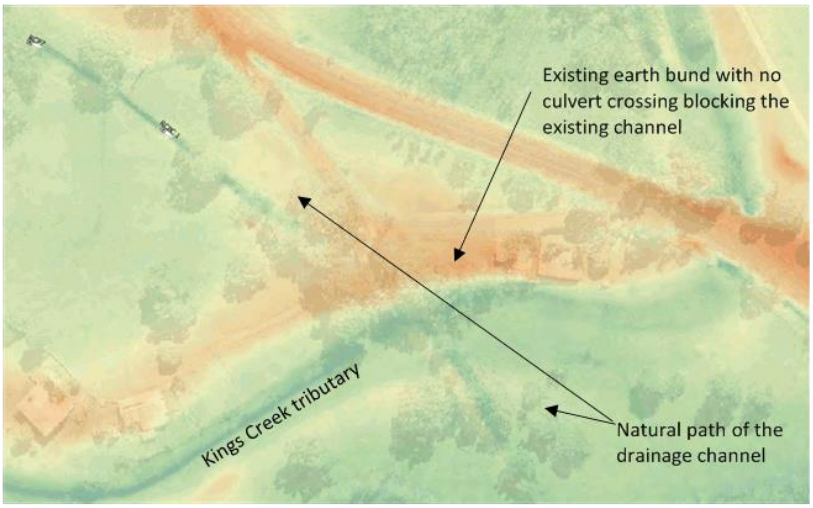


Figure 4.1: Blocked discharge point of the drainage channel to Kings Creek tributary

4.3 Insufficient Capacity at Culvert Crossings

The details of the existing culverts along the drainage channel is listed in Table 4.1. The location of these culverts are shown in Figure 5, Attachment 1. Review of the system and assessment of the hydraulic modelling results indicates insufficient capacity at the existing culvert crossings. It should be noted that the low discharge capacities computed at most of the crossings are also due to the current tailwater restrictions. With tailwater restrictions removed, the potential discharge capacity of the existing culverts will be increased.

Table 4.1: Specification of the culvert crossings within the study area

ID	US IL (m AHD)	DS Invert (m AHD)	Type	Diameter (m)	Number of	Q_{max} (m^3/s)	Q_{min} (m^3/s)
RCP1	0.82	0.82	RCP	0.6	2	1.02	0
RCP2	1.12	1.05	RCP	0.5	1	0.439	0
RCP3	0.65	0.72	RCP	0.675	1	0.604	0
RCP4	0.67	0.67	RCP	0.675	1	0.366	0
RCP12	1	1	RCP	0.375	1	0.123	-0.122
RCP6	0.65	0.63	RCP	0.7	1	0.477	-0.155
RCP7	0.54	0.54	RCP	1.05	1	0.045	-0.1
RCP8	0.52	0.52	RCP	1.05	1	0.21	-0.018
RCBC 1	1	1	RCBC	4 x 0.8	1	0.255	-0.168
RCP11	1.16	1.12	RCP	0.3	1	0	-0.086
RCP5	0.95	0.95	RCP	0.3	1	0.076	0

Note: *Q_{min} denotes inverse flow*

The drainage channel begins downstream of King Street with a peak runoff of 4.55m^3/s for a 5 year ARI event generated from Upper Open Drain & Urban Catchment 1 (Table 2.1). The majority of this runoff discharges to the channel from the existing three RCP culverts under King Street shown in Photo 10, Attachment 2. Flows from Urban Catchment 2 are captured by the channel upstream of the first crossing 'RCP1' within the modelling area. However, as shown in Table 3.1 the current capacity at RCP1 crossing is 1.02 m^3/s, much less than the target 5 year ARI event flows. This inspection can be continued toward the end of the channel revealing insufficient capacity at all crossings and an inconsistency of the culvert sizes and numbers along the channel.

4.4 Land fill

The insufficient capacity of the system is not just from the lack of conveyance capacity at the crossings. Inspection of the culvert levels show that crossing RCBC1 with the largest flow conveyance area is located 0.45m higher than the upstream culvert resulting in no discharge capacity at this crossing. In fact the current fill along the Kings Creek is not limited to the location of the earth bund. The fill is extended toward the site creating the large water ponding issues at the site internal areas with lower elevation. The current surface levels within the site is presented in Figure 3, Attachment 1.

4.5 Sedimentation and Vegetation

The site inspections show that the crossings are not the only parts of this stormwater system creating drainage issues. Silting and dense vegetation along the channel also results in the drainage system inefficiency.

A long profile of the drainage channel in its current condition is shown in Figure 4.2.

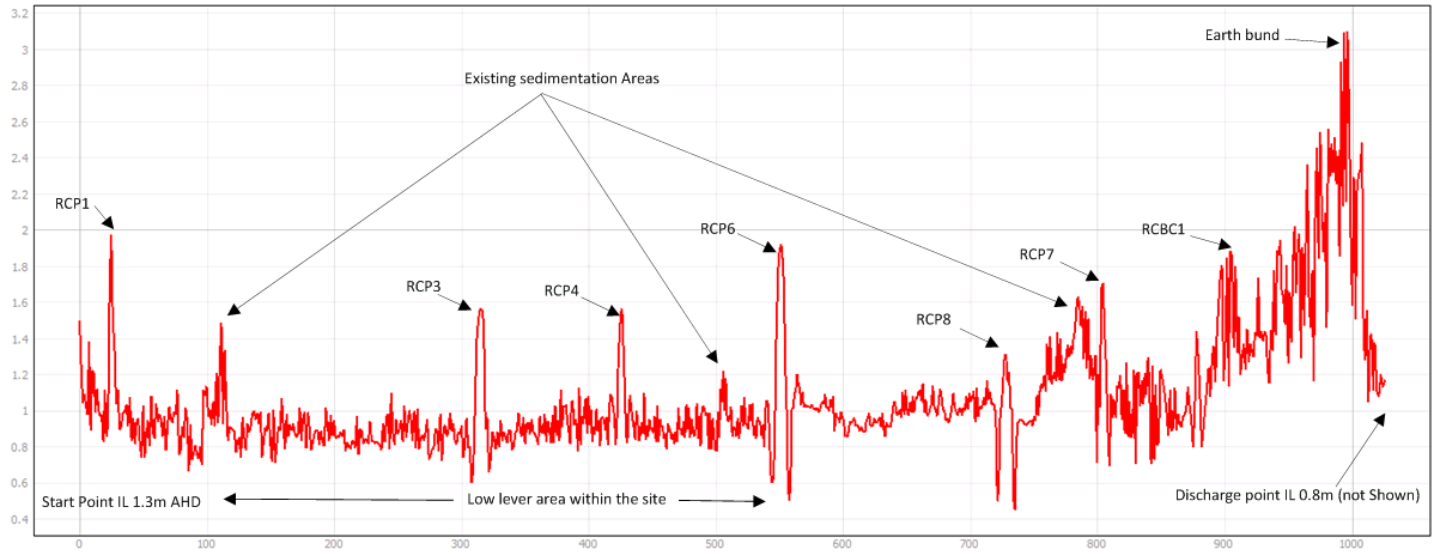


Figure 4.2: Drainage channel long profile, location of the culvert crossings and invert level variations

5. Drainage Upgrade and Mitigation Options

5.1 General

Hydraulic modelling of a series of mitigation measures shows that increasing the number/size of the existing culverts and provision of a new culvert crossing under the existing earth bund to some extent alleviates the existing drainage issues. However, implementing these options will not completely resolve the problem.

A major part of the drainage channel is located on low level areas with an invert level of 0.5m at the drainage channel. This level is lower than the invert level of o.8m AHD for Kings Creek tributary at the site drainage channel discharge point. This means that either filling the site central areas or deepening the Kings Creek tributary in vicinity of the proposed culverts discharge point will be required to provide a minimum hydraulic gradient along the channel. We note that the latter option requires hydraulic modelling to be extended to Kings Creek for further investigations.

Based on the numbers extracted from Council's regional hydraulic model Kings Creek maximum water level in a 5 year ARI event is 2.35m AHD. Therefore, backflows from the creek to the site through the proposed culvert crossing under the earth bund will result in much worse flooding problems at the site. Therefore, in re-establishing the channel discharge point, backflows have to be prevented by installation of flap gates on the proposed culverts outlets. Kings Creek response time to rainfall events is longer than the site local catchment. Therefore, it is anticipated that in rainfall events the site flows can discharge to the creek prior to significant raise of water level in the creek. Location of the proposed culverts as included in the hydraulic model are shown in Figure 5.1.

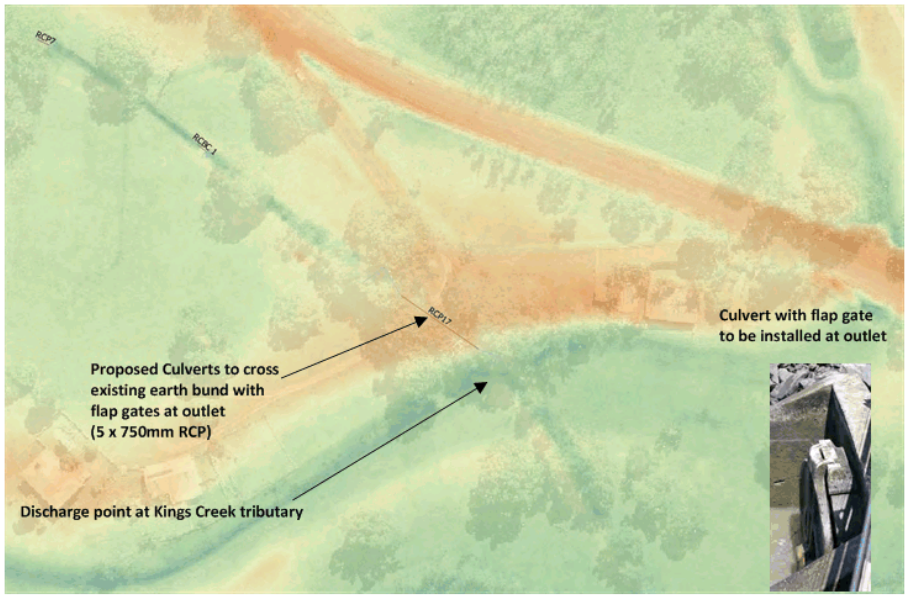


Figure 5.1: Proposed culvert crossing under the existing earth bund

The mitigation works and their effect in alleviating the current issues are discussed in the rest of this section.

5.2 Mitigation Options

5.2.1 Construct culverts under earth bund - Option 1

Creating a discharge point for the site drainage channel is the foremost mitigation option and considered to be a requirement rather than an option. Council has requested the outlet to have 5 year ARI discharge capacity. Trial runs of the hydraulic model illustrated that with the limiting upstream restrictions the upstream channel will not be able to pass the 5 year ARI peak flow to the discharge point and as such design of a high capacity discharge for the low capacity upstream channel will be unnecessary. The modelling shows that 5 x 750mm RCP culverts will provide an optimal discharge capacity for the system with all proposed upgrades.

The site maximum inundation depths with provision of a discharge point for the channel is shown in Figure 6, Attachment 1. A comparison of the site flooding extent in the existing condition and with implication of the mitigation option is shown in Figure 8, Attachment 1.

A range of hydraulic information can be extracted from the model at any location within the modelling area. Hydraulic information including discharge, water level and flow velocity was extracted at the points and along the lines shown in Figure 8, Attachment 1. This information was used in option assessments and selection of the proposed culvert sizes. Figure 5.2 has been prepared based on the water level readings at point 'P4' located inside the drainage channel at the site low level central areas.

The figure provides a comparison between the site water level drawdown in the current condition and that which occurs with implementing the proposed mitigation options. The time duration in this figure has been extended to 12 hours. It is expected that after 12 hours of initiation of a storm event with raising water level in the downstream creek no further discharge from the site will be possible. In preparing the figure, no reduction to the site runoff due to evaporation and infiltration was accounted. The infiltration losses during the rainfall duration was already considered in the hydrologic model. The additional losses in a few remaining hours would be insignificant.

The figure shows no reduction in the ponded water levels for the current condition. The drawdown achieved with Option 1 may not appear significant in the figure. However, the reduction of the flooding extent in such flat site even with a low reduction of water level is significant. The flooding extent and depths 12 hours after the storm event is shown in Figure 9. A comparison of the flooding extent with Option 1 and the existing condition is shown in Figure 11**. Figure 11 provides the clearest evidence of the impact on flood levels of the various options. Because of the limited flow capacity of the system it is only after some time has passed that mitigation effects kick in**.

5.2.2 Option 1 Plus crossings upgrade – Option 2

It is speculated that the existing driveways and drainage crossings within the site were developed in time by the private property owners with no systematic stormwater quantity assessments. Based on the ownership issues and relatively high capital costs, upgrade of

these crossings in a short time period may not be achievable. Nevertheless, being informed about the mitigation achieved through the crossings upgrade was an important matter in planning the future drainage upgrade in the area.

The size of the culverts in the proposed upgrade works are presented in Table 5.1. The location of the culverts except for the earth bund crossing are shown in Figure 2, Attachment 1. The heights of the proposed box culverts were selected with consideration of the site and drainage channel levels and provision of enough cover for the culverts. It was assumed that the existing vegetation and sediment along the channel between the crossings will be removed as part of the upgrade work. The drainage channel modification was included in the hydraulic model by removing the existing localised high level areas within the model DEM and reducing the manning's friction loss n at the channel from 0.04 to 0.025.

Table 5.1: Existing culverts and proposed upgrade work at crossings

Crossing	Current Condition		Proposed upgrade	
ID	Type	Number	Type	Number
RCP1	600mm RCP	2	2.1m x 0.6m RCBC	1
RCP2	500mm RCP	1	No upgrade	
RCP3	675mm RCP	1	2.4m x 0.6m RCBC	1
RCP4	675mm RCP	1	2.4m x 0.6m RCBC	1
RCP12	450mm RCP	1	1.2m x 0.45m RCBC	1
RCP6	700mm RCP	1	2.7m x 0.9m RCBC	1
RCP7	1050mm RCP	1	2.7m x 0.9m RCBC	1
RCP8	1050mm RCP	1	2.4m x 0.9m RCBC	1
RCBC 1	4m x 1m RCBC	1	No upgrade	
RCP11	300mm RCP	1	No upgrade	
RCP5	300mm RCP	1	1.2m x 0.3m RCBC	1
RCP 17	At earth bund-not existing		750mm RCP	5

Note: current size of RCP12 was not surveyed

A comparison between the peak flows through the culvert crossings in Options 1 and 2 is shown in Table 5.2. As discussed earlier the effect of crossings upgrade regarding the ponding water drawdown speed is shown in Figure 5.2. The flooding extent and depths 12 hours after the storm event is shown in Figure 10. A comparison of the flood mitigation effect of the proposed upgrade after 12 hours is shown in Figure 11. As for other options the mitigation options are of their greatest value after 12 hours or so have passed.

Table 5.2: Existing culverts and proposed upgrade work at crossings

Crossing	Maximum Discharge at each crossing (m^3/s)	
	Option 1 – No crossing upgrade	Option 2 – with crossing upgrade
RCP1	1.070	1.883
RCP2	0.449	0.449
RCP3	0.625	1.986
RCP4	0.415	0.922
RCP12	0.132	0.407
RCP6	0.493	2.334
RCP7	0.135	2.020
RCP8	0.329	5.073
RCBC 1	2.376	2.234
RCP11	0.000	0.000
RCP5	0.079	0.000
RCP 17	1.736	2.302

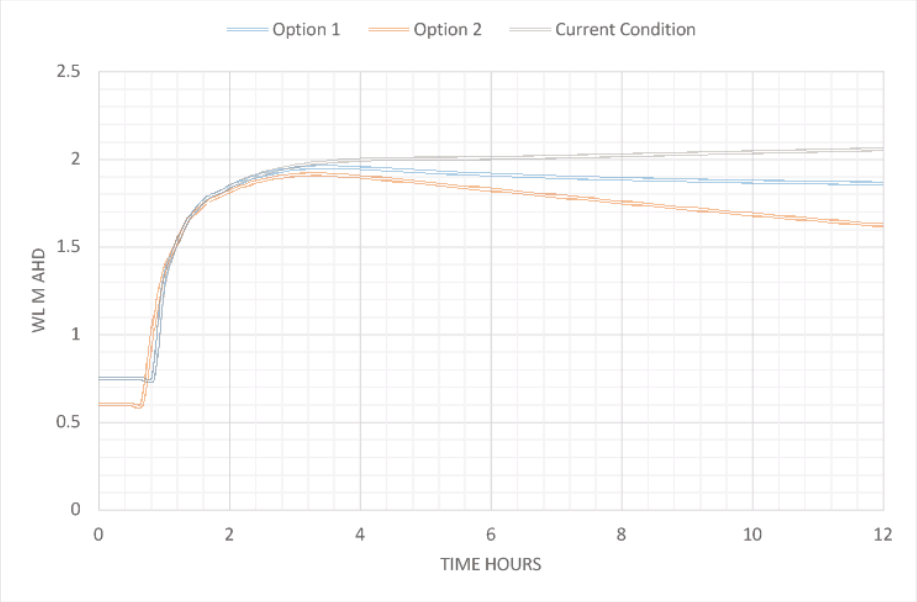


Figure 5.2: Site drawdown in current condition and with provision of the proposed mitigation Options

5.3 Limitations and Considerations

The performance and limitations of the proposed mitigation options have been briefly discussed in Table 5.3 below.

Table 5.3: Overall assessment of the proposed mitigation options

Option	Priority	Reliability	Certainty	Feasibility	Effectiveness
Option 1 – Provide a discharge point for the site drainage channel	Highest-Take immediate action	Flap gates need to be installed at the earth bund culverts outlets. Outlet works to be perform with proper placement and design to minimise interference with flows in downstream channel and ensure durability	Drainage efficiency is highly dependent on the tailwater condition at the downstream channel. Anticipated to be less effective in long duration rainfalls.	Coordination with property land owner will be required. Pipe jacking under the earth bund and existing driveway is the preferred option.	Marginal effect in reduction of the current flooding extent. Fairly effective in speeding up the ponding water drawdown
Option 2 – Upgrade the existing channel and culverts in addition to Option 1	High-Perform as soon as practically possible	Effective only if the discharge point for the channel is provided. More effective with dredging and maintenance of the channel	The proposed upgrade is based on the current site condition and levels. The proposed culvert sizes may not provide an optimal design for likely future subdivisions with much higher site levels due to fill earth works for flood immunity	Coordination and cost sharing with property owners may slow down the process	Some reduction in the peak water ponding levels with considerable reduction in 12 hours

6. Conclusion

The source of the drainage issues at the area of interest at Mullumbimby, NSW was investigated and a series of mitigation options proposed. The investigation included hydrologic modelling for quantification of the site flows and hydraulic modellings to assess the existing drainage system performance.

This study indicates that for frequent storm events up to 5 year ARI the current water ponding issues are mainly due to the local drainage problems rather than regional flooding from the nearby river system. The identified issues include:

- Natural discharge point of the drainage channel to Kings Creek is blocked by an earth bund
- Capacity of the culverts at many of the crossings is not enough
- Sufficient hydraulic gradient along the drainage channel is not provided and the channel runs with ascending slopes at the end part

The mitigation options were identified and discussed in the report. The key upgrade requirements to provide acceptable drainage through the site include:

- Construction of culvert outlets with flap gates under the existing earth bund to enable discharge of the channel to Kings Creek
- Upgrade of the culvert crossings and thorough maintenance of the drainage channel by slashing the existing vegetation, dredging and sediment removal

The proposed options have been optimised by hydraulic modelling using the developed site specific model and the improvement achieved is included in the report.

Because of the low flow capacity of the system created by the low hydraulic gradient, short term gains provided by the mitigation options are minor. The best effect of the mitigation options is prevention of long term water ponding at the site.

7. Scope of Engagement

This report has been prepared by Ardill Payne & Partners (APP) at the request of Byron Shire Council for the purpose of assessment of the localised drainage issues at Mullumbimby and is not to be used for any other purpose or by any other person or corporation.

This report has been prepared from the information provided to us and from other information obtained as a result of enquiries made by us. APP accepts no responsibility for any loss or damage suffered howsoever arising to any person or corporation who may use or rely on this document for a purpose other than that described above.

No part of this report may be reproduced, stored or transmitted in any form without the prior consent of APP.

APP declares that it does not have, nor expects to have, a beneficial interest in the subject project.

To avoid this advice being used inappropriately it is recommended that you consult with APP before conveying the information to another who may not fully understand the objectives of the report. This report is meant only for the subject site/project and should not be applied to any other.

8. Attachments

Attachment 1	Figures
Attachment 2	Photos
Attachment 3	Land Survey

ATTACHMENT 1

Attachment 1: Figures



Figure 1: Study area and local catchments



Figure 2: Hydraulic modelling boundary, location of existing culvert crossings and flow boundary conditions

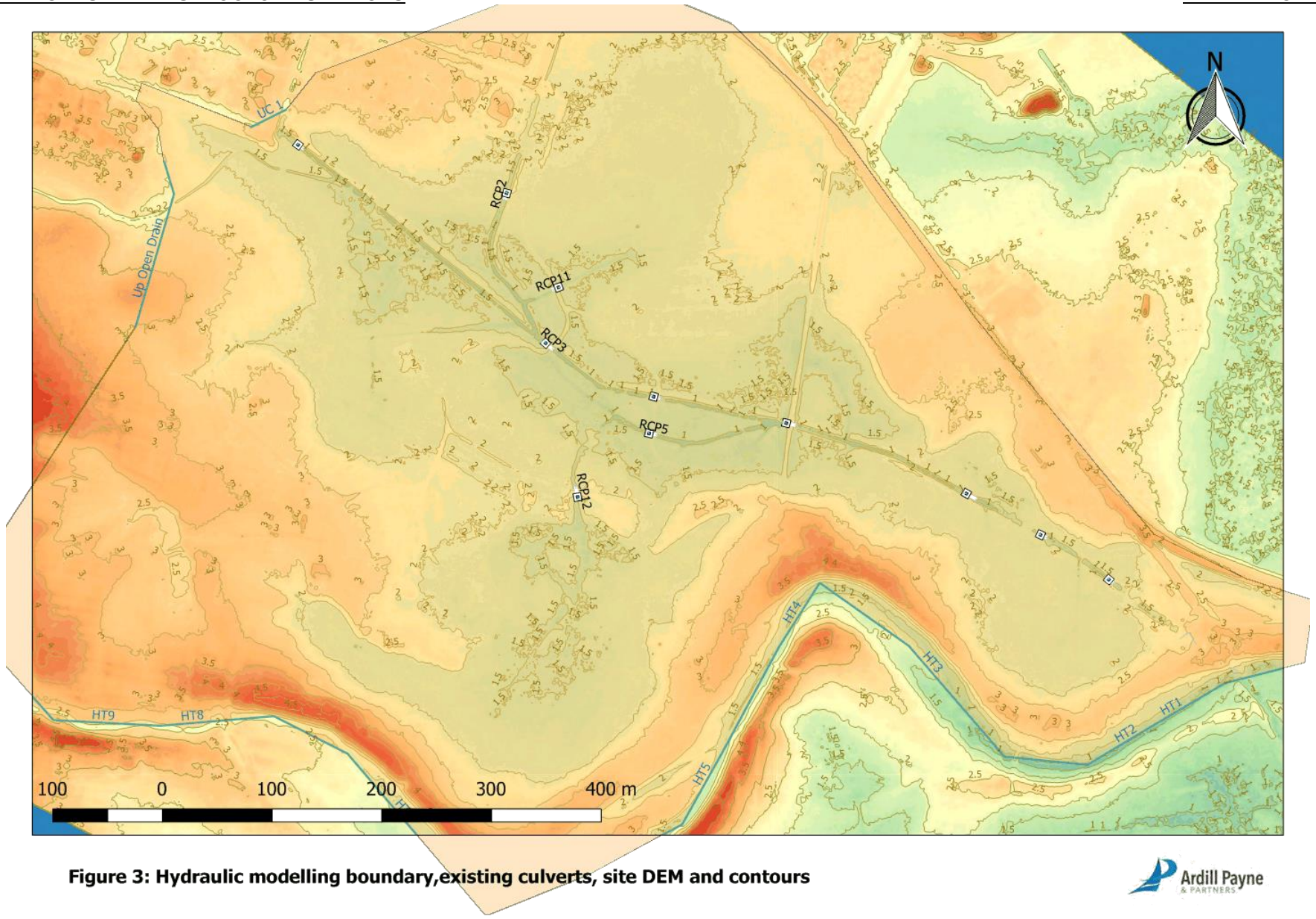


Figure 3: Hydraulic modelling boundary,existing culverts, site DEM and contours

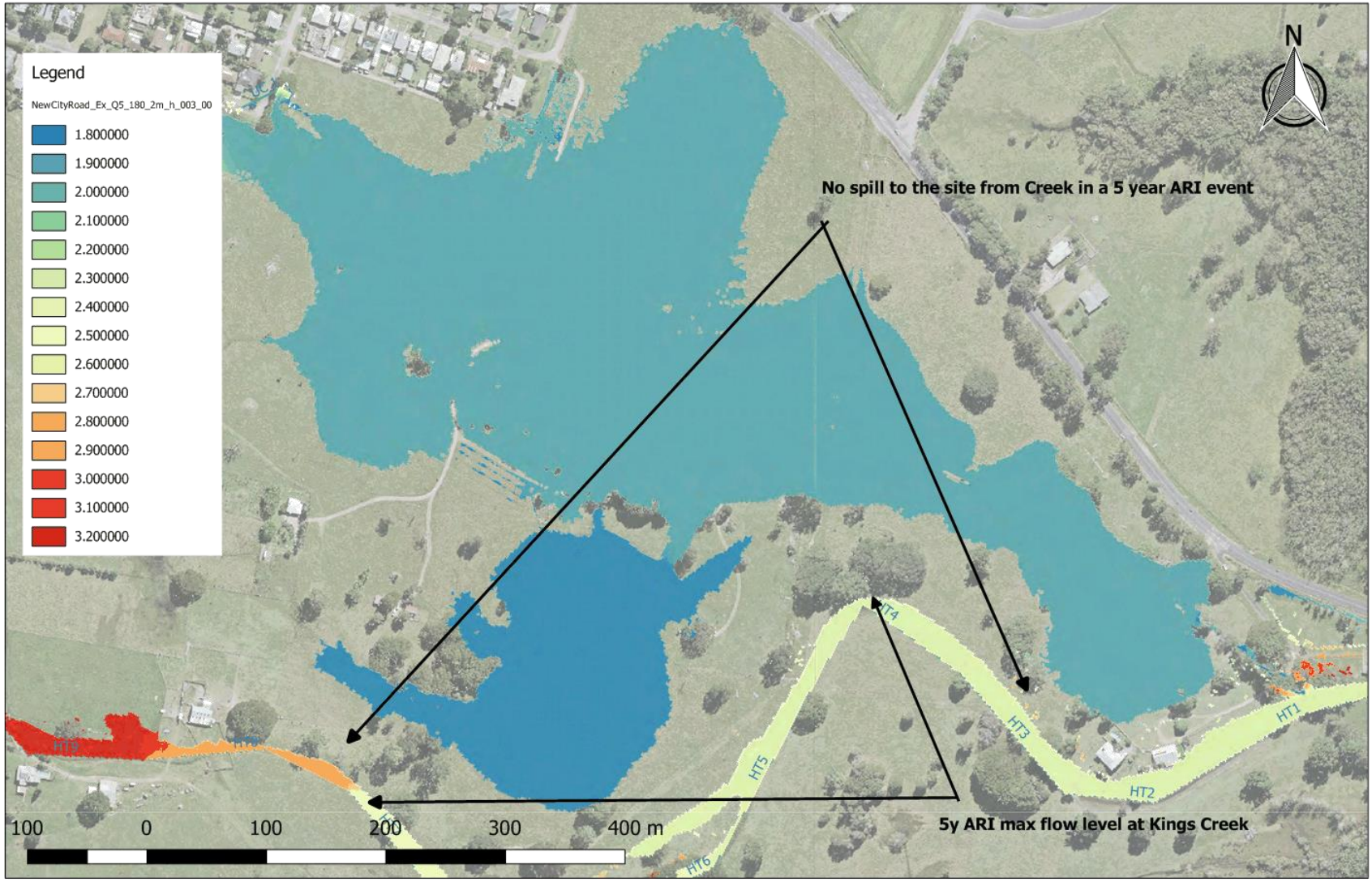


Figure 4: 5 year ARI flood levels and extent at the site implementing maximum water levels at Kings Creek

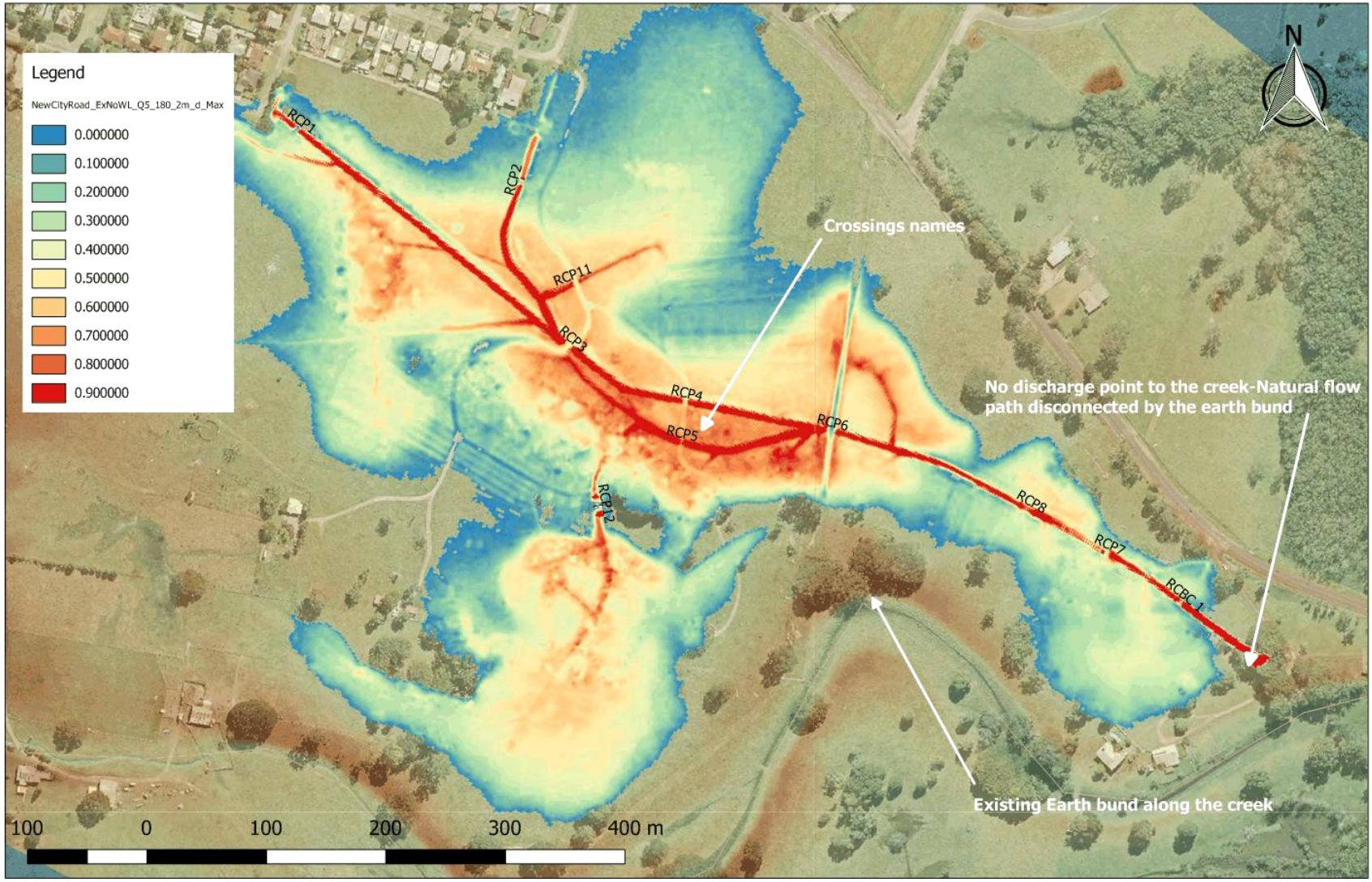


Figure 5: Water ponding depths at the site in a 5 year ARI design event - Existing condition

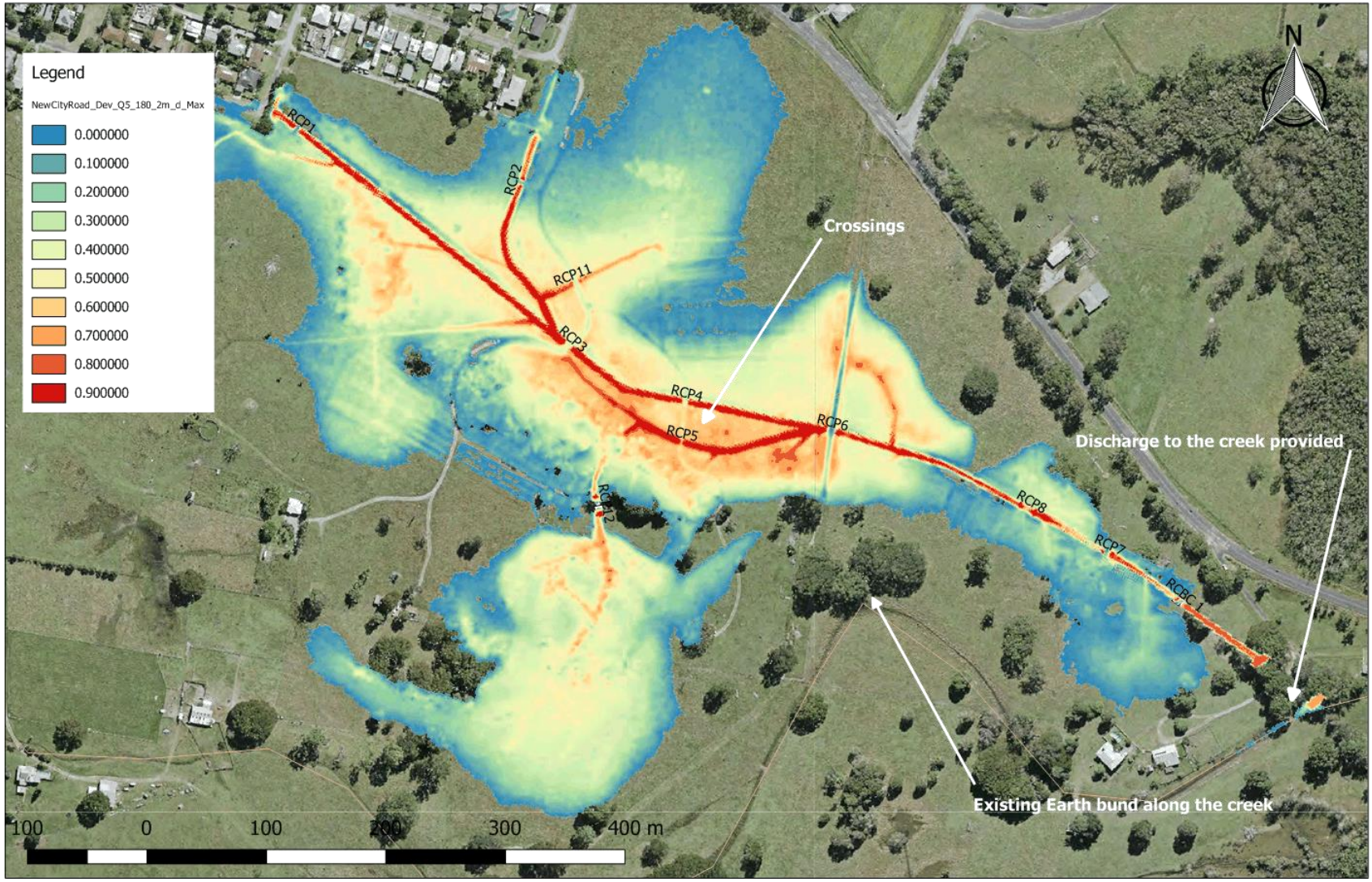


Figure 6: Maximum water ponding depths and extent at the site in a 5 year ARI design event with provision of discharge point - Option 1

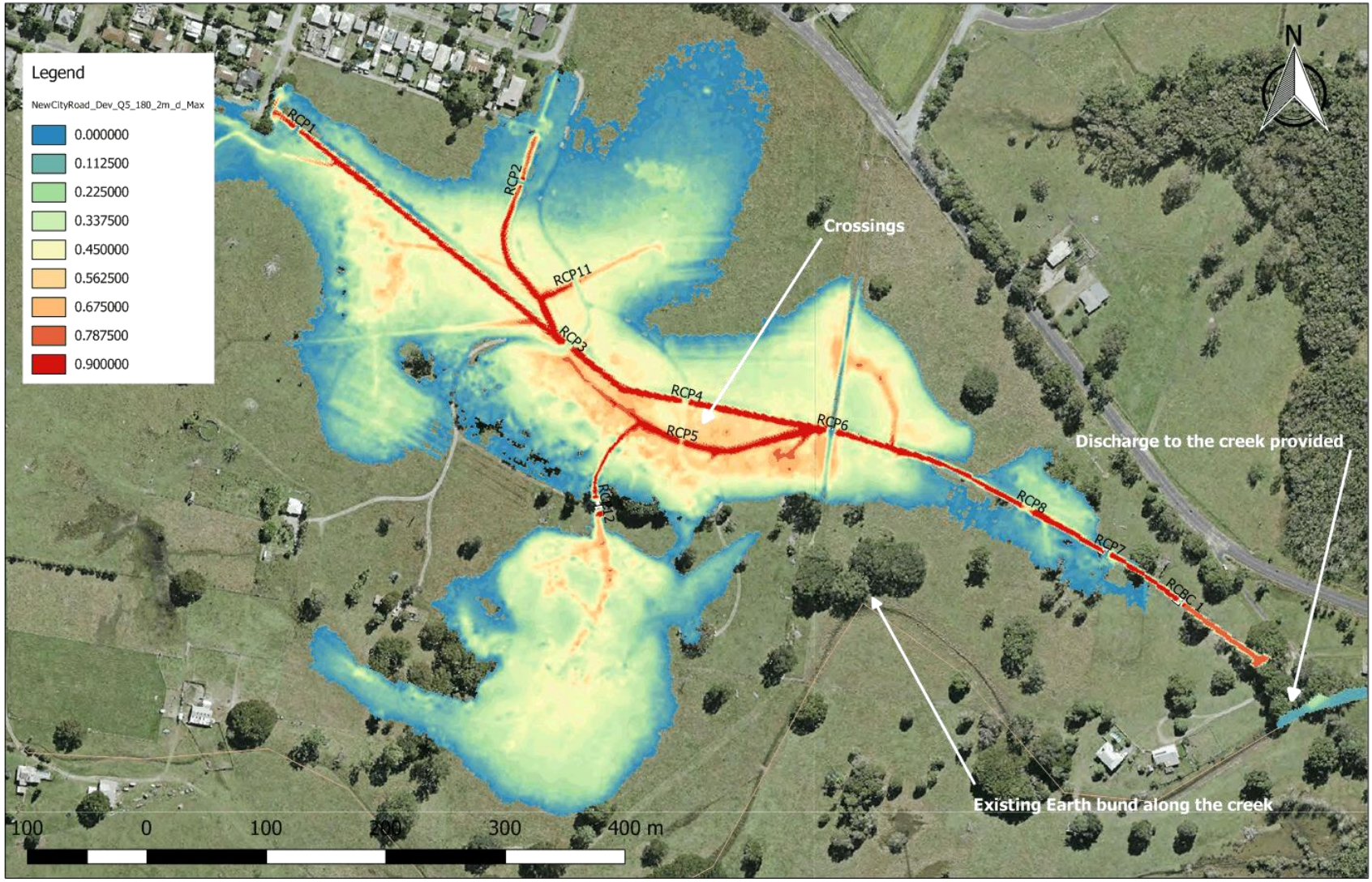


Figure 7: Maximum water ponding depths and extent at the site in a 5 year ARI design event with provision of dischage culverts and crossings upgrade - Option 2

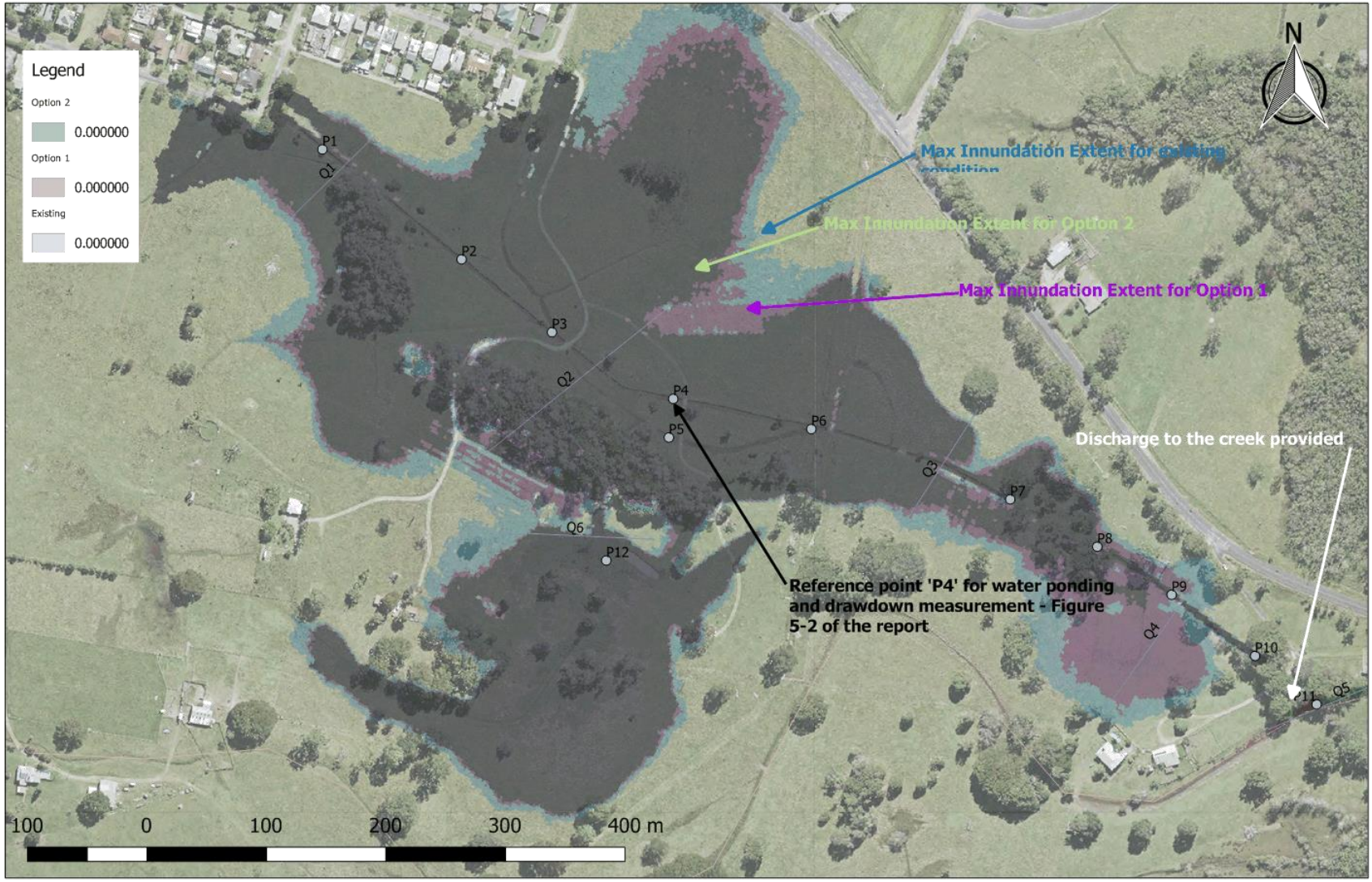


Figure 8: Comparison of maximum flooding extent in pre and post mitigation conditions

