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Queensland Government

# Caloundra South Development:
# Flood Risk Management Strategy

October 2015

Stockland

# Caloundra South: Flood Risk Management Strategy

| | |
|---|---|
| Prepared for: | Stockland |
| Prepared by: | BMT WBM Pty Ltd (Member of the BMT group of companies) |

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| | **Client:** | Stockland |
| | **Client Contact:** | Adrian Allen |
| | **Client Reference:** | |
| **Synopsis:** | This report presents the flood risk management strategy for the proposed 'Caloundra South' master-planned community. | |

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# Executive Summary

BMT WBM has been commissioned by Stockland (in support of a Development Application to the Minister for Economic Development Queensland) to prepare a Flood Risk Mitigation Strategy for the 'Caloundra South' master-planned community (hereafter referred to as 'the site'), located on the Sunshine Coast. This report has been prepared in support of a Reconfiguration of Lot application for the Town Centre of the proposed Caloundra South development.

While this report supports the Town Centre application, the flood impacts for the full Caloundra South development have been assessed. This ensures that the flood strategy for the overall development mitigates the overall flooding constraints. However, the flood impacts for the Town Centre area and previous RoL application areas without the remaining proposed development across the PDA have also been checked to ensure that the proposed development works (from a flooding perspective) in isolation. The proposed development will include a variety of land uses including residential lots, retail and commercial areas, sports and recreational areas, and public open spaces.

A portion of the broader Priority Development Area (PDA) drains to Lamerough Creek, which discharges to the Pelican Waters canal estate and subsequently Pumicestone Passage. The remainder of the PDA and the Town Centre area flows towards Bells Creek (via Bells Creek North and Bells Creek South) and subsequently Pumicestone Passage.

This flood risk management strategy describes what areas of the site are susceptible to flooding and what strategies can be implemented to manage the flood risk of the proposed development. It is the objective of this assessment to ensure no adverse impact on flood inundation of properties outside the site, whilst simultaneously providing appropriate levels of flood immunity for those areas of the site to be developed for urban uses.

This investigation includes the following key activities:

- Development of site hydrologic and hydraulic models for the existing and developed site
- Testing and evaluation of a range of potential site development/floodplain management scenarios to support the selection and design of an appropriate flood risk management strategy
- Refinement of the preferred design solution to ensure no adverse offsite impacts and to optimise site design characteristics.

This study has shown that portions of the existing site are flood prone, but flood risk in areas outside the immediate proximity of waterway corridors is extremely low.

Having identified the above and developed robust numerical models of key flooding processes, evaluations were conducted on mitigation measures to ensure the development can proceed without unacceptable or detectable offsite impacts. In summary, these proposed mitigation measures are as follows:

- The site will be configured with relevant dedicated flood detention storage, flood conveyance and other appropriate mitigation measures to ensure no offsite impacts
- Land within the site boundary, proposed for development, will be filled (where required) to ensure flood immunity in the 100 year average recurrence interval flood event with consideration of climate change.

The site can be developed in a manner which will provide appropriate levels of flood immunity within Caloundra South (including the potential influences of future climate change factors such as sea level rise and increases in rainfall intensities). Furthermore, the development can occur with no adverse offsite flooding impacts.

Small impacts in flood level (50mm) upstream of the Bruce Highway on Bells Creek North do occur when considering the overall development across the full PDA; peak flood levels remain below the Bruce Highway road level. However, these impacts are not caused by the Town Centre development. Also, an application for a borrow pit west of the Bruce Highway is being lodged separately with Council. This borrow pit will eliminate the flood impacts in the vicinity of the highway by creating additional flood storage. The flood impact, and opportunities to reduce them, will be revisited in this area prior to the RoL application for this area.

# Contents

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# 1 Introduction

BMT WBM has undertaken numerous flooding assessments of the proposed mixed use development for the Caloundra South Priority Development Area. The previous assessments were undertaken to support EPBC Act, Material Change of Use (MCU) and Reconfiguration of Lot (RoL) approvals, as well as to inform the design of proposed development. The work documented in this report builds on the previous work in support of a RoL application for the Town Centre area.

The purpose of this Flood Risk Management Strategy is to inform Stockland and Economic Development Queensland (EDQ) about the strategies that have been developed to manage flood risk within the proposed Caloundra South Priority Development Area (PDA), and the impact these strategies have on flooding. As such, the Flood Risk Management Strategy aims to ensure:

- The proposed development is not subject to an unacceptable level of flood risk (including consideration of climate change);
- The proposed development does not worsen flood risk or flood warning times external to the PDA; and
- Peak flows downstream of the site are not increased by the proposed development.

The main elements of the flood risk management strategy are as follows:

- Develop flood models to define the flooding characteristics of the pre and post developed Caloundra South site;
- Determine the flood impacts caused by the proposed development;
- Develop strategies to mitigate flood impacts; and
- Identify what actions are required to manage flood risk.

While this report has been prepared specifically to support the RoL application for the Town Centre area, the broader Caloundra South development has been considered to ensure that flooding constraints have been mitigated within the context of the broader development. However, the flood impacts for the Town Centre area and previous RoL application areas excluding the remaining proposed development across the PDA have also been checked to ensure that the proposed development works (from a flooding perspective) in isolation.

# 2 Site Description

## 2.1 Location

The Caloundra South site is located within the Sunshine Coast Regional Council area, to the east of the Bruce Highway and to the south-west of Caloundra. This report supports a RoL application for the Town Centre area. The locality of the site surrounding the Town Centre is presented in Figure 2-1, and the broader PDA in Figure 2-2.

The Caloundra South PDA covers an area of approximately 2,400 hectares and has been identified under the SEQ Regional Plan as being contained within the Urban Footprint.

## 2.2 Site Topography and Drainage

There are three watercourses that flow through the Caloundra South PDA – Lamerough Creek, Bells Creek North and Bells Creek South. On site, these three watercourses are characterised by a network of smaller channels with a relatively wide and flat floodplain. The site generally slopes downwards to the east with a typical channel slope of about 1 in 400 to 1 in 500 in the upper reaches (western part of the Caloundra South PDA).

Further downstream, the eastern part of the Caloundra South PDA is characterised as typical coastal plains. In this area, the site is relatively flat with ground levels generally ranging between 1m AHD and 2m AHD (around the eastern boundary of the site).

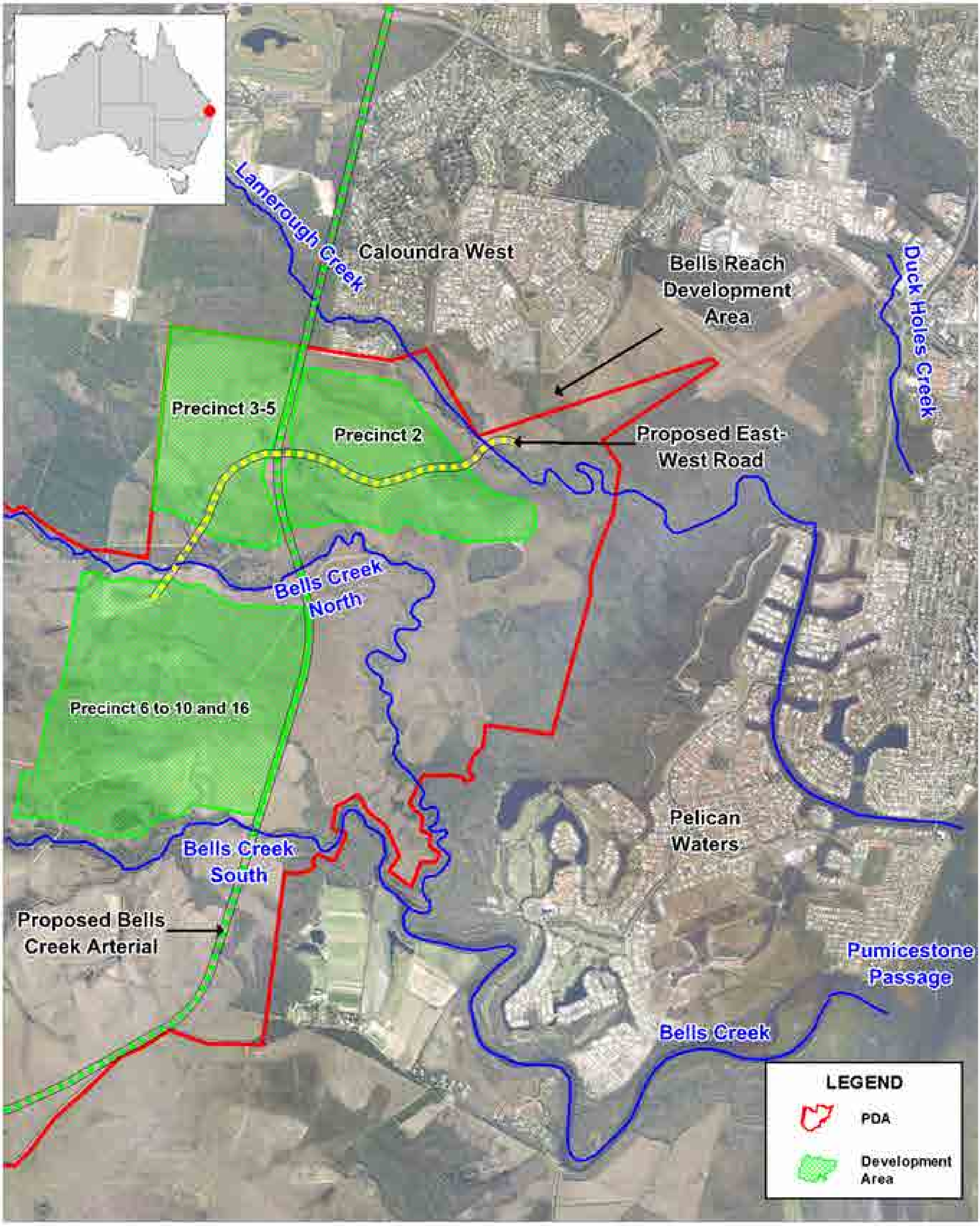
The highest ground elevations on the Caloundra South site occur adjacent to the Bruce Highway with levels of up to approximately 31m AHD in these areas.

The topography of the existing site is shown in Figure 2-2 (based on a LiDAR survey flown in 2012).

## 2.3 Existing Land Usage

The existing site is a highly modified catchment largely cleared and denuded of vegetation through previous forestry and grazing practices.  The site is currently being actively grazed by cattle. Landuse downstream of the site includes a turf farm, golf course and urban development. The BMT WBM (2011)"*Caloundra South Consolidated Water Report*" further describes the temporal land use changes across the Caloundra South area.

An aerial photo of the site is provided in Figure 2-1. Images of the existing site are presented in Figure 2-3.

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**Locality Map**

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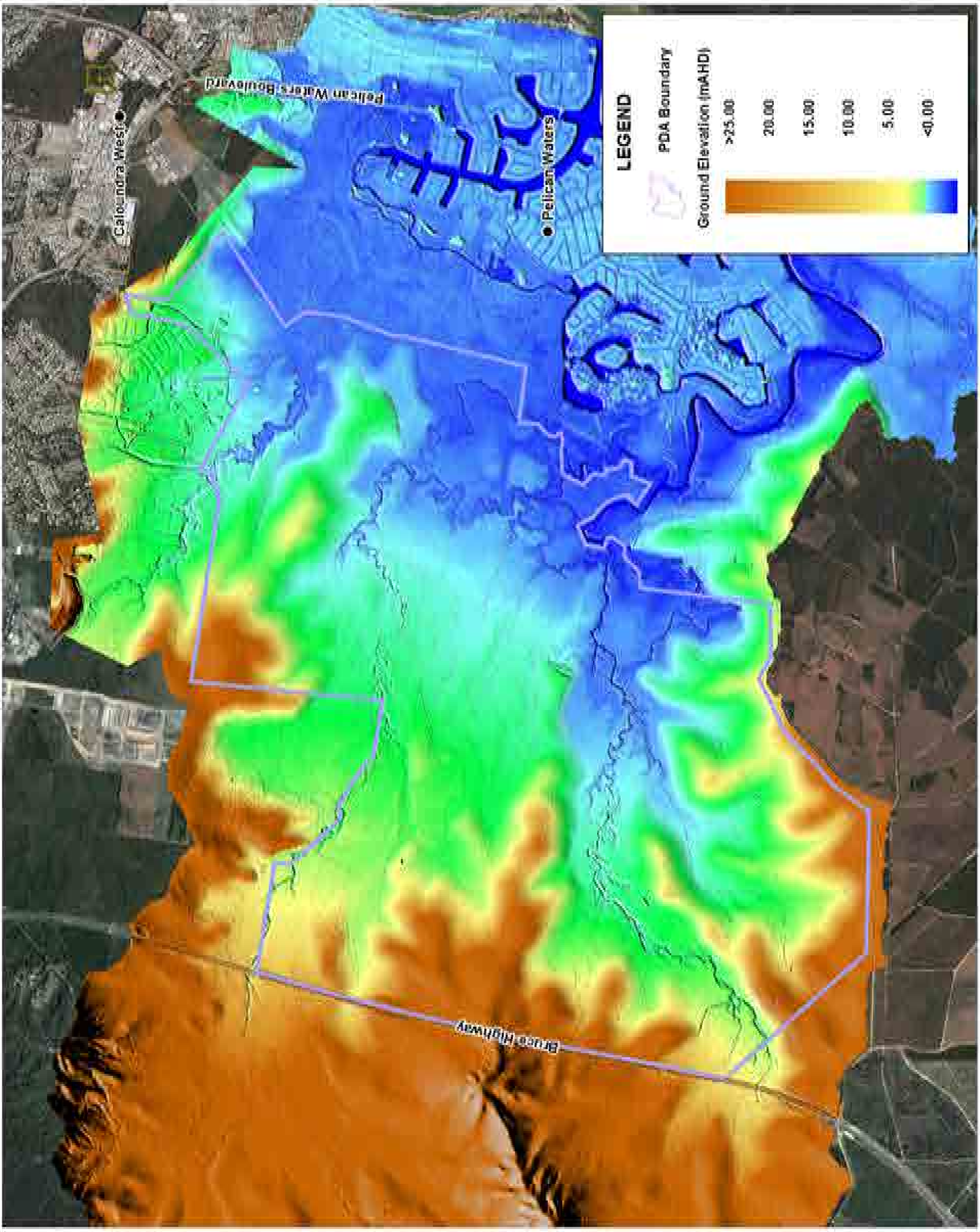


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**Existing Topography of Site**

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Figure 2-3 Images of the Caloundra South PDA

## 2.4 Proposed Development

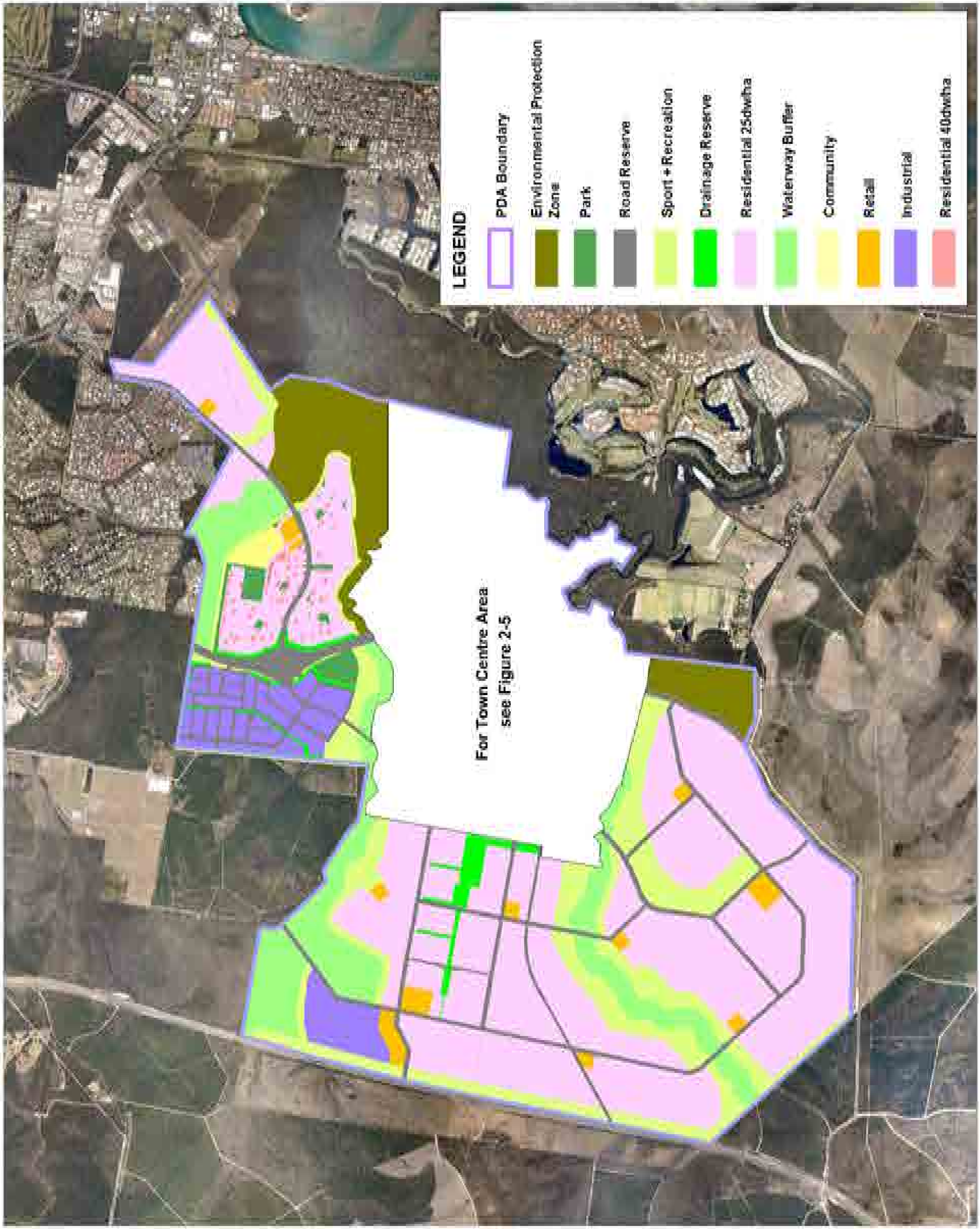
The proposed development of the site includes a variety of land uses including residential and commercial areas, sports and recreational areas and public open spaces. A general layout plan of the proposed development over the Caloundra South PDA is provided in Figure 2-4 and Figure 2-5 shows the layout for the Town Centre area. Features of the development that constitute components of the flood mitigation strategy are discussed in Section 5.

The creek frontages along the northern and southern edges of the Town Centre include proposed recreational areas. The proposed ground levels moving from the urban development through the recreational areas and into the floodplain are proposed to cascade through diminishing flood immunities. The flood immunities are shown in Figure 5-1.

The proposed Bells Creek Arterial road crosses Bells Creek North on the northern side of the Town Centre and Bells Creek South on the Southern side of the Town Centre. The Bells Creek South crossing is a key component of the flood mitigation strategy as discussed in Section 5. The Bells Creek North crossing comprises a 100m span bridge. While it's not a specific component of the flood mitigation strategy, the Bells Creek North crossing restricts the passage of flood flows through Bells Creek North, thereby providing additional flood detention and a flood risk benefit to downstream communities.

The proposed development also includes an overland flow reconfiguration along a section of Bells Creek South immediately south of the Town Centre. The aim of the reconfiguration is to create additional wetland immediately south west of the Town Centre. The impact of this proposal was investigated prior to this RoL application. The investigation showed that the proposed reconfiguration did not cause an increase in velocity downstream of the proposed reconfiguration. See Appendix D for a discussion on the investigation.

It is noted that the configuration of the overland flow path has been adjusted since the worked discussed in this report was completed. The adjustment includes a bend in the alignment. This change makes no difference to the outcomes of this report, as changes in flood levels will be small and only occur in close proximity to the reconfigured overland flow path. Small localised changes in flood level can easily be accommodated by adjustments to the flood planning level (and fil level) on the southern side of the Town Centre. The future proposed alignment will be subject to detailed design and will be reassessed at Operational Works Stage.

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**Proposed Site Layout**

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# Town Centre Layout

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# 3 Assessment Approach

## 3.1 Preamble

This flood risk assessment utilises a number of computer based flood models in determining flood risk and developing mitigation strategies. The term ‘flood model’ is used in this report to refer to the hydrological and hydraulic models in combination. The hydrological models were used to estimate runoff rates through the site based on design rainfall events, and the hydraulic models to estimate the hydraulic properties of flood flows (such as flood levels and depths) within the site based on the runoff rates derived from the hydrological models.

The reason for developing flood models of the site is that they were essential tools for assessing flood risk within the vicinity of the proposed development, as well as the effects of the development on flood risk external to the Caloundra South PDA.

The river systems through the Caloundra South PDA are ungauged. Therefore, it has not been possible to calibrate the model against observed catchment rainfall runoff conditions. Appropriate, conservative model parameters have been adopted.

Appendix C provides a detailed description of the modelling methodology applied in this assessment.

## 3.2 Flooding Mechanisms

Two flooding mechanisms have been considered in the analysis:

- Fluvial flooding derived from precipitation over the Bells Creek and Lamerough Creek catchment; and
- Tidal flooding derived from ocean storm surges.

These two flooding mechanisms were considered to occur independently. This approach is consistent with a previous SKM flood study of the site, which justifies the approach on outcomes from a joint probability analysis undertaken by Connell Wagner (SKM 2006, Connell Wagner 2005).

The 100 year ocean storm surge in the vicinity of Golden Beach has been reported as 1.95mAHD (Connell Wagner 2003) and 1.65mAHD based on “*Sunshine Coast Storm Tide Study*” (Aurecon, 2013). The latter, more contemporary, 1.65mAHD level has been adopted. Fluvial flood levels are much higher in the vicinity of the proposed development. The creek banks in the vicinity of the proposed development are higher than the 100 year ocean storm surge flood level. Thus, tidal flooding does not pose a significant flood risk to the proposed development and has not been modelled under current climate conditions.