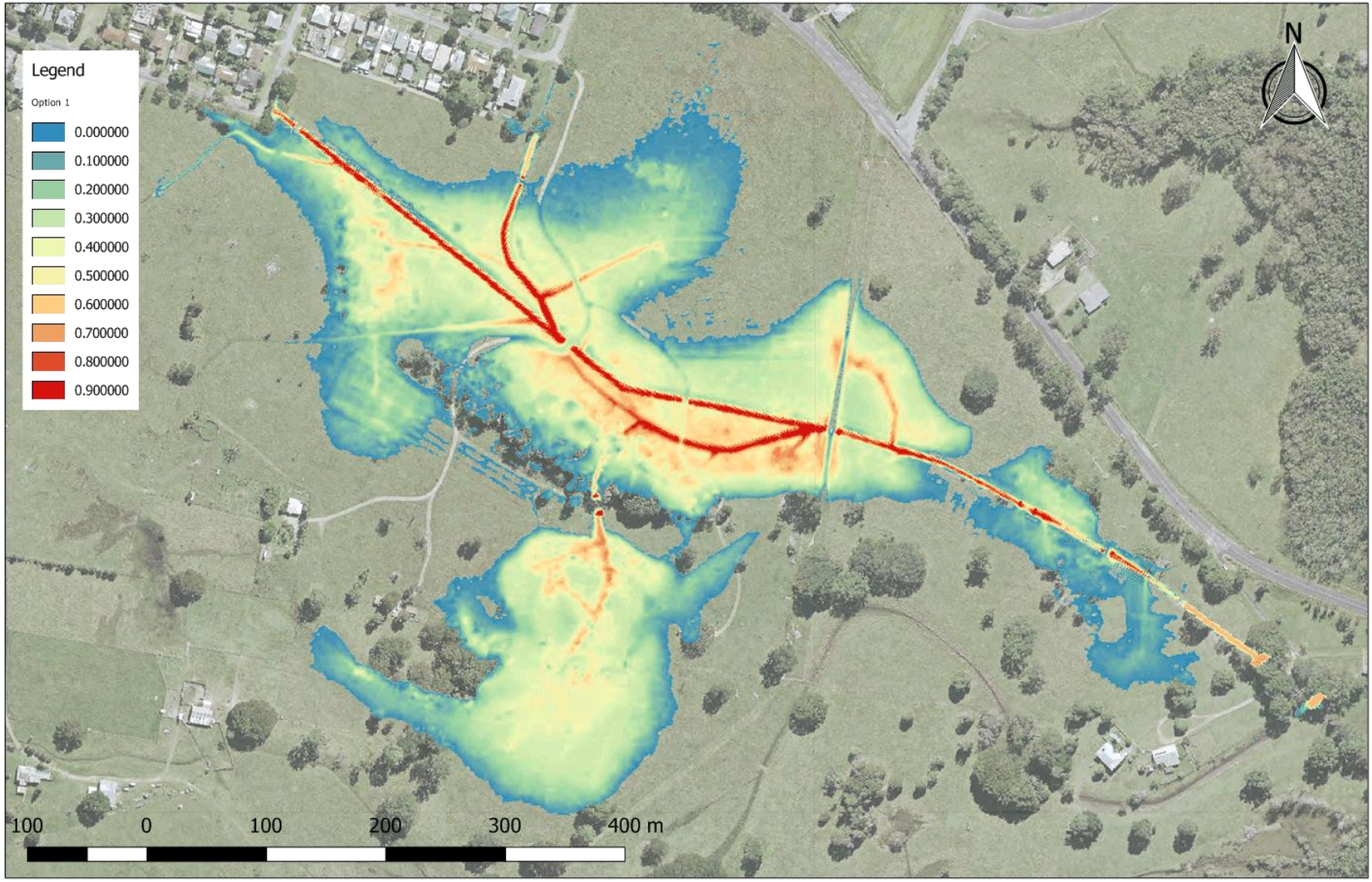


Figure 9: Flood innundation extent after 12 hours from initiation of 5 year ARI storm for Option 1 mitigation

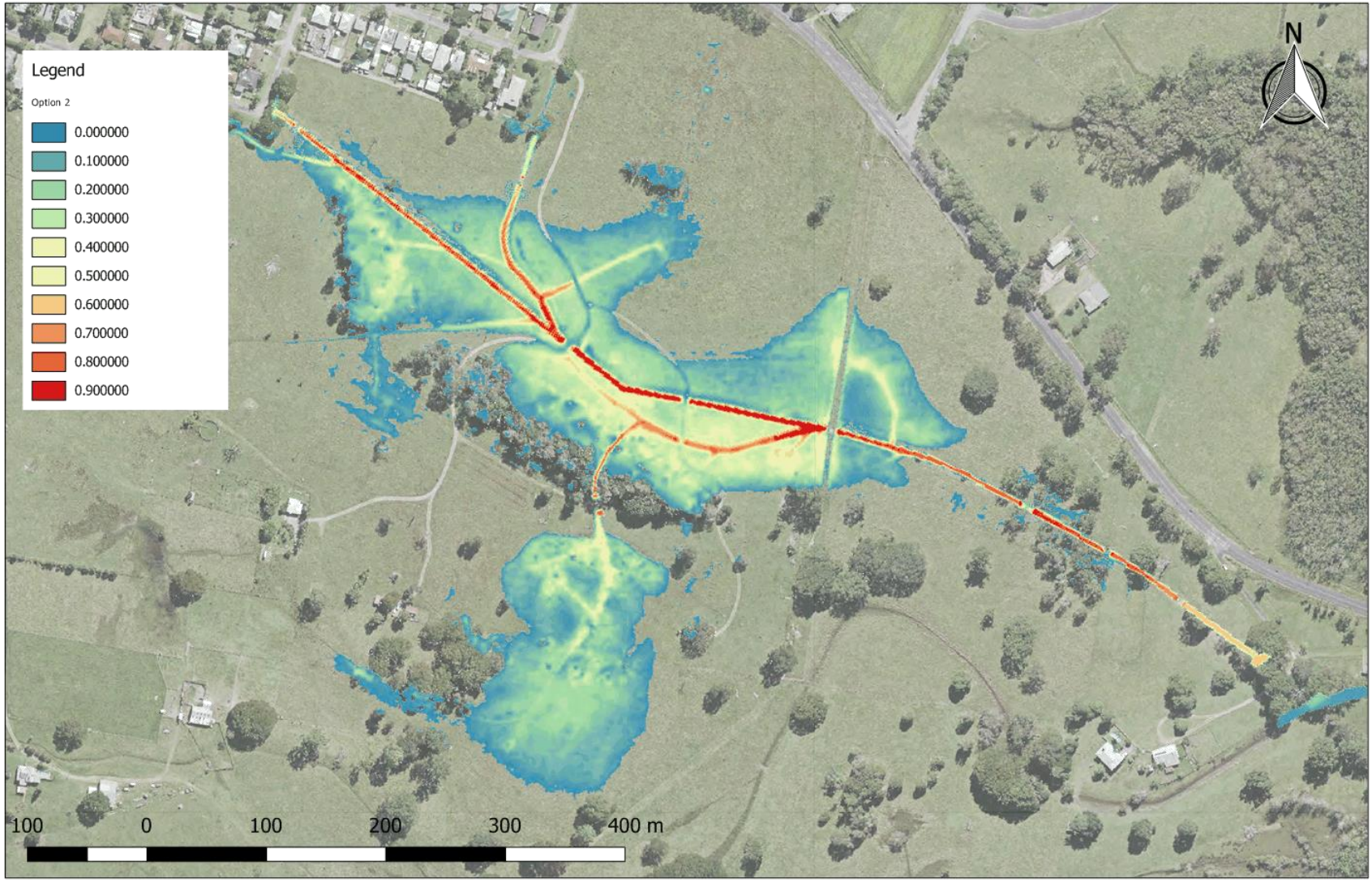


Figure 10: Flood innundation extent after 12 hours from innitiation of 5 year ARI storm for Option 2 mitigation

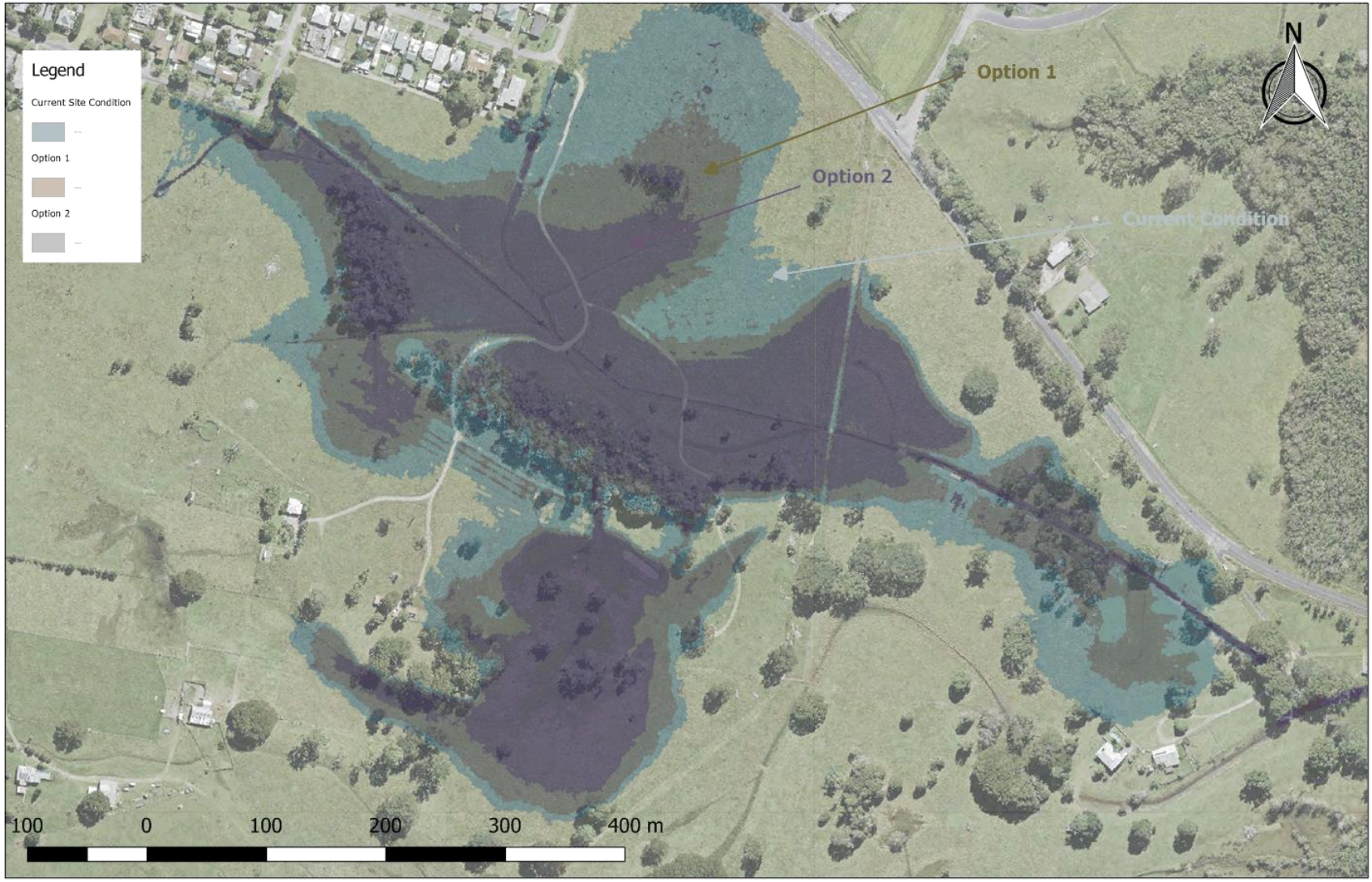


Figure 11: Comparison of maximum flooding extent in pre and post mitigation conditions 12 hours after start of storm event

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ATTACHMENT 2

Attachment 2: Photos



Photos location



Photo 1: Shallow overland flow under north of the existing channel looking from the driveway to the south-west



Photo 2: Shallow overland flow under north of the existing channel looking from the driveway to the north-east



Photo 3: Subject channel looking from New City Road driveway to the west



Photo 4: Existing culvert under the driveway



Photo 5: Subject Channel at the third crossing



Photo 6: Channel looking from the third crossing to east



Photo 7: Channel looking from the third crossing to west



Photo 8: Subject channel looking from Mullumbimby Road to west



Photo 9: Subject channel panographic photo looking from Mullumbimby Road to west



Photo 10: Urban catchment discharge point to channel at King Street



Photo 11: Existing waterway along Ann Street



Photo 12: Open drainage system at Prince Street

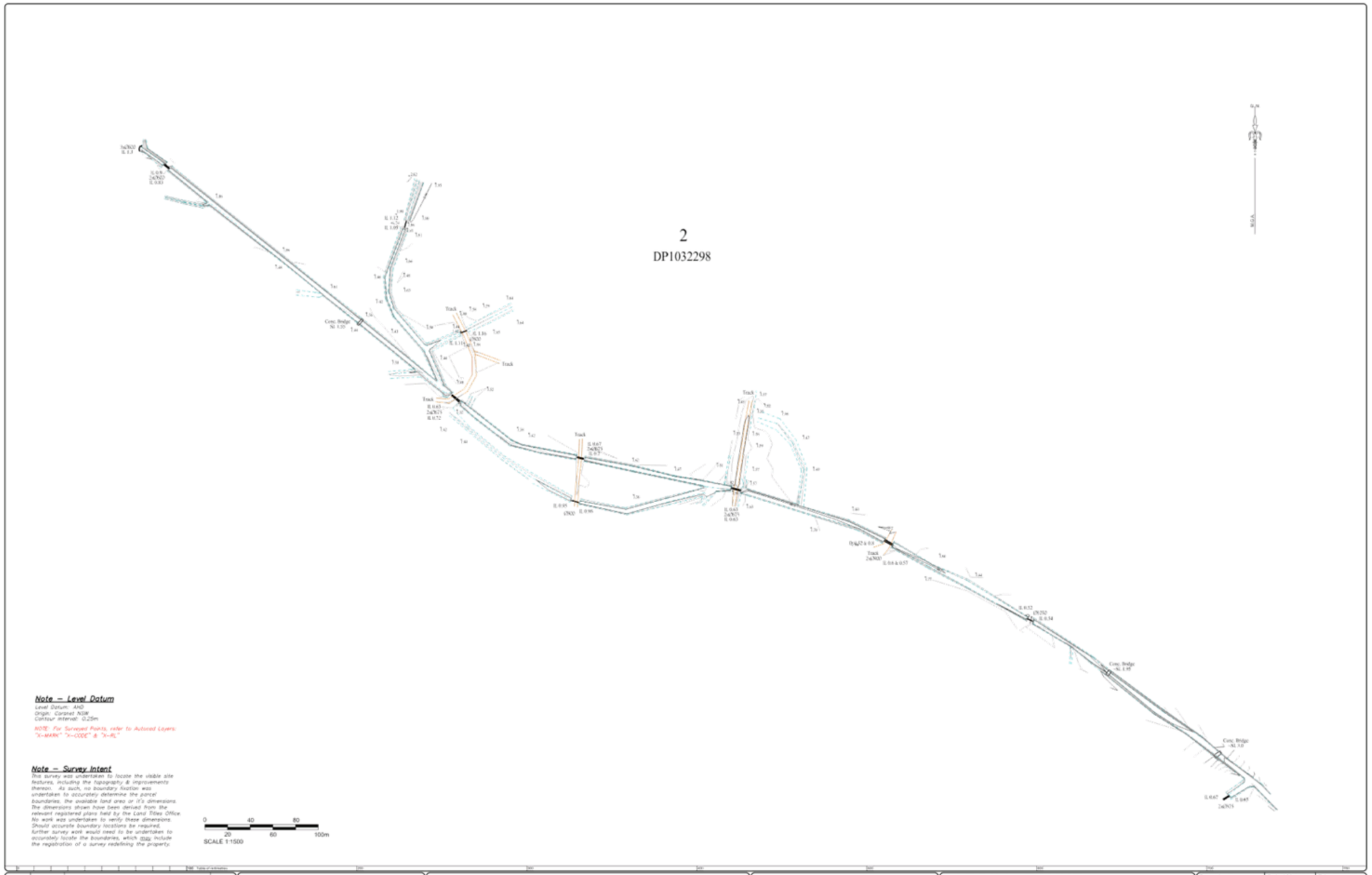


Photo 13: kerb inlet pit at Ann Street

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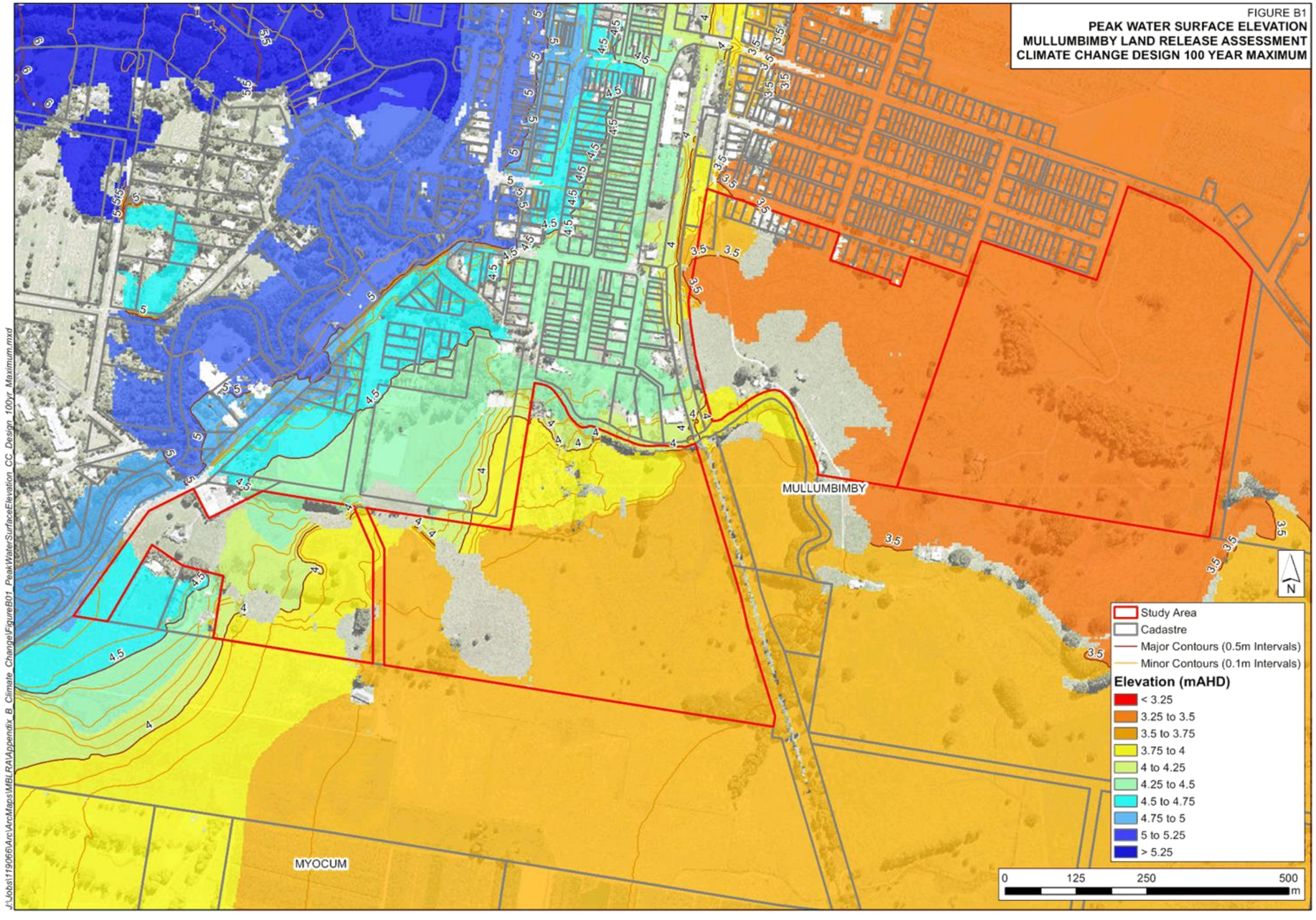
ATTACHMENT 3

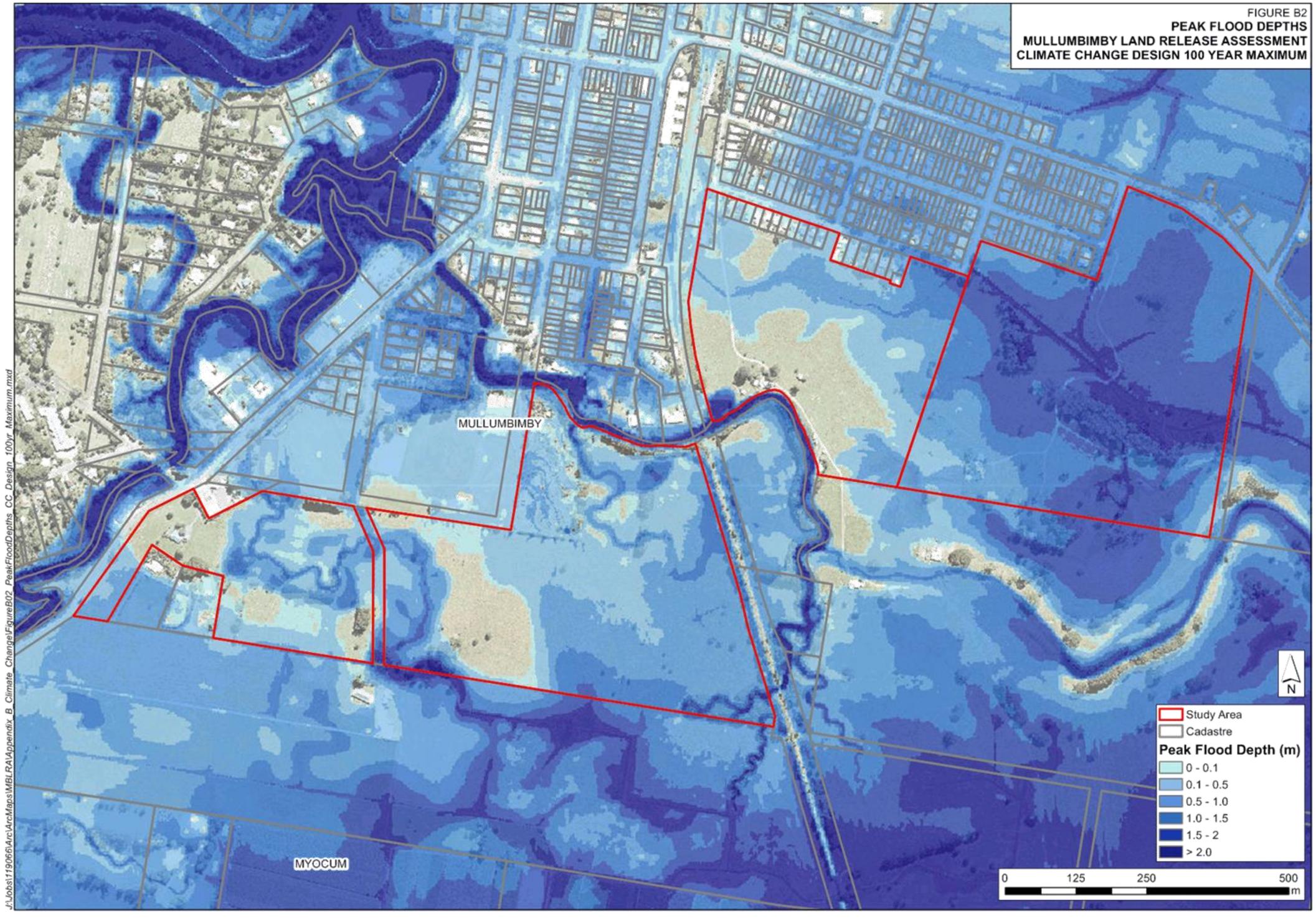
Attachment 3: Land Survey

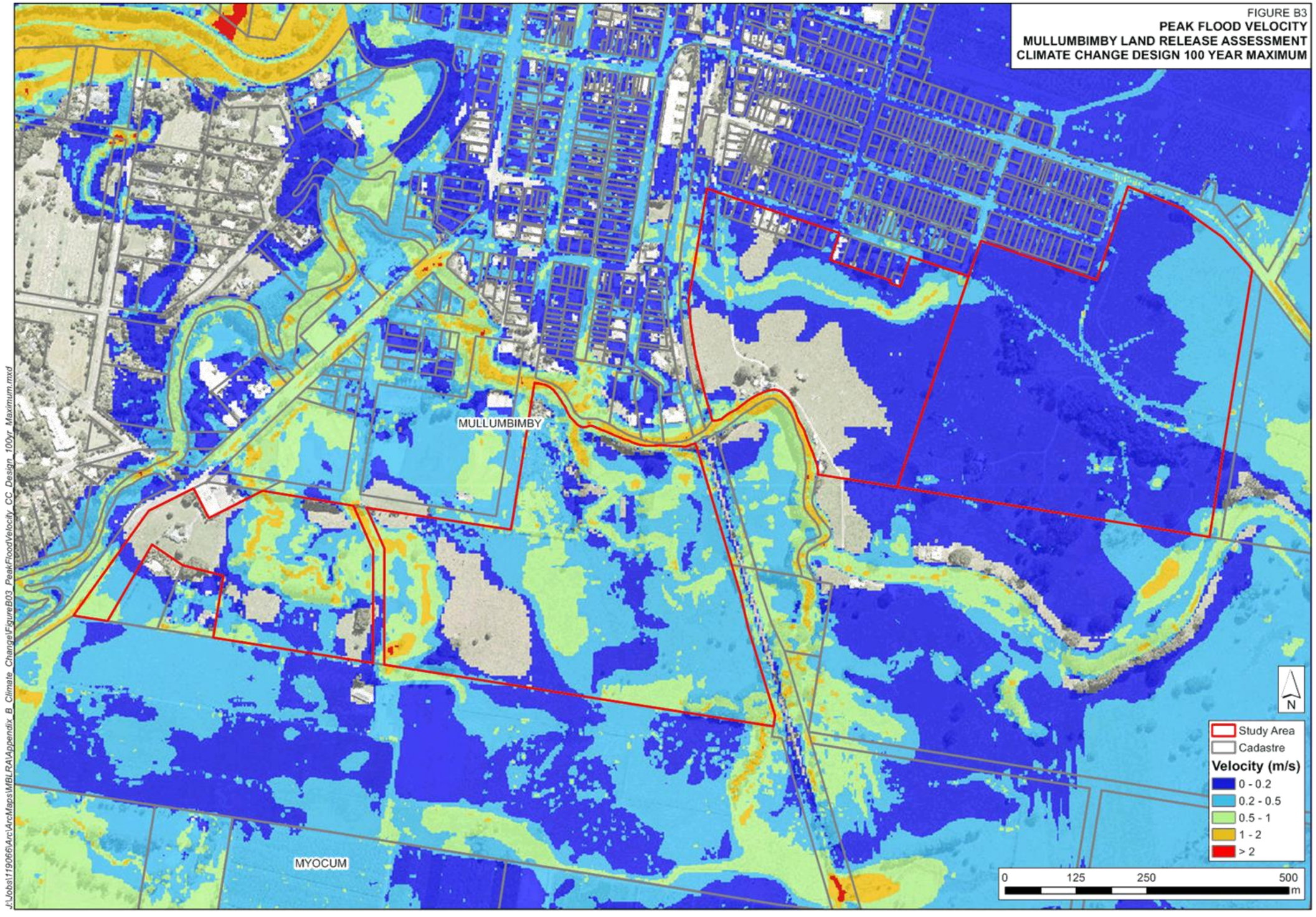

2
DP1032298
Note – Level Datum
Level Datum: AHD
Origin: Coraki NSW
Contour Interval: 0.25m
NOTE: For Surveyed Points, refer to Autocad Layers:
"X-MARK" "X-CODE" & "X-RL"
Note – Survey Intent
This survey was undertaken to locate the visible site features, including the topography & improvements thereon. As such, no boundary fixation was undertaken to accurately determine the parcel boundaries, the available land area or it's dimensions. The dimensions shown have been derived from the relevant registered plans held by the Land Titles Office. No work was undertaken to verify these dimensions. Should accurate boundary locations be required, further survey work would need to be undertaken to accurately locate the boundaries, which may include the registration of a survey redefining the property.
0 20 40 60 80 100m
SCALE 1:1500
Orig 29/1/18 RJJ
Issue Date Amendment App'd
Client: BYRON SHIRE COUNCIL
Project: Drainage Investigation
75 New City Rd, Mullumbimby
Title: CONTOUR & DETAIL SURVEY
Do not scale drawing. Use written dimensions only
This plan is copyright © All rights reserved
ARDILL PAYNE
ENGINEERS PLANNERS SURVEYORS
ENVIRONMENTAL PROJECT MANAGEMENT
BALLINA 45 River Street Ph. 02 6686 3280
GUNNEDAH 285 Conadilly Street Ph. 02 6742 9955
A.B.N. 51 808 558 977 e-mail: info@ardillpayne.com.au
Surveyed: JB
Drawn: RJJ
Checked: RJJ
Approved:
Scale at A1: 1:1500
Date: 15/1/18
Datum: A.H.D.
Acad File: 8550DS.DWG
Magnet File: 8550DS.MJO
Job No.: 8550
Dwg No.: S01
Issue

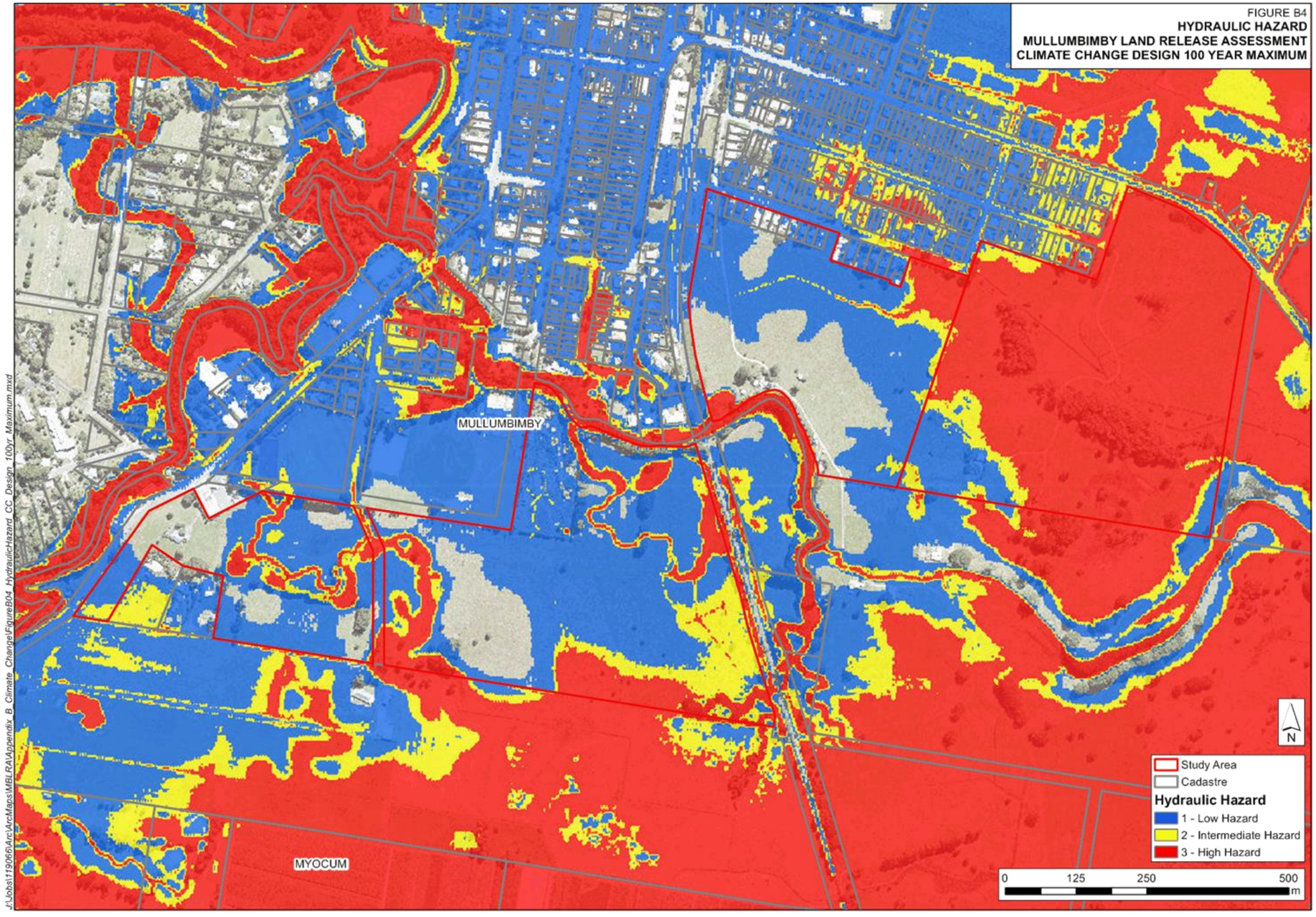


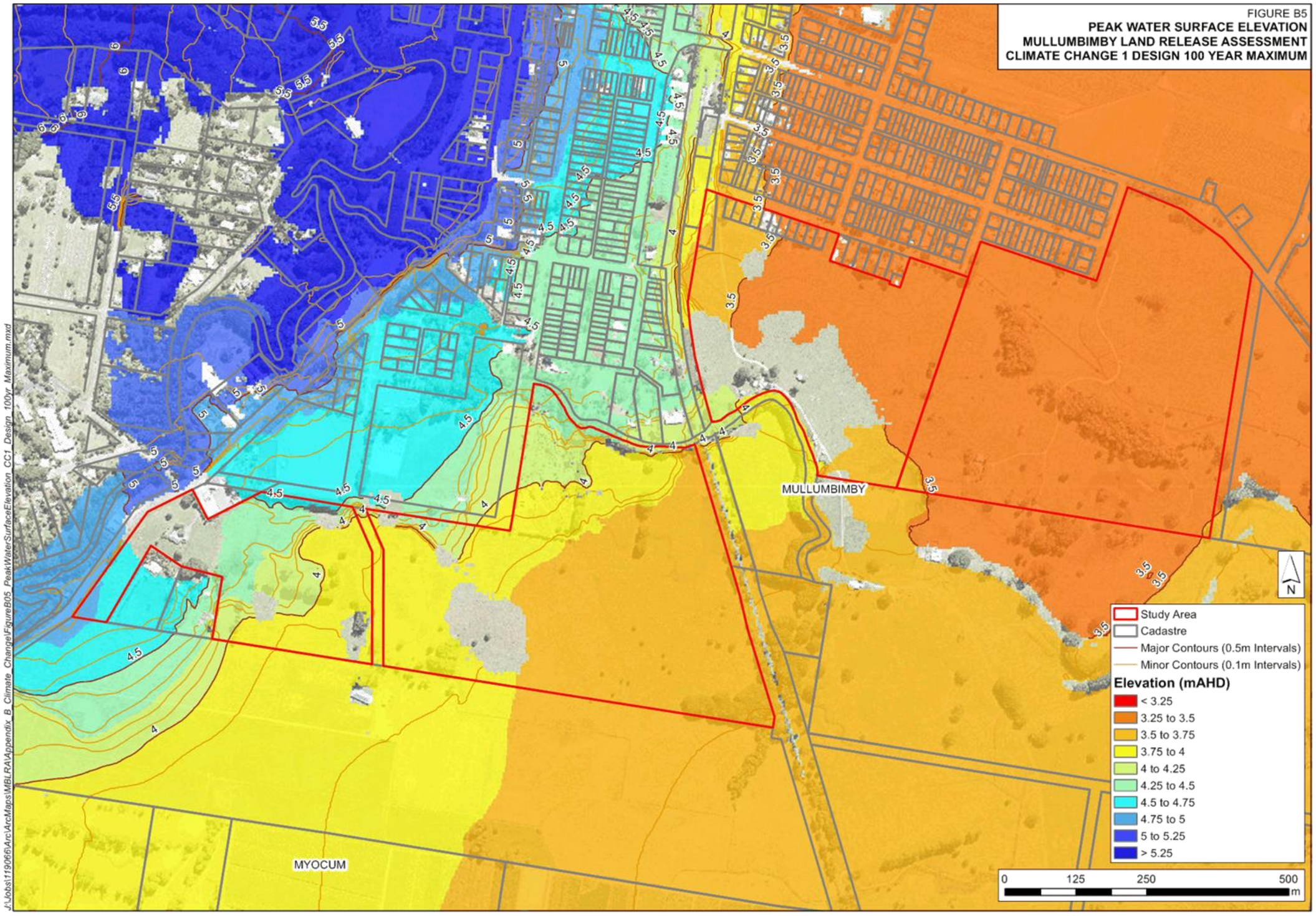
Appendix B

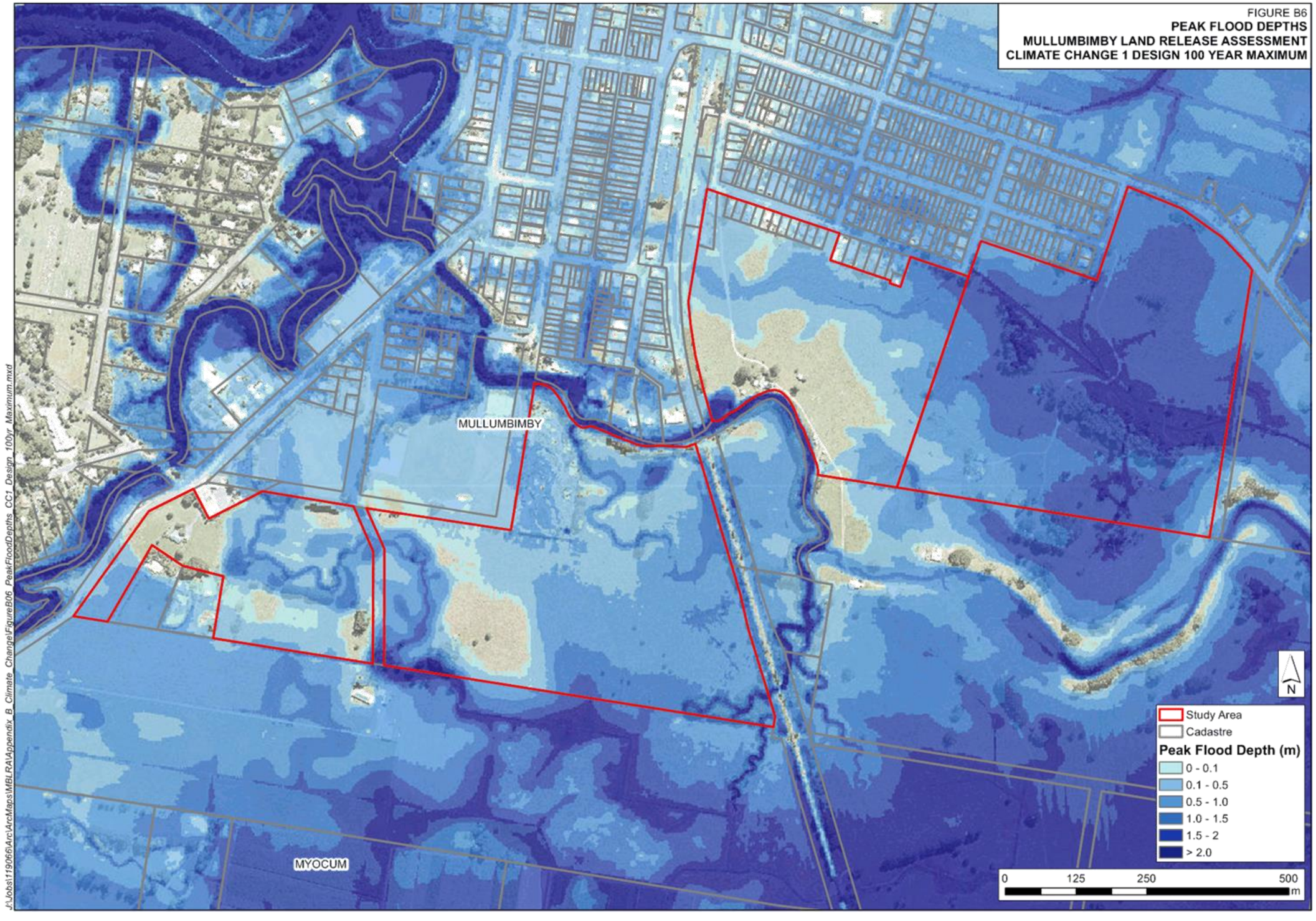

FIGURE B1
PEAK WATER SURFACE ELEVATION
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Major Contours (0.5m Intervals)
Minor Contours (0.1m Intervals)
Elevation (mAHD)
< 3.25
3.25 to 3.5
3.5 to 3.75
3.75 to 4
4 to 4.25
4.25 to 4.5
4.5 to 4.75
4.75 to 5
5 to 5.25
> 5.25
0
125
250
500
m
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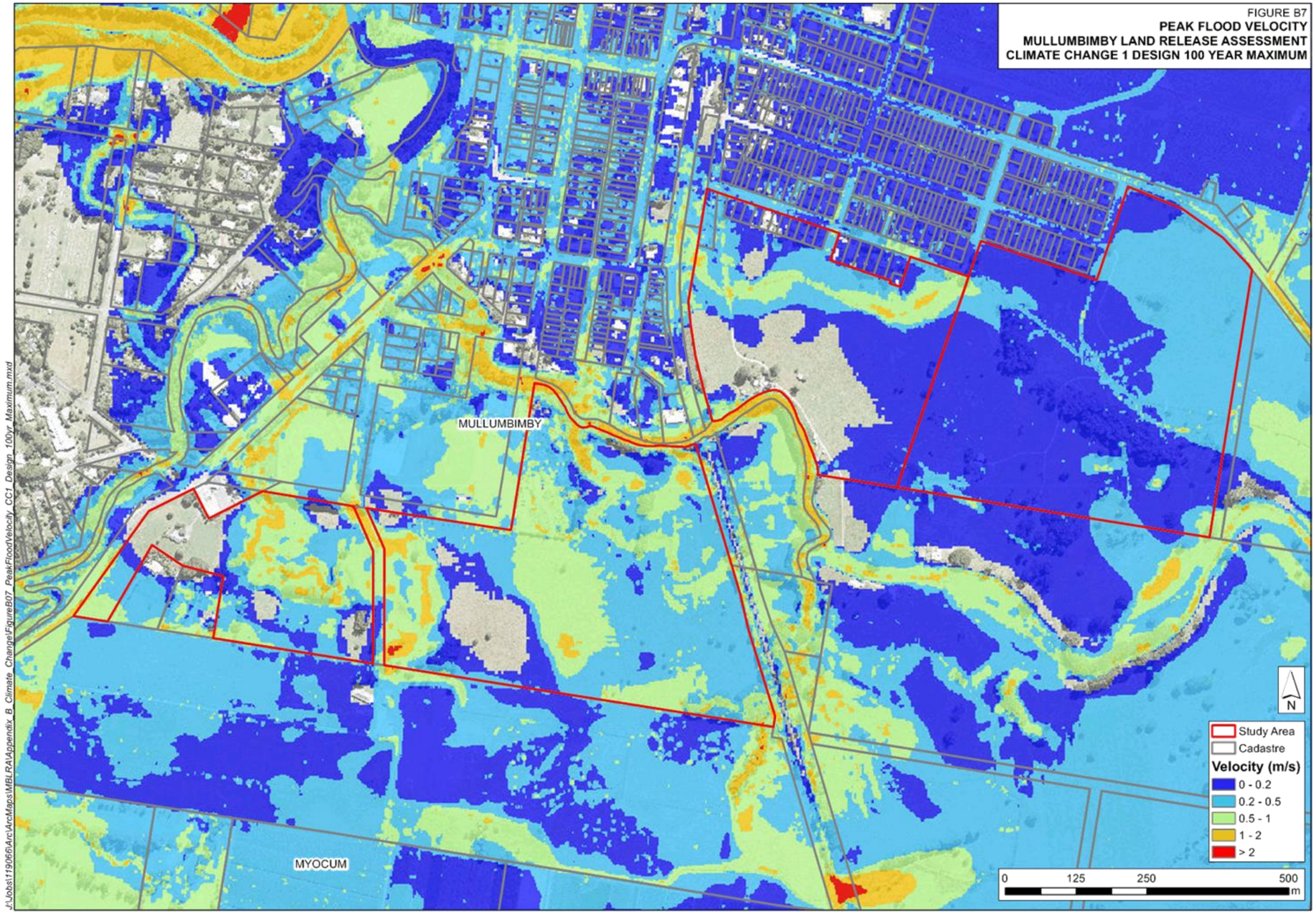