However, the 100 year ocean storm surge level under a future climate (with sea level rise) results in a more notable flood risk in the vicinity of the site. Thus, for the climate change scenario the 100 year ocean storm tide level was merged with the 100 year fluvial peak flood level to establish the overall 100 year peak flood level. This approach ensures that the proposed development is above the 100 year flood level including climate change for both flooding mechanisms.

For the fluvial flooding mechanism, two critical storm durations were modelled. The critical storm durations adopted in the 2006 SKM flood study (i.e. 6 hours and 12 hours) was used for this flooding assessment. These storm durations were verified by BMT WBM via a critical duration assessment on the 100 year ARI flood event.

The two critical durations were modelled independently. The 6 hour storm duration results in higher flood levels along Bells Creek North, upstream of the detention basin on Bells Creek South and Lamerough Creek. The 12 hour duration storm results in higher flood levels in the Environmental Protection Zone downstream of the proposed development and at the detention basin on Bells Creek South (proposed as part of the development of the site).

# 4 Pre-developed Flooding Conditions

## 4.1 Preamble

The flood model for the Base Case (i.e. pre-developed situation) was simulated for the 1, 2, 5, 10, 20, 50 and 100 year ARI design fluvial flood events. The resulting peak flood levels (also showing flood extent), peak flood depth and peak flood velocity are presented in Appendix D. Results were derived by merging the peak 6 hour storm duration model results with the peak 12 hour storm duration model results.

## 4.2 Pre-developed flooding results

The existing flooding behaviour of the Caloundra South PDA and surroundings is characterised as follows:

- The critical storm duration varies throughout the site with the shorter events critical in the upper part (Bells Creek North, Bells Creek South and Lamerough Creek) and storm tides critical in the low lying areas (downstream of the site).
- The general flooding pattern for larger flood events is characterised by diffuse overland flows with relatively wide and shallow inundated areas. The inundated areas are generally centred around Bells Creek North, Bells Creek South and Lamerough Creek.
- The area downstream of the proposed development area, (i.e. adjacent to Pelican Waters and the airstrip) is characterised by extensive flooding that stores large volumes of flood water. Flood depths in this area reach up to approximately 4m during the 100 year ARI event. Flood water is mostly slow flowing in this area with flow velocities generally less than about 0.1m/s during most events.
- The maximum inundation depth within the proposed development area is generally low and less than 0.5m at most locations during the 100 year ARI event. An exception is the area located directly west of the proposed town centre, where there is an overland flow path during major events.
- Flow velocities of overland flood flows are generally low, with peak flow velocities during the 5 year ARI flood event typically less than 0.2m/s and peak velocities during the 100 year ARI event typically less than 0.3m/s. An exception is the area immediately to the west of the proposed town centre where, during major flood events, flow velocities up to about 0.5 m/s are predicted.

# 5 Flood Risk Mitigation Strategy

## 5.1 Preamble

In general, without mitigation measures, proposed development has the potential to affect flooding in the following ways:

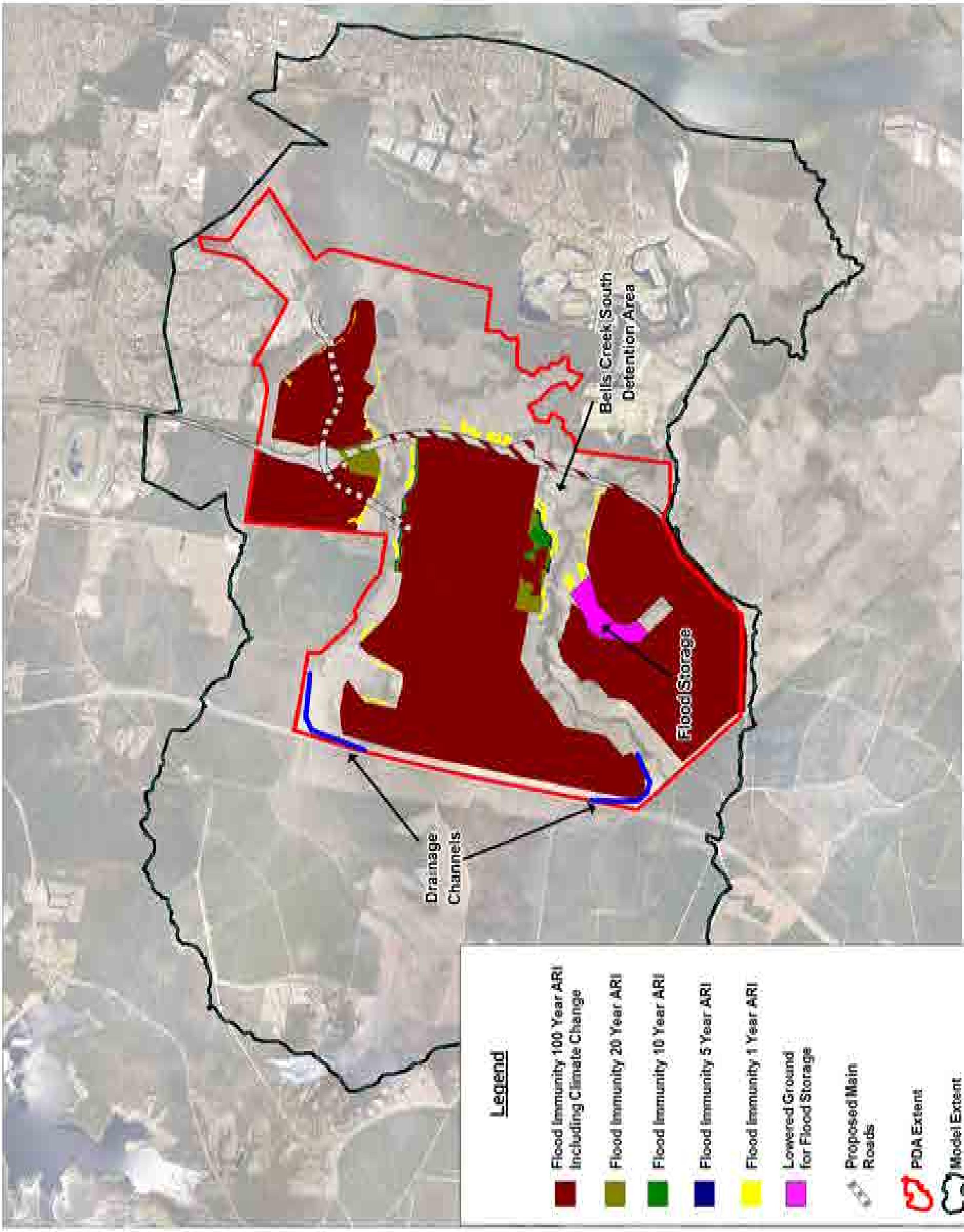
- The paved areas associated with urban areas of proposed development have the tendency to reduce infiltration of rainfall into the ground and cause a quicker and more intense flood water runoff response during storm events. This can lead to earlier and greater peak creek inflows.
- In areas where fill is proposed in the floodplain to provide onsite flood immunity, existing floodplain flow paths may be obstructed. This can impact on the hydraulic conveyance of the creek systems and distort flooding behaviour offsite. In addition, fill can reduce the floodwater storage capacity of a floodplain, resulting in an increase in flood levels both onsite and in areas upstream and downstream of the development.

This flood risk management strategy report shows how the Caloundra South PDA development can be implemented without causing adverse implications for flood risk such as those described above.

## 5.2 Flood Risk Mitigation Strategy

The flood model was iteratively adapted during this study to develop the proposed flood mitigation concepts. Several key flood mitigation features are included in the proposed site layout (see Figure 5-1):

- Raise developed ground levels (fill) within the proposed development to mitigate flooding to the proposed development. Flood immunities are shown on Figure 5-1.
- Implementation of drainage channels to drain flood water from the various Bruce Highway culvert crossings to the creeks.
- The Bells Creek Arterial road embankment has been used to form an 'online' detention basin on Bells Creek South. The culvert configuration has been designed to ensure low flows can pass through the basin while high flows are 'throttled', minimising flooding impacts downstream of the site. One set of culverts consisting of three 3000 x 900 RCBCs is proposed to be located within the creek channel and one set of culverts consisting of five 3000 x 900 RCBCs is proposed to be located on the flood plain.
- An area of 24ha within the Bells Creek South floodplain is proposed to be lowered to provide additional floodwater storage capacity. Proposed ground elevations in this detention area vary between 2.75mAHD and 3.75mAHD (an average lowering of about 1.1m).

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**Proposed Flood Mitigation Strategy**

Figure:
**5-1**

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# 6 Developed Case Flood Conditions

## 6.1 Caloundra South PDA Development

The results of the developed case flooding assessment are presented in Appendix E of this report. Appendix E shows the peak flood surface levels, peak flood depths and peak flood velocities for the developed case with development layout and mitigation strategy outlined above. The following points are made in this regard:

- Flood flows are generally contained within Bells Creek North during major flood events. Of particular note in this regard is the obstruction of flood flows through the proposed Caloundra South development. The pre-developed flood simulations predicted diffuse overland flow through this area. Due to filling within the proposed urban footprint, flood flows will be contained within the Bells Creek North drainage corridor.
- The detention basin within Bells Creek South is predicted to detain flows during major flood events, causing inundation of the floodplain west of the proposed Bells Creek Arterial.

## 6.2 RoL Application Area (Precincts 1 to 10 and 16)

A developed case flooding assessment was also undertaken excluding the full Caloundra South PDA development. These results account only for development for which RoL applications have been lodged and the Town Centre area. The proposed development for this scenario includes the following:

- Precinct 1 – Bells Reach area off the eastern bank of Lamerough Creek;
- Precinct 2 – Residential development area off the western bank of Lamerough Creek;
- Precinct 3 to 5 – Commercial development area east of Precinct 2 (divided by the Bells Creek Arterial) and off the northern bank of Bells Creek North;
- Precinct 6 – Bells Creek North corridor along northern edge of the Town Centre;
- Precinct 7 to 10 – Town Centre area;
- Precinct 16 – Bells Creek South corridor along southern edge of the Town Centre area;
- The Bells Creek Arterial Crossing over both Bells Creek North and Bells Creek South; and
- Ground lowering in the Bells Creek South floodplain to create flood storage.

This assessment was undertaken primarily as a check on flood impacts. Therefore, only flood impact maps for this case have been presented in this report (see Section 7.2).