FIGURE B2
PEAK FLOOD DEPTHS
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Peak Flood Depth (m)
0 - 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2
> 2.0
0
125
250
500
m
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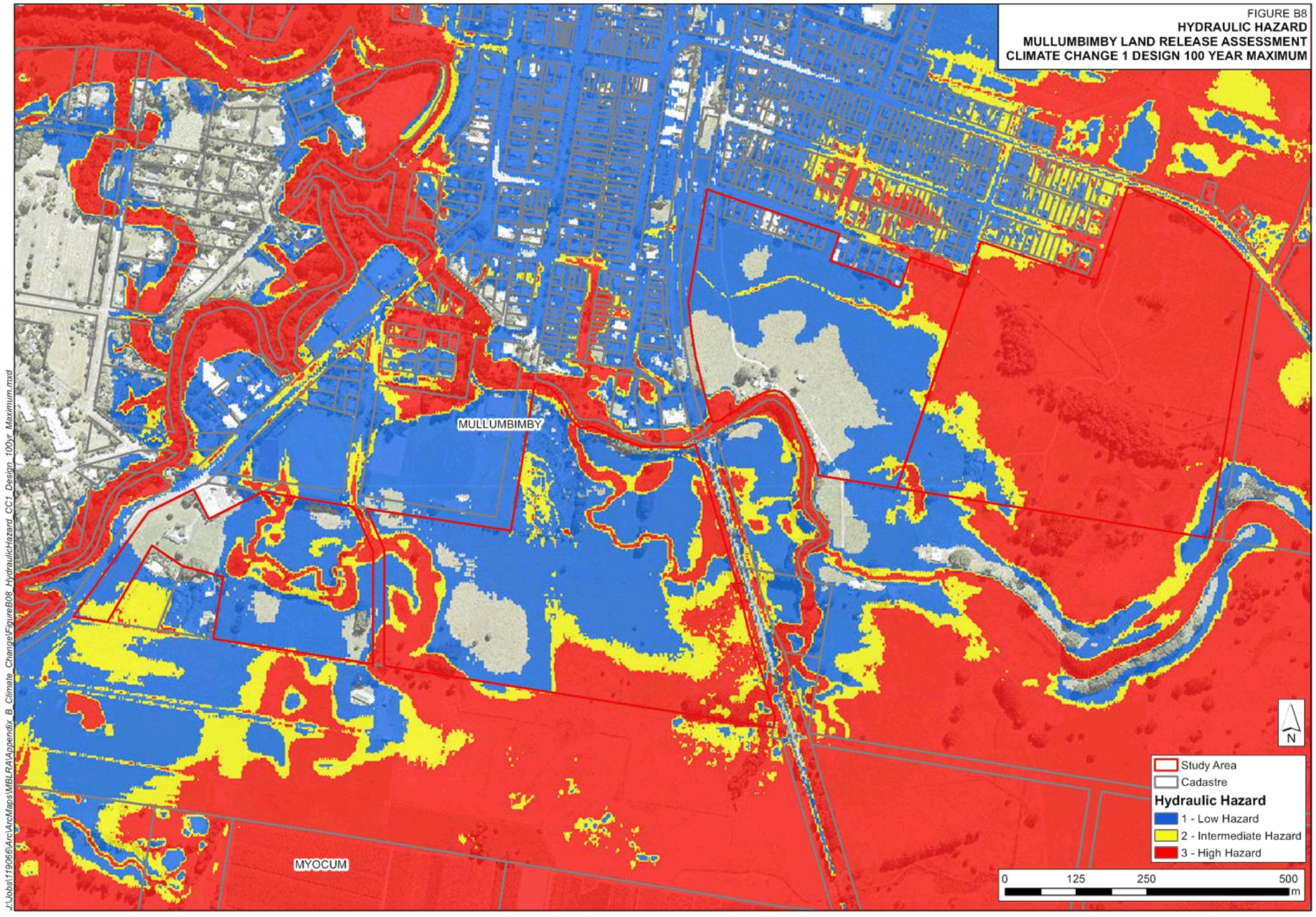

FIGURE B3
PEAK FLOOD VELOCITY
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Velocity (m/s)
0 - 0.2
0.2 - 0.5
0.5 - 1
1 - 2
> 2
0
125
250
500
m
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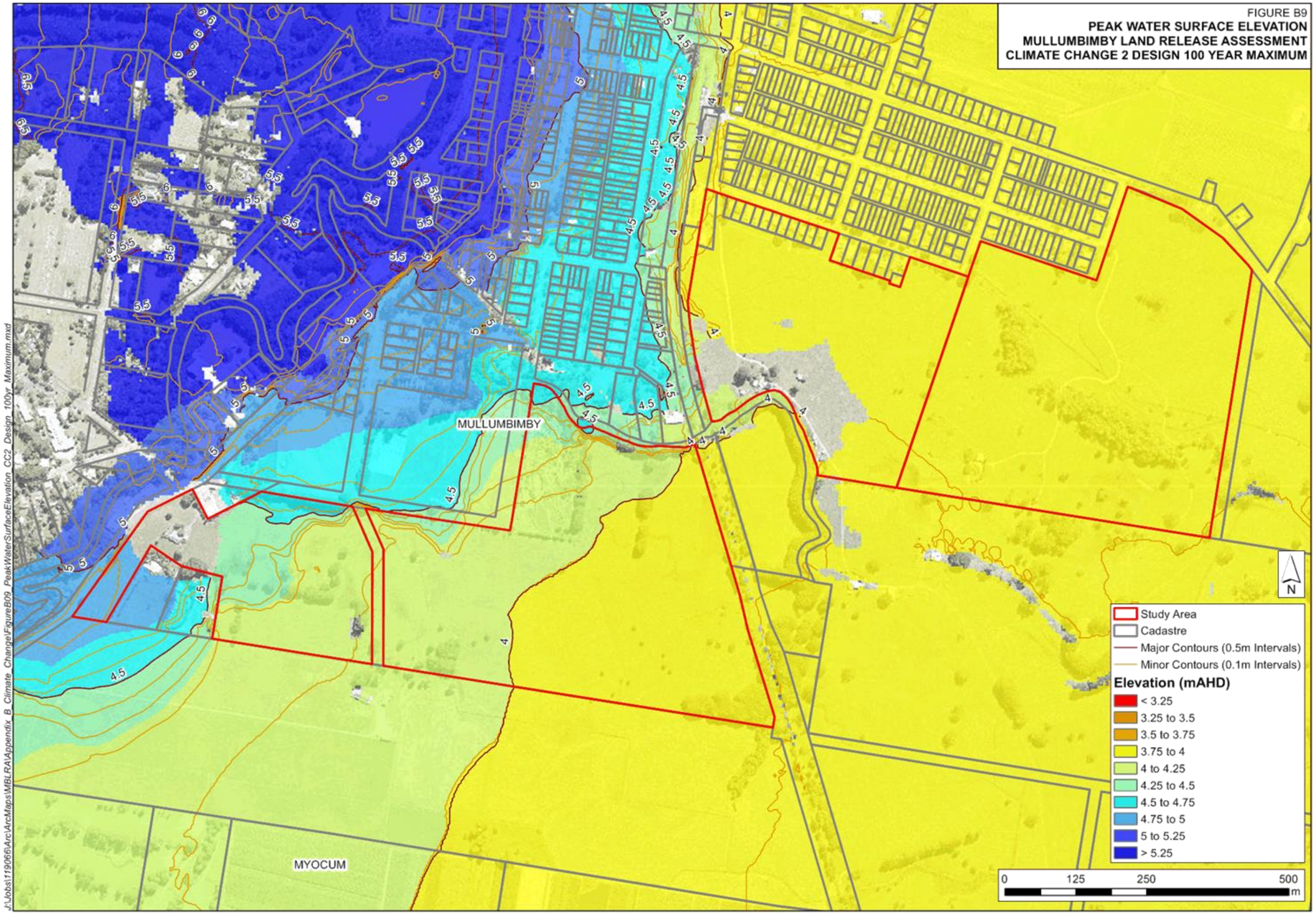

FIGURE B4
HYDRAULIC HAZARD
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Hydraulic Hazard
1 - Low Hazard
2 - Intermediate Hazard
3 - High Hazard
0
125
250
500
m
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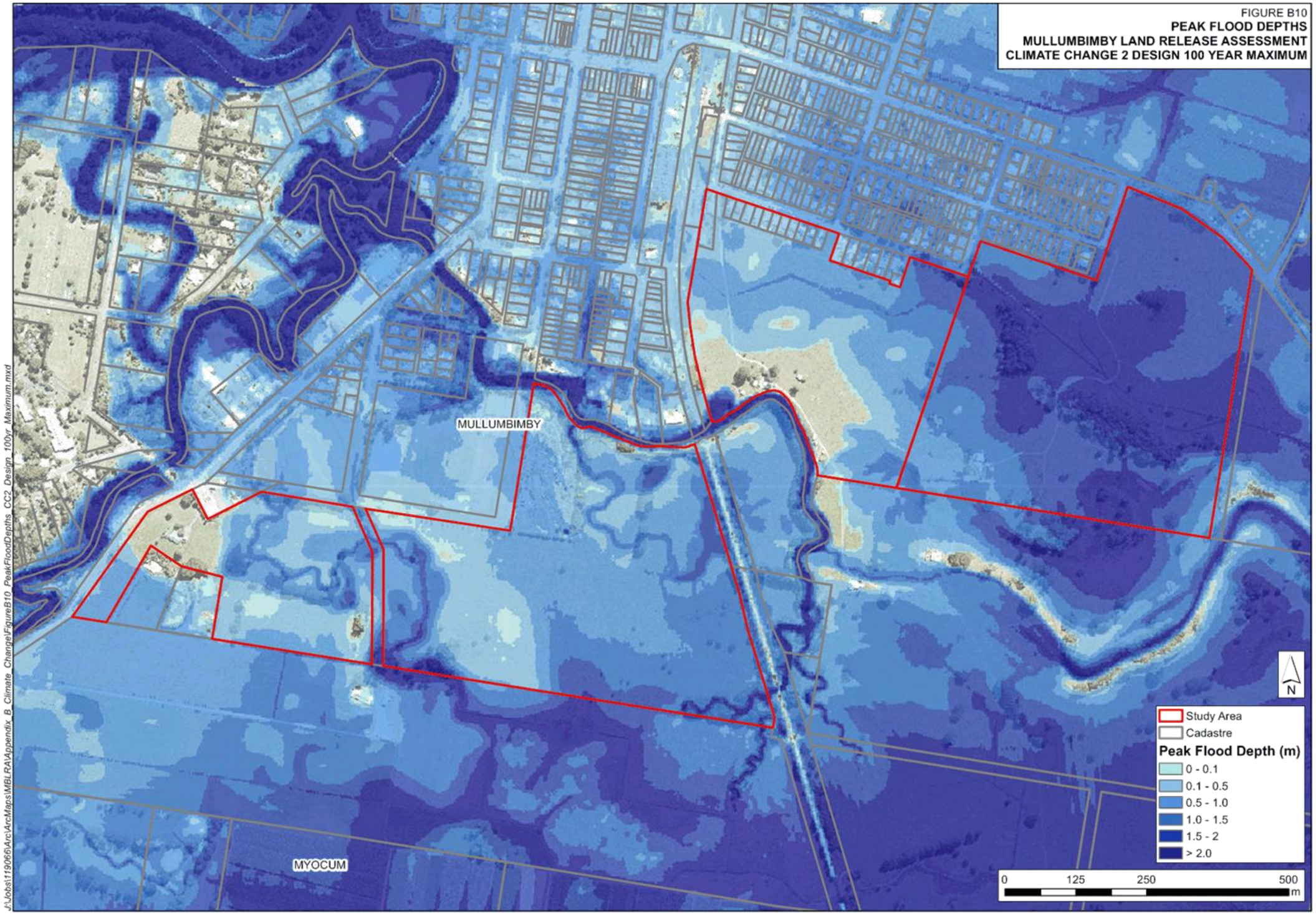

FIGURE B5
PEAK WATER SURFACE ELEVATION
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 1 DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Major Contours (0.5m Intervals)
Minor Contours (0.1m Intervals)
Elevation (mAHD)
< 3.25
3.25 to 3.5
3.5 to 3.75
3.75 to 4
4 to 4.25
4.25 to 4.5
4.5 to 4.75
4.75 to 5
5 to 5.25
> 5.25
0
125
250
500
m
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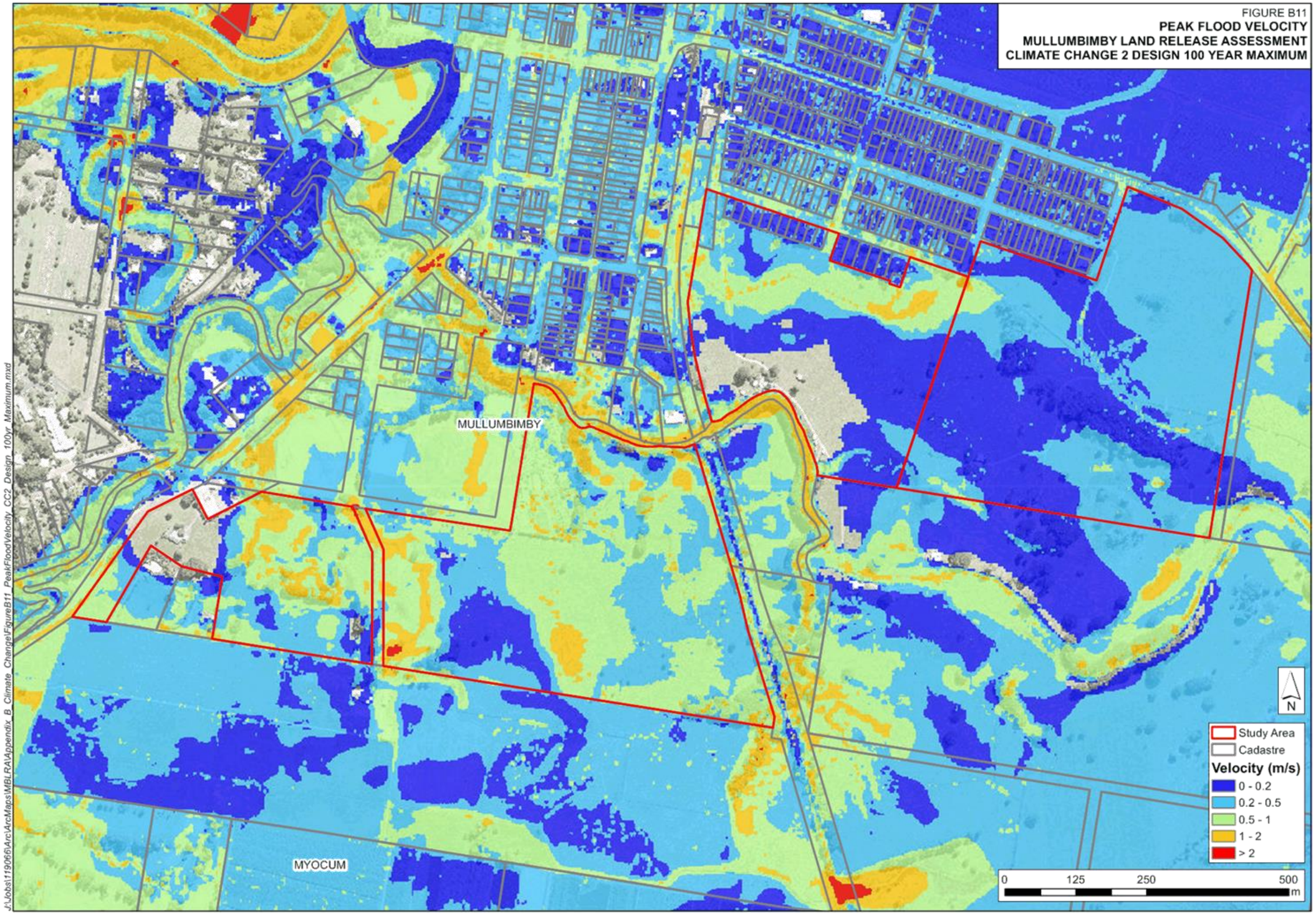

FIGURE B6
PEAK FLOOD DEPTHS
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 1 DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Peak Flood Depth (m)
0 - 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2
> 2.0
0
125
250
500
m
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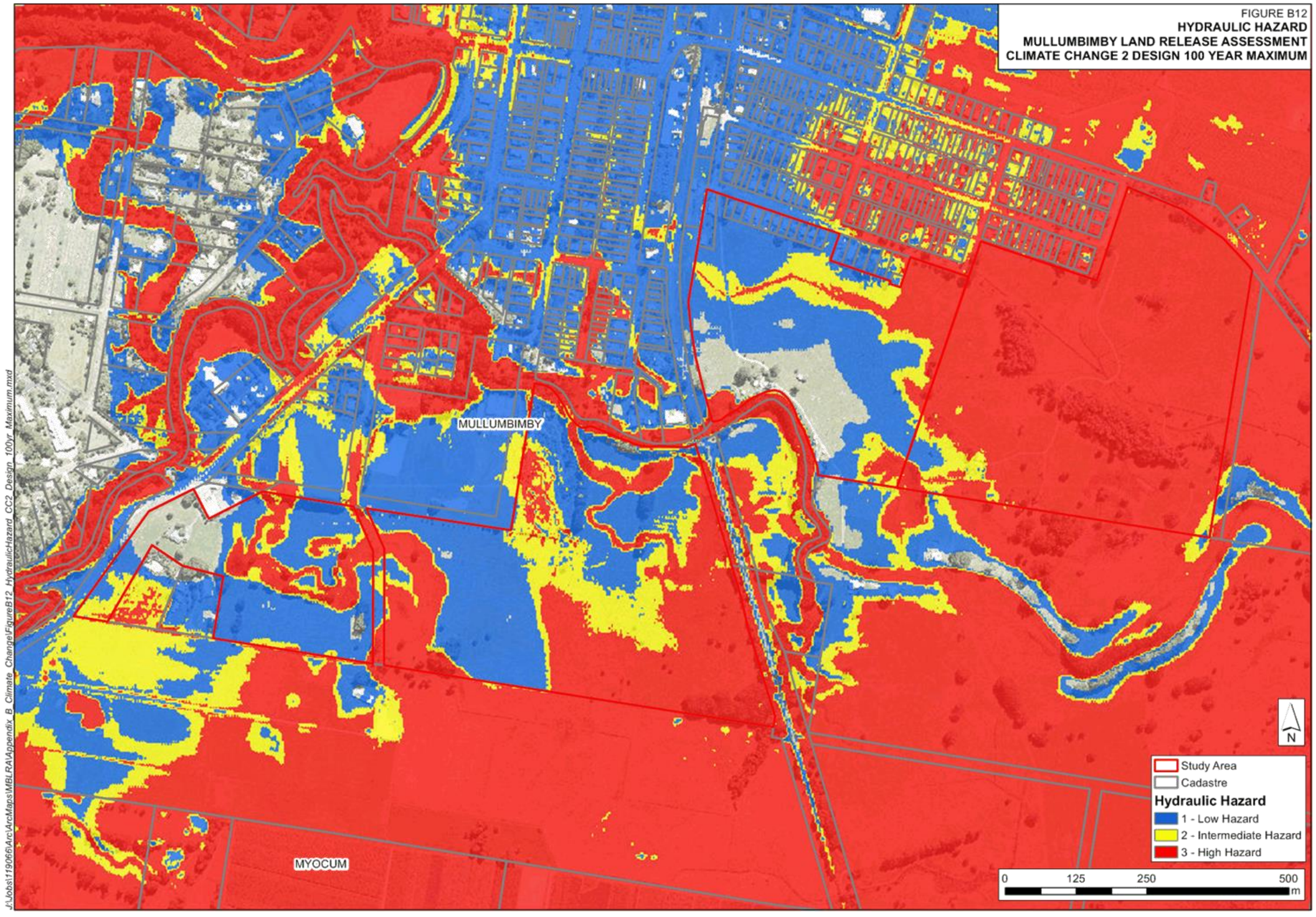

FIGURE B7
PEAK FLOOD VELOCITY
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 1 DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Velocity (m/s)
0 - 0.2
0.2 - 0.5
0.5 - 1
1 - 2
> 2
0
125
250
500
m
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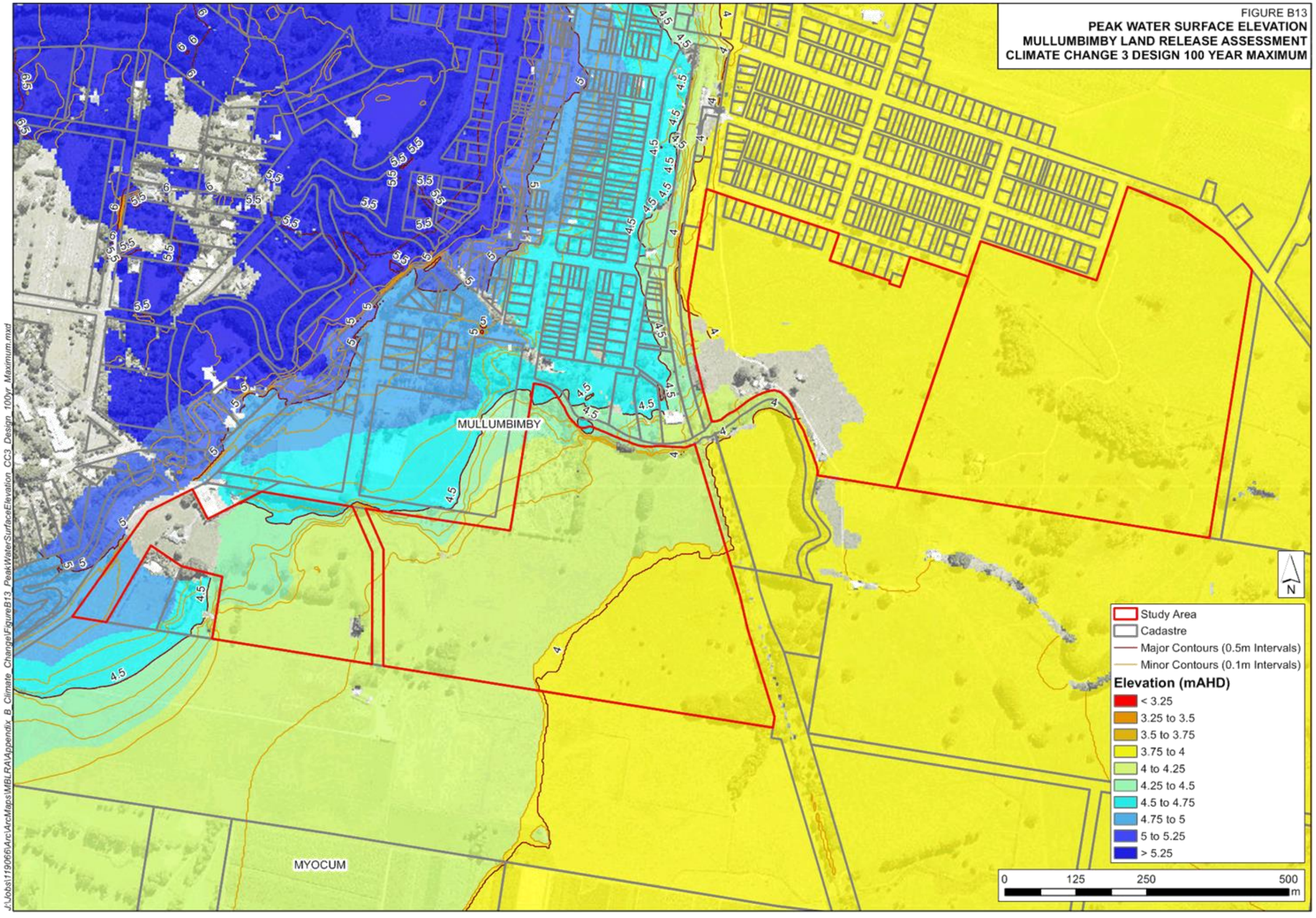

FIGURE B8
HYDRAULIC HAZARD
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 1 DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Hydraulic Hazard
1 - Low Hazard
2 - Intermediate Hazard
3 - High Hazard
0
125
250
500
m
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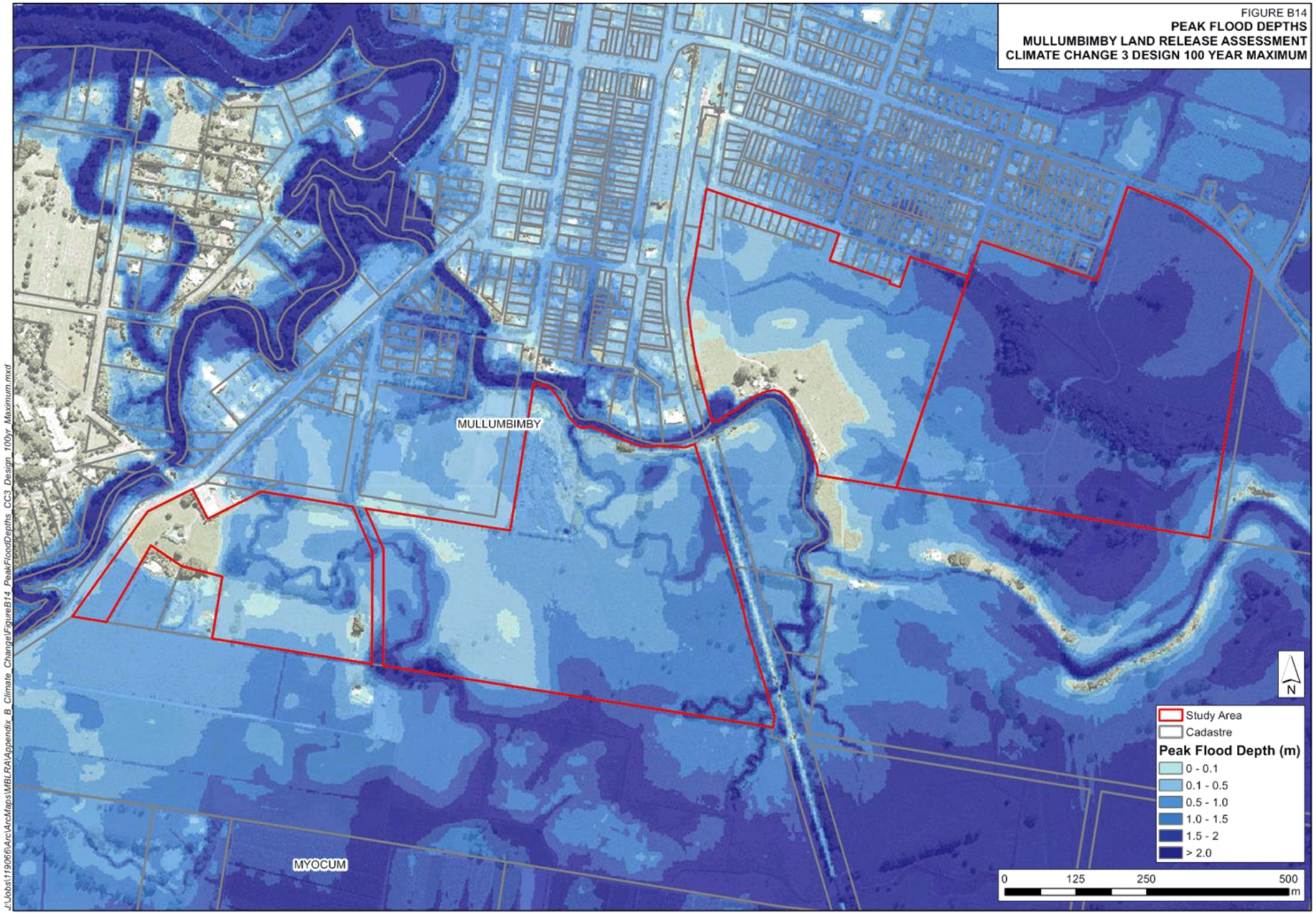

FIGURE B9
PEAK WATER SURFACE ELEVATION
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 2 DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Major Contours (0.5m Intervals)
Minor Contours (0.1m Intervals)
Elevation (mAHD)
< 3.25
3.25 to 3.5
3.5 to 3.75
3.75 to 4
4 to 4.25
4.25 to 4.5
4.5 to 4.75
4.75 to 5
5 to 5.25
> 5.25
0
125
250
500
m
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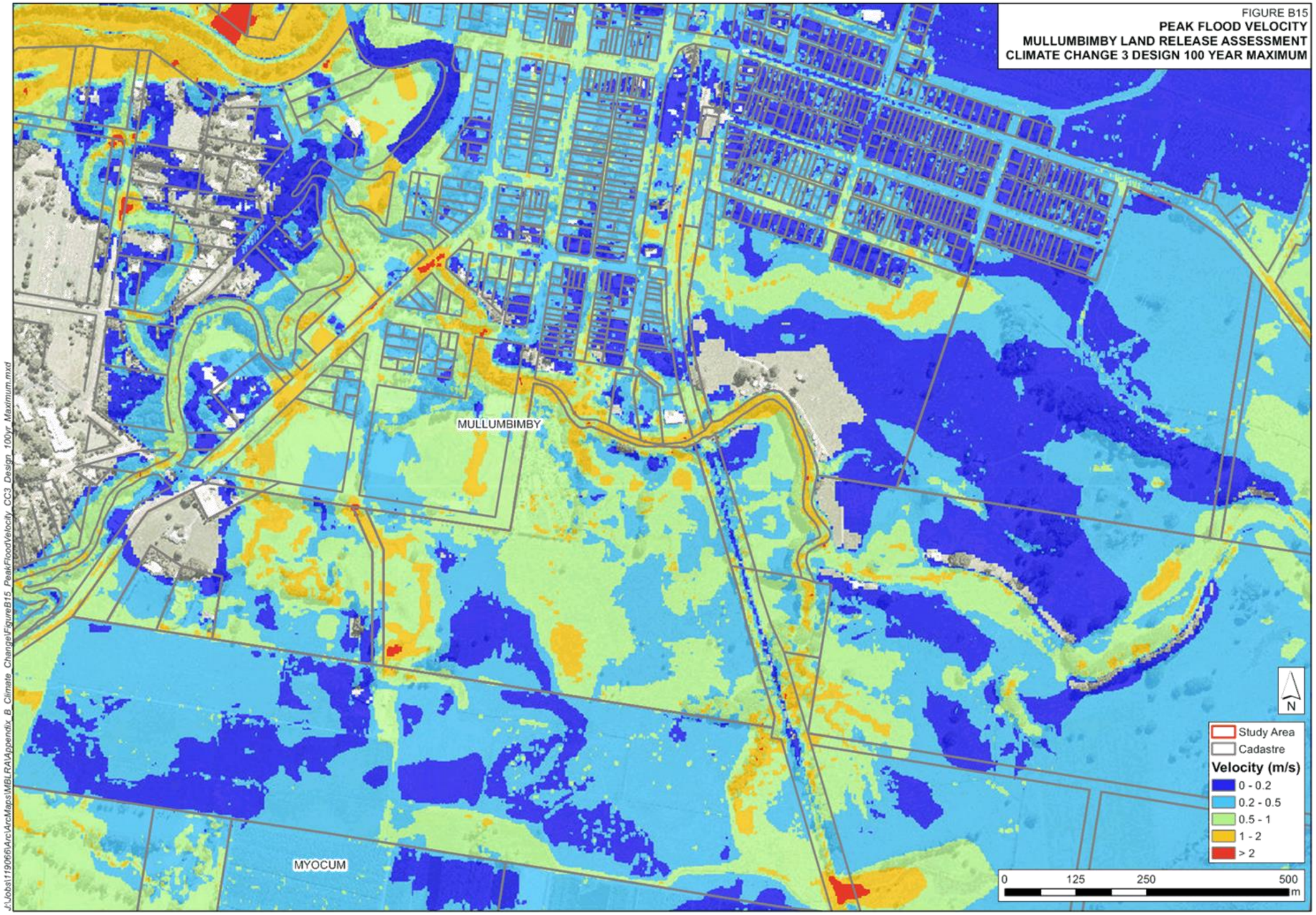

FIGURE B10
PEAK FLOOD DEPTHS
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 2 DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Peak Flood Depth (m)
0 - 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2
> 2.0
0
125
250
500
m
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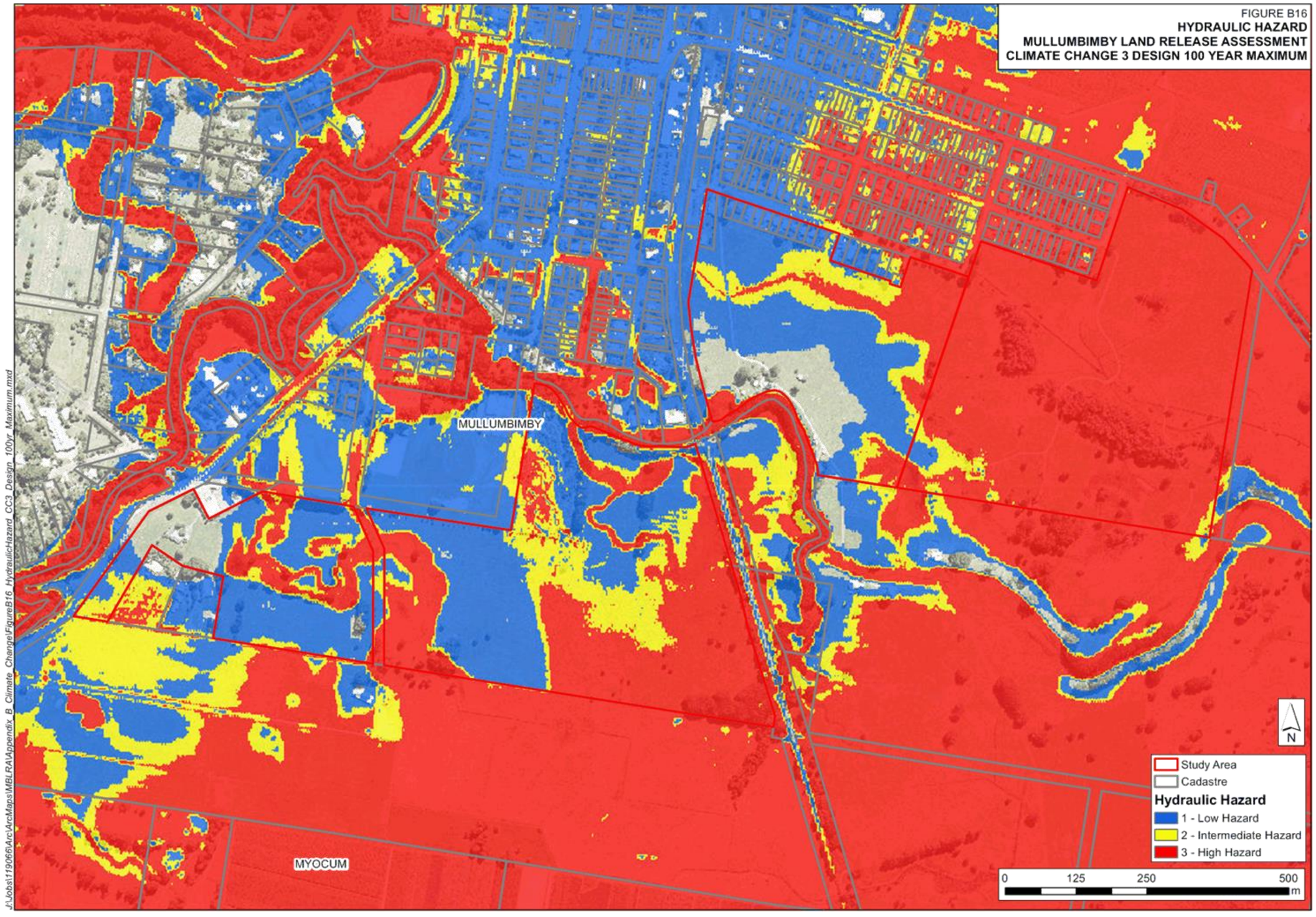

FIGURE B11
PEAK FLOOD VELOCITY
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 2 DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Velocity (m/s)
0 - 0.2
0.2 - 0.5
0.5 - 1
1 - 2
> 2
0
125
250
500
m
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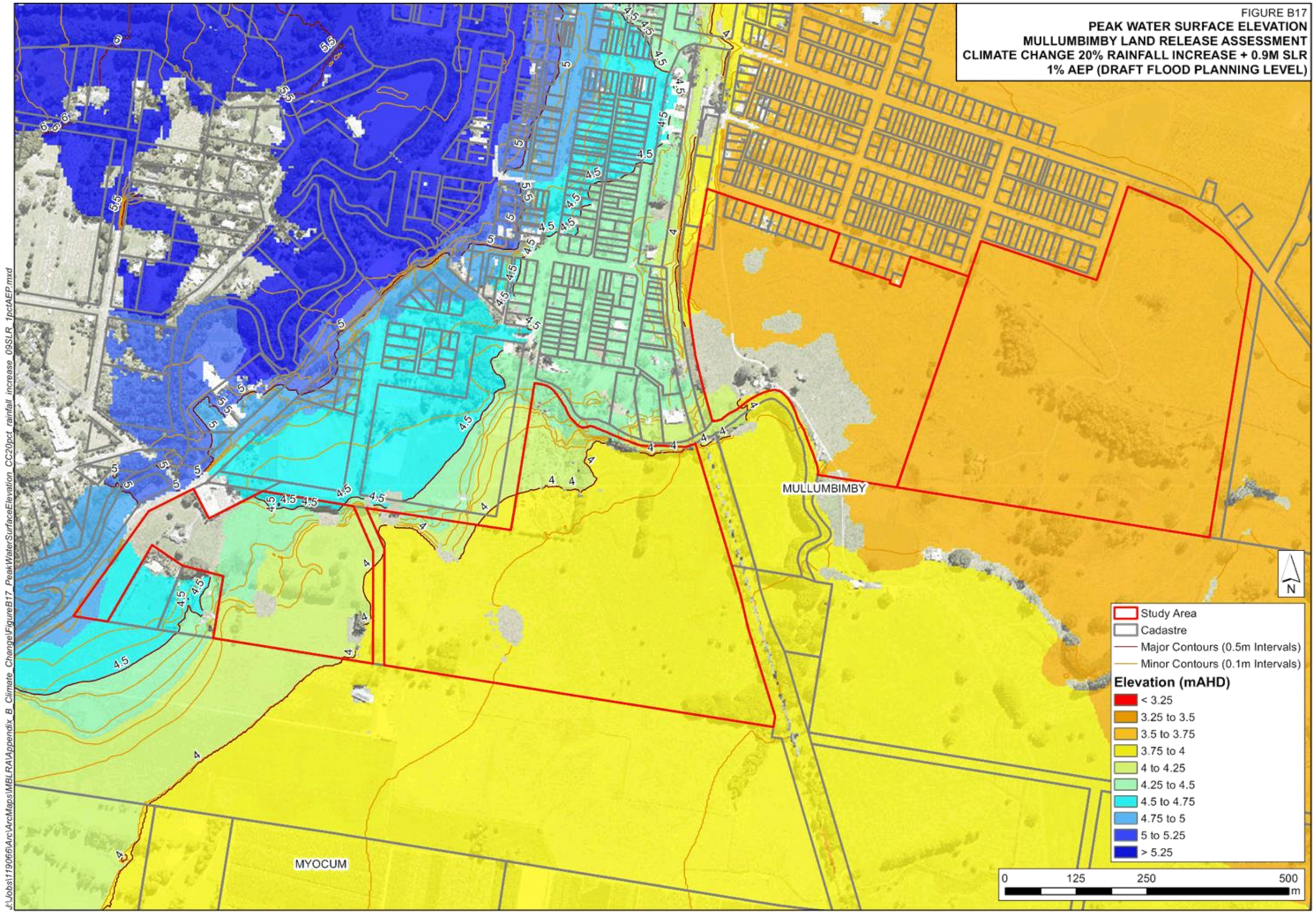

FIGURE B12
HYDRAULIC HAZARD
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 2 DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Hydraulic Hazard
1 - Low Hazard
2 - Intermediate Hazard
3 - High Hazard
0
125
250
500
m
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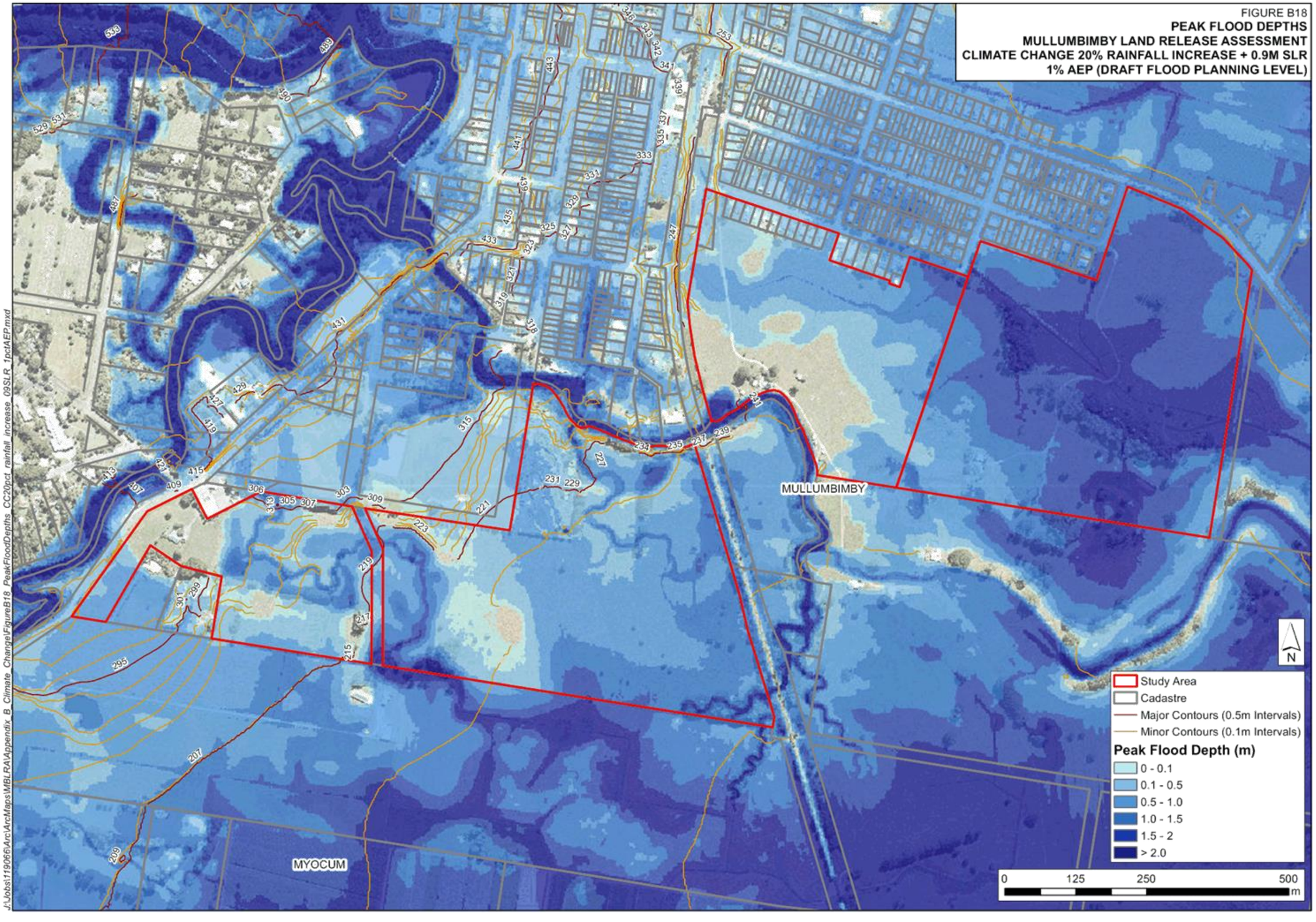

FIGURE B13
PEAK WATER SURFACE ELEVATION
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 3 DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Major Contours (0.5m Intervals)
Minor Contours (0.1m Intervals)
Elevation (mAHD)
< 3.25
3.25 to 3.5
3.5 to 3.75
3.75 to 4
4 to 4.25
4.25 to 4.5
4.5 to 4.75
4.75 to 5
5 to 5.25
> 5.25
0
125
250
500
m
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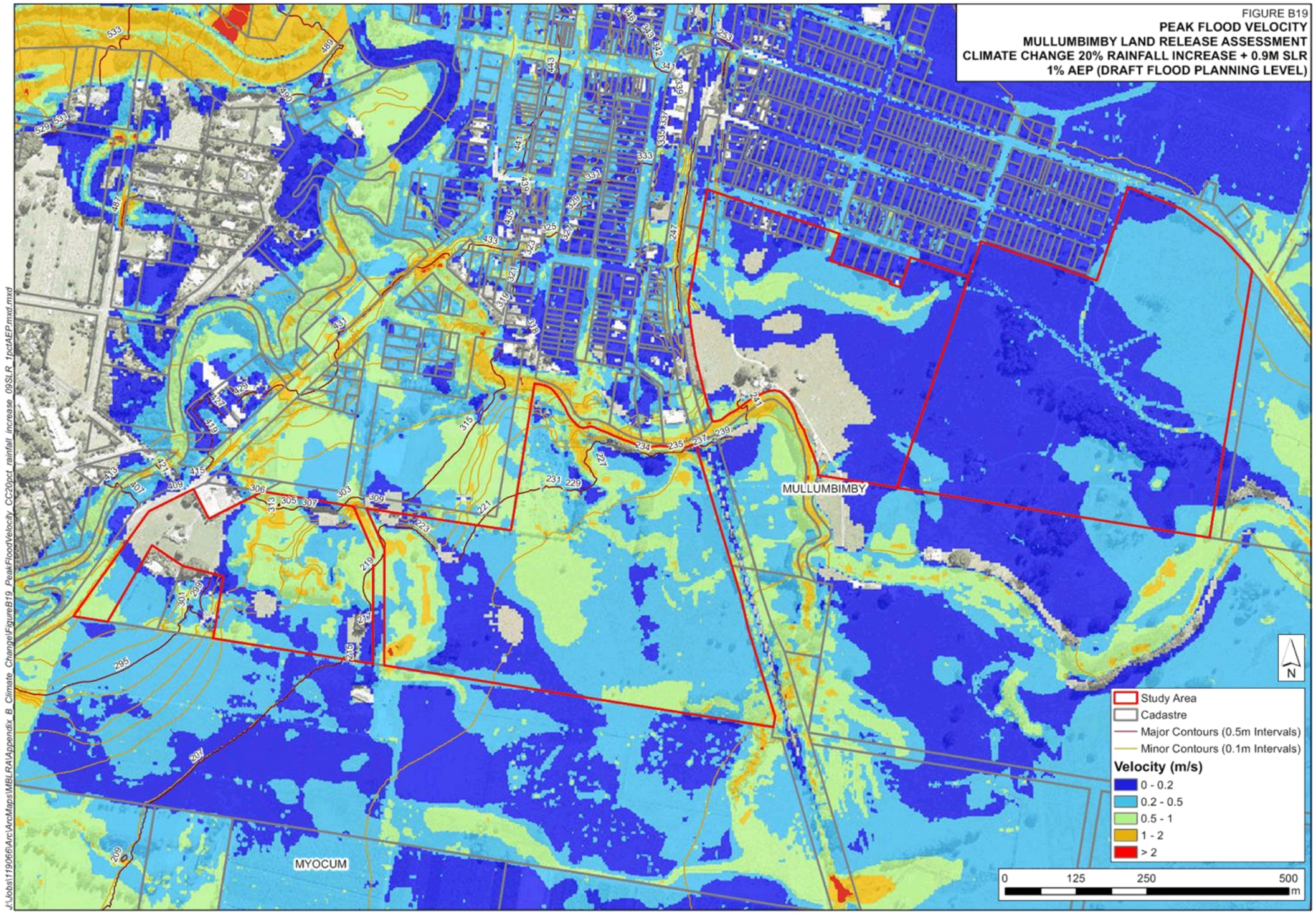

FIGURE B14
PEAK FLOOD DEPTHS
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 3 DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Peak Flood Depth (m)
0 - 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2
> 2.0
0
125
250
500
m
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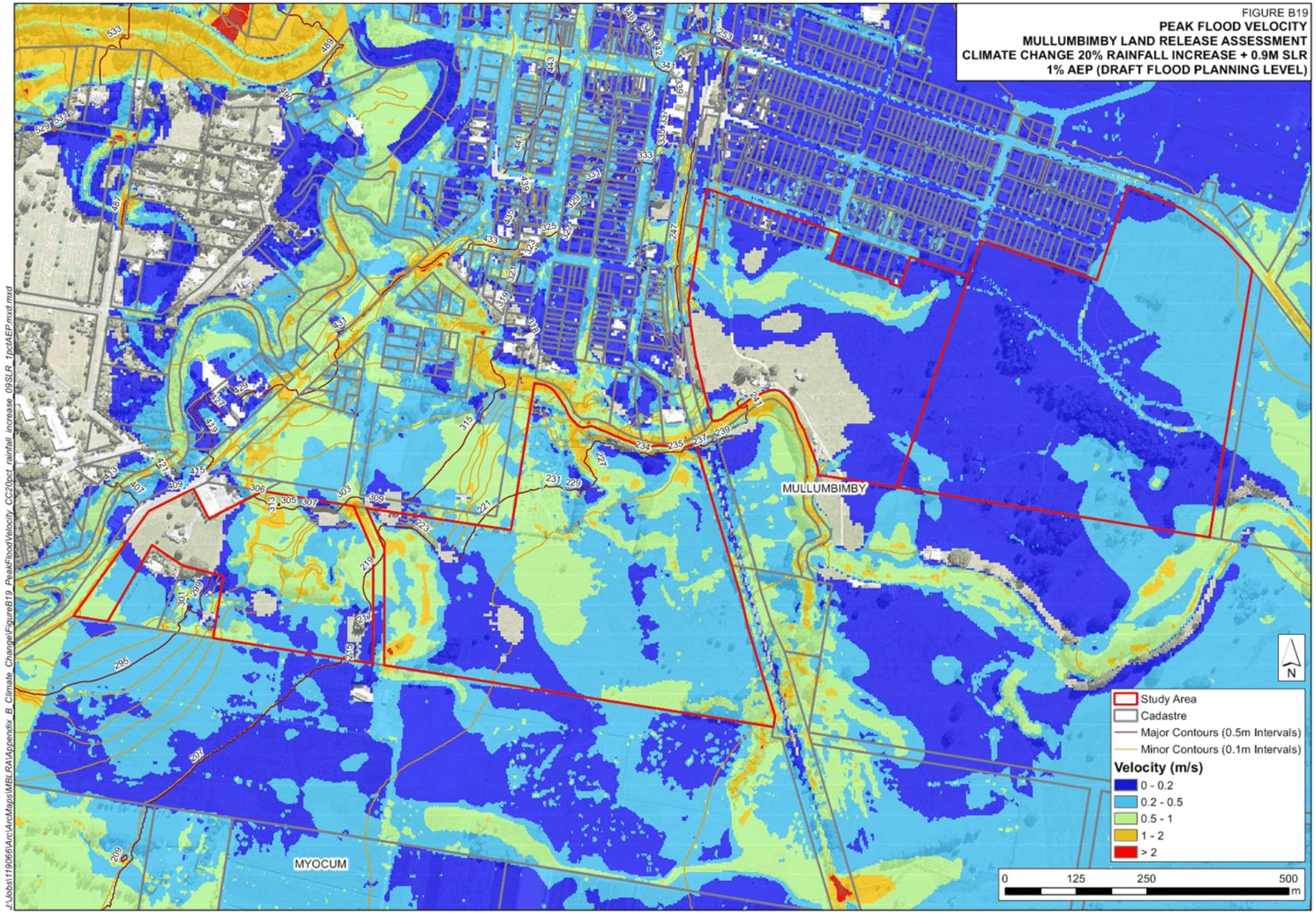

FIGURE B15
PEAK FLOOD VELOCITY
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 3 DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Velocity (m/s)
0 - 0.2
0.2 - 0.5
0.5 - 1
1 - 2
> 2
0
125
250
500
m
J:\Jobs\119066\ArcMaps\MBLRA\Appendix_B_Climate_Change\FigureB15_PeakFloodVelocity_CC3_Design_100yr_Maximum.mxd

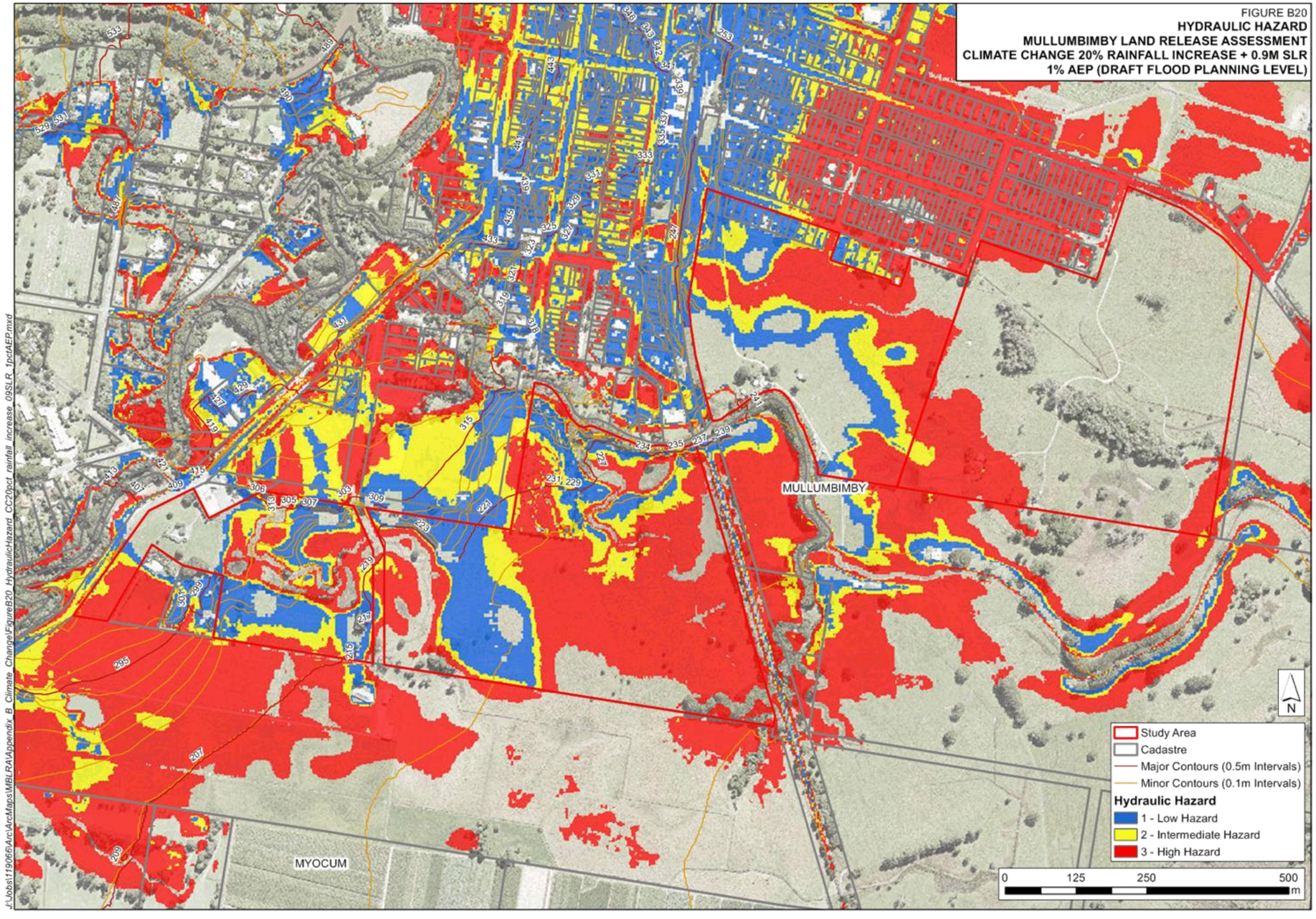

FIGURE B16
HYDRAULIC HAZARD
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 3 DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Hydraulic Hazard
1 - Low Hazard
2 - Intermediate Hazard
3 - High Hazard
0
125
250
500
m
J:\Jobs\119066\ArcMaps\MBLRA\Appendix_B_Climate_Change\FigureB16_HydraulicHazard_CC3_Design_100yr_Maximum.mxd


FIGURE B17
PEAK WATER SURFACE ELEVATION
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 20% RAINFALL INCREASE + 0.9M SLR
1% AEP (DRAFT FLOOD PLANNING LEVEL)
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Major Contours (0.5m Intervals)
Minor Contours (0.1m Intervals)
Elevation (mAHD)
< 3.25
3.25 to 3.5
3.5 to 3.75
3.75 to 4
4 to 4.25
4.25 to 4.5
4.5 to 4.75
4.75 to 5
5 to 5.25
> 5.25
0
125
250
500
m
J:\Jobs\119066\Arc\ArcMaps\MBLRAAppendix_B_Climate_Change\FigureB17_PeakWaterSurfaceElevation_CC20pct_rainfall_increase_09SLR_1pctAEP.mxd


FIGURE B18
PEAK FLOOD DEPTHS
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 20% RAINFALL INCREASE + 0.9M SLR
1% AEP (DRAFT FLOOD PLANNING LEVEL)
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Major Contours (0.5m Intervals)
Minor Contours (0.1m Intervals)
Peak Flood Depth (m)
0 - 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2
> 2.0
0
125
250
500
m
J:\Jobs\119066\ArcMaps\MBLRA\Appendix_B_Climate_ChangeFigureB18_PeakFloodDepths_CC20pct_rainfall_increase_09SLR_1pctAEP.mxd

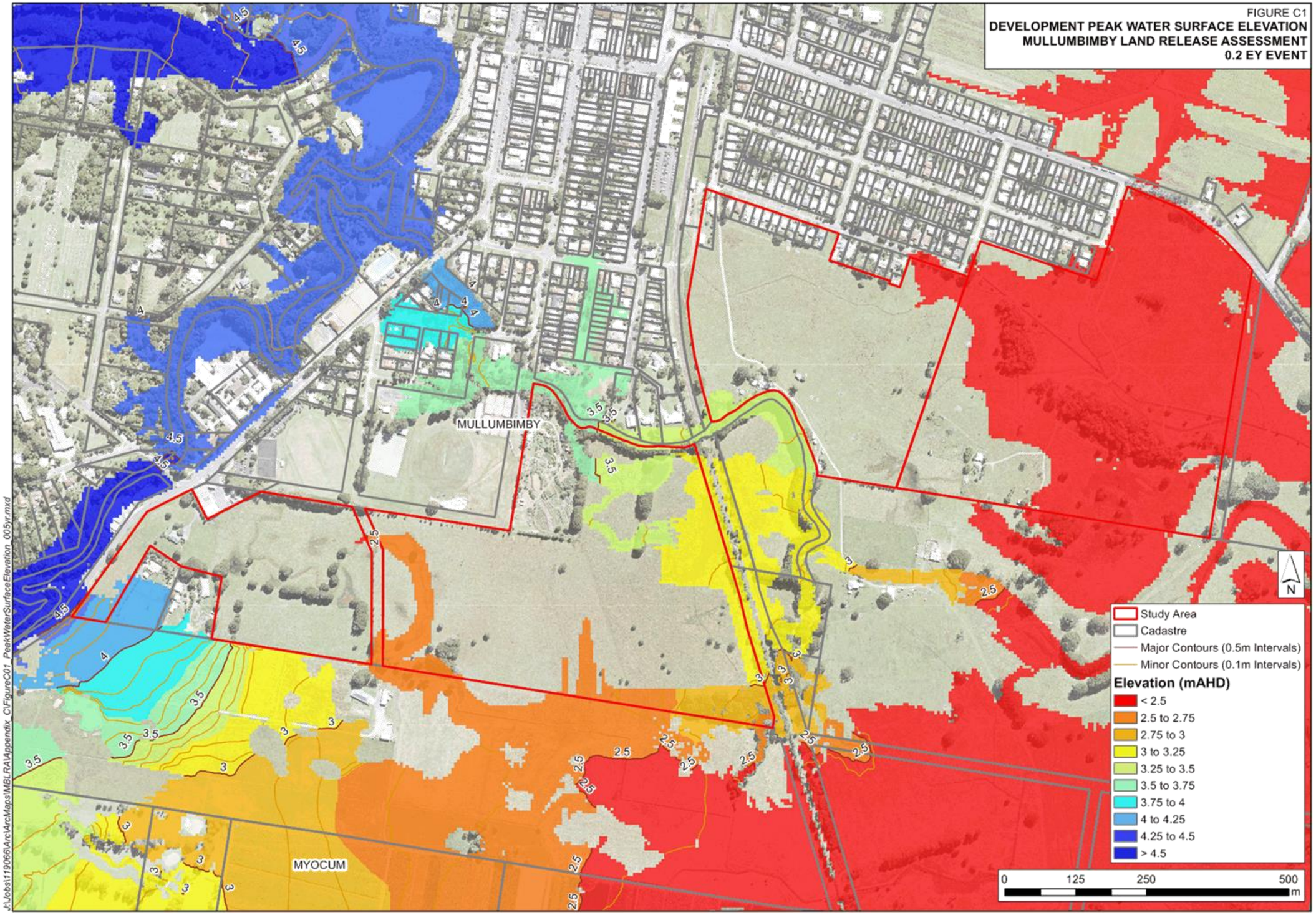

FIGURE B19
PEAK FLOOD VELOCITY
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 20% RAINFALL INCREASE + 0.9M SLR
1% AEP (DRAFT FLOOD PLANNING LEVEL)
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Major Contours (0.5m Intervals)
Minor Contours (0.1m Intervals)
Velocity (m/s)
0 - 0.2
0.2 - 0.5
0.5 - 1
1 - 2
> 2
0
125
250
500
m
J:\Jobs\1190661\Arc\ArcMaps\MBLRAVAppendix_B_Climate_Change\FigureB19_PeakFloodVelocity_CC20pct_rainfall_increase_09SLR_1pctAEP.mxd

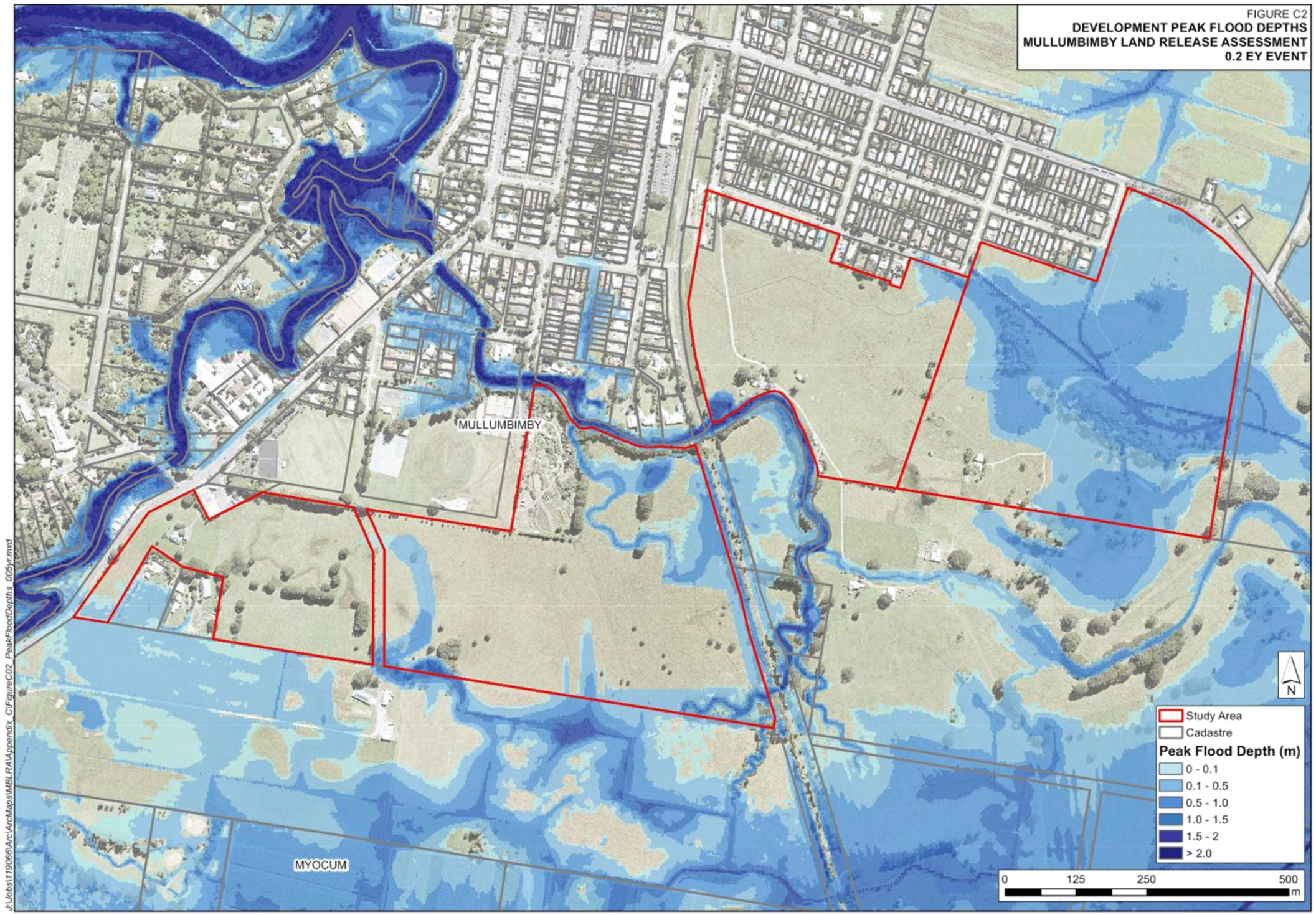

FIGURE B19
PEAK FLOOD VELOCITY
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 20% RAINFALL INCREASE + 0.9M SLR
1% AEP (DRAFT FLOOD PLANNING LEVEL)
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Major Contours (0.5m Intervals)
Minor Contours (0.1m Intervals)
Velocity (m/s)
0 - 0.2
0.2 - 0.5
0.5 - 1
1 - 2
> 2
0
125
250
500
m
J:\Jobs\1190661\ArcMaps\MBLRAVAppendix_B_Climate_Change\FigureB19_PeakFloodVelocity_CC20pct_rainfall_increase_09SLR_1pctAEP.mxd

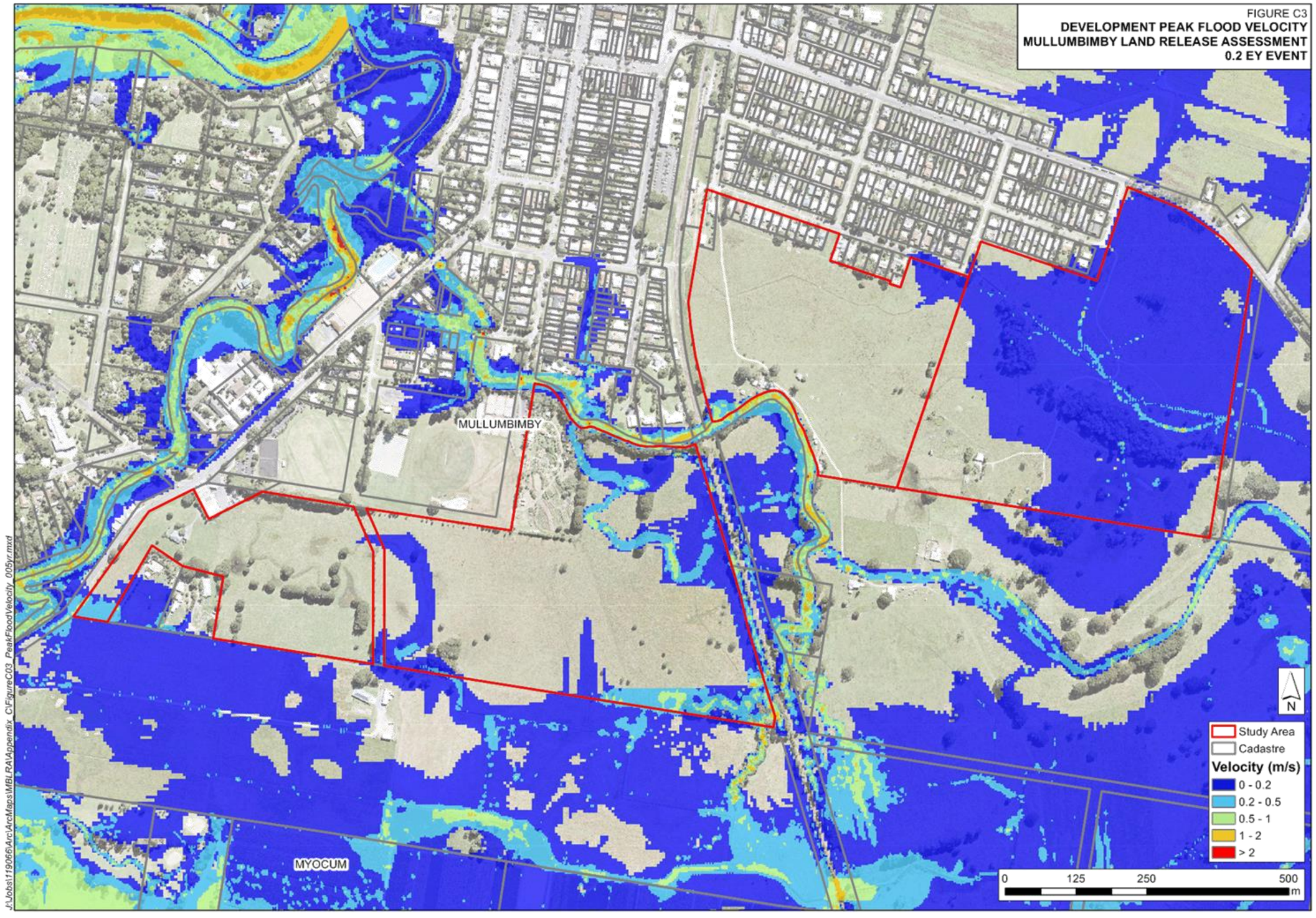

FIGURE B20
HYDRAULIC HAZARD
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 20% RAINFALL INCREASE + 0.9M SLR
1% AEP (DRAFT FLOOD PLANNING LEVEL)
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Major Contours (0.5m Intervals)
Minor Contours (0.1m Intervals)
Hydraulic Hazard
1 - Low Hazard
2 - Intermediate Hazard
3 - High Hazard
0
125
250
500
m
J:\Jobs\119065\ArcArcMaps\MBLRA\Appendix_B_Climate_Change\FigureB20_HydraulicHazard_CC20pct_rainfall_increase_09SLR_1pctAEP.mxd

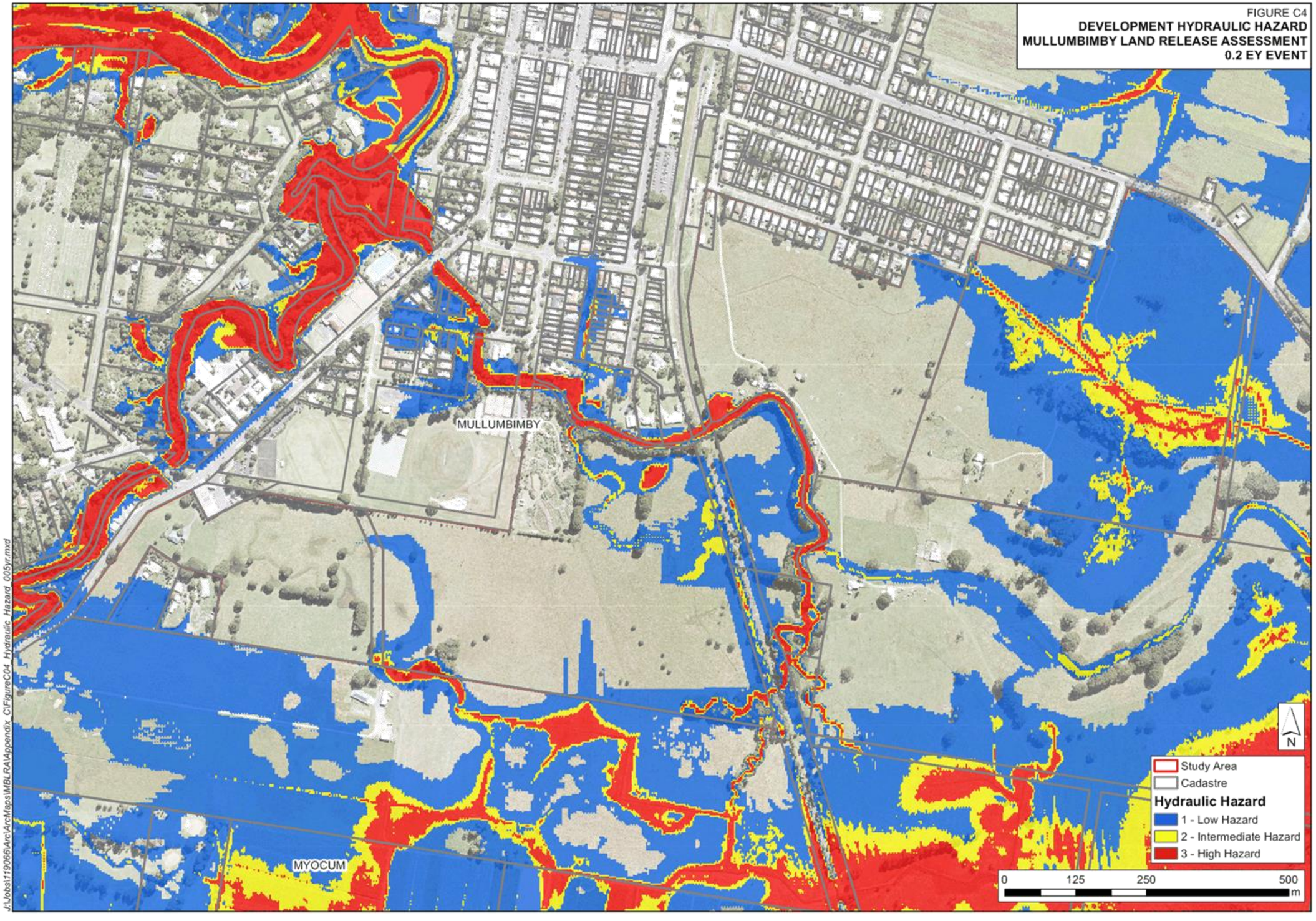


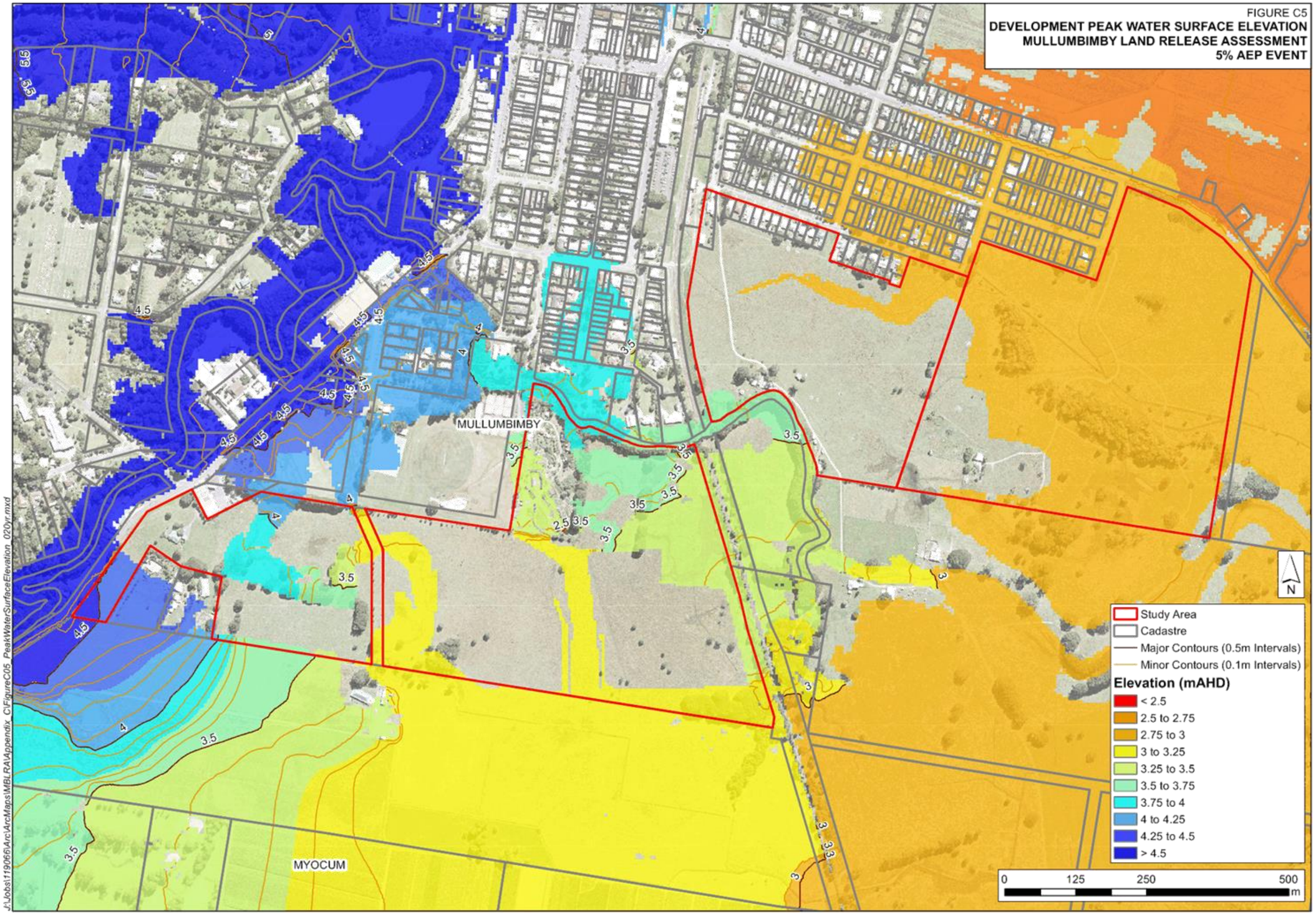
Appendix C

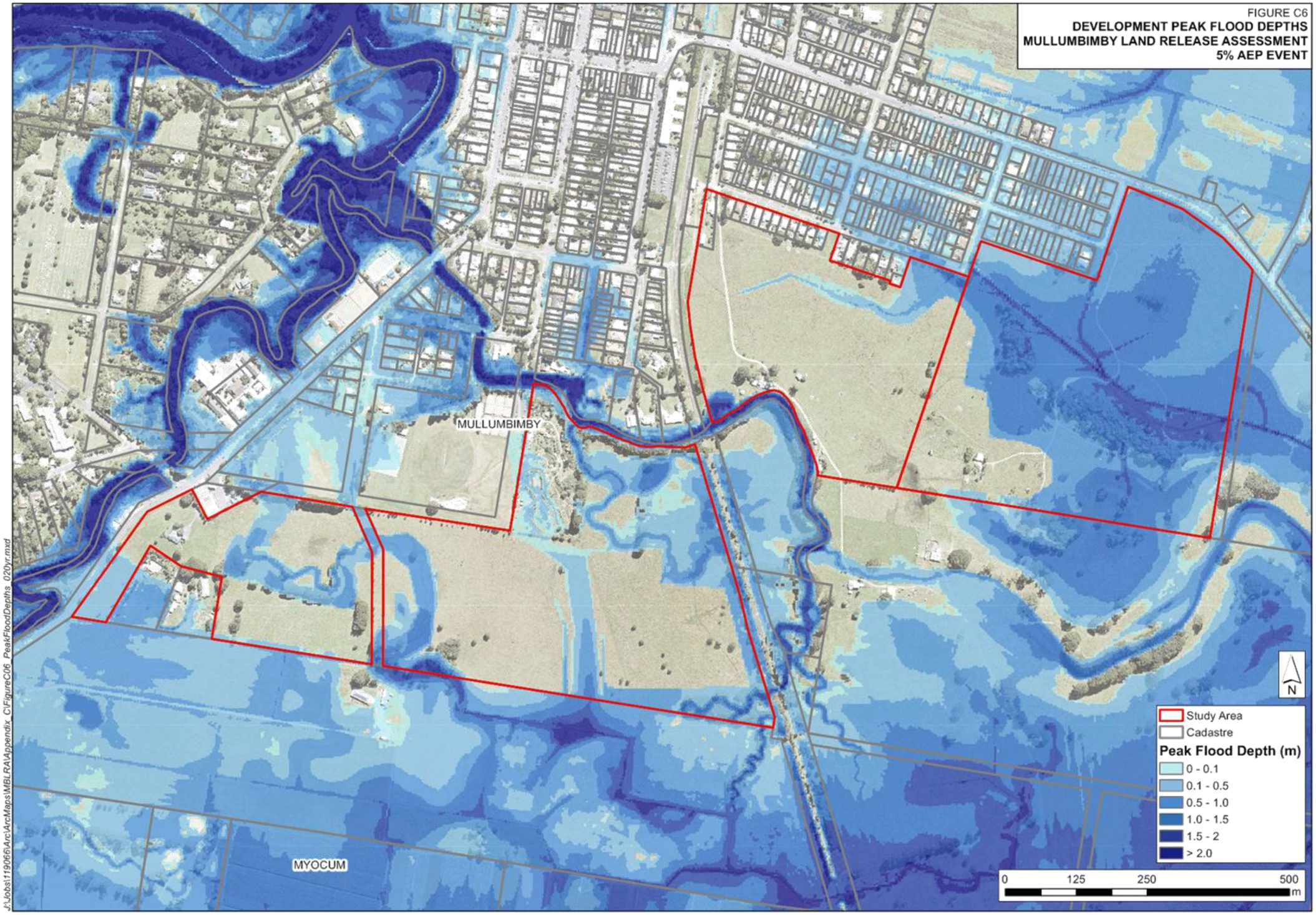

FIGURE C1
DEVELOPMENT PEAK WATER SURFACE ELEVATION
MULLUMBIMBY LAND RELEASE ASSESSMENT
0.2 EY EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Major Contours (0.5m Intervals)
Minor Contours (0.1m Intervals)
Elevation (mAHD)
< 2.5
2.5 to 2.75
2.75 to 3
3 to 3.25
3.25 to 3.5
3.5 to 3.75
3.75 to 4
4 to 4.25
4.25 to 4.5
> 4.5
0
125
250
500
m
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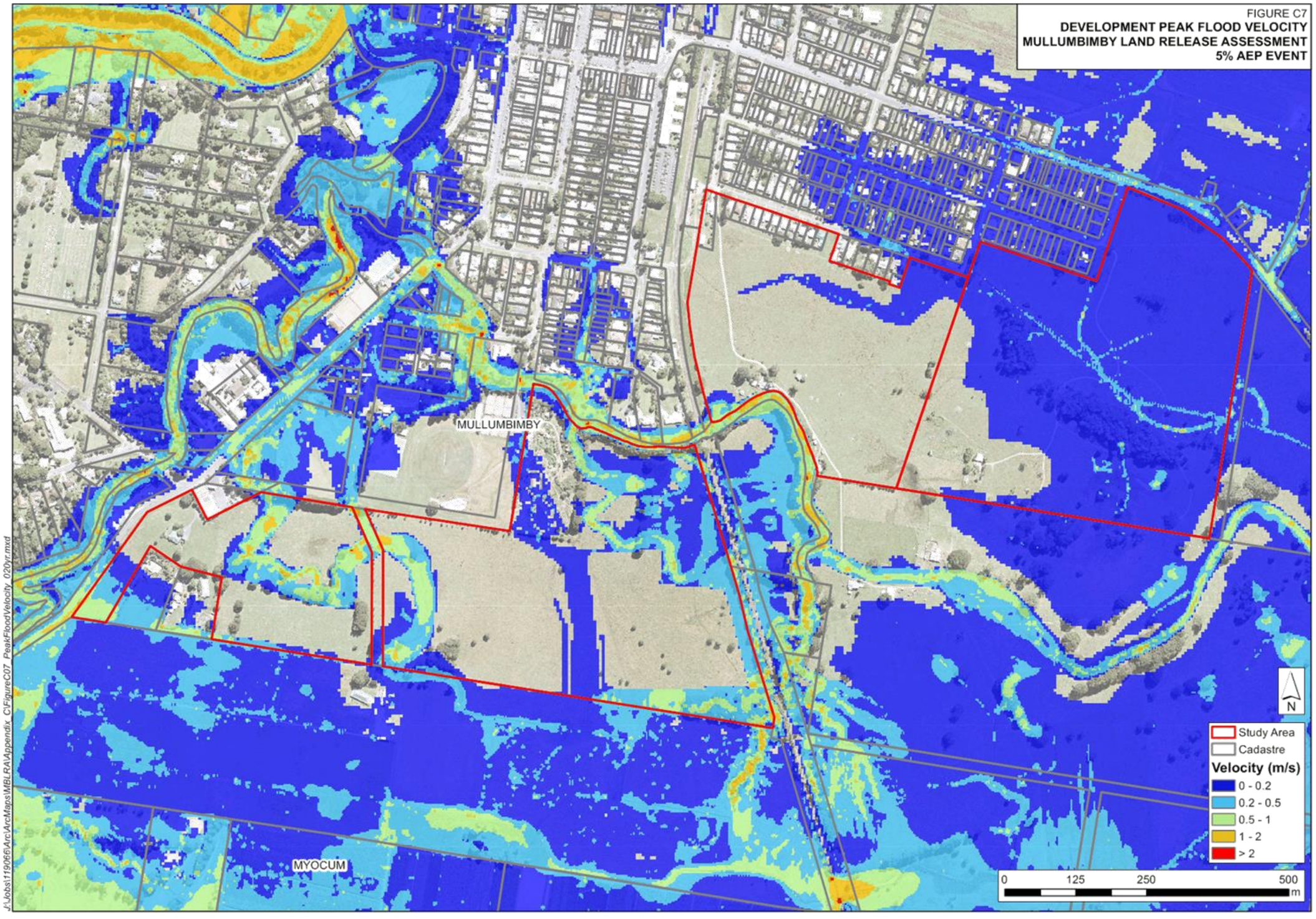