# 7 Flood Assessment

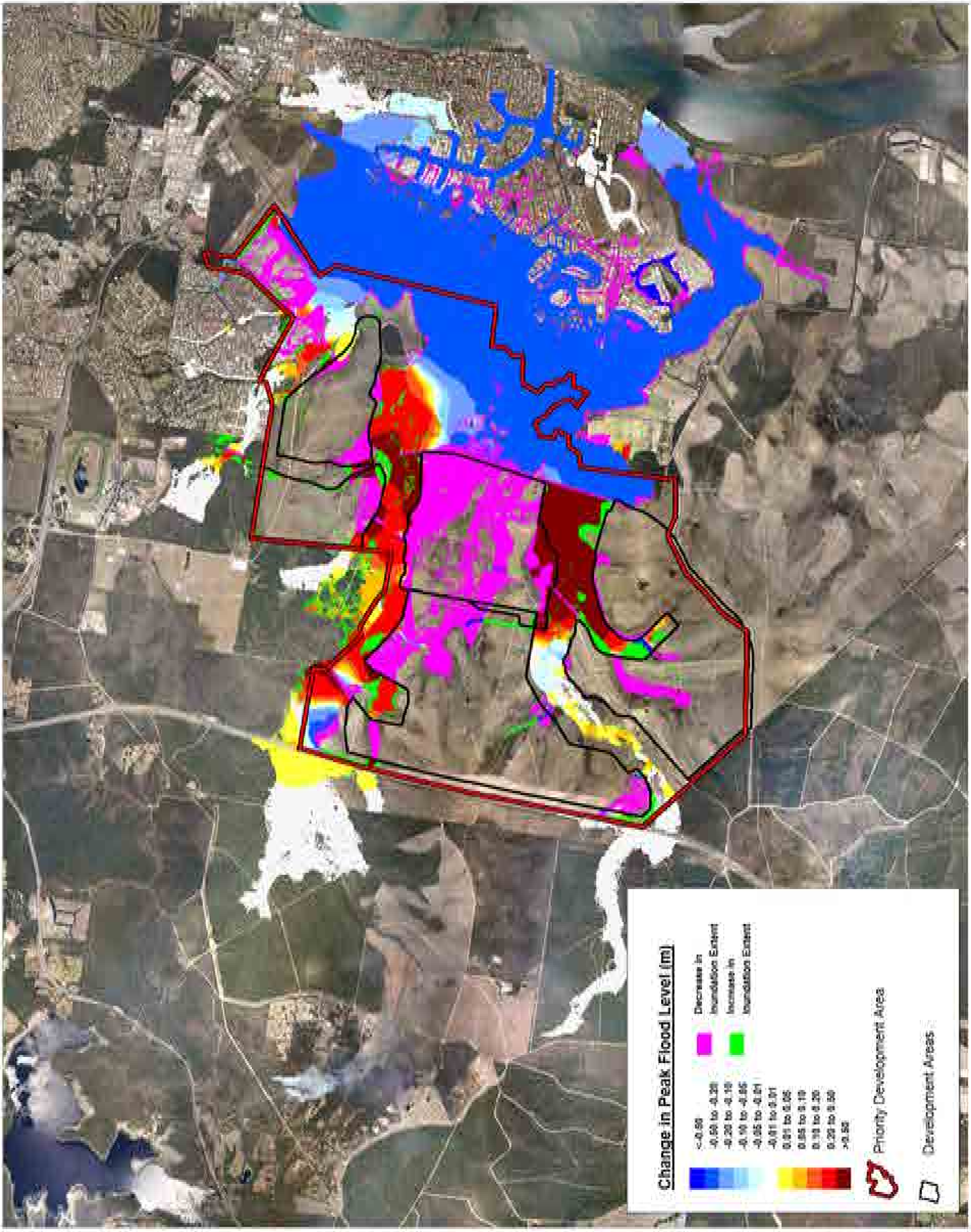
## 7.1 Flood Impact Assessment – Full Caloundra South PDA

Peak flood levels for the developed case were compared with those of the Base Case to investigate the influence of the proposed development on flood risk. Figure 7-1 shows the impacts of the proposed works on peak flood levels.

The flood modelling indicates that 100 year ARI peak flood levels in the areas adjacent to Pelican Waters will generally decrease by 200mm to 250mm. There are generally no adverse flood impacts outside the PDA, apart from two areas:

- Upstream of the Bruce Highway on Bells Creek North impacts of up to 50mm occur and peak flood levels remain below the Bruce Highway road level. Much of this land is owned by Stockland. However, a small portion belongs to another landholder. The impact is caused by a combination of backup from a proposed road crossing 1km downstream of the Bruce Highway and proposed riparian vegetation reestablishment. The relative contribution of these influences has not been investigated at this stage. The flood impact, and opportunities to reduce them, will be revisited in this area prior to the RoL application for this area. The proposed Town Centre development does not cause flood impacts in this area (see Figure 7-4). An application for a borrow pit west of the Bruce Highway is being lodged separately with Council. This borrow pit will eliminate the flood impacts in the vicinity of the highway by creating additional flood storage.
- The undeveloped floodplain on land currently owned by Council, external to the PDA on the northern bank of Bells Creek North shows some flooding impacts. The following comments are made in regard to this area:
  - There are three flooding mechanisms:
    - A drainage path flowing in a south easterly direction draining the local sub-catchment runoff towards Bells Creek North. The lower part of this drainage path, where it meets the proposed development, incurs flood impacts of up to 250mm at the PDA boundary. The impact abates to negligible impact 200m upstream.
    - A floodplain (100m to 150m wide) off the northern bank of Bells Creek north conveying floodwaters parallel to the creek. The flood impacts are generally less than 100mm.
    - Diffuse flooding in the forest caused by flood waters breaking out of Bells Creek North flowing in a northerly direction into the forest along forest tracks and depressions. The impacts associated with this mechanism are generally less than 150mm for the 100 year and 50 year events.
  - These flood impacts are caused by proposed raised ground levels (fill) in the floodplain and the link road crossing across Bells Creek North. Modifications to the proposed development have been implemented to abate these impacts. This includes, truncating a portion of the developable footprint and adding culverts to the Link Road crossing.
  - The extent of flooding in this area is predicted to increase by approximately 30% in the 100 year event.

- Given that the subject area is used for pine plantation, the flood impact caused by the proposed development will not significantly increase the potential for actionable nuisance and real flood damage arising from flood events over the existing situation.
- The predicted flood impacts are small and mostly on land that is currently under risk of flooding. Future development on this land would require flood mitigation regardless of the Caloundra South development, and the flood risk strategy developed for this area could easily account for the increases in flood levels. Therefore, the proposed Caloundra South development is not expected to inhibit the future development potential of the subject area.
- While there are slight differences in the flood impacts across Council's land (due to the use of more contemporary topographic data and alterations to the Town Centre concept design) **the flood impacts are, on average, no different to that assessed for the previous Precincts 3 to 5 RoL approval**.




Title:

**100 Year ARI Difference in Peak Flood Levels**

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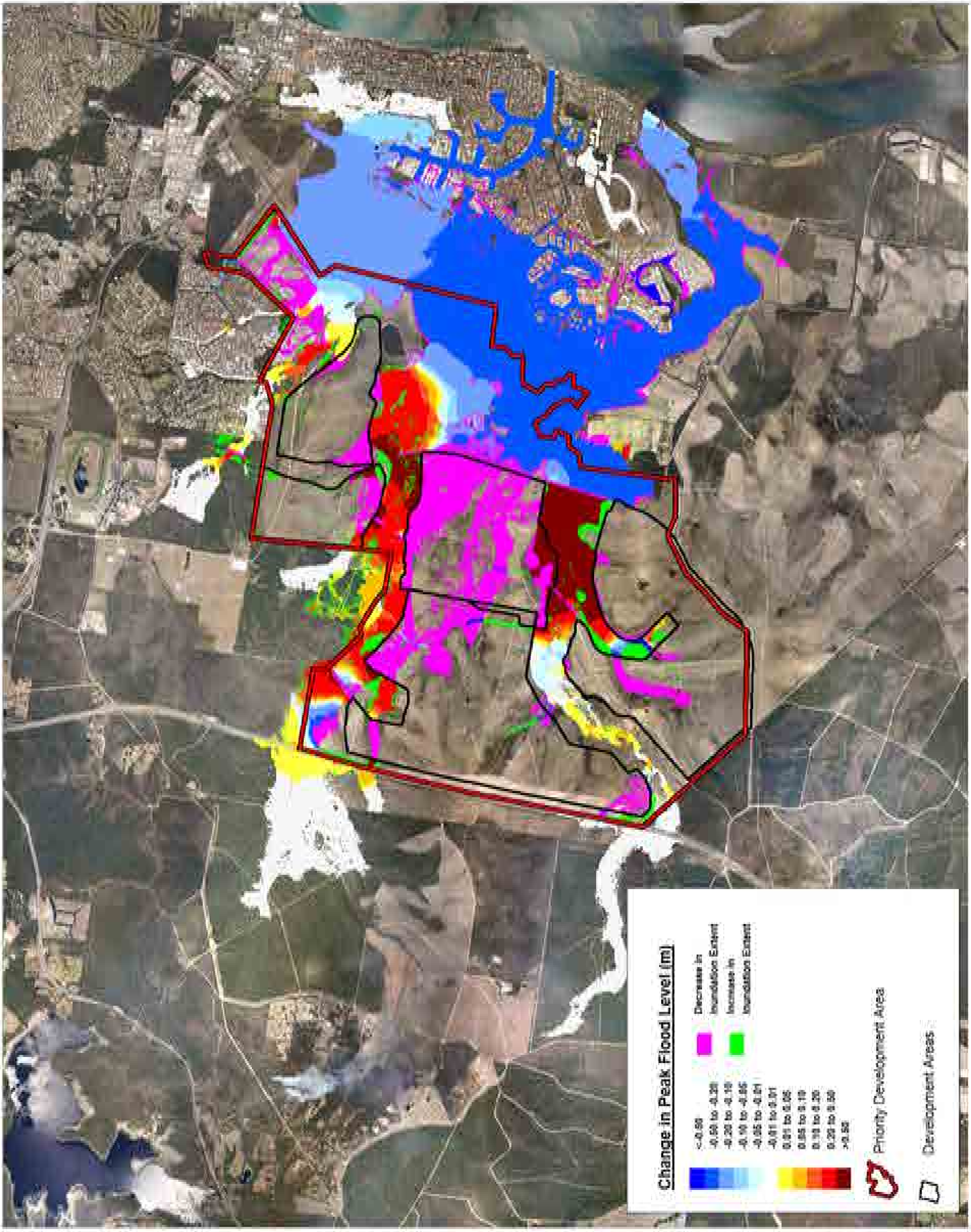


Title:

**50 Year ARI Difference in Peak Flood Levels**

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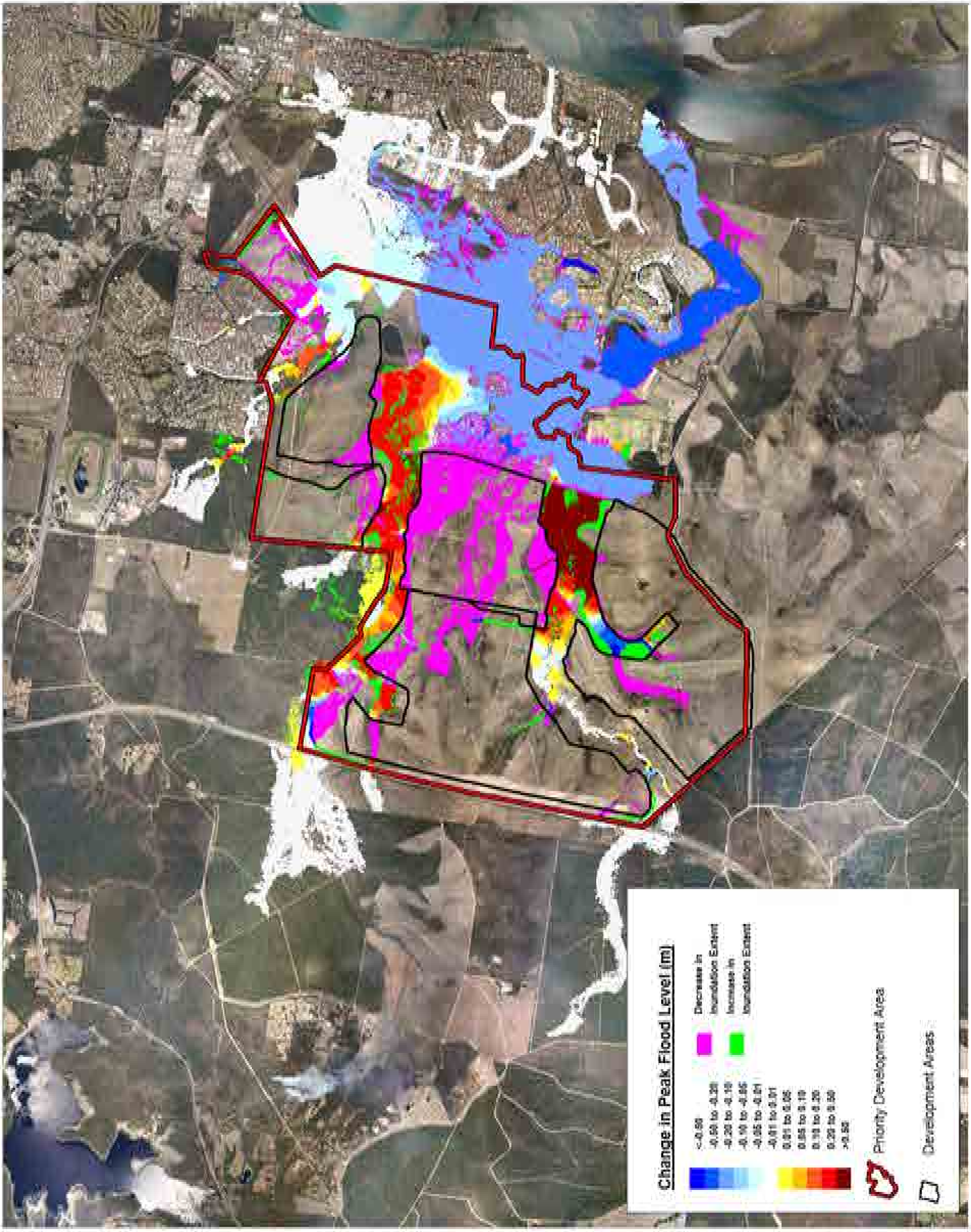


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**5 Year ARI Difference in Peak Flood Levels**

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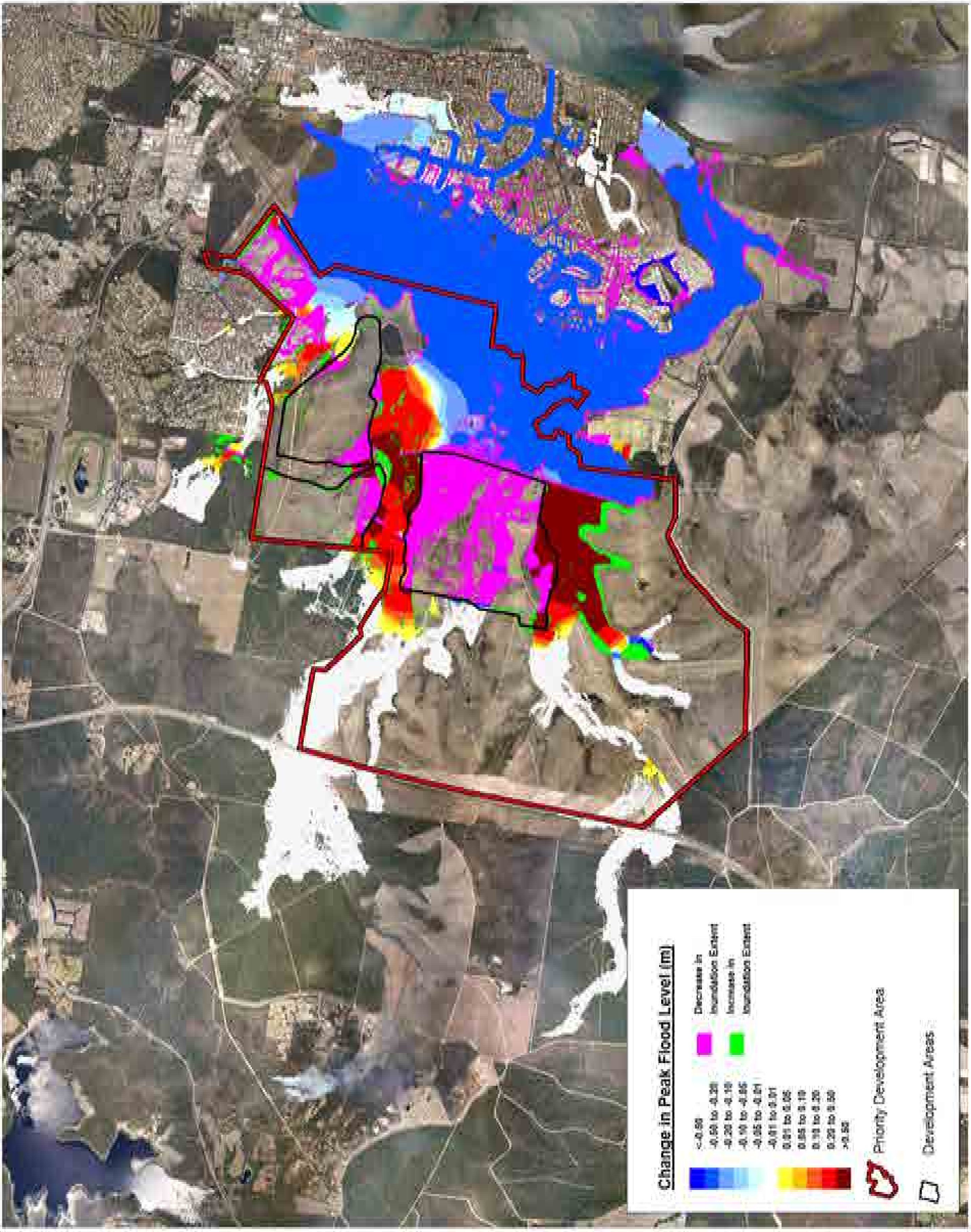
## 7.2 Flood Impact Assessment – RoL Application Areas

The flood impacts have also been investigated for the RoL application areas in isolation from the remaining development. The results are presented in Figure 7-4 to Figure 7-6.

The following comments on the flood impacts are made:

- Similar to the full PDA development assessment, increases in flood levels are generally contained within the PDA
- Similar to the full PDA development assessment, flood levels are predicted to reduced downstream of the proposed development
- There are no flood impacts in the vicinity of the Bruce Highway
- Similar to the full PDA development assessment, there is predicted to be an increase in peak flood level in a small area external to the PDA on land owned by Council. However, the impact is less pronounced than for the full PDA assessment and is consistent with the RoL approval for Precincts 3 to 5.




Title:

**100 Year ARI Difference in Peak Flood Levels Development Areas**

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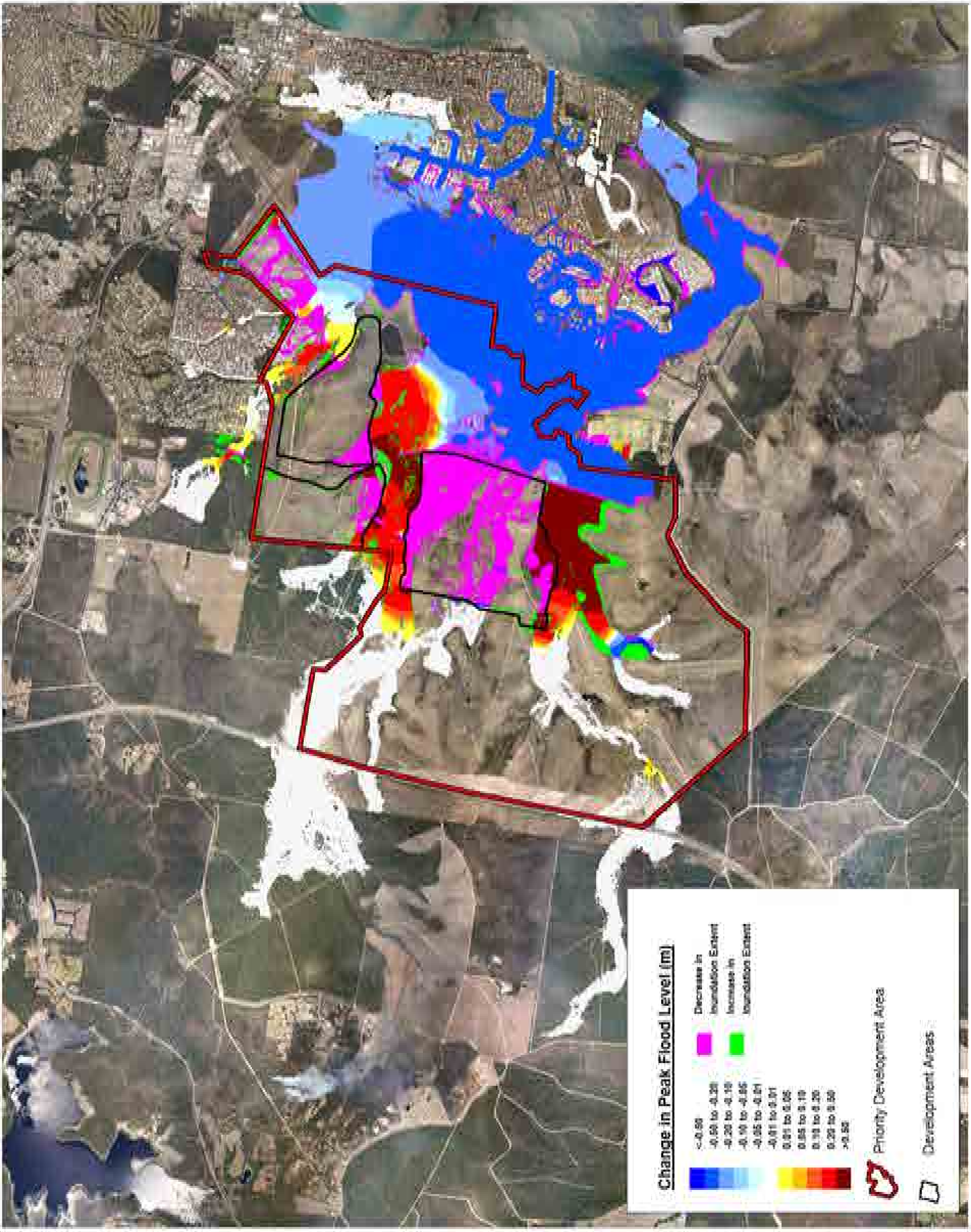


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**50 Year ARI Difference in Peak Flood Levels Development Areas**

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0 1.5 3km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

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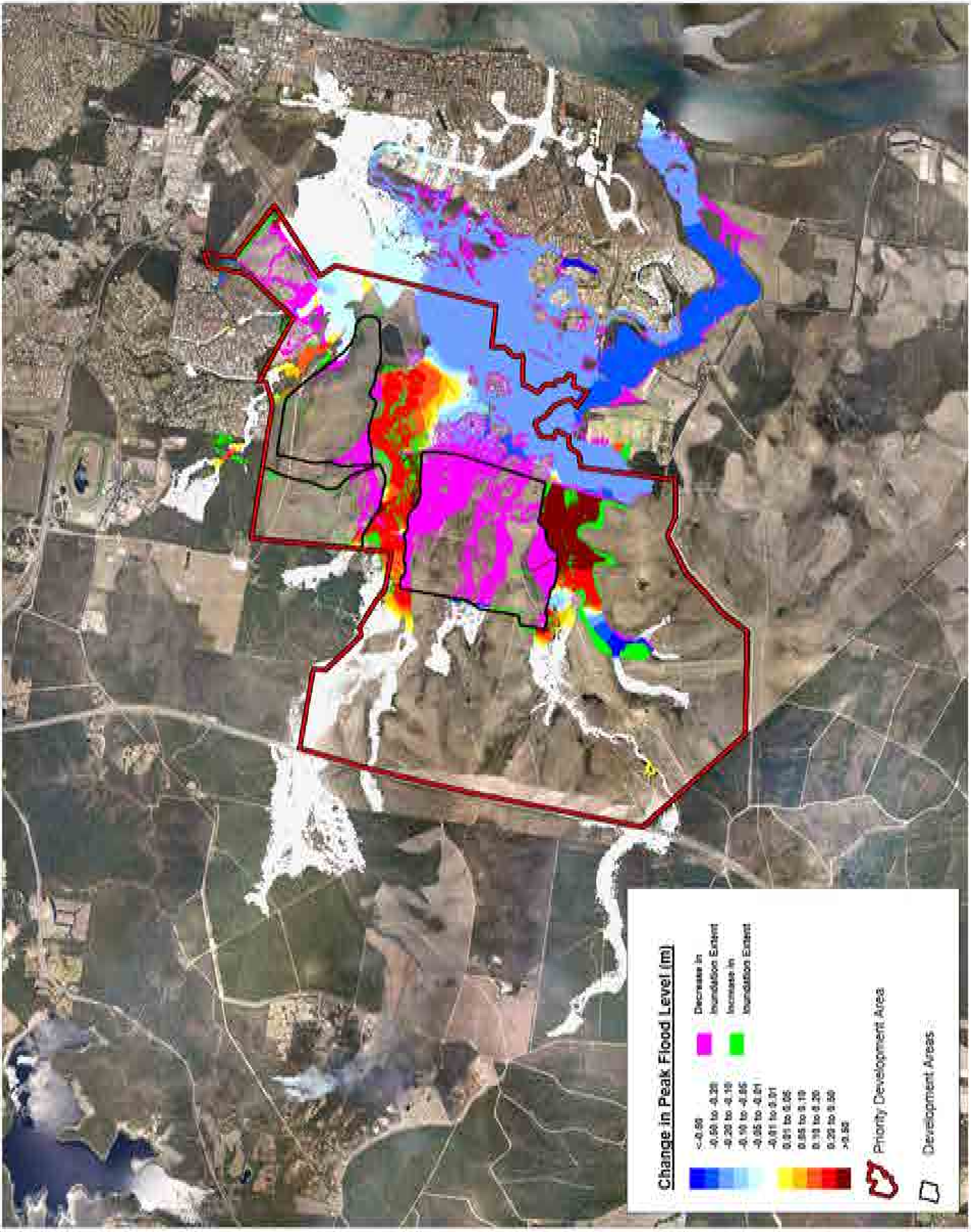


Title:

**5 Year ARI Difference in Peak Flood Levels Development Areas**

Figure: **7-6**

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Approx. Scale

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## 7.3 Changes in Flow Magnitudes and Timing

As previously noted, the proposed development has reduced downstream flood levels by confining flows along Bells Creek North and South through the PDA. This has resulted in later and smaller peak flows downstream of the development. Flows entering the Pelican Waters area downstream of the development are plotted in Figure 7-7 and Figure 7-8. Flows peak 3.5 hours later for the Bells Creek catchment. For the Lamerough Creek catchment the existing flow hydrograph is peaky, and the proposed development causes a much reduced flow and flattened hydrograph.

Thus, the proposed development is not considered to adversely impact flood warning times for downstream development.

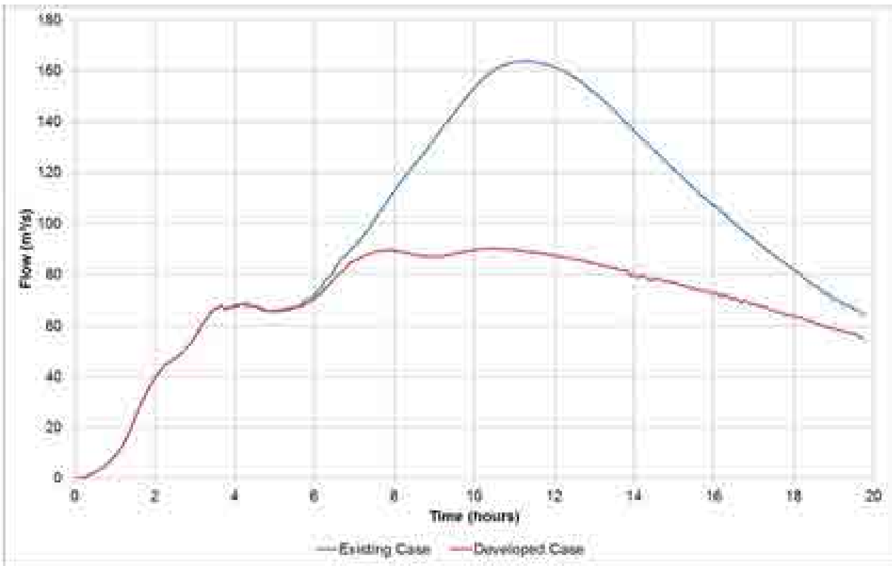



**Figure 7-7 Flow Entering Northern Pelican Waters Area from Lamerough Creek Catchment – 100 Year 12 Hour Storm Duration**

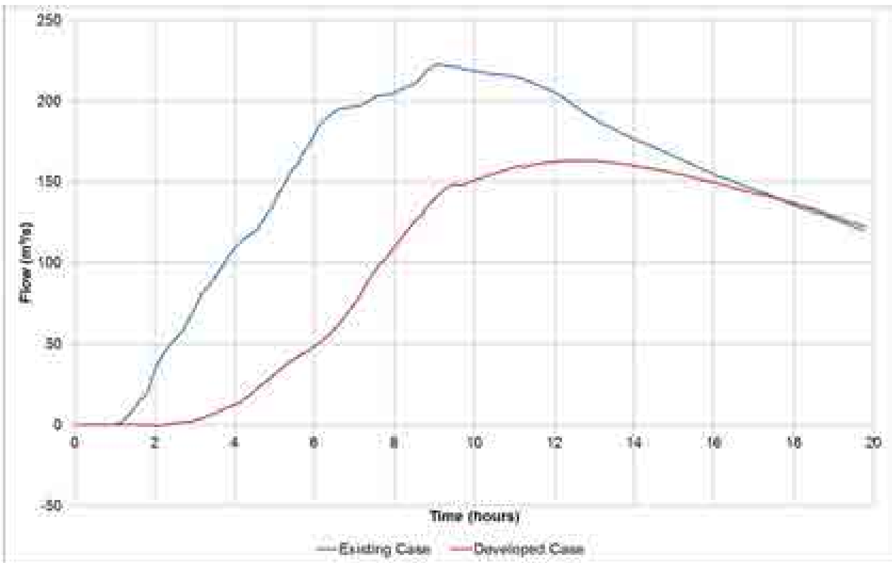



**Figure 7-8 Flow in the lower reaches of the Bells Creek Catchment – 100 Year 12 Hour Storm Duration**

Figure 7-9 shows that there has been negligible change in peak flood levels downstream at Pelican Water during the 1 year ARI event.

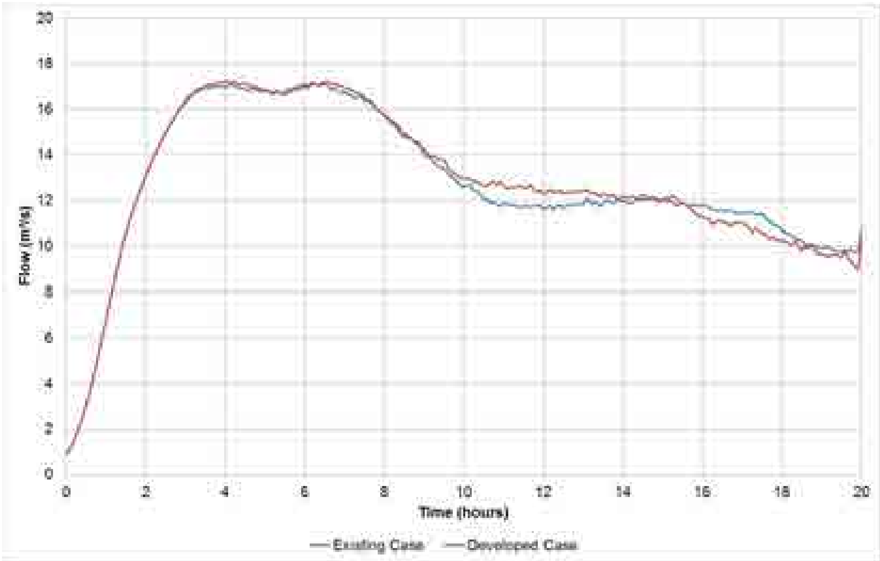



**Figure 7-9 Flow Through Pelican Waters Canal near Outlet – 1 Year ARI 12 Hour Storm Duration**

## 7.4 Flood Hazard and Emergency Management

The developed case flood hazard for the 100 year ARI fluvial flooding has been assessed. Flood hazard has been defined according to the AR&R Project 10 – *Appropriate Safety Criteria for People* (AR&R, 2010). The hazard categories are presented in Table 7-1. This table was used with the following additional limitation criteria, which are also specified in the AR&R Project 10 report:

- Limiting depth of 0.5m for children and 1.2m for adults in low flow areas; and
- Limiting velocity of 3m/s at shallow depths.