FIGURE C2
DEVELOPMENT PEAK FLOOD DEPTHS
MULLUMBIMBY LAND RELEASE ASSESSMENT
0.2 EY EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Peak Flood Depth (m)
0 - 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2
> 2.0
0
125
250
500
m
J:\Jobs\119066\ArcIArcMaps\MBLRA\Appendix_C\FigureC02_PeakFloodDepths_005yr.mxd

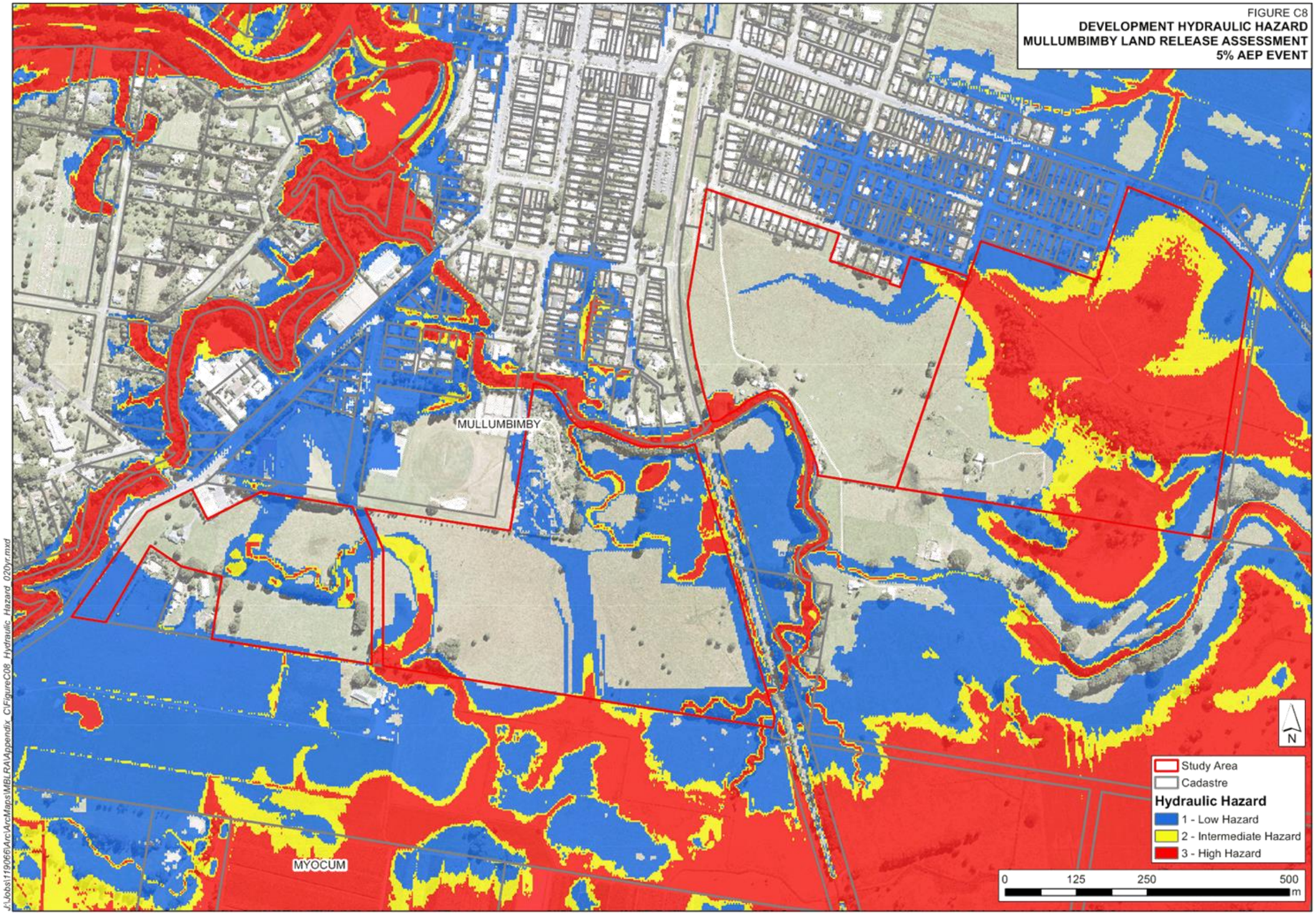

FIGURE C3
DEVELOPMENT PEAK FLOOD VELOCITY
MULLUMBIMBY LAND RELEASE ASSESSMENT
0.2 EY EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Velocity (m/s)
0 - 0.2
0.2 - 0.5
0.5 - 1
1 - 2
> 2
0
125
250
500
m
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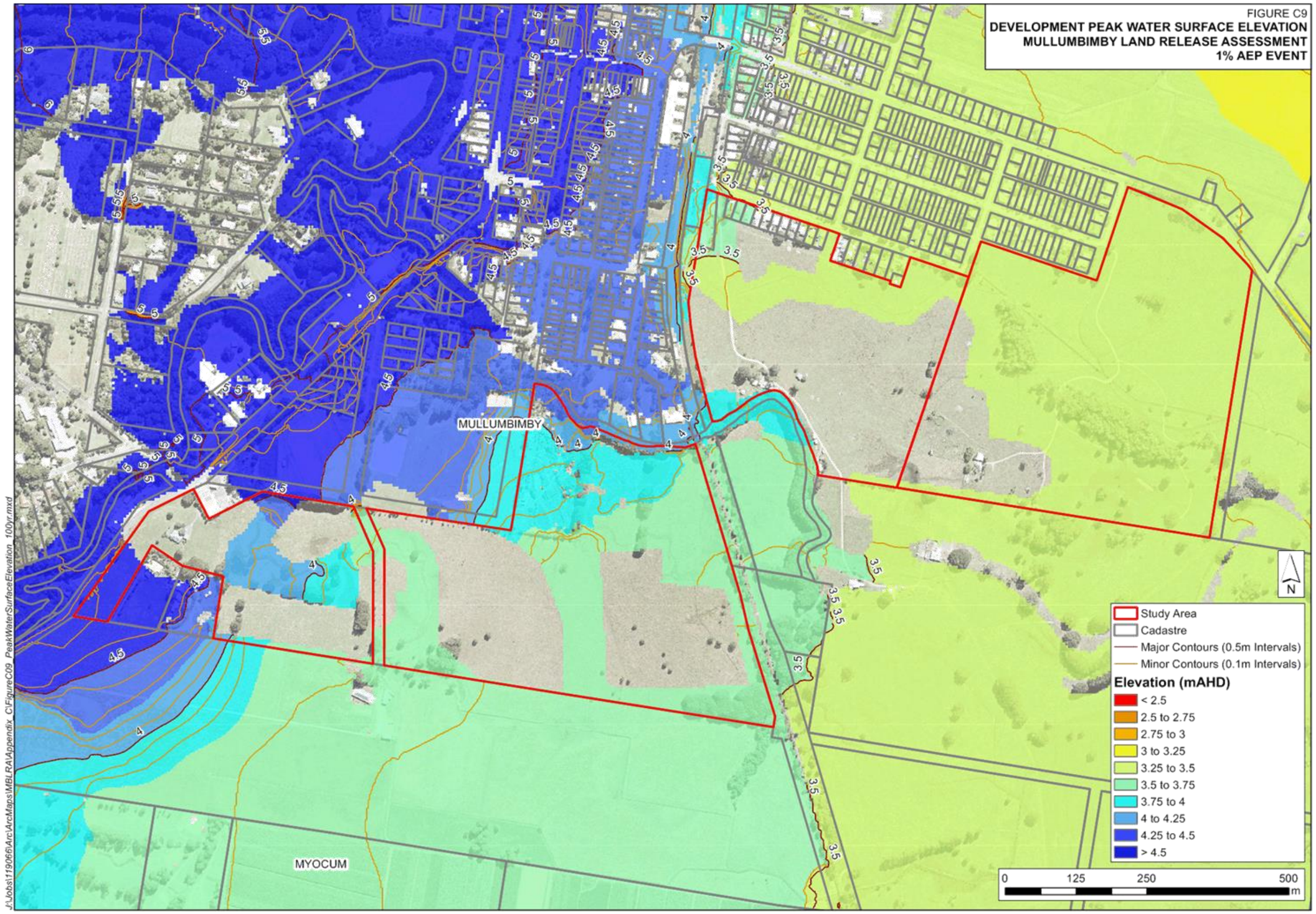

FIGURE C4
DEVELOPMENT HYDRAULIC HAZARD
MULLUMBIMBY LAND RELEASE ASSESSMENT
0.2 EY EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Hydraulic Hazard
1 - Low Hazard
2 - Intermediate Hazard
3 - High Hazard
0
125
250
500
m
J:\Jobs\119066\ArcArcMaps\MBLRA\Appendix_C\FigureC04_Hydraulic_Hazard_005yr.mxd

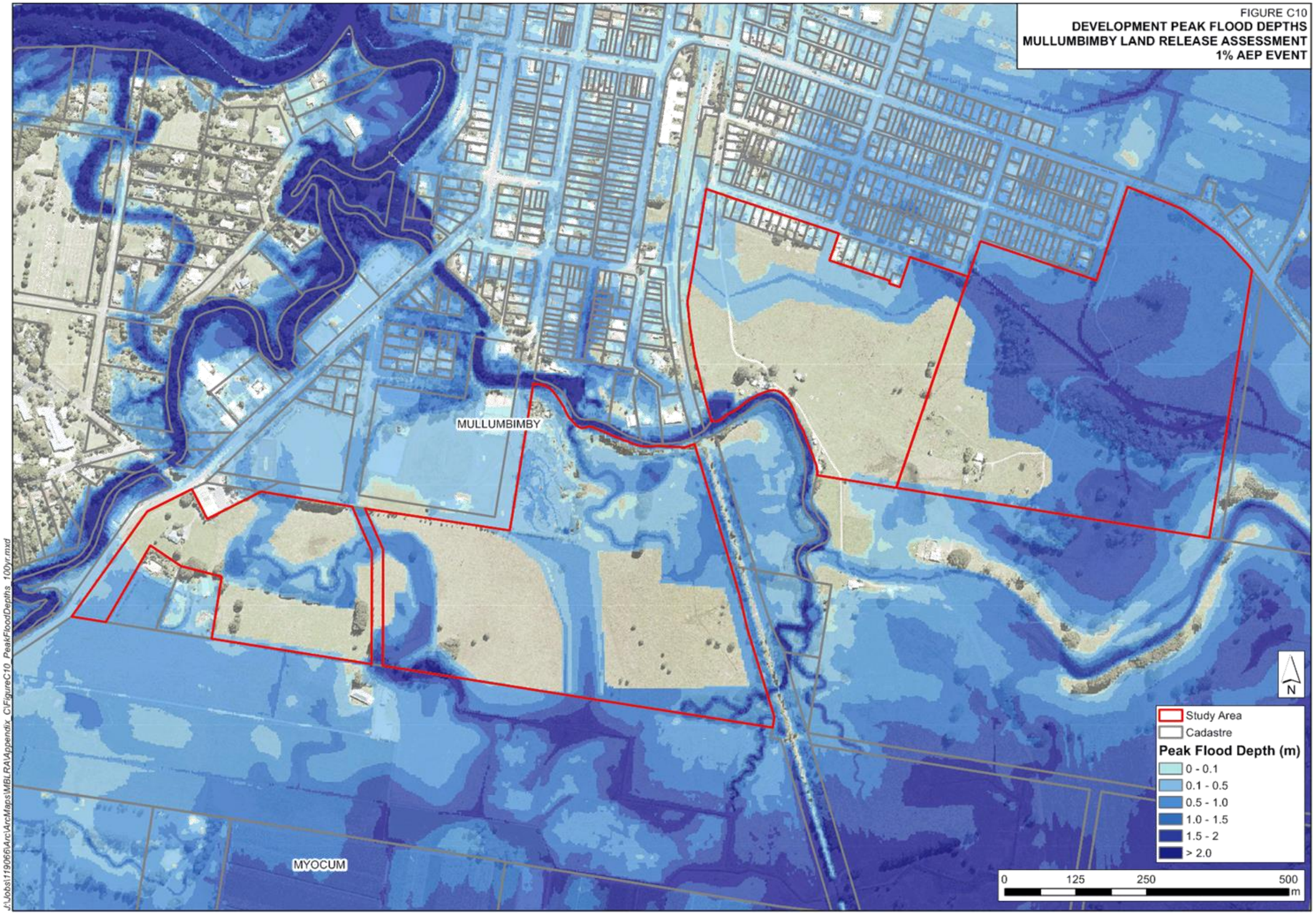

FIGURE C5
DEVELOPMENT PEAK WATER SURFACE ELEVATION
MULLUMBIMBY LAND RELEASE ASSESSMENT
5% AEP EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Major Contours (0.5m Intervals)
Minor Contours (0.1m Intervals)
Elevation (mAHD)
< 2.5
2.5 to 2.75
2.75 to 3
3 to 3.25
3.25 to 3.5
3.5 to 3.75
3.75 to 4
4 to 4.25
4.25 to 4.5
> 4.5
0
125
250
500
m
J:\Jobs\119066\ArcMaps\MBLRA\Appendix_C\FigureC05_PeakWaterSurfaceElevation_020yr.mxd

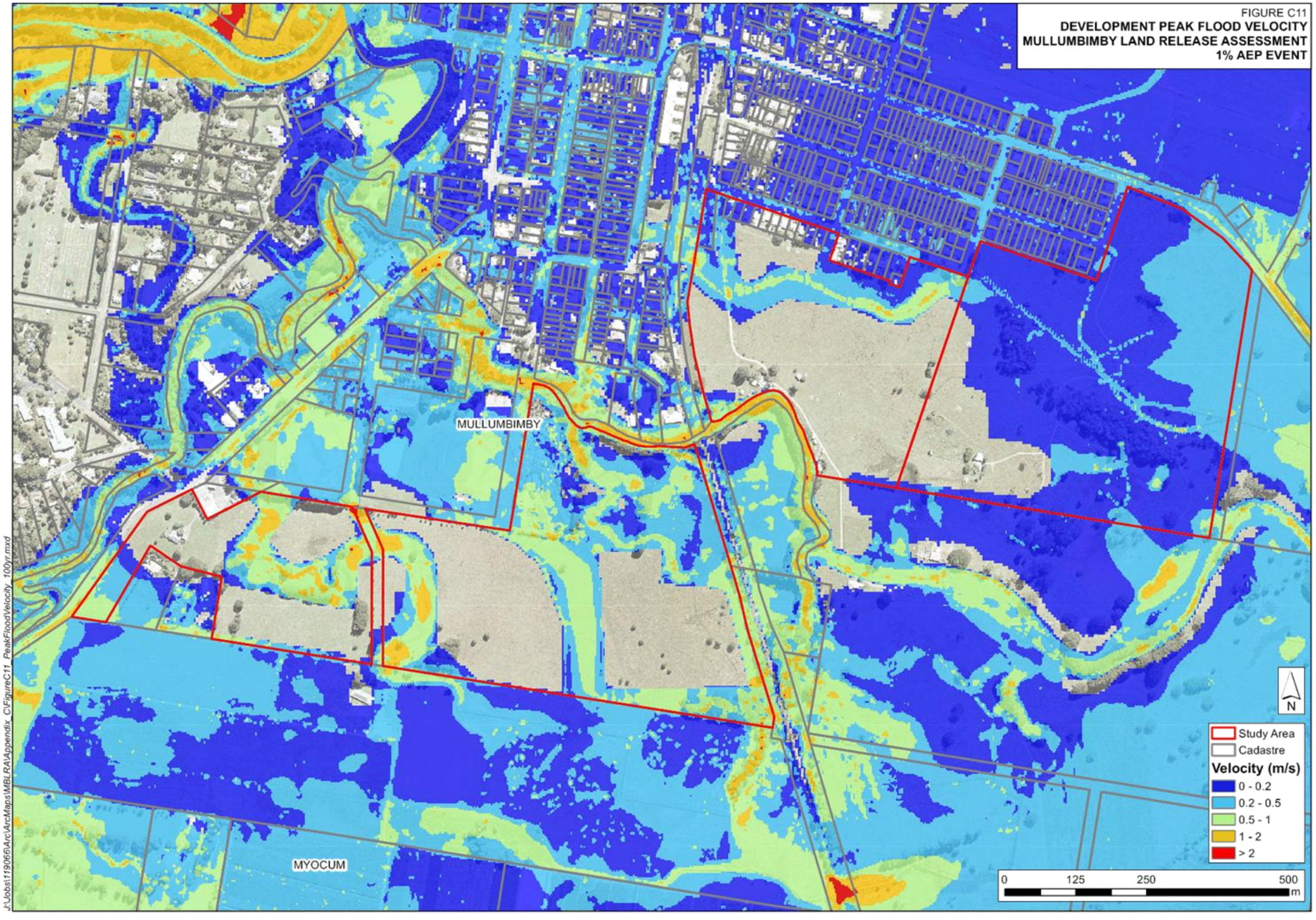

FIGURE C6
DEVELOPMENT PEAK FLOOD DEPTHS
MULLUMBIMBY LAND RELEASE ASSESSMENT
5% AEP EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Peak Flood Depth (m)
0 - 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2
> 2.0
0
125
250
500
m
J:\Jobs\119066\ArcMaps\MBLRA\Appendix_C\FigureC06_PeakFloodDepths_020yr.mxd

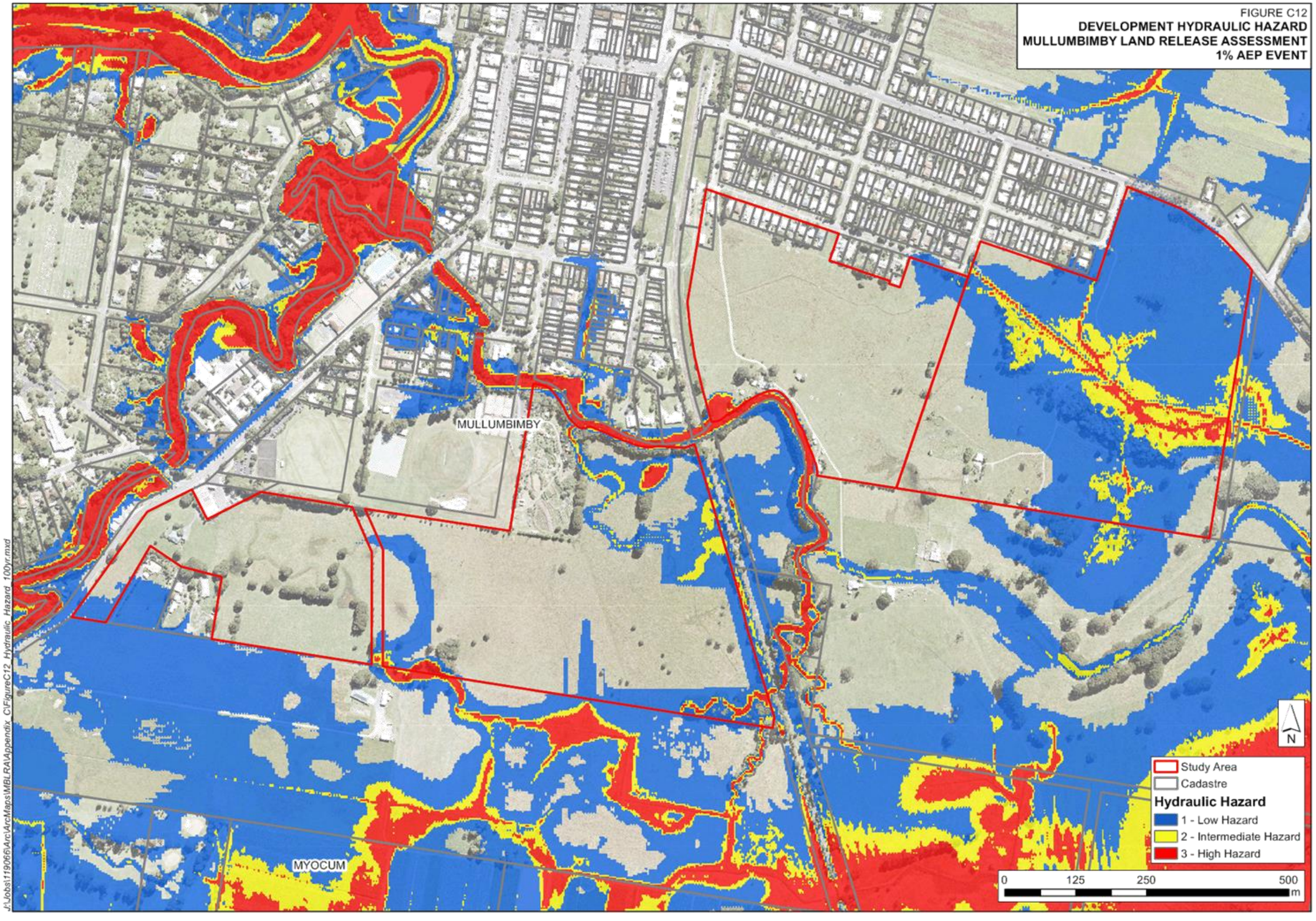

FIGURE C7
DEVELOPMENT PEAK FLOOD VELOCITY
MULLUMBIMBY LAND RELEASE ASSESSMENT
5% AEP EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Velocity (m/s)
0 - 0.2
0.2 - 0.5
0.5 - 1
1 - 2
> 2
0
125
250
500
m
J:\Jobs\119056\ArcArcMaps\MBLRA\Appendix_C\FigureC07_PeakFloodVelocity_020yr.mxd

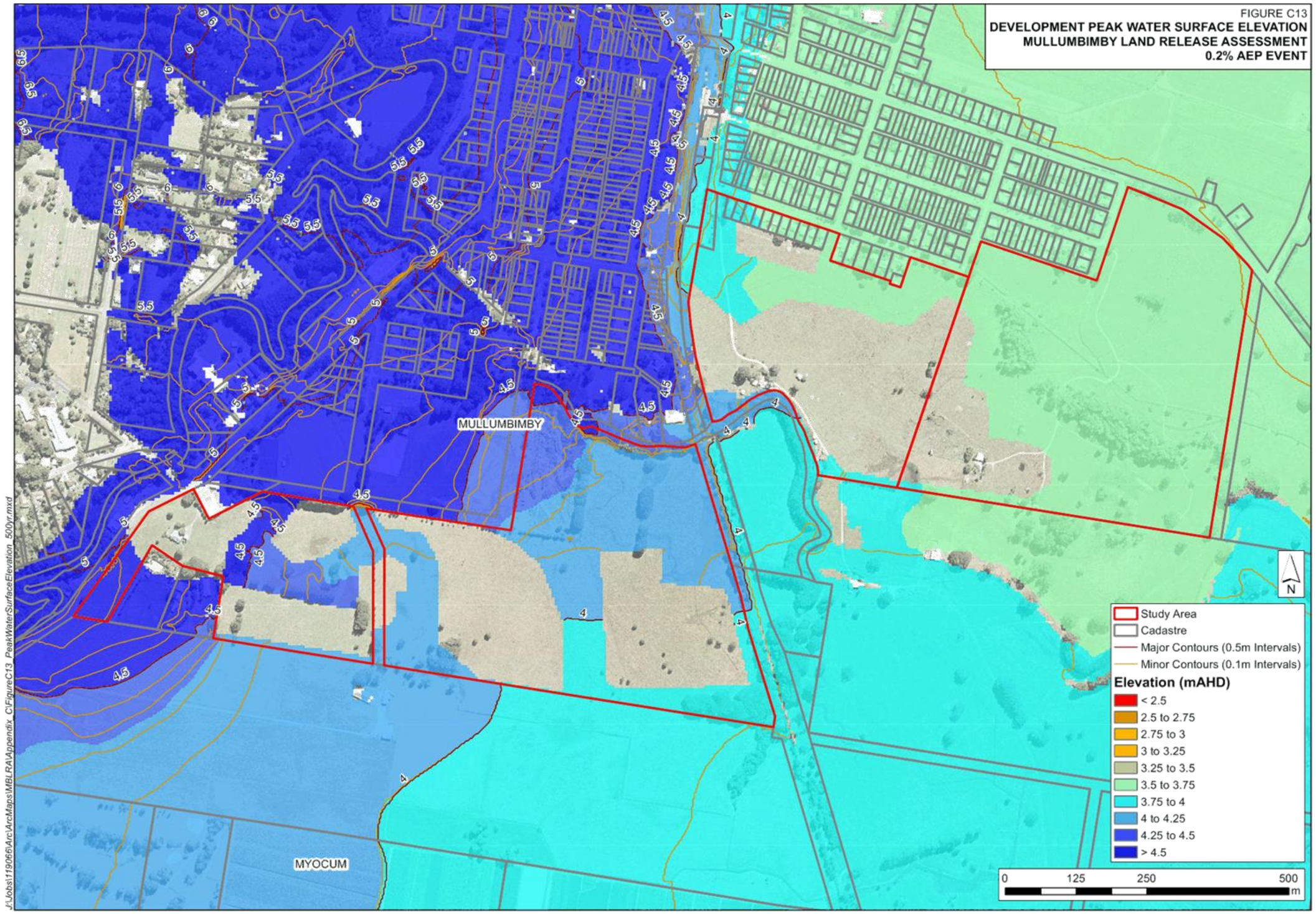

FIGURE C8
DEVELOPMENT HYDRAULIC HAZARD
MULLUMBIMBY LAND RELEASE ASSESSMENT
5% AEP EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Hydraulic Hazard
1 - Low Hazard
2 - Intermediate Hazard
3 - High Hazard
0
125
250
500
m
J:\Jobs\119066\ArcMaps\MBLRAAppendix C\FigureC08 Hydraulic Hazard 020yr.mxd

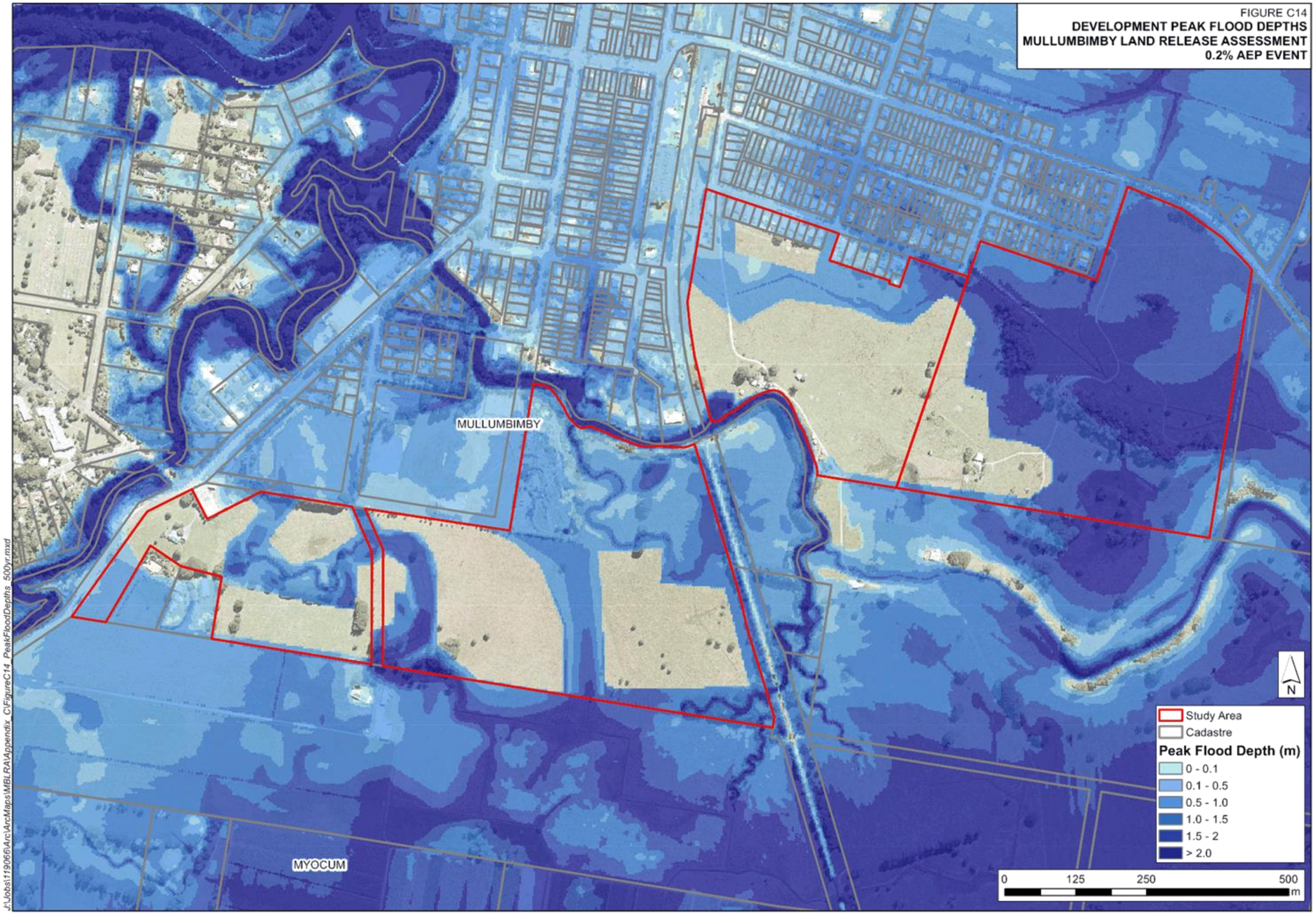

FIGURE C9
DEVELOPMENT PEAK WATER SURFACE ELEVATION
MULLUMBIMBY LAND RELEASE ASSESSMENT
1% AEP EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Major Contours (0.5m Intervals)
Minor Contours (0.1m Intervals)
Elevation (mAHD)
< 2.5
2.5 to 2.75
2.75 to 3
3 to 3.25
3.25 to 3.5
3.5 to 3.75
3.75 to 4
4 to 4.25
4.25 to 4.5
> 4.5
0
125
250
500
m
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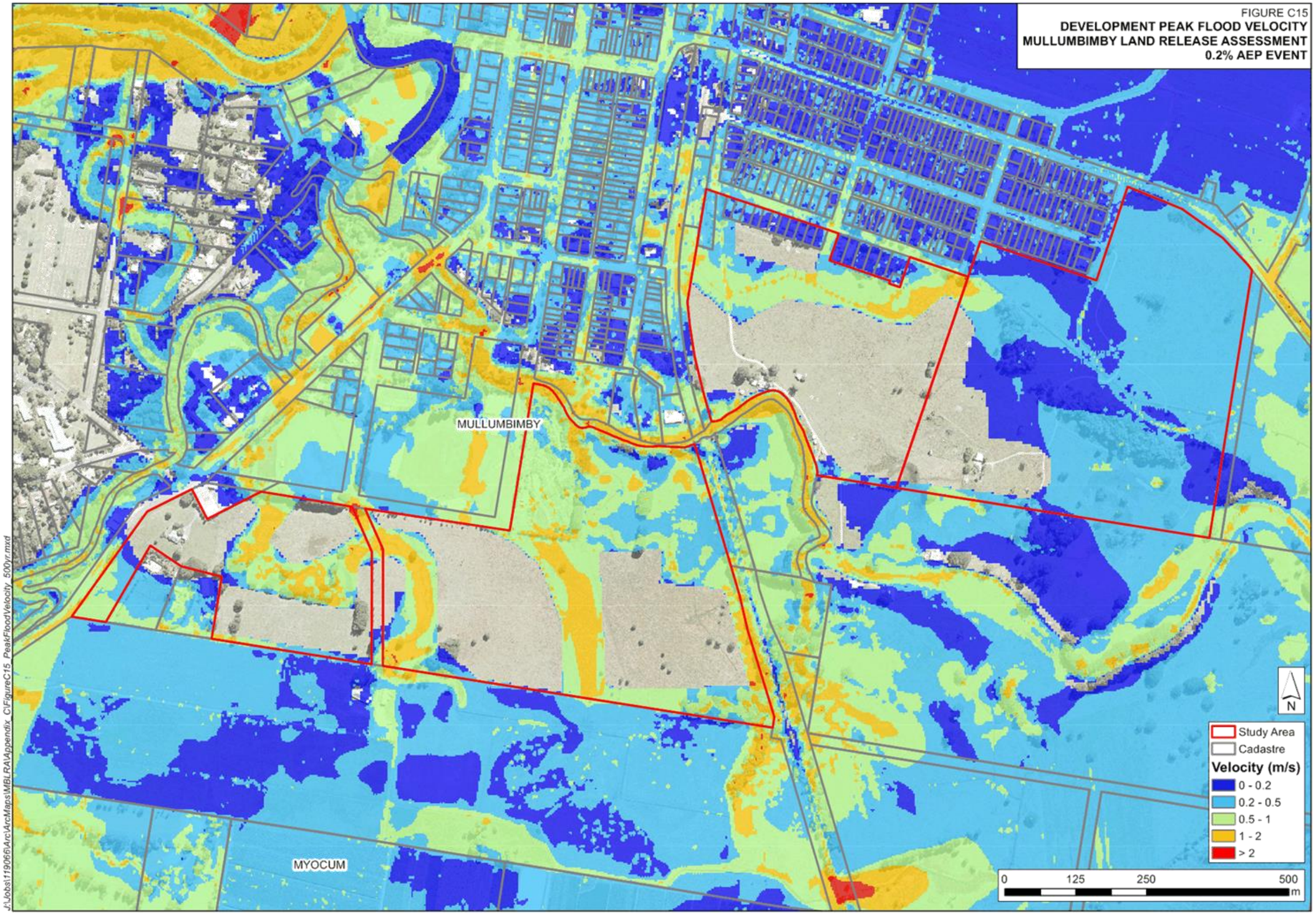

FIGURE C10
DEVELOPMENT PEAK FLOOD DEPTHS
MULLUMBIMBY LAND RELEASE ASSESSMENT
1% AEP EVENT
MULLUMBIMBY
MYOCUM
J:\Jobs\119066\ArcIArcMaps\MBLRA\Appendix_C\FigureC10_PeakFloodDepths_100yr.mxd
N
Study Area
Cadastre
Peak Flood Depth (m)
0 - 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2
> 2.0
0
125
250
500
m

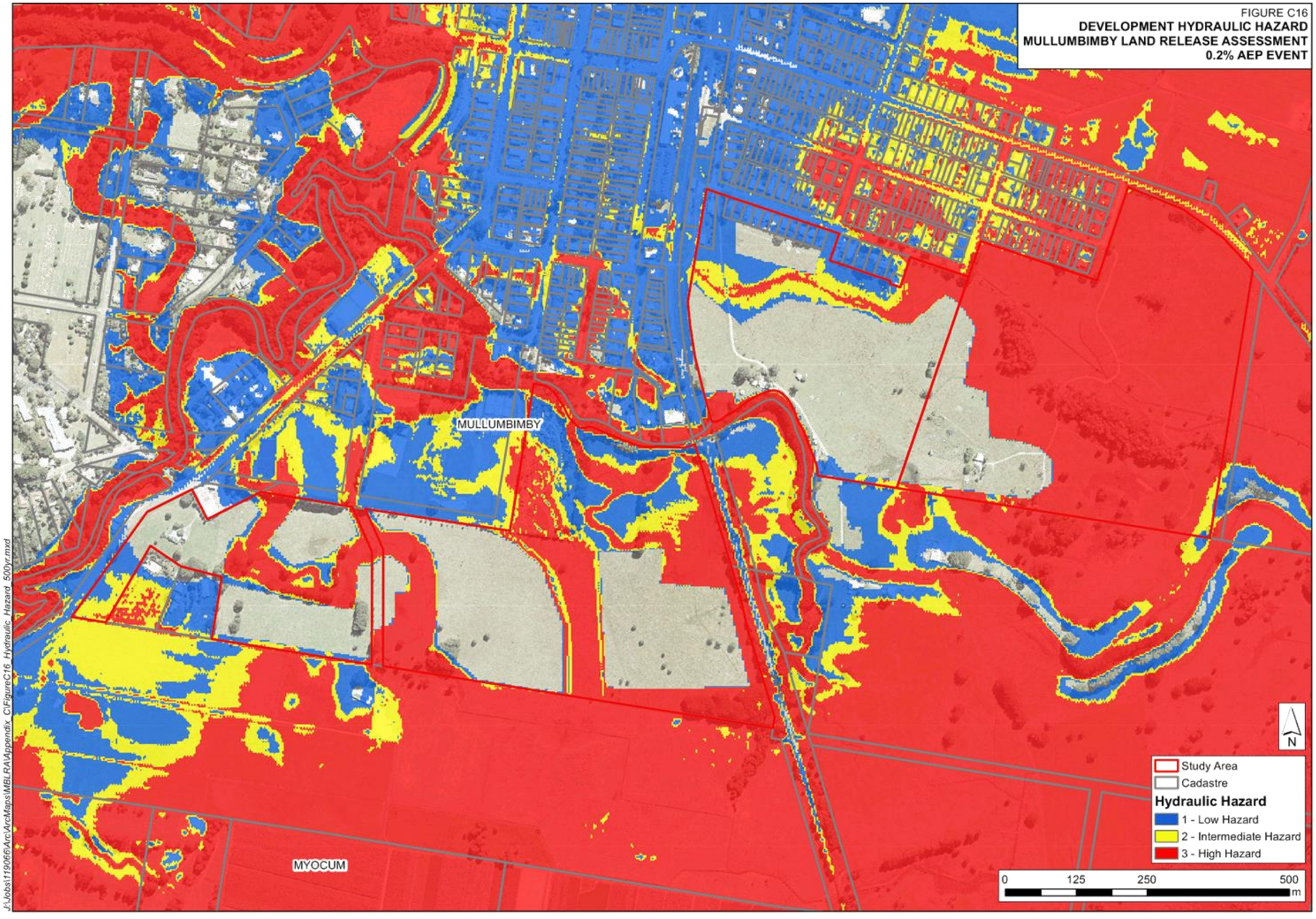

FIGURE C11
DEVELOPMENT PEAK FLOOD VELOCITY
MULLUMBIMBY LAND RELEASE ASSESSMENT
1% AEP EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Velocity (m/s)
0 - 0.2
0.2 - 0.5
0.5 - 1
1 - 2
> 2
0
125
250
500
m
J:\Jobs\119056\Arc\ArcMaps\MBLRA\Appendix_C\FigureC11_PeakFloodVelocity_100yr.mxd