**Table 7-1 Flow Hazard Regimes for Infants, Children and Adults**

<table>
<tr><th>Depth x Velocity (m²/s)</th><th>Infants, Small Children and Frail/Older Persons</th><th>Children</th><th>Adults</th></tr>
<tr><td>0</td><td>Safe</td><td>Safe</td><td>Safe</td></tr>
<tr><td>0-0.4</td><td rowspan="5">Extreme Hazard</td><td>Low Hazard</td><td rowspan="2">Low Hazard</td></tr>
<tr><td>0.4-0.6</td><td>Significant Hazard</td></tr>
<tr><td>0.6-0.8</td><td rowspan="3">Extreme Hazard</td><td>Moderate Hazard</td></tr>
<tr><td>0.8-1.2</td><td>Significant Hazard</td></tr>
<tr><td>>1.2</td><td>Extreme Hazard</td></tr>
</table>

The resulting flood hazard for adults for the developed case 100 year ARI flood event is shown in Figure 7-10.

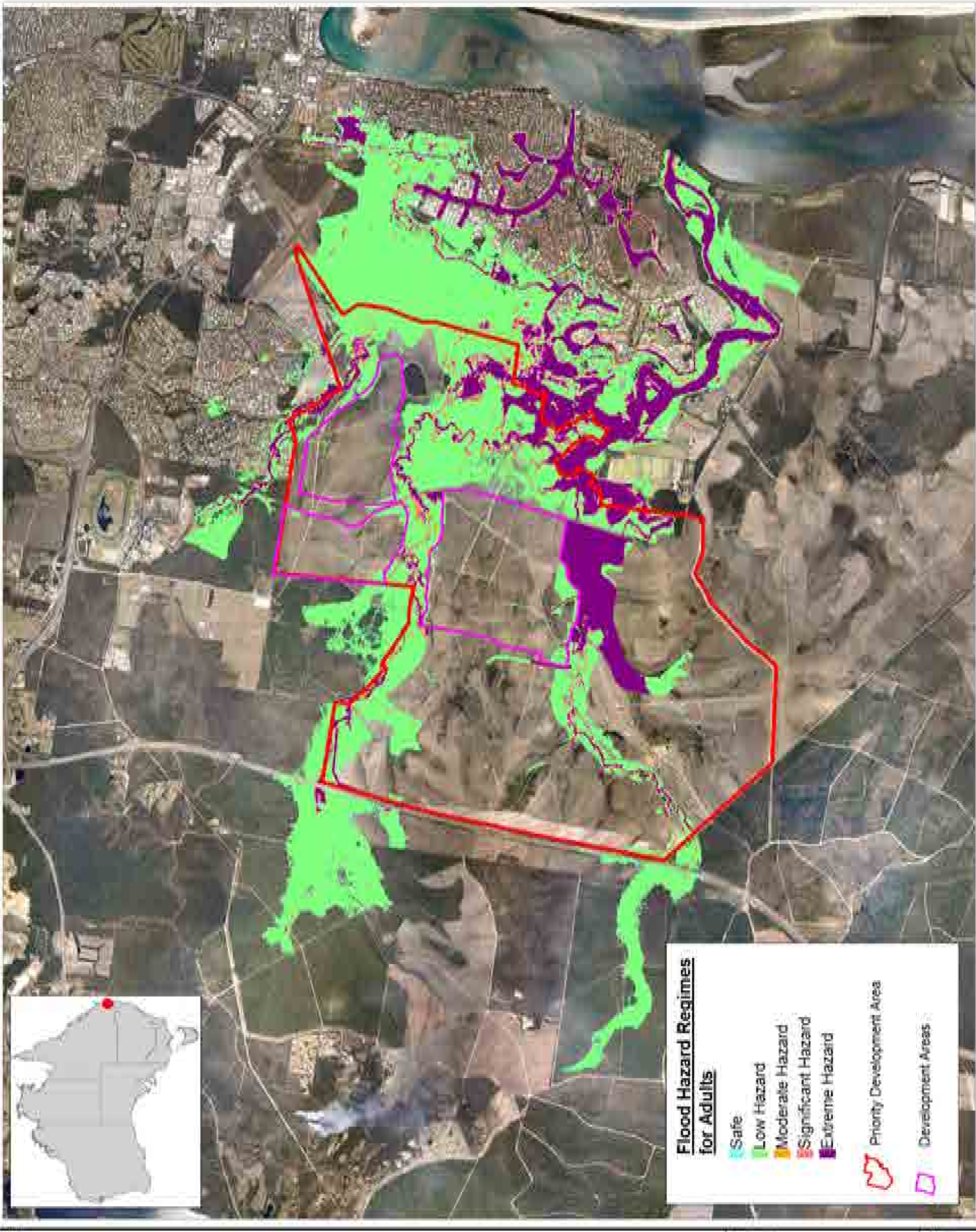
The results show that most of the inundated areas through the site are low hazard for adults. Extreme hazards occur within the river channels and detention basin areas, and moderate hazards occur along some drainage paths. Some of the low hazard areas are planned to be used for recreational purposes. Given that these areas abut developed areas with low flood risk, there is generally an escape route to high ground from recreational areas.

BMT WBM undertook a flood assessment in September 2014 (BMT WBM, 2014c) that investigated the extreme flood risk within the PDA. For this assessment, the 200 year, 500 year, 200 year and Probable Maximum Flood PMF were simulated. While it has not been possible to revise the extreme events modelling for this report, it is anticipated that the results will be similar as only minor changes to the development have occurred.

The results of this assessment suggest that:

- The adopted flood planning levels are generally higher than PMF flood levels. Some shallow flooding occurs on the outskirts of the development, but most of the development remains flood immune. Therefore, there is little residual flood risk.
- Apart from the Bells Creek Arterial crossing on Bells Creek South, all other access roads are flood immune up to the 2000 year event. Therefore, there is no isolation up to the 2000 year ARI flood event.
- Shallow flooding of road crossings occurs in the PMF event. This causes the central portion (between Bells Creek North and Bells Creek South including the Town Centre) of the development to become isolated. Without implementation of the proposed development west of the Town Centre, the Town Centre will become isolated. As stated above, the Bells Creek Arterial crossing and Link Road crossing are flood immune in the 2000 year event. Therefore, the Town Centre will only become isolated in an extreme flood event. However, the town centre area will be relatively self-sustaining and the road access will only be cut for approximately 7 hours.

In conclusion, the residual flood risk is manageable and emergency management concepts will be developed at the precinct scale.




Title:

# Developed Case 100 Year ARI Flood Hazard For Adults

Figure: 7-10

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Approx. Scale

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www.bmtwbm.com.au

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## 7.5 Floodplain Storage

A comparison of floodplain storage in the vicinity of the proposed development has been undertaken on the 100 year peak flood depth results. Based on the peak flood depths pre and post development within the portion of the catchment where development is proposed, there is 36% increase in floodplain storage volume. This is likely to be due to higher flood depths within the developed area, caused by the detention basin on Bells Creek South and constrictions/crossings on Bells Creek North. Therefore, it is concluded that the proposed development has not reduced the floodplain storage capacity.

## 7.6 Conclusions

The flood risk impacts of the proposed development were assessed by comparing modelled peak flood levels of the developed case with the base case. Various development schemes have been investigated to derive a scheme that has no adverse flood impacts off site.

The modelling demonstrates that the potential impacts of the development can generally be mitigated through the implementation of a series of flood mitigation measures. A key component of the Flood Risk Management Strategy presented in this report is the provision of additional floodwater storage capacity at Bells Creek South through the implementation of hydraulic controls on the Bells Creek Arterial crossing and lowering of the natural ground surface levels.

# 8 Climate Change Assessment and Flood Planning Levels

## 8.1 Preamble

To ensure that the proposed development has appropriate flood immunity now and in the future, the ground elevations of the proposed urban areas (i.e. roads, commercial and residential allotments) will be set to a minimum level that incorporates an allowance for climate change impacts. This minimum level is referred to as the Flood Planning Level (FPL).

To assess how climate change impacts could affect flood levels surrounding the development, the potential impacts of climate change on the flood risk of the Caloundra South site have been assessed. For the climate change impact assessment, a planning horizon to the year 2100 has been adopted.

## 8.2 Potential Impacts of Climate Change

Scientific research documented by the *Intergovernmental Panel on Climate Change* IPCC (2007) and the *Department of Environment and Resource Management* DEHP (2010) indicates future climate change resulting from global warming is likely to result in:

- Changes in extreme rainfall intensity;
- Sea level rise; and
- Changes to storm occurrences and storm wind intensity, affecting storm surge levels.

The predicted changes in extreme rainfall intensity, sea level rise and storm surge levels to the 2100 planning horizon have been documented below.

### 8.2.1 Extreme Rainfall Intensity

Rainfall intensity is likely to vary as a result of global warming. Guidance on expected rainfall intensity increases in Queensland is discussed in Increasing Queensland's resilience to inland flooding in a changing climate: Final report on the Inland Flooding Study (Queensland Government 2010). This report recommends that rainfall intensities are increased by 5% per degree increase in global mean temperature.

For the 2100 planning horizon timeframes, the predicted increase in global mean temperature is 4.0˚C. Therefore, in the climate change assessment the design rainfall intensity utilised by the Caloundra South hydrology model was increased by 20%.

### 8.2.2 Future Sea Level Rise

For planning purposes, a 0.8m mean sea level rise has been adopted. This is consistent with the sea level rise factor adopted by the Department of Environment and Heritage Protection for the updated coastal hazard mapping of the Queensland Coast (released on 8th July 2015).

### 8.2.3 Changes to Storm Occurrences and Storm Intensities

The potential impacts of increased frequency and intensity of tropical cyclones at Golden Beach due to climate change were investigated in the *Oceans Hazard Assessment Stage 2 Report* (Hardy et al 2004). Hardy et al (2004) assessed the likely impact of a 10% increase in cyclone intensity and frequency including a poleward shift in cyclone track by 1.3 degrees. Hardy et al (2004) indicate these changes to cyclone intensity, frequency and path may increase the 100 year ARI storm tide level around Bribie Island by approximately 0.15 m. This is in addition to the mean sea level rise.

### 8.2.4 Summary

A climate change assessment has been undertaken for the Caloundra South PDA development. The assessment accounted for a predicted increase in extreme rainfall intensity, sea level rise and changes to storm occurrences and storm intensities (storm surge). The values adopted, to represent to likely variation in these parameters to 2100, are outlined in Table 8-1.