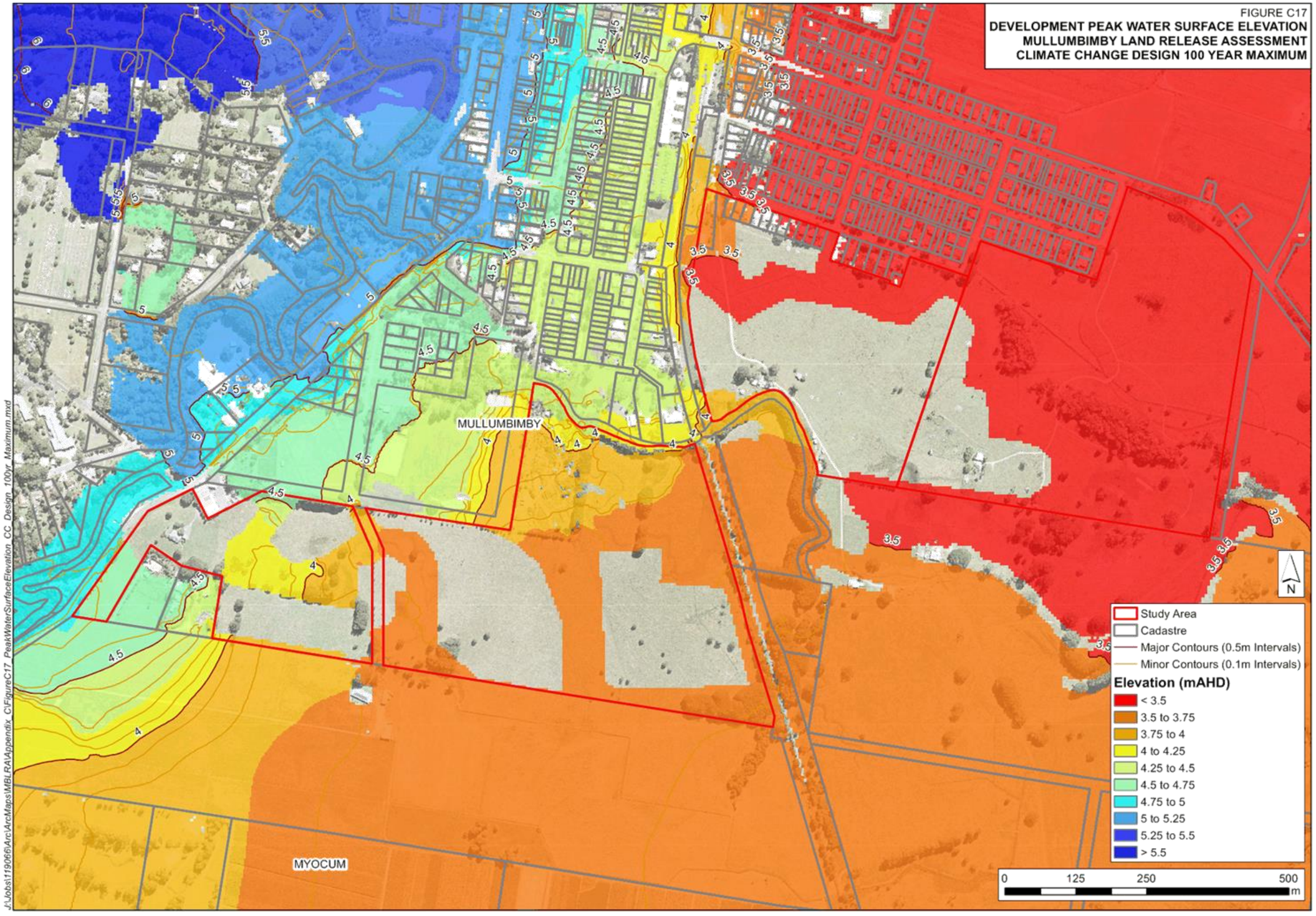

FIGURE C12
DEVELOPMENT HYDRAULIC HAZARD
MULLUMBIMBY LAND RELEASE ASSESSMENT
1% AEP EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Hydraulic Hazard
1 - Low Hazard
2 - Intermediate Hazard
3 - High Hazard
0
125
250
500
m
J:\Jobs\119066\ArcArcMaps\MBLRA\Appendix_C\FigureC12_Hydraulic_Hazard_100yr.mxd

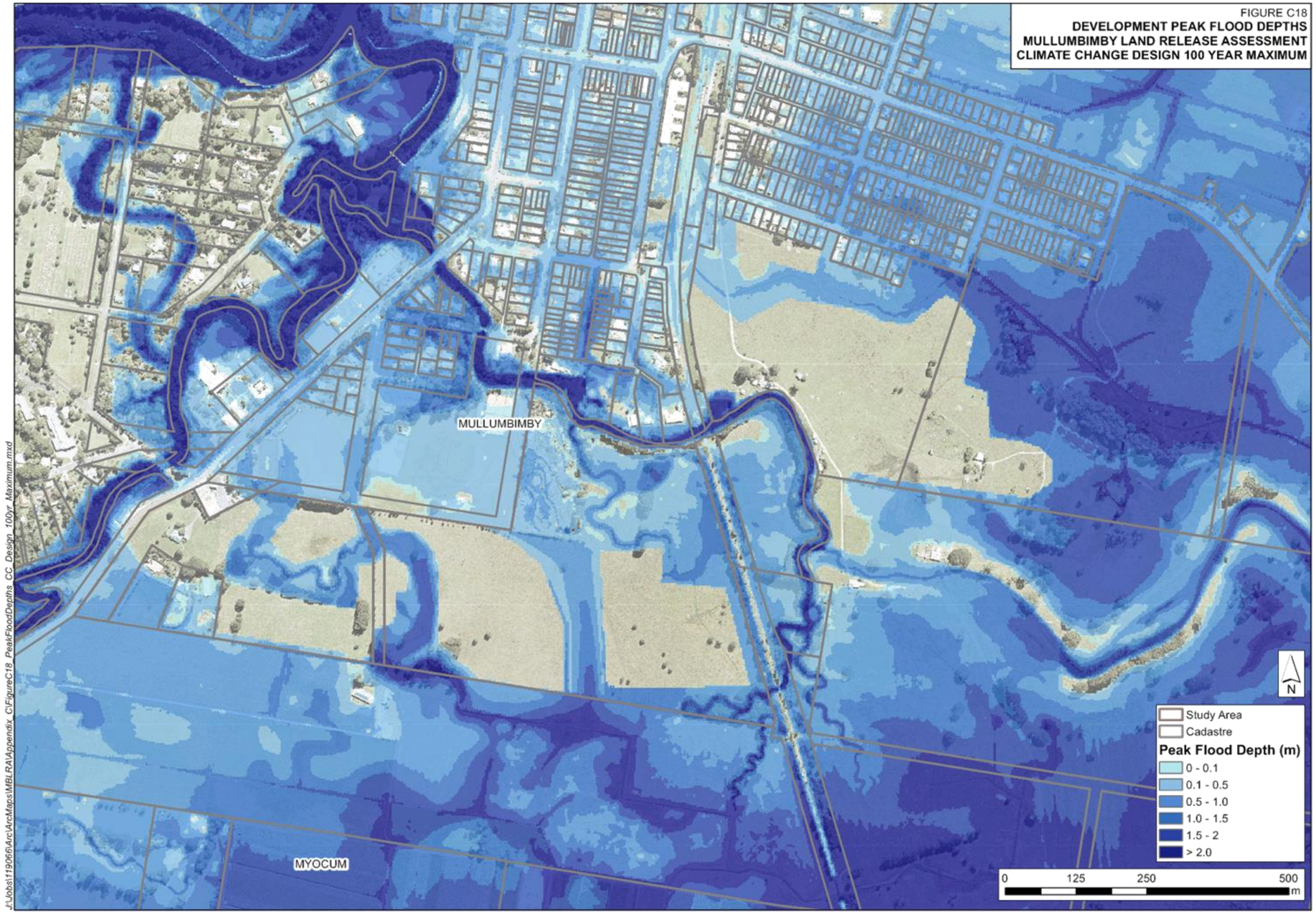

FIGURE C13
DEVELOPMENT PEAK WATER SURFACE ELEVATION
MULLUMBIMBY LAND RELEASE ASSESSMENT
0.2% AEP EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Major Contours (0.5m Intervals)
Minor Contours (0.1m Intervals)
Elevation (mAHD)
< 2.5
2.5 to 2.75
2.75 to 3
3 to 3.25
3.25 to 3.5
3.5 to 3.75
3.75 to 4
4 to 4.25
4.25 to 4.5
> 4.5
0
125
250
500
m
J:\Jobs\119066\ArcMaps\MBLRAAppendix_C\FigureC13_PeakWaterSurfaceElevation_500yr.mxd

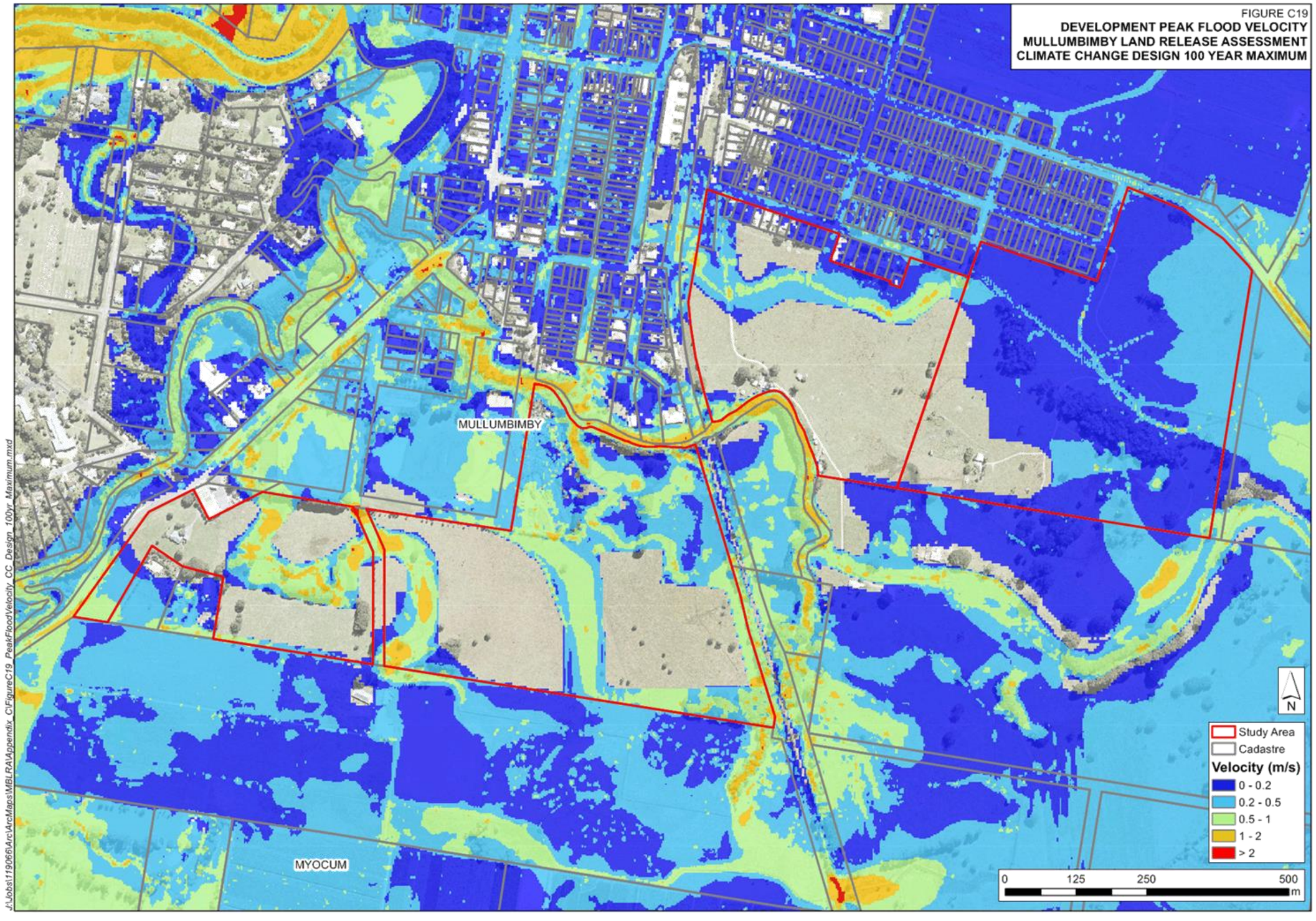

FIGURE C14
DEVELOPMENT PEAK FLOOD DEPTHS
MULLUMBIMBY LAND RELEASE ASSESSMENT
0.2% AEP EVENT
MULLUMBIMBY
MYOCUM
J:\Jobs\119066\Arc\ArcMaps\MBLRA\Appendix C\FigureC14_PeakFloodDepths_500yr.mxd
N
Study Area
Cadastre
Peak Flood Depth (m)
0 - 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2
> 2.0
0
125
250
500
m

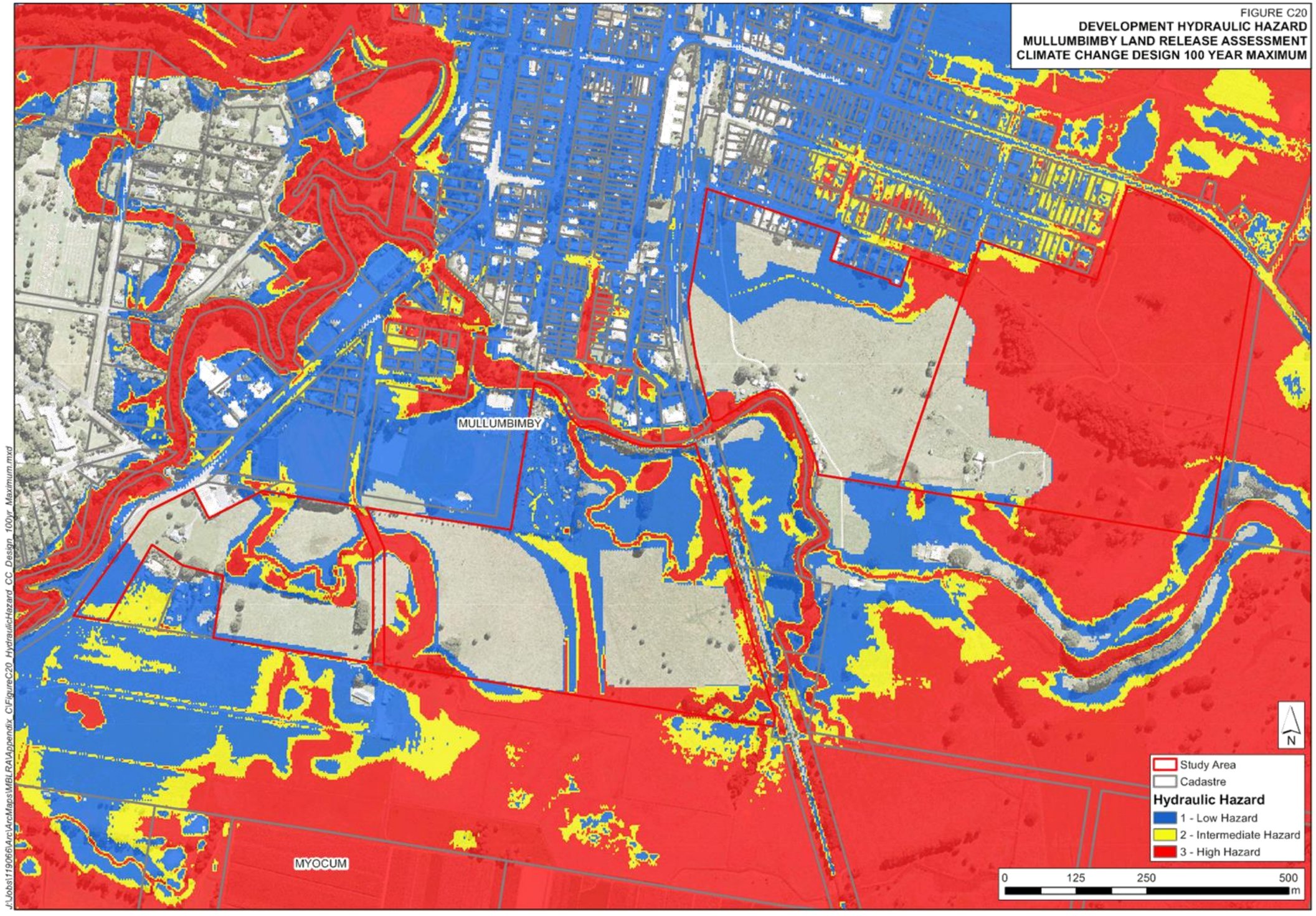

FIGURE C15
DEVELOPMENT PEAK FLOOD VELOCITY
MULLUMBIMBY LAND RELEASE ASSESSMENT
0.2% AEP EVENT
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Velocity (m/s)
0 - 0.2
0.2 - 0.5
0.5 - 1
1 - 2
> 2
0
125
250
500
m
J:\Jobs\119056\4\Arc\ArcMaps\MBLRAAppendix C\FigureC15_PeakFloodVelocity_500yr.mxd

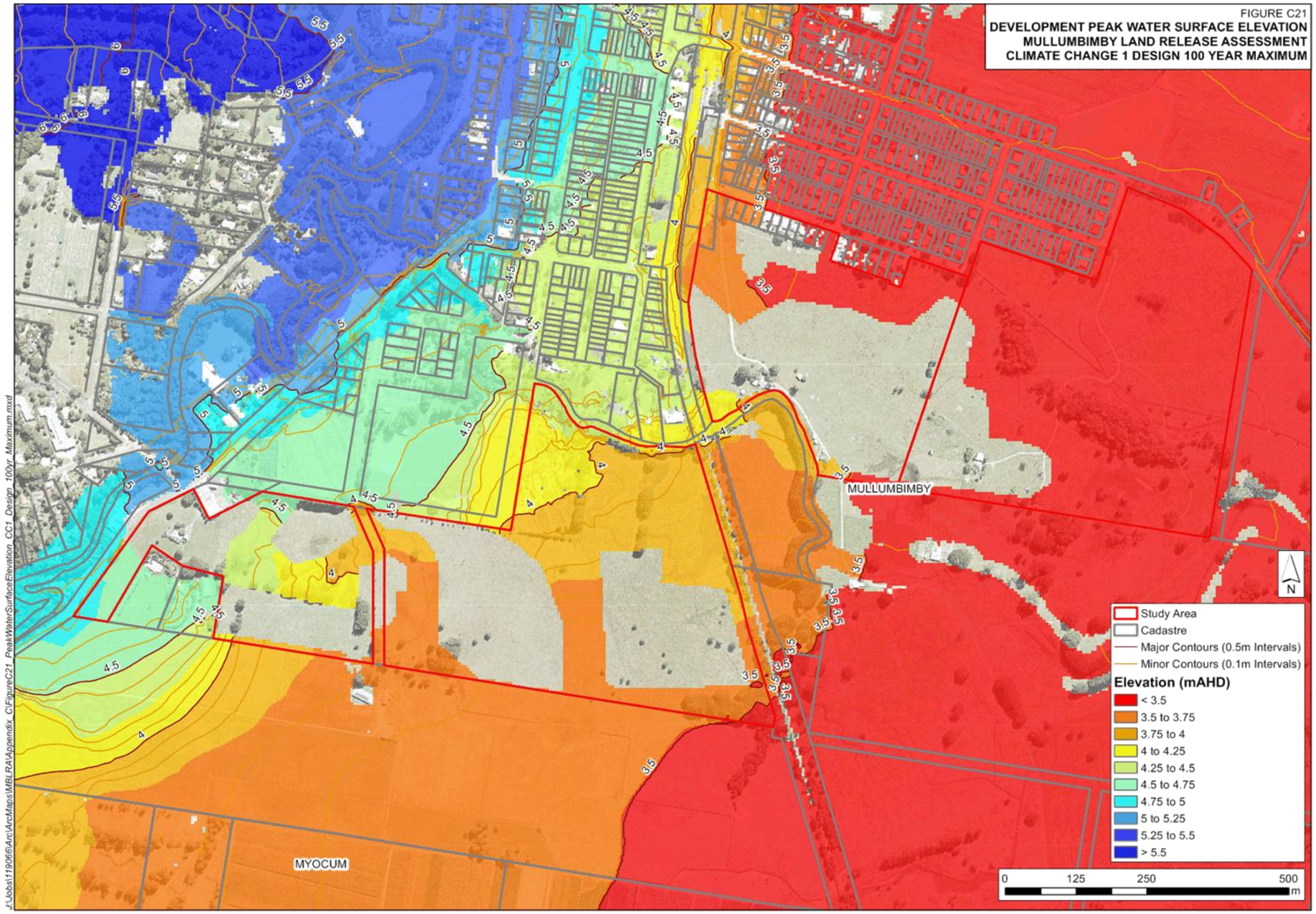

FIGURE C16
DEVELOPMENT HYDRAULIC HAZARD
MULLUMBIMBY LAND RELEASE ASSESSMENT
0.2% AEP EVENT
MULLUMBIMBY
MYOCUM
J:\Jobs\119066\ArcArcMaps\MBLRA\Appendix_C\FigureC16_Hydraulic_Hazard_500yr.mxd
N
Study Area
Cadastre
Hydraulic Hazard
1 - Low Hazard
2 - Intermediate Hazard
3 - High Hazard
0
125
250
500
m

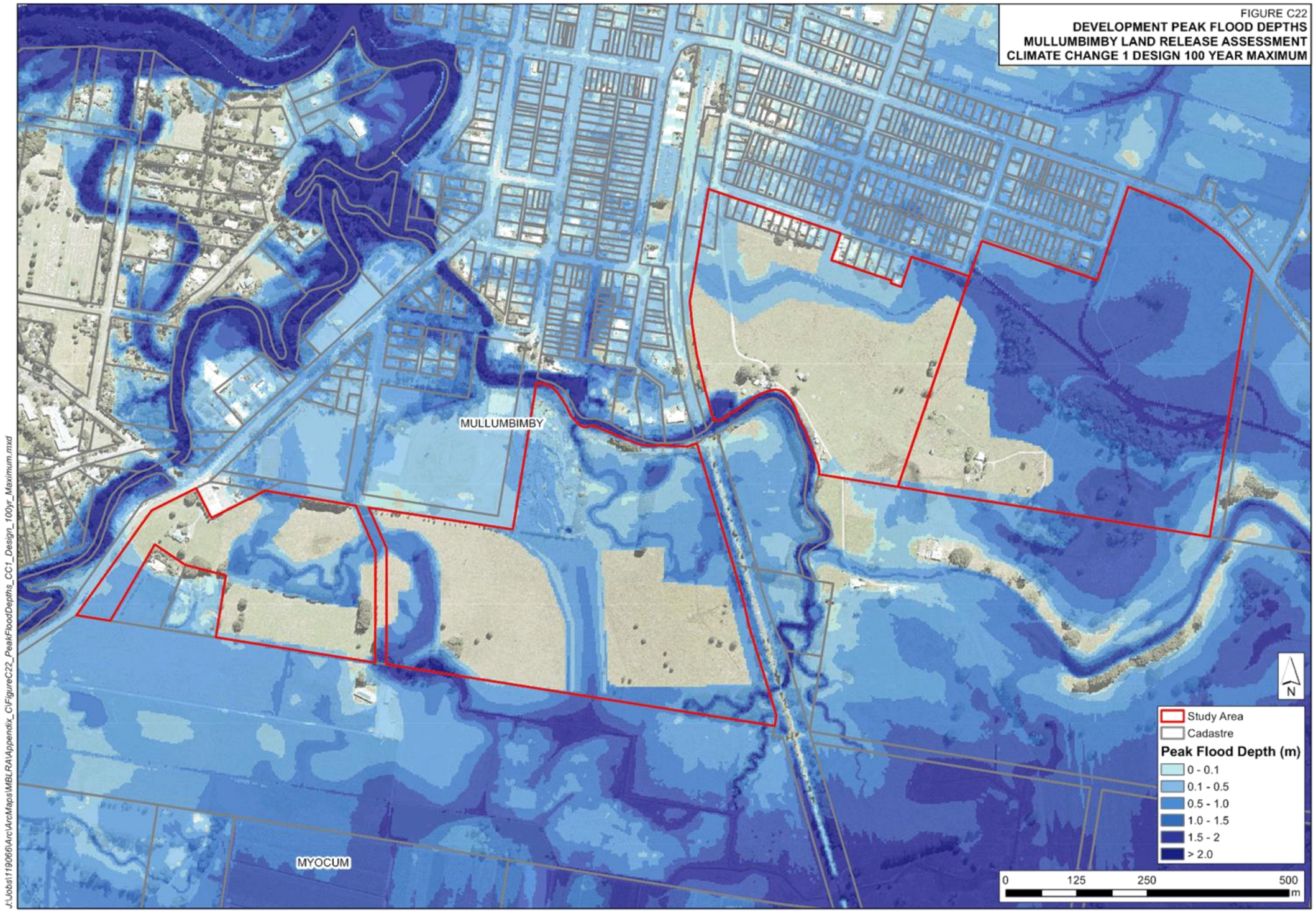

FIGURE C17
DEVELOPMENT PEAK WATER SURFACE ELEVATION
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Major Contours (0.5m Intervals)
Minor Contours (0.1m Intervals)
Elevation (mAHD)
< 3.5
3.5 to 3.75
3.75 to 4
4 to 4.25
4.25 to 4.5
4.5 to 4.75
4.75 to 5
5 to 5.25
5.25 to 5.5
> 5.5
0
125
250
500
m
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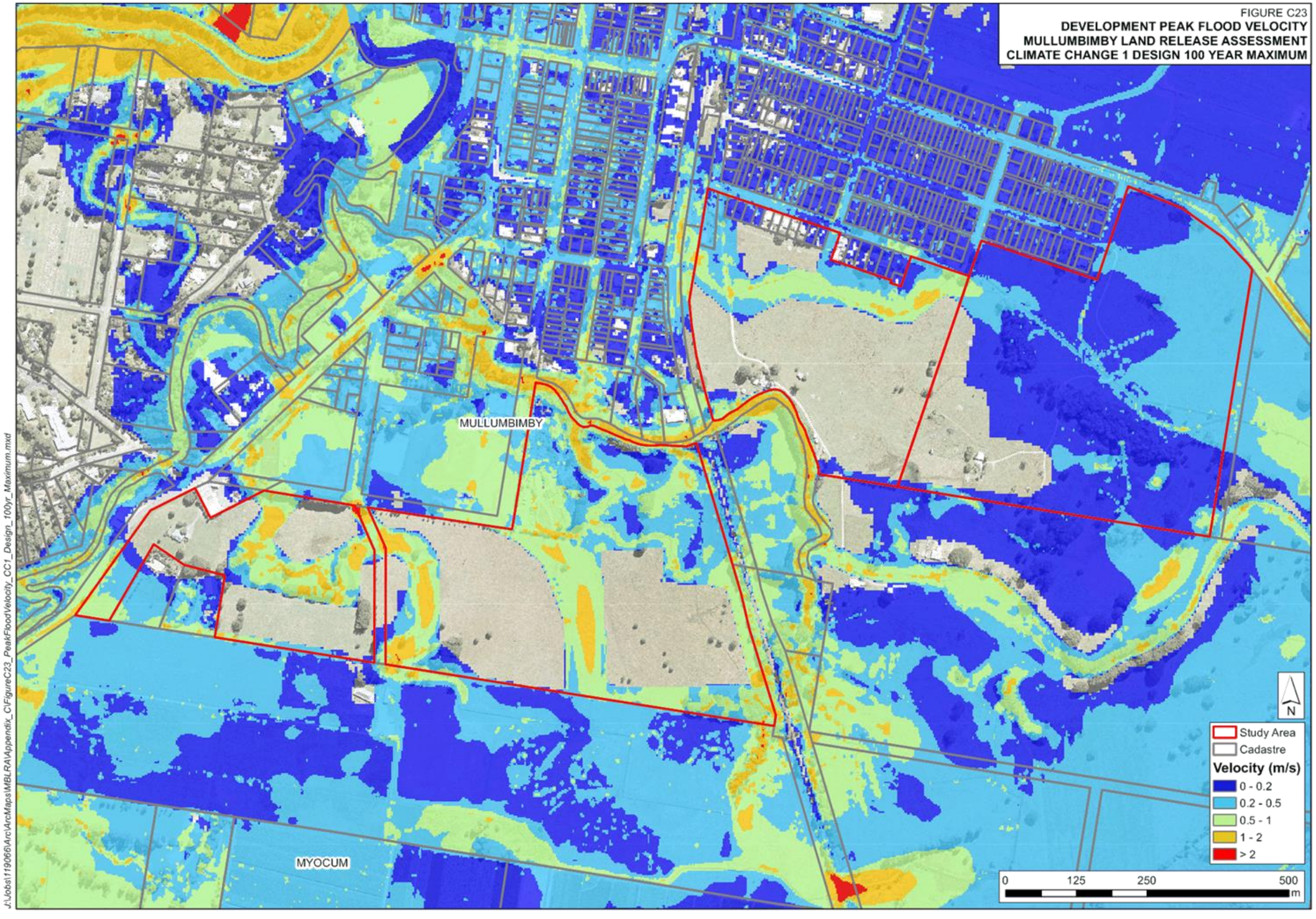

FIGURE C18
DEVELOPMENT PEAK FLOOD DEPTHS
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Peak Flood Depth (m)
0 - 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2
> 2.0
0
125
250
500
m
J:\Jobs\119066\Arc\ArcMaps\MBLRA\Appendix_C\FigureC18_PeakFloodDepths_CC_Design_100yr_Maximum.mxd

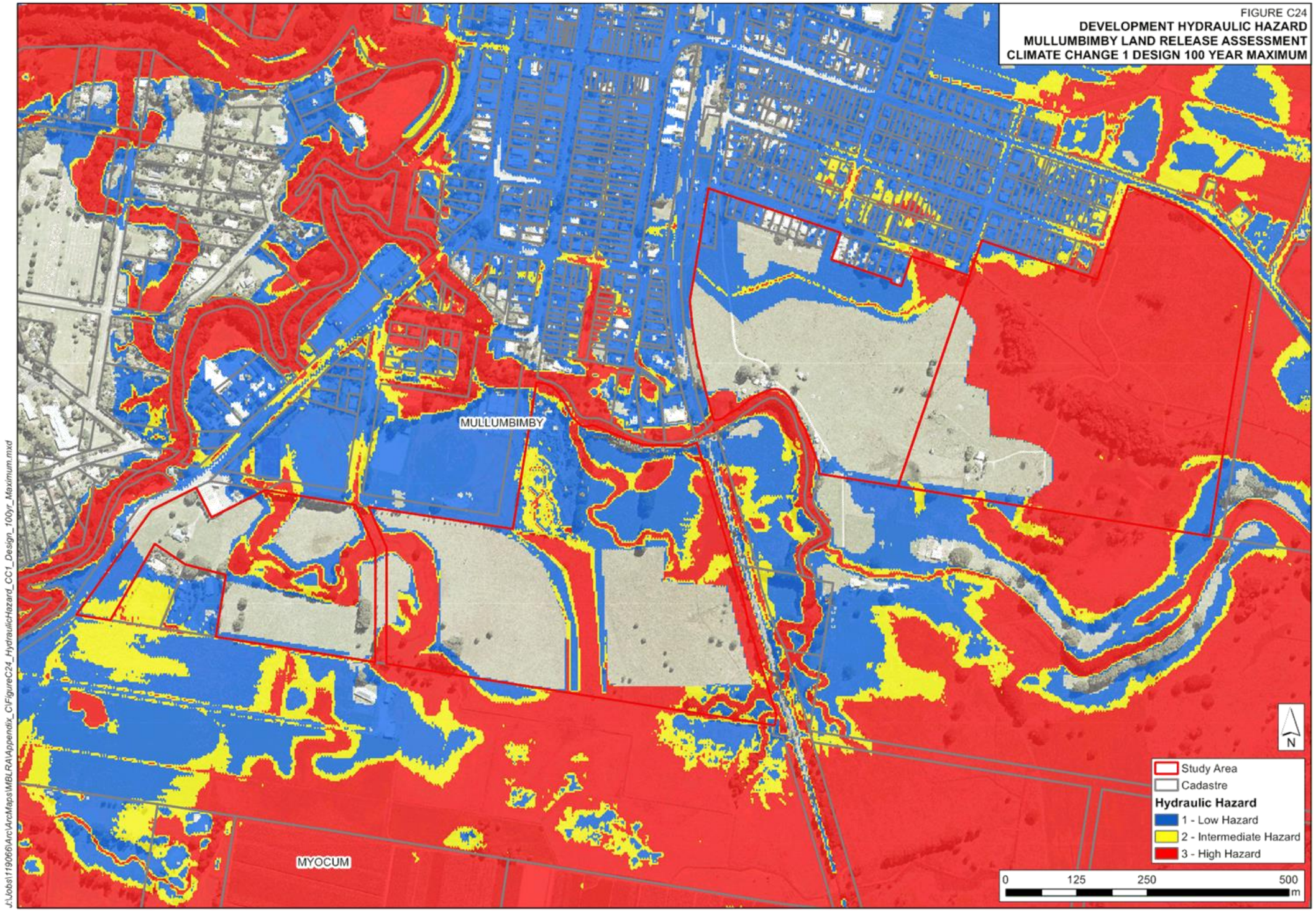

FIGURE C19
DEVELOPMENT PEAK FLOOD VELOCITY
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Velocity (m/s)
0 - 0.2
0.2 - 0.5
0.5 - 1
1 - 2
> 2
0
125
250
500
m
J:\Jobs\119066\ArcMaps\MBLRAAppendix_C\FigureC19_PeakFloodVelocity_CC_Design_100yr_Maximum.mxd

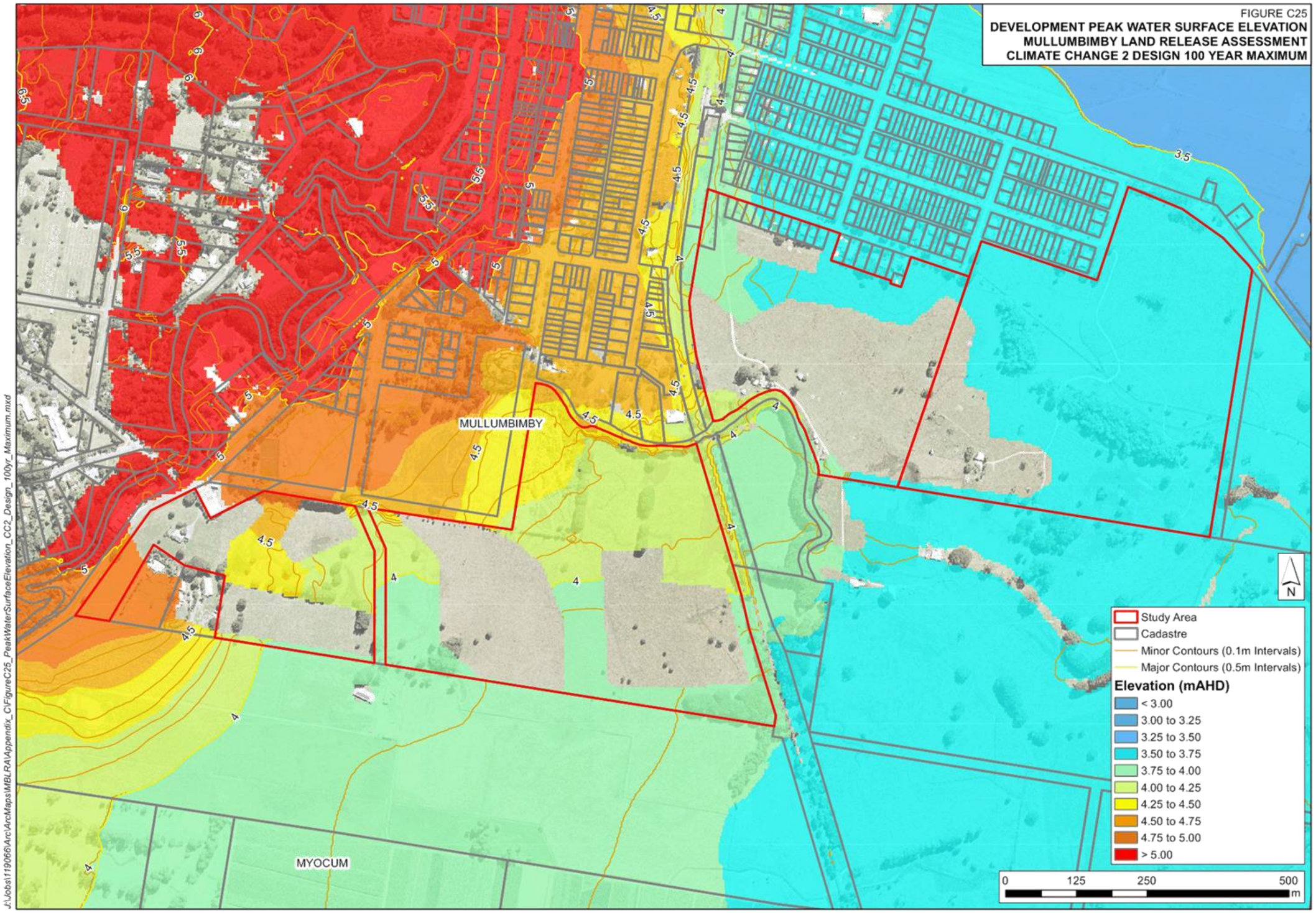

FIGURE C20
DEVELOPMENT HYDRAULIC HAZARD
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Hydraulic Hazard
1 - Low Hazard
2 - Intermediate Hazard
3 - High Hazard
0
125
250
500
m
J:\Jobs\119066\ArcMaps\MBLRA\Appendix_C\FigureC20_HydraulicHazard_CC_Design_100yr_Maximum.mxd

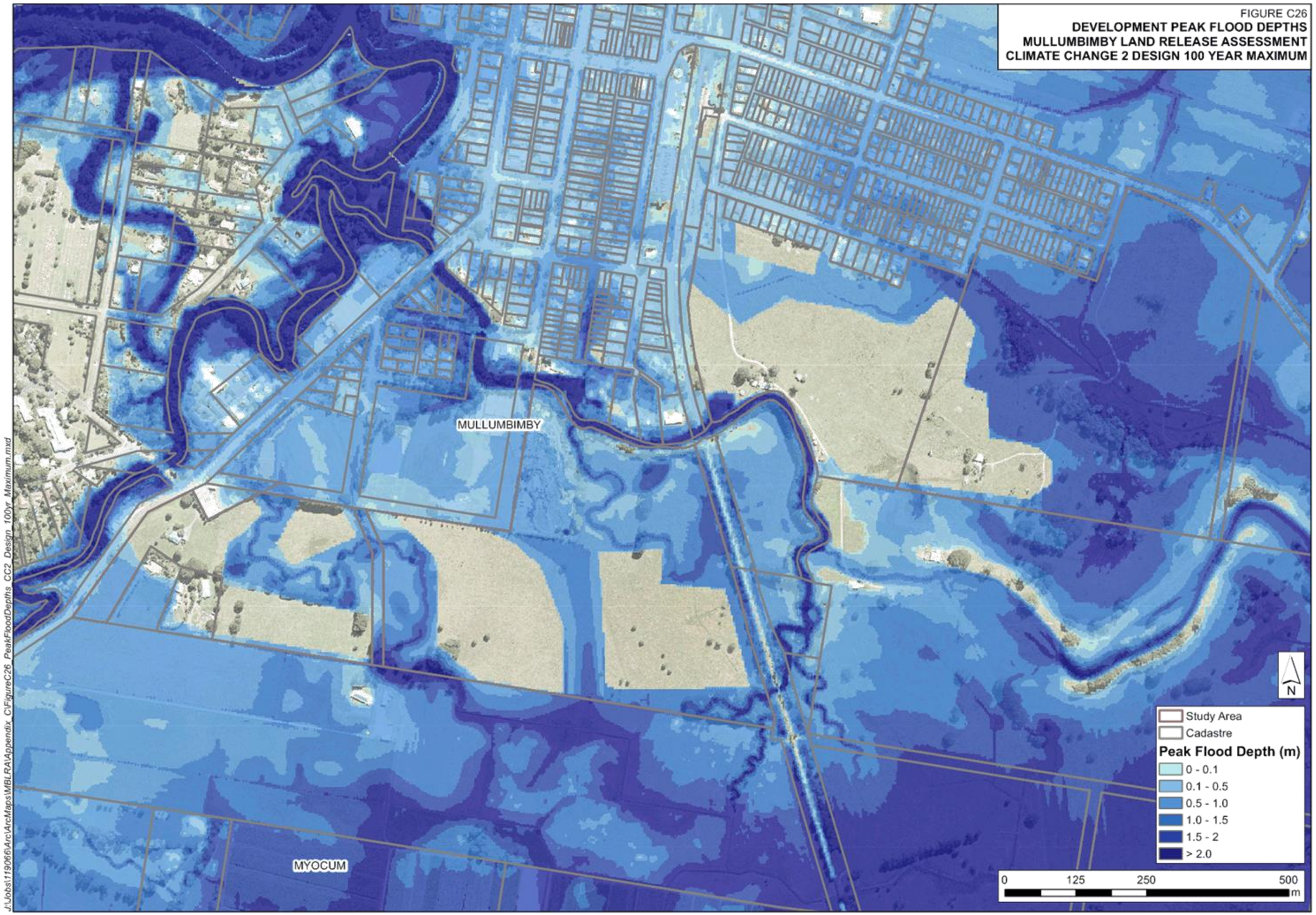

FIGURE C21
DEVELOPMENT PEAK WATER SURFACE ELEVATION
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 1 DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Major Contours (0.5m Intervals)
Minor Contours (0.1m Intervals)
Elevation (mAHD)
< 3.5
3.5 to 3.75
3.75 to 4
4 to 4.25
4.25 to 4.5
4.5 to 4.75
4.75 to 5
5 to 5.25
5.25 to 5.5
> 5.5
0
125
250
500
m
J:\Jobs\119066\ArcIArcMaps\MBLRA\Appendix_C\FigureC21_PeakWaterSurfaceElevation_CC1_Design_100yr_Maximum.mxd

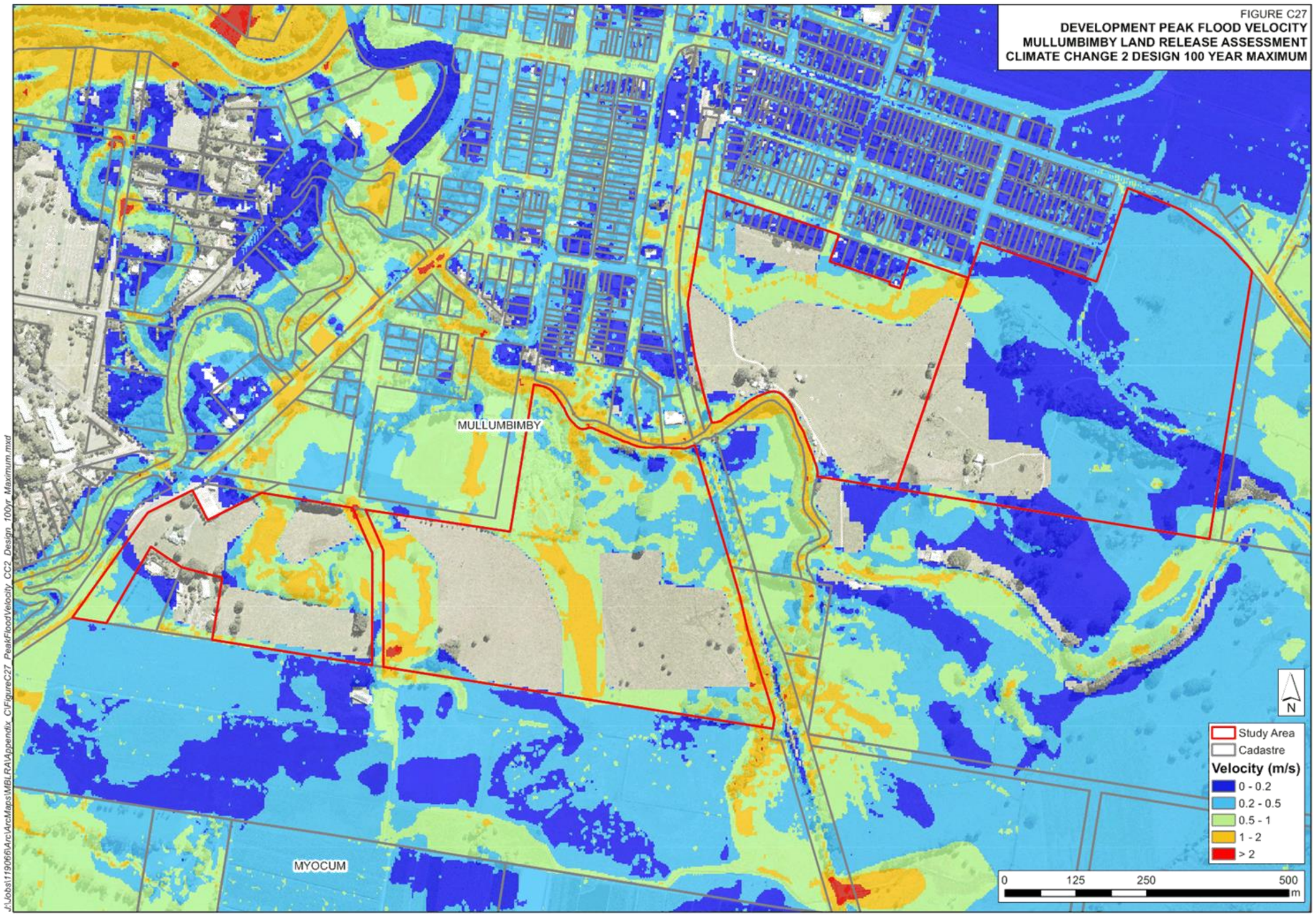

FIGURE C22
DEVELOPMENT PEAK FLOOD DEPTHS
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 1 DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Peak Flood Depth (m)
0 - 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2
> 2.0
0
125
250
500
m
J:\Jobs\119066\ArcMaps\MBLRA\Appendix_C\FigureC22_PeakFloodDepths_CC1_Design_100yr_Maximum.mxd

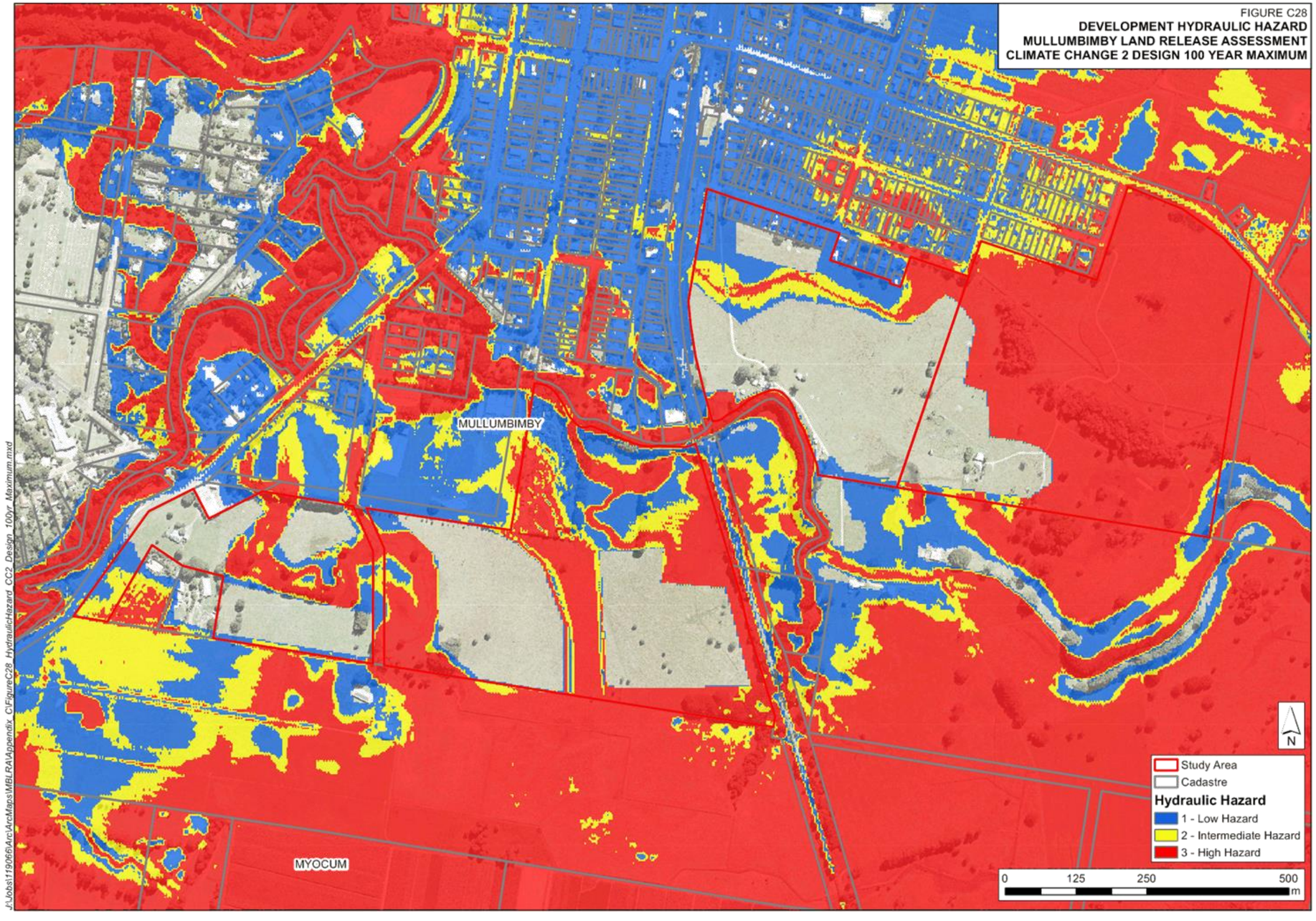

FIGURE C23
DEVELOPMENT PEAK FLOOD VELOCITY
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 1 DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Velocity (m/s)
0 - 0.2
0.2 - 0.5
0.5 - 1
1 - 2
> 2
0
125
250
500
m
J:\Jobs\119066\ArcMaps\MBLRA\Appendix_C\FigureC23_PeakFloodVelocity_CC1_Design_100yr_Maximum.mxd

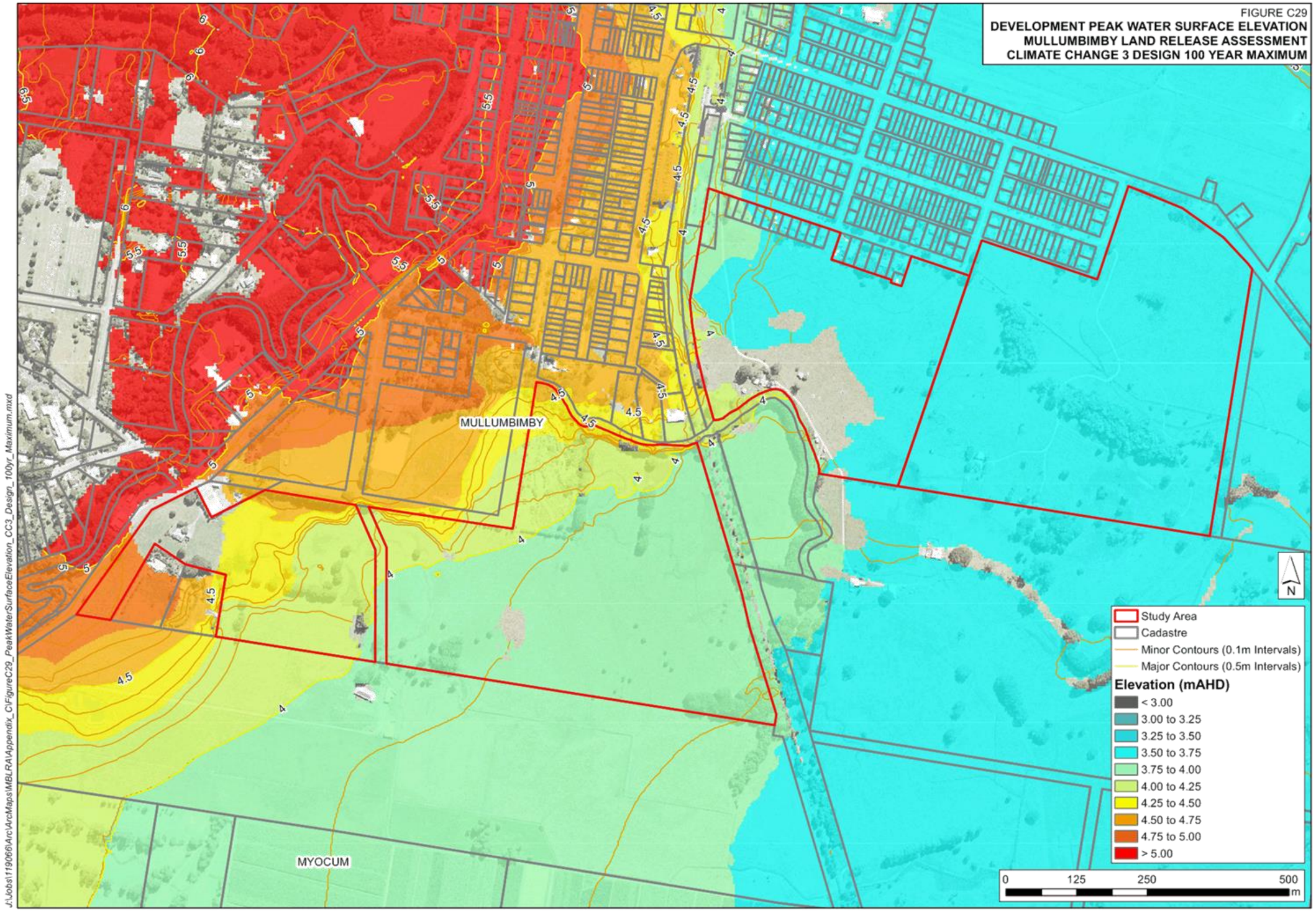

FIGURE C24
DEVELOPMENT HYDRAULIC HAZARD
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 1 DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Hydraulic Hazard
1 - Low Hazard
2 - Intermediate Hazard
3 - High Hazard
0
125
250
500
m
J:\Jobs\119066\ArcMaps\MBLRA\Appendix_C\FigureC24_HydraulicHazard_CC1_Design_100yr_Maximum.mxd

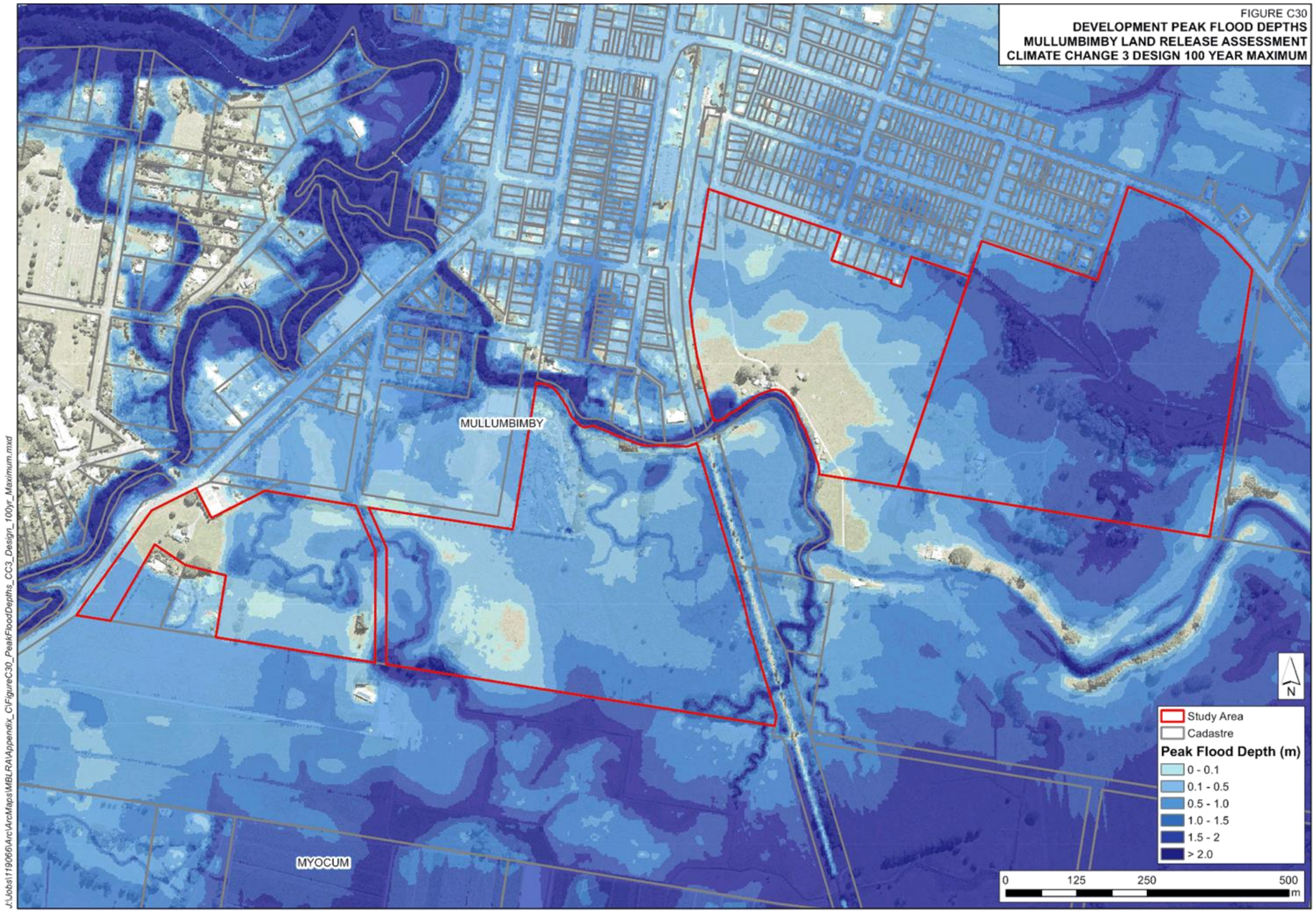

FIGURE C25
DEVELOPMENT PEAK WATER SURFACE ELEVATION
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 2 DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Minor Contours (0.1m Intervals)
Major Contours (0.5m Intervals)
Elevation (mAHD)
< 3.00
3.00 to 3.25
3.25 to 3.50
3.50 to 3.75
3.75 to 4.00
4.00 to 4.25
4.25 to 4.50
4.50 to 4.75
4.75 to 5.00
> 5.00
0
125
250
500
m
J:\Jobs\119066\Arc\ArcMaps\MBLRAAppendix_C\FigureC25_PeakWaterSurfaceElevation_CC2_Design_100yr_Maximum.mxd

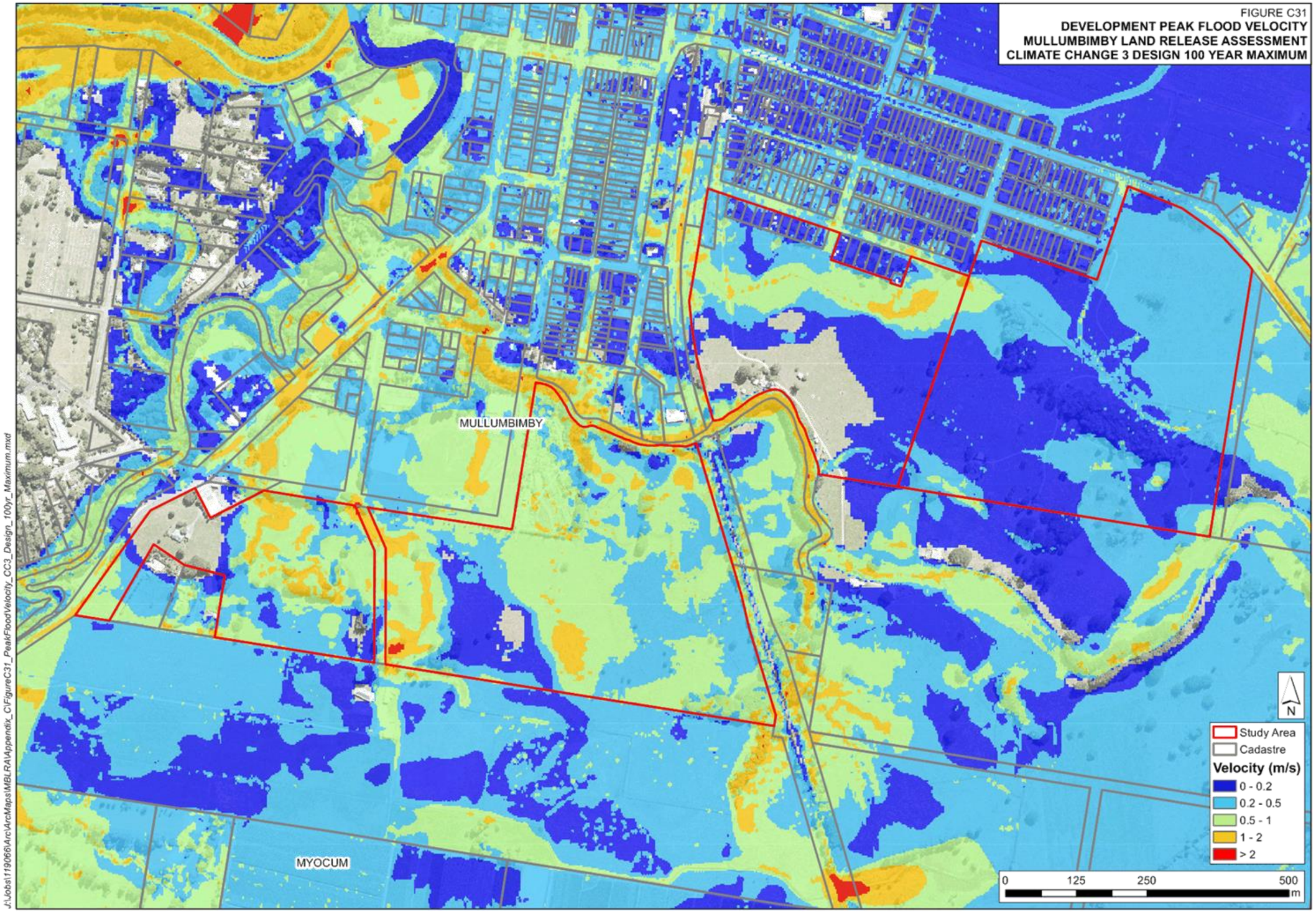

FIGURE C26
DEVELOPMENT PEAK FLOOD DEPTHS
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 2 DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Peak Flood Depth (m)
0 - 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2
> 2.0
0
125
250
500
m
J:\Jobs\119066\ArcMaps\MBLRA\Appendix_C\FigureC26_PeakFloodDepths_CC2_Design_100yr_Maximum.mxd

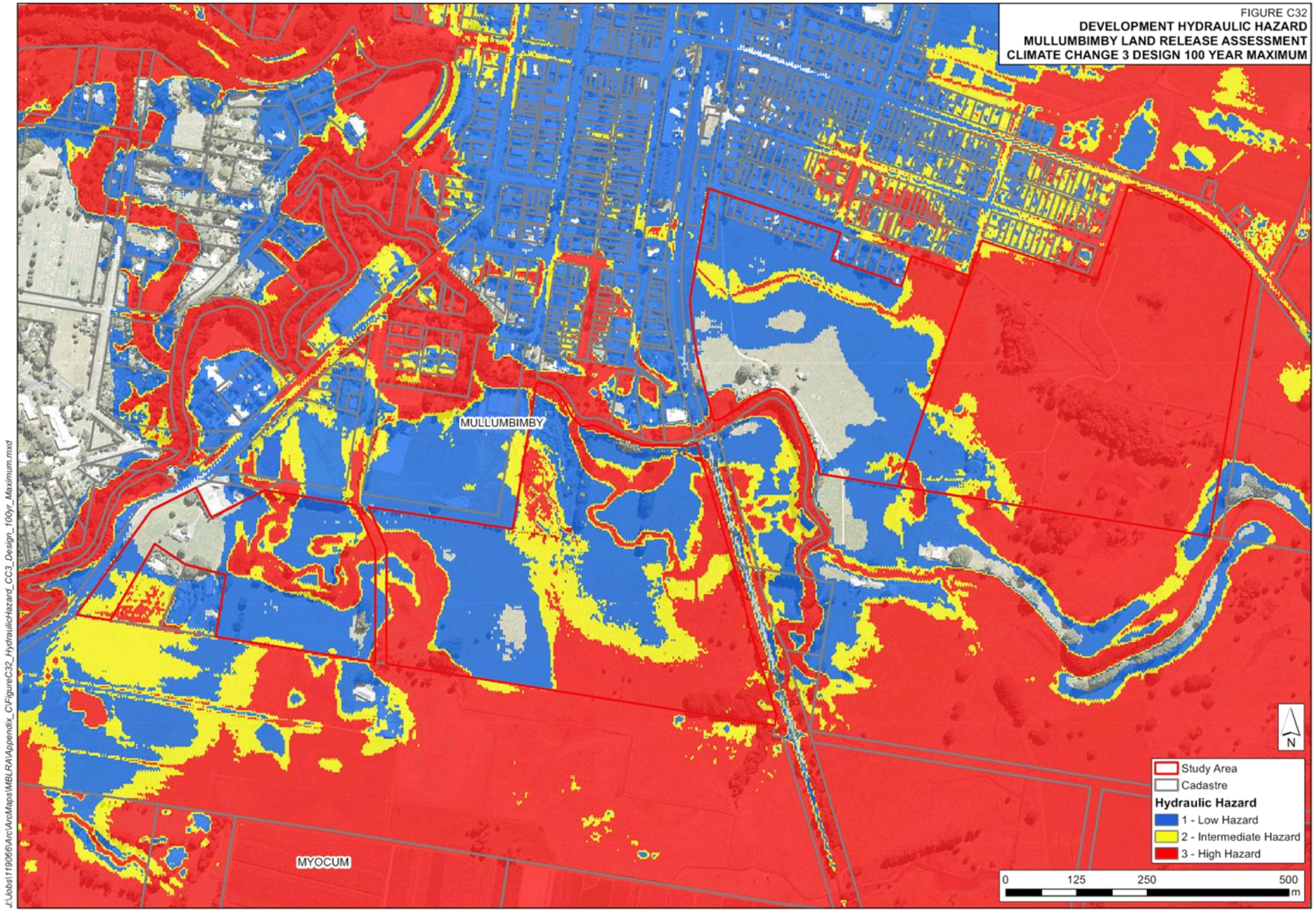

FIGURE C27
DEVELOPMENT PEAK FLOOD VELOCITY
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 2 DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Velocity (m/s)
0 - 0.2
0.2 - 0.5
0.5 - 1
1 - 2
> 2
0
125
250
500
m
J:\Jobs\119066\4\Arc\ArcMaps\MBLRAVAppendix_C\FigureC27_PeakFloodVelocity_CC2_Design_100yr_Maximum.mxd

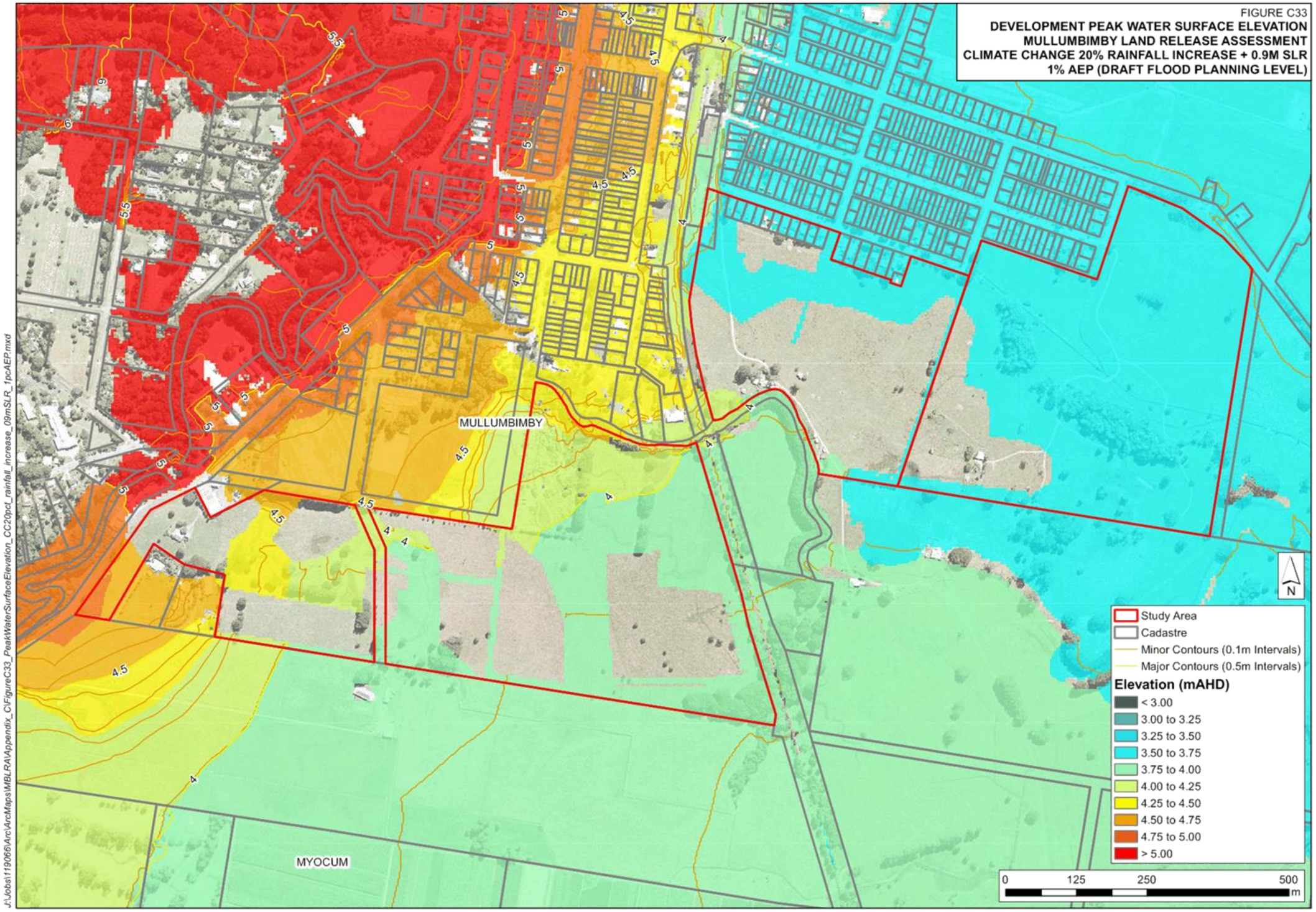

FIGURE C28
DEVELOPMENT HYDRAULIC HAZARD
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 2 DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Hydraulic Hazard
1 - Low Hazard
2 - Intermediate Hazard
3 - High Hazard
0
125
250
500
m
J:\Jobs\119066\ArcArcMaps\MBLRA\Appendix_C\FigureC28_HydraulicHazard_CC2_Design_100yr_Maximum.mxd

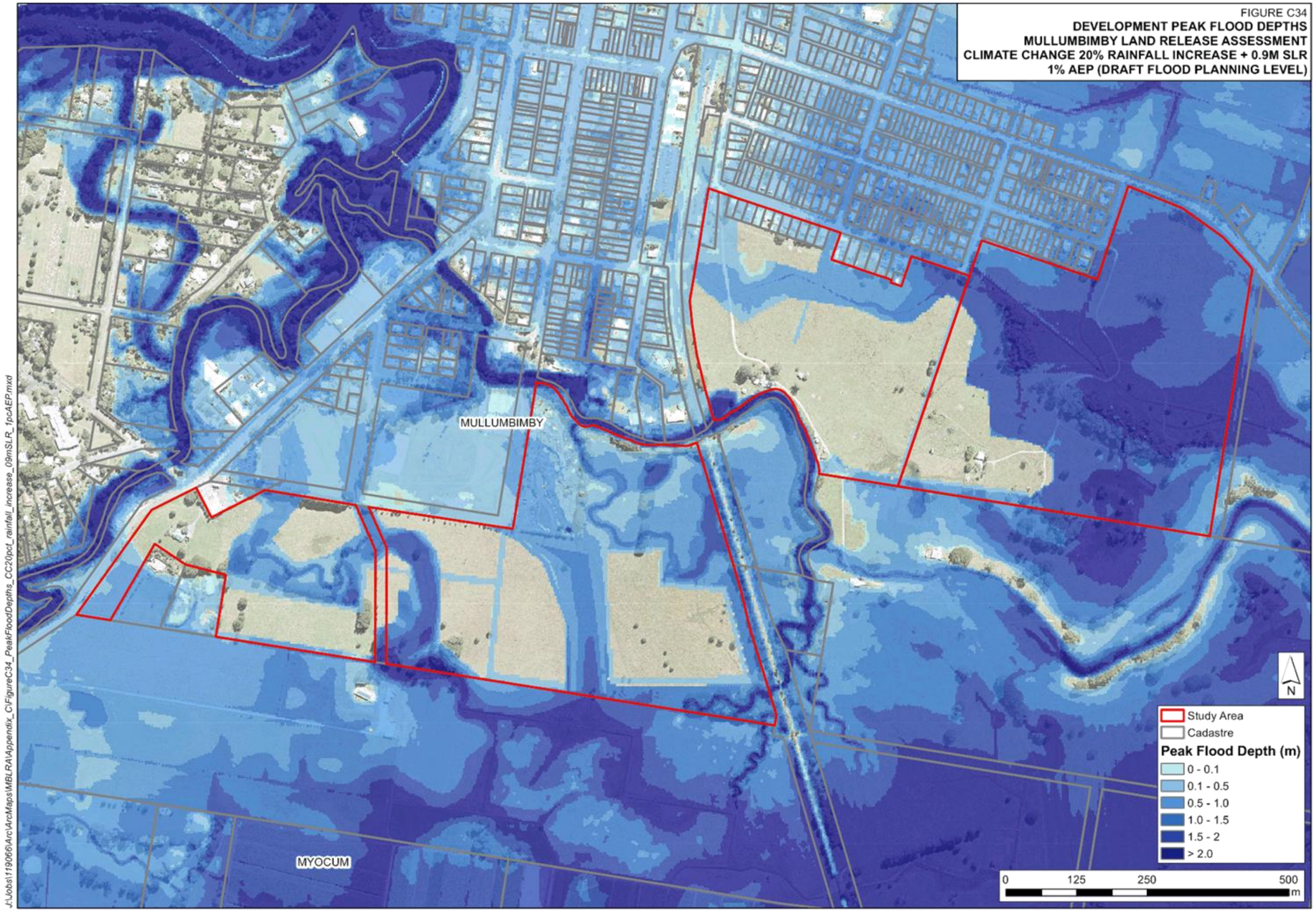

FIGURE C29
DEVELOPMENT PEAK WATER SURFACE ELEVATION
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 3 DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Minor Contours (0.1m Intervals)
Major Contours (0.5m Intervals)
Elevation (mAHD)
< 3.00
3.00 to 3.25
3.25 to 3.50
3.50 to 3.75
3.75 to 4.00
4.00 to 4.25
4.25 to 4.50
4.50 to 4.75
4.75 to 5.00
> 5.00
0
125
250
500
m
J:\Jobs\119066\Arc\ArcMaps\MBLRA\Appendix_C\FigureC29_PeakWaterSurfaceElevation_CC3_Design_100yr_Maximum.mxd

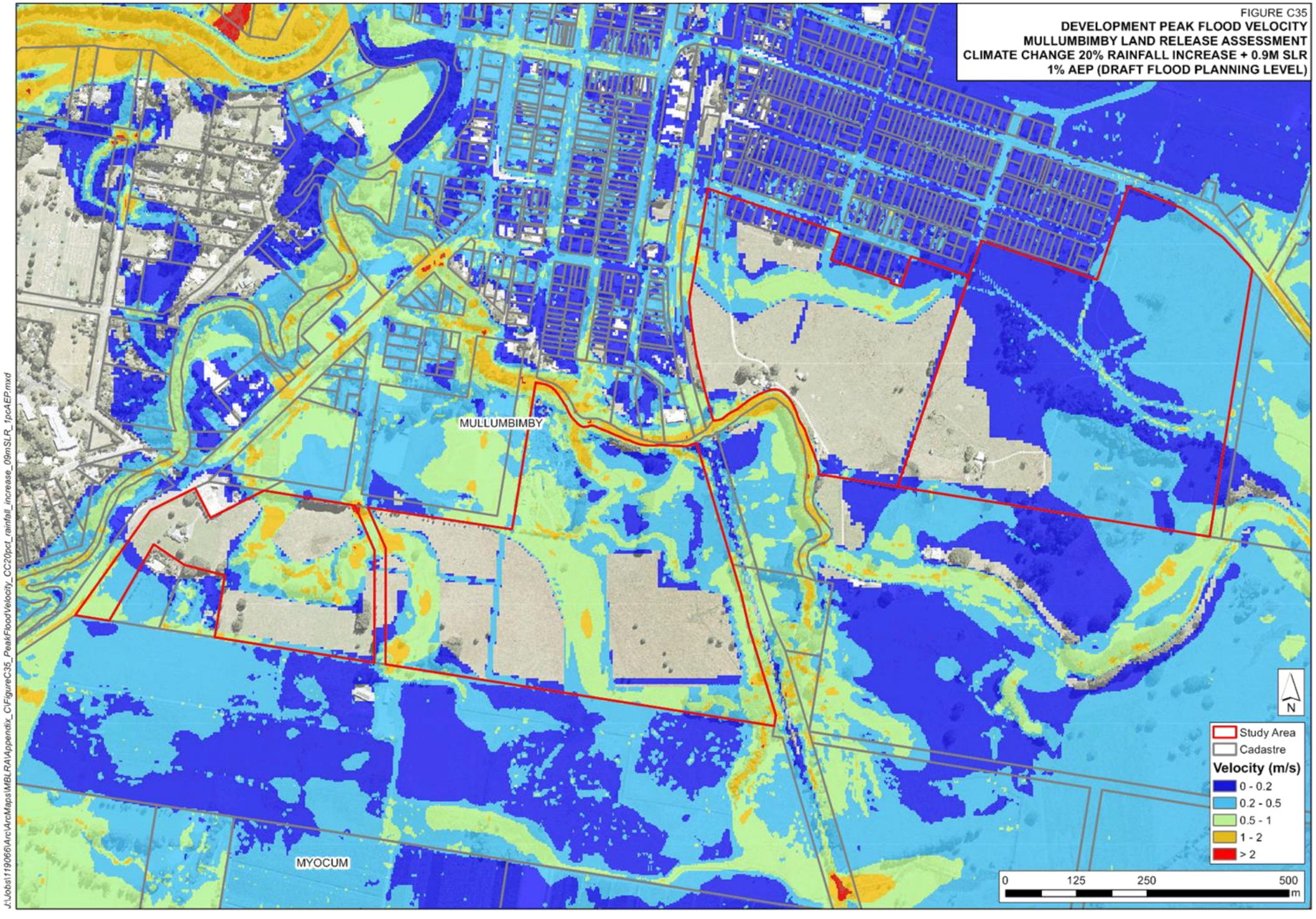

FIGURE C30
DEVELOPMENT PEAK FLOOD DEPTHS
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 3 DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Peak Flood Depth (m)
0 - 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2
> 2.0
0
125
250
500
m
J:\Jobs\119066\ArcMaps\MBLRA\Appendix_C\FigureC30_PeakFloodDepths_CC3_Design_100yr_Maximum.mxd


FIGURE C31
DEVELOPMENT PEAK FLOOD VELOCITY
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 3 DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Velocity (m/s)
0 - 0.2
0.2 - 0.5
0.5 - 1
1 - 2
> 2
0
125
250
500
m
J:\Jobs\119066\ArcMaps\MBLRA\Appendix_C\FigureC31_PeakFloodVelocity_CC3_Design_100yr_Maximum.mxd


FIGURE C32
DEVELOPMENT HYDRAULIC HAZARD
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 3 DESIGN 100 YEAR MAXIMUM
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Hydraulic Hazard
1 - Low Hazard
2 - Intermediate Hazard
3 - High Hazard
0
125
250
500
m
J:\Jobs\1190666\ArcMaps\MBLRA\Appendix_C\FigureC32_HydraulicHazard_CC3_Design_100yr_Maximum.mxd


FIGURE C33
DEVELOPMENT PEAK WATER SURFACE ELEVATION
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 20% RAINFALL INCREASE + 0.9M SLR
1% AEP (DRAFT FLOOD PLANNING LEVEL)
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Minor Contours (0.1m Intervals)
Major Contours (0.5m Intervals)
Elevation (mAHD)
< 3.00
3.00 to 3.25
3.25 to 3.50
3.50 to 3.75
3.75 to 4.00
4.00 to 4.25
4.25 to 4.50
4.50 to 4.75
4.75 to 5.00
> 5.00
0
125
250
500
m
J:\Jobs\119066\ArcMaps\MBLRA\Appendix_C\FigureC33_PeakWaterSurfaceElevation_CC20pct_rainfall_increase_09mSLR_1pcAEP.mxd


FIGURE C34
DEVELOPMENT PEAK FLOOD DEPTHS
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 20% RAINFALL INCREASE + 0.9M SLR
1% AEP (DRAFT FLOOD PLANNING LEVEL)
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Peak Flood Depth (m)
0 - 0.1
0.1 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2
> 2.0
0
125
250
500
m
J:\Jobs\119066\ArcMaps\MBLRA\Appendix_C\FigureC34_PeakFloodDepths_CC20pct_rainfall_increase_09mSLR_1pcAEP.mxd


FIGURE C35
DEVELOPMENT PEAK FLOOD VELOCITY
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 20% RAINFALL INCREASE + 0.9M SLR
1% AEP (DRAFT FLOOD PLANNING LEVEL)
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Velocity (m/s)
0 - 0.2
0.2 - 0.5
0.5 - 1
1 - 2
> 2
0
125
250
500
m
J:\Jobs\119066\ArcMaps\MBLRA\Appendix_C\FigureC35_PeakFloodVelocity_CC20pct_rainfall_increase_09mSLR_1pcAEP.mxd

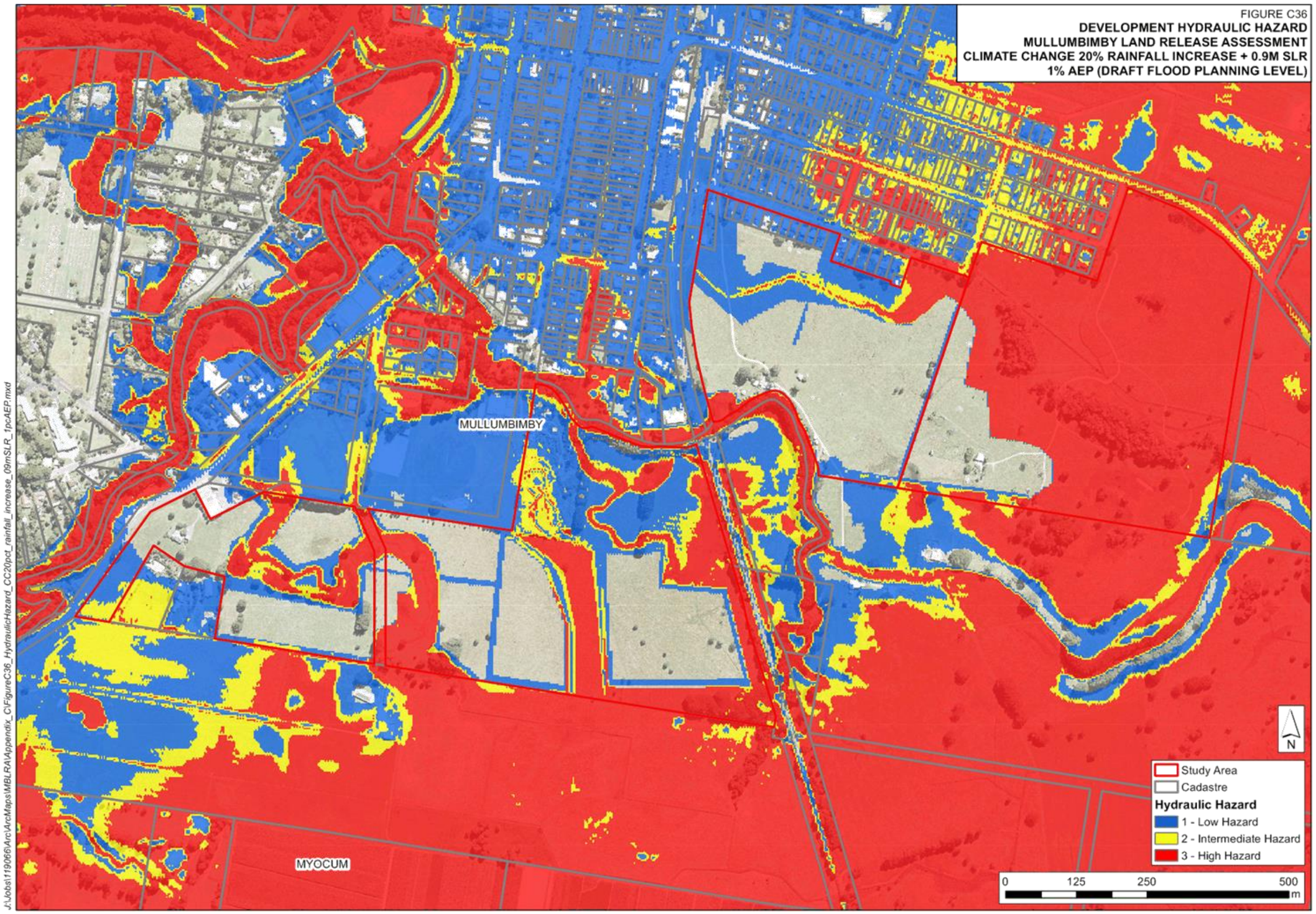
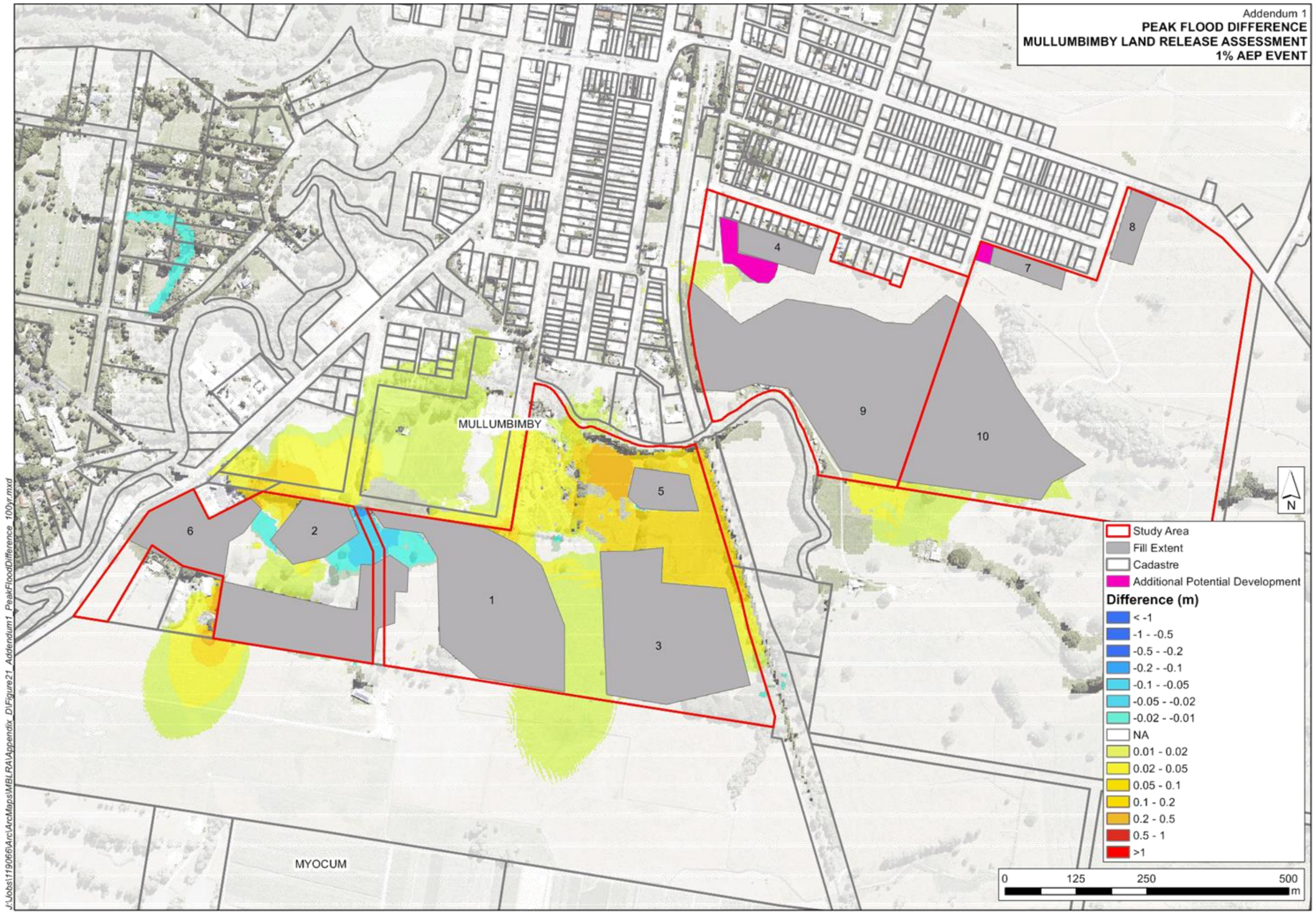

FIGURE C36
DEVELOPMENT HYDRAULIC HAZARD
MULLUMBIMBY LAND RELEASE ASSESSMENT
CLIMATE CHANGE 20% RAINFALL INCREASE + 0.9M SLR
1% AEP (DRAFT FLOOD PLANNING LEVEL)
MULLUMBIMBY
MYOCUM
N
Study Area
Cadastre
Hydraulic Hazard
1 - Low Hazard
2 - Intermediate Hazard
3 - High Hazard
0
125
250
500
m
J:\Jobs\119066\ArcVArcMaps\MBLRAIAppendix_CiFigureC36_HydraulicHazard_CC20pct_rainfall_increase_09mSLR_1pcAEP.mxd


FIGURE C37
DEVELOPMENT PEAK FLOOD DIFFERENCE
MULLUMBIMBY LAND RELEASE ASSESSMENT
1% AEP EVENT (DRAFT FLOOD PLANNING LEVEL)
MULLUMBIMBY
MYOCUM
Study Area
Cadastre
Difference (m)
< -1
-1 - -0.5
-0.5 - -0.2
-0.2 - -0.1
-0.1 - -0.05
-0.05 - -0.02
-0.02 - -0.01
-0.01 - 0.01
0.01 - 0.02
0.02 - 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.5
0.5 - 1
>1
No Longer Flooded
Newly Flooded
0
125
250
500
m
J:\Jobs\119066\Arc\ArcMaps\MBLRA\Appendix_C\FigureC37_PeakFloodDifference_1pcAEP.mxd



Appendix D


Addendum 1
PEAK FLOOD DIFFERENCE
MULLUMBIMBY LAND RELEASE ASSESSMENT
1% AEP EVENT
MULLUMBIMBY
MYOCUM
1
2
3
4
5
6
7
8
9
10
N
Study Area
Fill Extent
Cadastre
Additional Potential Development
Difference (m)
< -1
-1 - -0.5
-0.5 - -0.2
-0.2 - -0.1
-0.1 - -0.05
-0.05 - -0.02
-0.02 - -0.01
NA
0.01 - 0.02
0.02 - 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.5
0.5 - 1
>1
0
125
250
500
m
J:\Jobs\119066\Arc\ArcMaps\MBLRAIAppendix_D\Figure21_Addendum1_PeakFloodDifference_100yr.mxd



Appendix E

- Cost Estimate Rates and Examples

Cost Estimate Unit Prices (used in Section 7)

	Fixed Costs	UNIT	Rate (ex GST)
Design	Design, Consultations, Approvals and Construction Management	item	$ 20,000
General	Project Management & General Construction Cost (15% of subtotal) (Site establishment, security fencing etc) (15% of earthworks))	item	15%
Basin Earthworks	Removal of top soil and vegetation (100 mm)	m^3	$ 16
	Excavation	m^3	$ 28
	Improvement of Excavated material	m^3	$ 18
	Disposal of Contaminated Spoil	m^3	$ 80
	Haulage of imported Fill	m^3	$ 18
	Fill in embankment	m^3	$ 55
	Fuel	l/m^3	$ 0.75
	Landscape Planting	m^2	$ 63.00
	Rock	m^3	$ 70.00
	Boulders	m^3	$ 410.00
	Compaction	m^3	$ 8
	Top soil placement/seeding	m^2	$ 15
	Bio-Detention Basin	m^2	$ 280
	Wetland	m^2	$ 112
Pipe and Culvert Upgrades	Pipe 450 x 2.44 RJ Class 4	m	$ 120
	Pipe 600 x 2.44 RJ Class 4	m	$ 172
	Pipe 675 x 2.44 RJ Class 4	m	$ 220
	Pipe 750 x 2.44 RJ Class 4	m	$ 280
	Pipe 825 x 2.44 RJ Class 4	m	$ 340
	Pipe 900 x 2.44 RJ Class 4	m	$ 356
	Pipe 1050 x 2.44 RJ Class 4	m	$ 437
	Single Cell Headwall to suit 450DN pipe	item	$ 380
	Single Cell Headwall to suit 600DN pipe	item	$ 410
	Single Cell Headwall to suit 675DN pipe	item	$ 550
	Single Cell Headwall to suit 750DN pipe	item	$ 720
	Single Cell Headwall to suit 825DN pipe	item	$ 840
	Single Cell Headwall to suit 900DN pipe	item	$ 945
	Single Cell Headwall to suit 1050DN pipe	item	$ 1,501
	Excavate Trench	m^3	$ 80
	Install Culvert	m	$ 280
	Backfill and Site Remediation	m	$ 180
Fill Pad Earthworks	Removal of top soil and vegetation (100 mm)	m^3	$ 16
	Total Fill Volume in Pad (assume all imported, including delivery)	m^3	$ 80
	Cut Available*	m^3	$ 28
	Improvement of Excavated material*	m^3	$ 18
	Remaining Imported Fill Required (includes delivery)*	m^3	$ 80
	Fuel	l/m^3	$ 0.75
	Compaction	m^2	$ 8
extra	Contingency	item	20%

Lot 1 - Fill Cost Estimates (Table 23 and 24)

	Fixed Costs	UNIT	QUANTITY	Rate (ex GST)	COST
General	Design, Consultations, Approvals and Construction Management	item	1	$ 20,000.00	$ 20,000.00
	Project Management & General Construction Cost (15% of subtotal) (Site establishment, security fencing etc) (15% of	item	1	15%	$ 44,460.00
Basin and Fill Pad Earthworks	Removal of top soil and vegetation (100 mm)	m^3	1,900	$ 16.00	$ 30,400.00
	Excavation	m^3	1,900	$ 28.00	$ 53,200.00
	~~Improvement of Excavated material~~	~~m^3~~	~~0~~	~~$ 18.00~~	~~$ -~~
	~~Disposal of Contaminated Spoil~~	~~m^3~~	~~0~~	~~$ 80.00~~	~~$ -~~
	~~Haulage of Imported Fill~~	~~m^3~~	~~0~~	~~$ 18.00~~	~~$ -~~
	~~Fill in embankment~~	~~m^3~~	~~0~~	~~$ 55.00~~	~~$ -~~
	~~Fuel~~	~~l/m^3~~	~~0~~	~~$ 0.75~~	~~$ -~~
	~~Compaction~~	~~m^2~~	~~0~~	~~$ 8.00~~	~~$ -~~
	~~Top soil placement/seeding~~	~~m^2~~	~~0~~	~~$ 12.50~~	~~$ -~~
	~~Bio-Detention Basin~~	~~m^2~~	~~0~~	~~$ 280.00~~	~~$ -~~
	~~Wetland~~	~~m^2~~	~~0~~	~~$ 112.00~~	~~$ -~~
Pipe and Culvert Upgrades	~~Pipe 450 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 119.84~~	~~$ -~~
	~~Pipe 600 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 172.31~~	~~$ -~~
	~~Pipe 675 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 220.00~~	~~$ -~~
	~~Pipe 750 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 279.81~~	~~$ -~~
	~~Pipe 825 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 340.00~~	~~$ -~~
	~~Pipe 900 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 356.00~~	~~$ -~~
	~~Pipe 1050 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 436.79~~	~~$ -~~
	~~Single Cell Headwall to suit 450DN pipe~~	~~item~~	~~0~~	~~$ 380.00~~	~~$ -~~
	~~Single Cell Headwall to suit 600DN pipe~~	~~item~~	~~0~~	~~$ 410.00~~	~~$ -~~
	~~Single Cell Headwall to suit 675DN pipe~~	~~item~~	~~0~~	~~$ 550.00~~	~~$ -~~
	~~Single Cell Headwall to suit 750DN pipe~~	~~item~~	~~0~~	~~$ 720.00~~	~~$ -~~
	~~Single Cell Headwall to suit 825DN pipe~~	~~item~~	~~0~~	~~$ 840.00~~	~~$ -~~
	~~Single Cell Headwall to suit 900DN pipe~~	~~item~~	~~0~~	~~$ 945.00~~	~~$ -~~
	~~Single Cell Headwall to suit 1050DN pipe~~	~~item~~	~~0~~	~~$ 1,501.04~~	~~$ -~~
	~~Excavate Trench~~	~~m^3~~	~~0~~	~~$ 80.00~~	~~$ -~~
	~~Install Culvert~~	~~m~~	~~0~~	~~$ 280.00~~	~~$ -~~
	~~Backfill and Site Remediation~~	~~m~~	~~0~~	~~$ 180.00~~	~~$ -~~
Fill Pad Earthworks	~~Removal of top soil and vegetation (100 mm)~~	~~m^3~~	~~0~~	~~$ 16.00~~	~~$ -~~
	Total Fill Volume in Pad (assume all imported, including delivery)	m^3	1,600	$ 80.00	$ 128,000.00
	Cut Available*	m^3	1,900	$ 28.00	$ 53,200.00
	~~Improvement of Excavated material*~~	~~m^3~~	~~0~~	~~$ 18.00~~	~~$ -~~
	Remaining Imported Fill Required (includes delivery)*	m^3	80	$ 80.00	$ 6,400.00
	Fuel	l/m^3	1,600	$ 0.75	$ 1,200.00
	Compaction	m^2	19,000	$ 8.00	$ 152,000.00
	Total (if 100% fill imported) + 20% Contingency	m^2			**$0.46 M**
	Total (if Cut is usable with no improvement) + 20% contingency				**$0.37 M**

Lot 1 - Stormwater Cost Estimate (Table 23)

	Fixed Costs	UNIT	QUANTITY	Rate (ex GST)	COST
General	Design, Consultations, Approvals and Construction Management	item	1	$ 20,000.00	$ 20,000.00
	Project Management & General Construction Cost (15% of subtotal) (Site establishment, security fencing etc) (15% of	item	1	15%	$ 43,021.13
Basin and Fill Pad Earthworks	Removal of top soil and vegetation (100 mm)	m^3	147	$ 16.00	$ 2,358.40
	Excavation	m^3	1,173	$ 28.00	$ 32,832.80
	~~Improvement of Excavated material~~	~~m^3~~	~~0~~	~~$ 18.00~~	~~$ -~~
	~~Disposal of Contaminated Spoil~~	~~m^3~~	~~0~~	~~$ 80.00~~	~~$ -~~
	~~Haulage of Imported Fill~~	~~m^3~~	~~0~~	~~$ 18.00~~	~~$ -~~
	Fill in embankment	m^3	1,173	$ 55.00	$ 64,515.00
	Fuel	l/m^3	1,173	$ 0.75	$ 879.75
	Compaction	m^2	857	$ 8.00	$ 6,856.00
	Top soil placement/seeding	m^2	143	$ 12.50	$ 1,785.55
	Bio-Detention Basin	m^2	386	$ 280.00	$ 108,080.00
	~~Wetland~~	~~m^2~~	~~0~~	~~$ 112.00~~	~~$ -~~
Pipe and Culvert Upgrades	~~Pipe 450 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 119.84~~	~~$ -~~
	~~Pipe 600 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 172.31~~	~~$ -~~
	Pipe 675 x 2.44 RJ Class 4	m	90	$ 220.00	$ 19,800.00
	~~Pipe 750 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 279.81~~	~~$ -~~
	~~Pipe 825 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 340.00~~	~~$ -~~
	~~Pipe 900 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 356.00~~	~~$ -~~
	~~Pipe 1050 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 436.79~~	~~$ -~~
	~~Single Cell Headwall to suit 450DN pipe~~	~~item~~	~~0~~	~~$ 380.00~~	~~$ -~~
	~~Single Cell Headwall to suit 600DN pipe~~	~~item~~	~~0~~	~~$ 410.00~~	~~$ -~~
	Single Cell Headwall to suit 675DN pipe	item	2	$ 550.00	$ 1,100.00
	~~Single Cell Headwall to suit 750DN pipe~~	~~item~~	~~0~~	~~$ 720.00~~	~~$ -~~
	~~Single Cell Headwall to suit 825DN pipe~~	~~item~~	~~0~~	~~$ 840.00~~	~~$ -~~
	~~Single Cell Headwall to suit 900DN pipe~~	~~item~~	~~0~~	~~$ 945.00~~	~~$ -~~
	~~Single Cell Headwall to suit 1050DN pipe~~	~~item~~	~~0~~	~~$ 1,501.04~~	~~$ -~~
	Excavate Trench	m^3	90	$ 80.00	$ 7,200.00
	Install Culvert	m	90	$ 280.00	$ 25,200.00
	Backfill and Site Remediation	m	90	$ 180.00	$ 16,200.00
Misc.	Contingency	item	1	20%	
	Total				**$0.42 M**

Channel Revitalisation Cost Estimate (Lots 1, 2 and 3, Table 25)

	Fixed Costs	UNIT	QUANTITY	Rate (ex GST)	COST
General	Design				
	Design, Consultations, Approvals and Construction Management	item	1	$ 20,000.00	$ 20,000.00
	Project Management & General Construction Cost (15% of subtotal) (Site establishment, security fencing etc) (15% of	item	1	15%	$ 310,531.35
Basin and Fill Pad Earthworks	~~Removal of top soil and vegetation (100 mm)~~	~~m^3~~	~~0~~	~~$ 16.00~~	~~$ -~~
	~~Excavation~~	~~m^3~~	~~0~~	~~$ 28.00~~	~~$ -~~
	Landscape Planting	m^3	25,000	$ 63.00	$ 1,575,000.00
	Rock	m^3	975	$ 70.00	$ 68,250.00
	Boulders	m^3	98	$ 410.00	$ 39,975.00
	~~Fill in embankment~~	~~m^3~~	~~0~~	~~$ 55.00~~	~~$ -~~
	~~Fuel~~	~~l/m^3~~	~~0~~	~~$ 0.75~~	~~$ -~~
	~~Compaction~~	~~m^2~~	~~0~~	~~$ 8.00~~	~~$ -~~
	Top soil placement/seeding	m^2	25,000	$ 15.00	$ 375,000.00
	~~Bio-Detention Basin~~	~~m^3~~	~~0~~	~~$ 280.00~~	~~$ -~~
	~~Wetland~~	~~m^2~~	~~0~~	~~$ 112.00~~	~~$ -~~
Pipe and Culvert Upgrades	Pipe 450 x 2.44 RJ Class 4	m	100	$ 119.84	$ 11,984.00
	~~Pipe 600 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 172.31~~	~~$ -~~
	~~Pipe 675 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 220.00~~	~~$ -~~
	~~Pipe 750 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 279.81~~	~~$ -~~
	~~Pipe 825 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 340.00~~	~~$ -~~
	~~Pipe 900 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 356.00~~	~~$ -~~
	~~Pipe 1050 x 2.44 RJ Class 4~~	~~m~~	~~0~~	~~$ 436.79~~	~~$ -~~
	~~Single Cell Headwall to suit 450DN pipe~~	~~item~~	~~0~~	~~$ 380.00~~	~~$ -~~
	~~Single Cell Headwall to suit 600DN pipe~~	~~item~~	~~0~~	~~$ 410.00~~	~~$ -~~
	~~Single Cell Headwall to suit 675DN pipe~~	~~item~~	~~0~~	~~$ 550.00~~	~~$ -~~
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	~~Single Cell Headwall to suit 825DN pipe~~	~~item~~	~~0~~	~~$ 840.00~~	~~$ -~~
	~~Single Cell Headwall to suit 900DN pipe~~	~~item~~	~~0~~	~~$ 945.00~~	~~$ -~~
	~~Single Cell Headwall to suit 1050DN pipe~~	~~item~~	~~0~~	~~$ 1,501.04~~	~~$ -~~
	~~Excavate Trench~~	~~m^3~~	~~0~~	~~$ 80.00~~	~~$ -~~
	~~Install Culvert~~	~~m~~	~~0~~	~~$ 280.00~~	~~$ -~~
	~~Backfill and Site Remediation~~	~~m~~	~~0~~	~~$ 180.00~~	~~$ -~~
Fill Pad Earthworks	~~Removal of top soil and vegetation (100 mm)~~	~~m^3~~	~~0~~	~~$ 16.00~~	~~$ -~~
	~~Total Fill Volume in Pad (assume all imported, including delivery)~~	~~m^3~~	~~0~~	~~$ 80.00~~	~~$ -~~
	~~Cut Available*~~	~~m^2~~	~~0~~	~~$ 28.00~~	~~$ -~~
	~~Improvement of Excavated material*~~	~~m^3~~	~~0~~	~~$ 18.00~~	~~$ -~~
	~~Remaining Imported Fill Required (includes delivery)*~~	~~m^3~~	~~0~~	~~$ 80.00~~	~~$ -~~
	~~Fuel~~	~~l/m^3~~	~~0~~	~~$ 0.75~~	~~$ -~~
	~~Compaction~~	~~m^2~~	~~0~~	~~$ 8.00~~	~~$ -~~
	Total + 20% Contingency	m^2			**$2.88 M**

Mullumbimby Release Areas Flood and Stormwater Assessment



Project Overview

- Residential Strategy currently being prepared by Council identified four (4) lots on the southern fringe of Mullumbimby
- Sites originally part of an 'early implementation' initiative for affordable housing
- Flooding was noted as a key issue to be addressed
- Council engaged WMAwater to:
  → assess the flood risk due to regional catchment flooding and to assess and mitigate the flood impacts caused by the proposed development of these four sites;

  → develop a concept level stormwater management plan for the area to inform the stormwater infrastructure that may be required to service the development

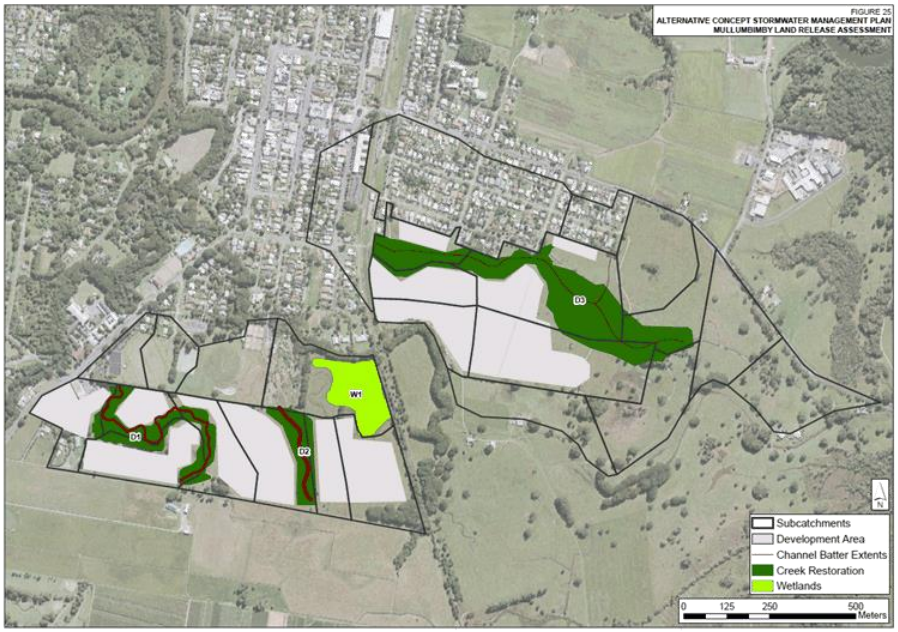


Project History to Date

- Sept 2019: Initial assessment and landowner engagement
- Oct/Nov 2019: Preliminary development fill pad and flood impact assessments completed for staff and landowner review
- Dec 2019 – presentation of preliminary findings to councillor workshop
- Early 2020: Review feedback (staff and landowners) incorporated into revised design of sites and stormwater management options developed
- March 2020: draft report update presented to councillor workshop
- July 2020: Final draft report completed, incorporating flood impact assessments, development fill pads and stormwater management options developed (including supporting costings)
- Oct 2020: presentation of draft report to Floodplain Risk Management Committee

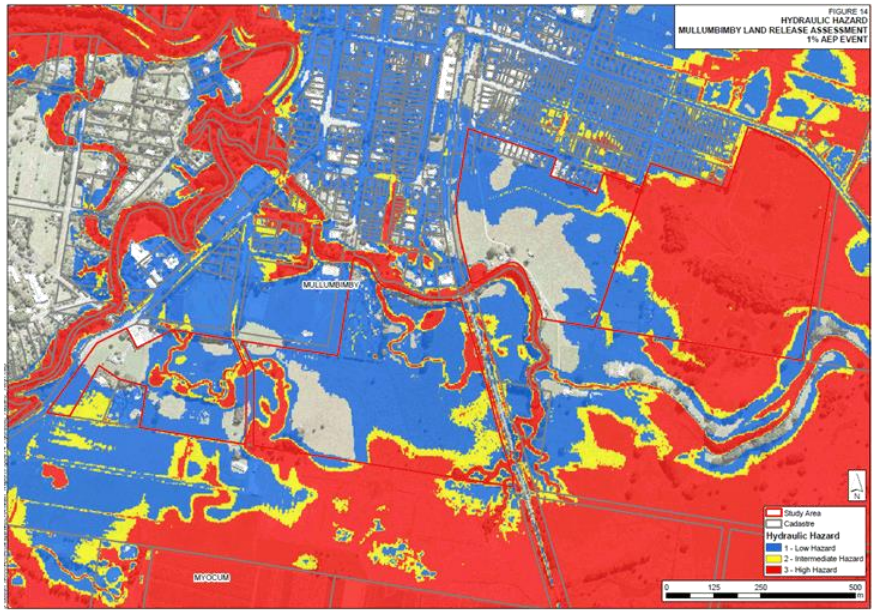
Changes since first draft report (in Dec 2019)

- Flood planning level revised to align with North Byron Flood Risk Management Study/Plan – **20% increase in rainfall intensity** and 0.9 m Sea Level Rise
- Further analysis undertaken on viability of maintenance of flood storage onsite
- Greater detail into potential alternative stormwater treatment options
- Revised costing and Multi-Criteria analysis
- Review of option to reduce fill onsite by pursuing raised (on stumps) housing options



Site Challenges

- Land is generally low lying, with majority of site is inundated in the 1% AEP Flood Event
- Inclusion of Draft Flood Planning Level (FPL) increases inundation onsite
- Several historic creek lines and urban drainage outlets present
- Large areas of High Risk Flood Zones (not developable)
- Direct access from Jubilee Avenue not possible due to sale of road easement to Co-Op

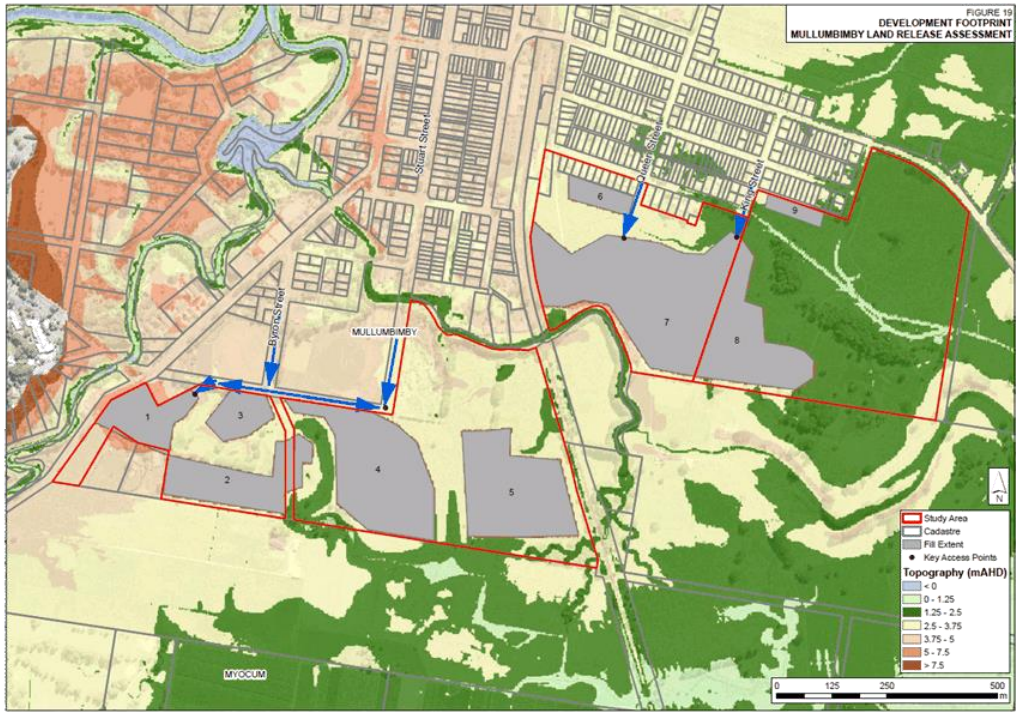


Fill Pad Arrangement

Limited by fill availability and location of 'low' and 'moderate' hazard flood zones

Arrangement presented considers:

- Impact of the development on surrounding properties
- Opportunity to achieve no net loss of floodplain storage
- Road access opportunities
- No encroachment into high risk flood areas
- Lowering of fill pads to levels to below the DFL not possible due to drainage requirements (roadways required to be designed to minimum of 0.3 m below DFL)

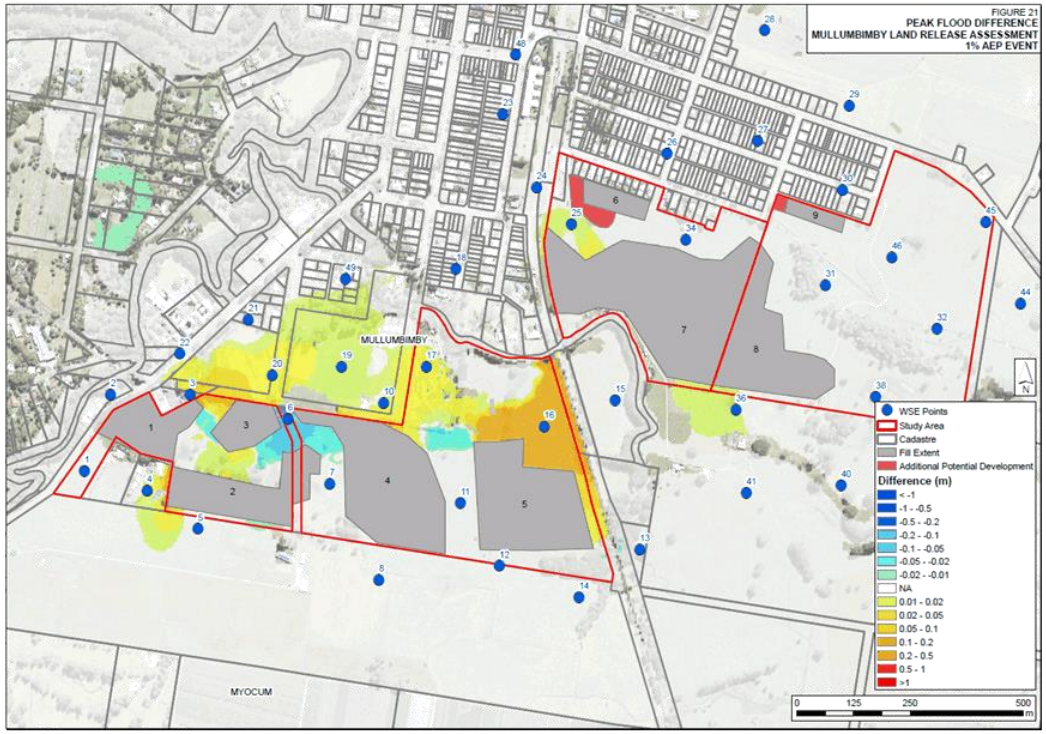


Flood Assessment Results

- Offsite flood impacts limited to less than 10 mm in general
- Modelled with no floodplain storage offset for conservatism
- High hazard flood areas limit additional areas of development
- Flood levels higher due to revised FPL from draft FRMS&P

Table 4 – Flood Levels and Flood Planning Levels

Lot ID	Flood Level (mAHD)	Flood Planning Level (mAHD)
1	4.5	5.0
2	4.3-4.0	4.8-4.5
3	4.6-4.0	5.1-4.5
4	4.4-3.9	4.9-4.4
5	3.9-3.8	4.4-4.3
6	3.7-3.6	4.2-4.1
7	4.1-3.6	4.6-4.1
8	3.6	4.1
9	3.6	4.1



Flood Assessment Results ...*cont'd*

- ✓ Cut to fill balance close to achieved at concept level (5%) difference
- ✓ Refinement of channels and options would likely achieve outcome
- ✓ East and west of train line can be developed independently and still meet floodplain storage offset requirements

Lot ID	Development Area (m^2)	Estimated Fill Volume (m^3)	Estimated Cut Volume (m^3)	Balance (m^3)
1*	19,000	1,600	-	-1,600
2	30,000	11,050	150	-10,900
3	11,000	4,700	50	-4,650
Cut from Surrounds			32,000	**14,650**
4	55,000	19,250	100	19,150
5	48,000	46,200	0	46,200
Cut from Surrounds			49,000	**-16,350**
6	7,000	2,550	50	2,500
7	89,000	30,450	12,700	17,750
8	38,000	40,450	0	40,450
9	4,350	6,750	0	6,750
Cut from Surrounds			60,000	**-7,450**
Total Balance		163,000	154,050	**-9,150**

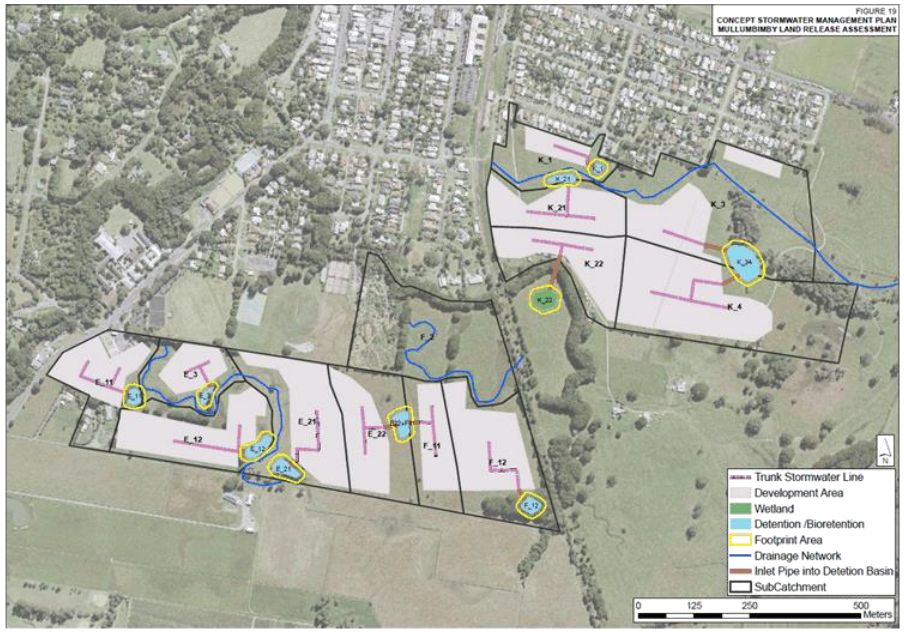
*This site was assumed to have no cut as it is understood the existing residence is to remain – therefore for conservatism it is assumed only fill will occur onsite.



Stormwater Options

Traditional (engineered) –vs-
Non-traditional ('natural' channel Rehabilitation and improvement) assessed

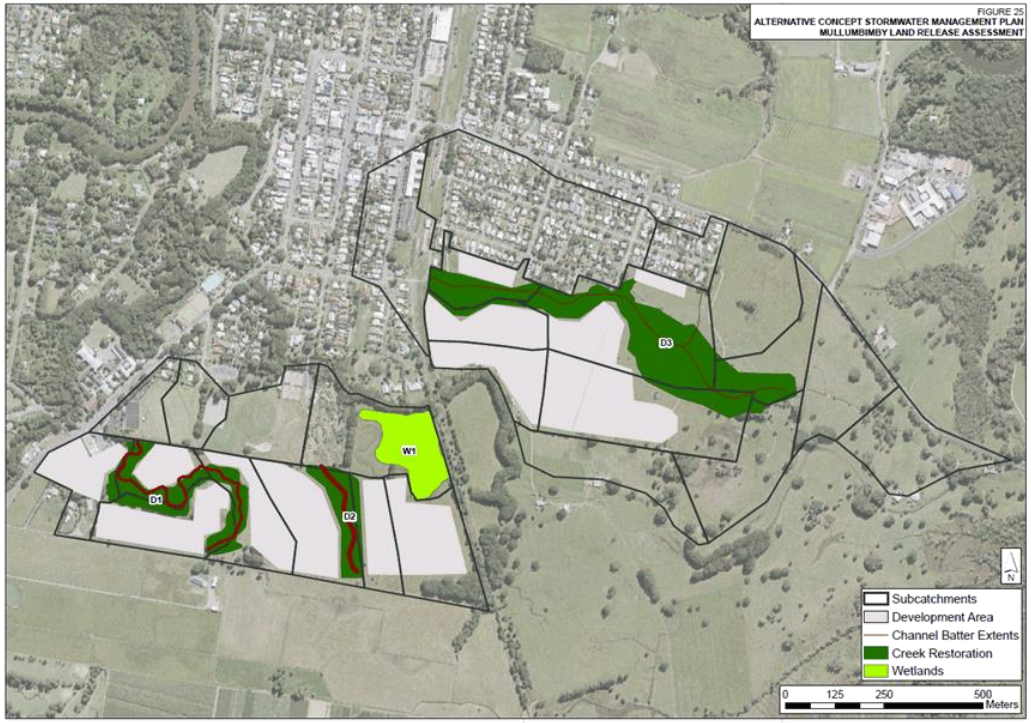
No change to traditional option from previous assessment (see concept plan at right)



Stormwater Options ... *cont'd*

- Further assessment of Non-traditional option undertaken to confirm required storage and footprint (see concept plan at right)
- Opportunity to incorporate into the floodplain storage offset (reshape and extract spoil for fill pads)

Cut to fill balance may be achievable however its viability is dependent on the soil quality onsite, which is currently unknown



Stormwater Options *... cont'd*

In addition to providing spoil for fill pads, Non-traditional option presents following opportunities:

- Improvement of stream water quality for both areas upstream of the site and around the development area;
- Reconnecting people to the natural environment through urban regeneration;
- Reduced likelihood of negative impacts caused by climate change through increased ecosystem resilience;
- Natural stream beds generally have slower moving flow than designed channels;
- Enhanced habitats for wildlife;
- Potential to integrate social and cultural experiences into the rejuvenated corridors; and,
- Detention storage can be incorporated into the overall design of the stream restoration (i.e. less hard engineering required).

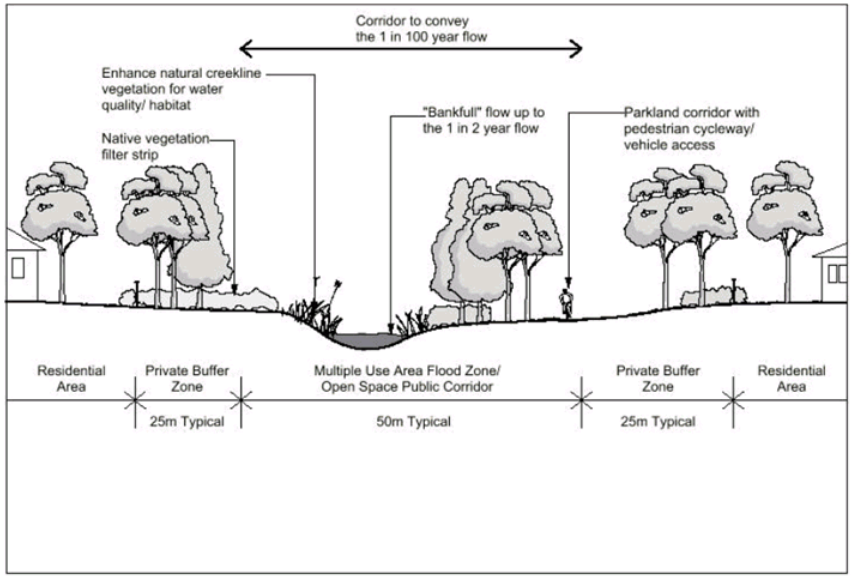


Plate 5 – Typical creek cross-section (Warriewood Valley Urban Land Release Water Management Specification – Revised Version, Pittwater Council, 2001)

Stormwater Options - Cost

Table 24 – Concept Level Cost Estimate – Traditional Stormwater Management – Cut Fill Balance

Lot ID	Fill Pad (Cut/Fill Balance)	Stormwater Quantity and Quality (Inc Trunk Drainage)	Excavation Area Rehab	Total Cost	Cost Per m^2
1	$0.37 M	$0.27 M	$0.09 M	$0.73 M	$38
2	$0.97 M	$0.18 M	$0.60 M	$1.75 M	$58
3	$0.43 M	$0.28 M	$0.25 M	$0.97 M	$88
4	$1.83 M	$0.38 M	$0.45 M	$2.66 M	$48
5	$3.23 M	$0.41 M	$1.08 M	$4.71 M	$98
6	$0.26 M	$0.32 M	$0.06 M	$0.65 M	$92
7	$2.90 M	$0.82 M	$0.74 M	$4.46 M	$50
8	$2.78 M	$0.41 M	$0.98 M	$4.17 M	$110
9	$0.46 M	N/A	$0.16 M	$0.62 M	$143
NCRDI	N/A	$0.27 M		$0.27 M	N/A

Table 25 – Concept Level Cost Estimate – Alternative Stormwater Management

Lot ID	Fill Pad (Cut/Fill Balance)	Trunk Drainage	Channel Revitalisation	Total Cost	Cost Per m^2
1	$0.37 M	$0.12 M	$0.27 M	$0.76 M	$40
2	$0.97 M	$0.20 M	$1.83 M	$3.01 M	$100
3	$0.43 M	$0.10 M	$0.78 M	$1.31 M	$119
4	$1.83 M	$0.37 M	$0.91 M	$3.11 M	$56
5	$3.23 M	$0.12 M	$2.18 M	$5.52 M	$115
6	$0.26 M	$0.12 M	$0.23 M	$0.61 M	$87
7	$2.90 M	$0.36 M	$2.78 M	$6.04 M	$68
8	$2.78 M	$0.36 M	$3.69 M	$6.83 M	$180
9	$0.46 M	N/A	$0.62 M	$1.07 M	$247
NCRDI	N/A	$0.27 M		$0.27 M	N/A

Traditional stormwater option is cheaper than channel revitalisation – primary difference is the cost of planting to improve the corridor as opposed to hard engineering of the corridor.

→ On average $19/$m^2$ more expensive to establish

However, cost does not take in to consideration long term maintenance costs or non quantifiable benefits

Note cost estimates are very 'high level' – alternative options difficult to cost due to uncertainty in planting and labour costs – rehabilitation estimated to be approx. $40/$m^2$

Stormwater Options – Multi Criteria Assessment

Assessment Criteria	Score and Definition			
	1	2	3	Weight (%)
Cost	High	Moderate	Low	25
Site Water Quality Improvement	Low	Moderate	High	10
Potential for local drainage and water quality improvements	Low	Moderate	High	10
Ecology /Habitat Improvement	Low	Moderate	High	20
Maintenance Cost	High	Moderate	Low	25
Potential for Social Engagement and Improved Social Amenity	Low	Moderate	High	10

Table 27 –Multi-Criteria Analysis Results

Assessment Criteria	Traditional WSUD (engineered basins and stormwater quality devices)	Natural Channel Rehabilitation	Mixed (both Engineered and channel rehab)
Cost	3 (0.75)	1 (0.25)	1 (0.25)
Site Water Quality Improvement	3 (0.3)	2 (0.2)	3 (0.3)
Potential for local drainage and water quality improvements	1 (0.1)	3 (0.3)	3 (0.3)
Ecology /Habitat Improvement	1 (0.2)	3 (0.6)	3 (0.6)
Maintenance Cost	1 (0.25)	3 (0.75)	1 (0.25)
Potential for Social Engagement and Improved Social Amenity	1 (0.1)	3 (0.3)	3 (0.3)
Weighted Score	**1.7**	**2.4**	**2.0**

Allows consideration of a number of factors such as cost, community acceptance, environmental impacts, to be included to provide weight to non-quantitative benefits of options.

When considering additional factors, **natural channel rehabilitation (non-traditional) considered the preferred option**

A mixed system is identified as the second preferred option, however due to the increased cost of maintenance and the likely incorporation of redundant infrastructure this is not recommended.