**Table 8-1 Adopted Climate Change Variation Estimates (Reference year 2100)**

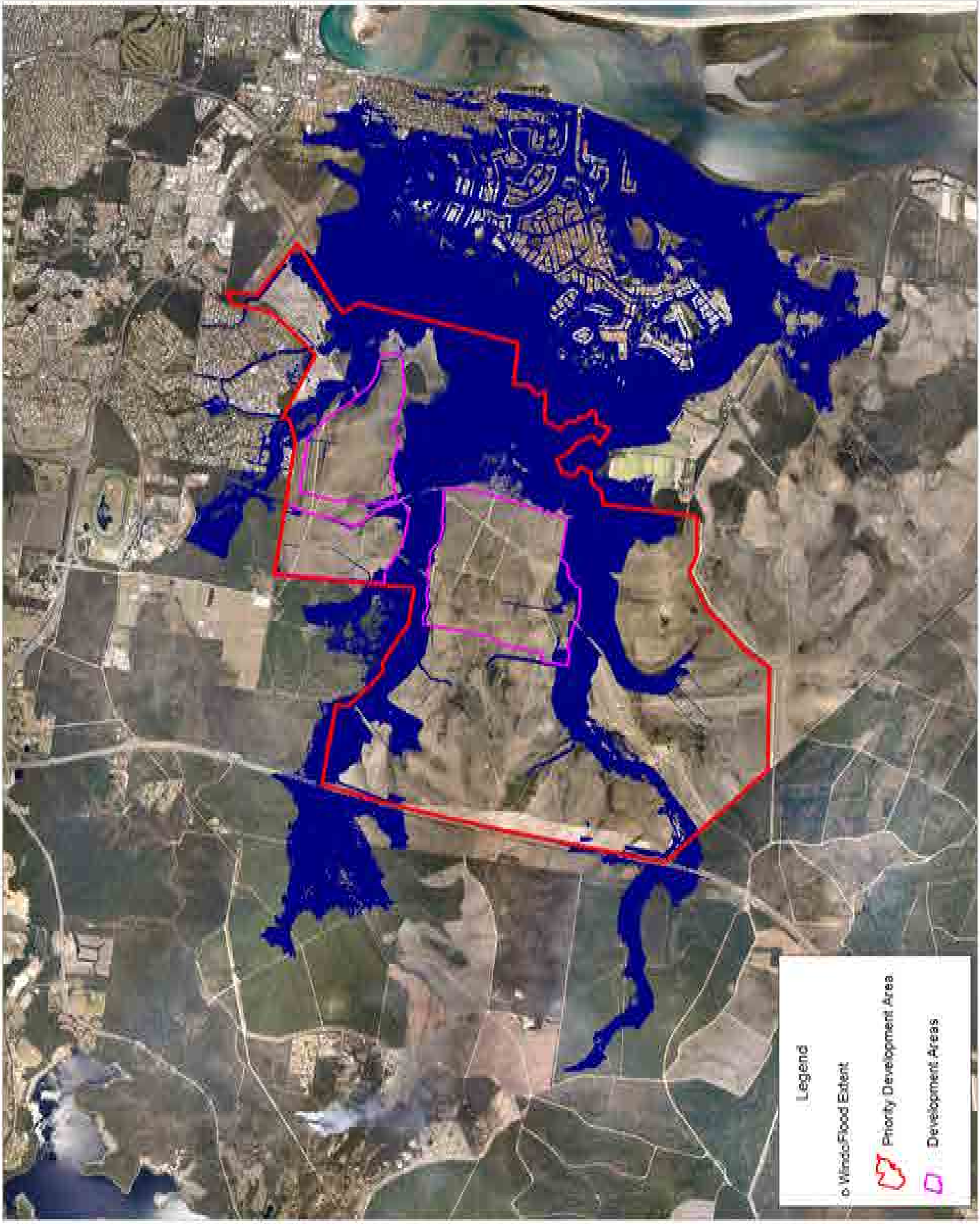
| Environmental Forcing | Adopted Climate Change Variation Estimate |
|---|---|
| Extreme rainfall intensity / depth | +20% |
| Mean sea level rise | +0.80m |
| Increase in design storm tide levels | +0.95m (0.8m + 0.15m) |

## 8.3 Climate Change and Flood Planning Levels

To establish the minimum ground elevations of the development, the flood impacts of the potential climate change variations have been determined as follows:

- For the fluvial flood events the rainfall depth was increased by 20% and the downstream boundary condition, which is a static Mean High Water Spring level in Pumicestone Passage, was raised by 0.8m; and
- The 100 year ARI design storm tide level of 1.65mAHD (Aurecon, 2013) was raised by 0.95mAHD to 2.60mAHD.

It is recommended that the FPLs are set according to the flood levels produced as part of this 100 year ARI climate change assessment with an additional freeboard allowance. It is understood that a freeboard of 0.35m has been adopted for the fill levels in proposed urban areas, and that the finished slab levels of buildings will be higher (with 0.5m freeboard) to facilitate the building services.




Title:

## 100 Year ARI Including Climate Change Flood Extent

Figure

8-1

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0 1.5 3km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

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# Appendix A Responses to Model Review

## A.1 Preamble

BMT WBM was commissioned by Stockland (in support of a Material Change of Use Master Plan Application to the Urban Land Development Authority) to prepare an Integrated Water Management Plan (IWMP) for the 'Caloundra South' development.

This IWMP provided a holistic approach to water management for the proposed master-planned community. The main elements of this IWMP were a flood risk management strategy, stormwater management plan and groundwater quantity and quality assessment.

On 15 June 2012, Urban Land Development Authority (ULDA) provided an approval for a material change of use for the Caloundra South Master Plan (ULDA Ref No.: DEV2011/200) based on a number of conditions.

## A.2 Responses to Conditions

Conditions related to flooding are listed in Table A-1 along with a response on how each condition has been achieved.

**Table A-1 Responses to Material Change of Use Application Conditions**

| | Condition | Response |
|---|---|---|
| **34b – Flooding** | | |
| | A Flood Risk Management Strategy Report shall be prepared which includes an appropriate flood model to determine a flood assessment of the pre and post development scenario. The Flood Risk Management Strategy Report shall be generally in accordance Section 3 of the approved Integrated Water Management Plan prepared by BMT WBM dated May 2012, with the following additional requirements | This report has been prepared in response to this condition, and this condition is subsequently satisfied. |
| (i) | No increase in flood level for events up to and including the 100 year event external to the site in areas other than open space unless the written consent of affected property owners is obtained. Afflux plots and the level of model accuracy for the purpose of determining impacts shall be+-10mm unless agreed otherwise. | This has been completed, Section 7.1. |
| (ii) | Flood modelling shall be completed with a grid spacing appropriate to the level of detail of the application | A grid spacing of 5m has been used, which is appropriate for the level of application (Appendix C) |
| (iii) | No increase in flood level at the boundary of the flood model. Flood model to be extended as required to achieve this outcome. | This condition has been satisfied by extending the model extent to ensure that there are no increases in flood levels at the Duck Holes Creek and Lamerough Creek boundaries. |

| | Condition | Response |
|---|---|---|
| (iv) | No increase in peak flow downstream of the site in Bells Creek or Lamerough Creek (upstream of the Pelican Waters canal) for events with recurrence levels of between 1 year and 100 years inclusive. | This has been completed, Section 7.3. |
| (v) | Flood modelling completed in support of the report shall consider the 1, 2, 5, 10, 20, 50 and 100 year recurrence interval events. | This has been completed see Appendix C, Appendix D, Appendix E and Appendix F. |
| (vi) | Community infrastructure shall be provided an appropriate level of flood immunity as defined in Appendix 9 of the State Planning Policy 1/03 Guideline 'Mitigating the Adverse Impacts of Flood, Bushfire and Landslide' or subsequent updated document. In accordance with the recommendations of the Queensland Flood Commission, the risk management strategy shall consider issues of resident egress from Caloundra South under flood conditions that exceed the defined flood event. | Community infrastructure such as schools and libraries have been located above the 100 year ARI flood level including allowances for climate change with a 2100 year horizon and a 500mm freeboard.<br>It is acknowledged that Appendix 9 of SPP Guideline 1/03 provides a guide for selecting minimum flood levels appropriate to specific community infrastructure. This will be considered during detailed design and adjustments to the bulk earthworks design made as necessary. |
| (vii) | Demonstrate that development will not result in a significant reduction in the flood warning time in existing developed areas subject to inundation. | This has been completed, see Section 7.3. |
| (viii) | The report shall include flood hazard mapping and shall address and provide appropriate risk management strategies for low, medium and high hazard areas. The strategy will need to consider velocity and depth of flow, rate of rise, and warning times. In particular, appropriate strategies shall be defined for recreational areas where a level of immunity less than 100 years is being proposed (for example the proposed lake area) prior to the use being permitted. | This has been completed, see Section 7.4. |
| (ix) | The allowance to be made for climate change (in terms of sea level rise and impacts of rainfall intensity) shall be in accordance with guidelines current or likely to be adopted in the short term at the time of preparation of the report. | This has been completed, see Section 8. |
| (x) | Minimum lot, non-habitable and habitable floor levels shall be identified based on the results of the flood modelling in accordance with the requirements of the Sunshine Coast Regional Council relative to the peak flood levels calculated for the climate change. | This has been completed, see Section 8. |

| | Condition | Response |
|---|---|---|
| (xi) | The report shall nominate the cross-drainage requirements at each crossing (road and pedestrian) of a watercourse. | This has been completed, see Appendix C Section C.4.3 |
| | The report shall also nominate the proposed conditions under which the crossing will be over-topped. | The crossings are flood immune up to and including the 100 year ARI design flood event including allowances for climate change. |
| | In the event of over-topping occurring for the 100 year event, the depth and velocity of any overflow shall satisfy the requirements of the 'Queensland Urban Drainage Manual' (2007 or later version). | Not Applicable |
| | It shall be demonstrated that lots do not become inundated in the event of the crossing (other than bridges) being 50 percent blocked by debris. | This has been completed see Appendix C.5 |
| | In all cases, the minimum level of the crossings shall be less than the minimum ground level of upstream lots unless a bridge crossing is proposed. | Road embankments crossing the river are proposed to be lower than the minimum ground level of upstream lots. |
| (xii) | For each nominated crossing point, measures taken to protect the Environmental Values of the watercourse (including fish passage as appropriate) shall be nominated. | Achieved – see Natural Environment Strategy. |
| (xiii) | Flood modelling will include all proposed works in the floodplain. In particular, the modelling shall include the ephemeral wetlands (and other treatment measures) proposed for the development. Ephemeral wetlands shall be immune to inundation for Bells and/ or Lamerough Creek flooding for events up to and including the 10 year event unless an alternative immunity is demonstrated to be satisfactory. | An alternative immunity of 1 year ARI has been demonstrated to be satisfactory. Treatment devices are included in the modelling – see Appendix C in Section C.4.5. |
| (xiv) | The flood modelling shall confirm that the peak flow velocity in treatment devices during regional flooding does not exceed the limits nominated in the Healthy Waterways publication 'Water Sensitive Urban Design Technical Design Guidelines' (2006 or later version) unless it can be demonstrated that higher velocities can be tolerated. | This has been completed see Appendix E. |

| | Condition | Response |
|---|---|---|
| (xv) | The report shall include a description of any water level data available for the catchment to allow the calibration of flood models. In the absence of calibration date, recourse shall be made to the following:<br>a. Comparison/ adjustment of hydrologic model to suit parameters derived from a hydrologically similar catchment<br>b. Comparison/ adjustment of hydrologic model to peak flow rates calculated using empirical methods such as the Rational Method.<br>c. Completion of a sensitivity analysis in relation to the hydraulic model by considering the 100 Year Post-Development Case with Mannings 'n' roughness values increased by 20 percent. In cases where the resultant levels could inundate floor areas, minimum lot and floor levels shall be raised accordingly | Calibration is not possible due to insufficient historical flood data in the catchment.<br>The MCU application hydrological modelling builds on modelling undertaken for a prior flood study which used recourse (a). Further to this, recourse (b) and (c) have been undertaken – see Appendix C. |
| | Electronic copies of the hydrologic and hydraulic models shall be submitted for review. | RoL Modelling was provided previously. The revised modelling reported in this document can be provided on request. |

# Appendix B Responses to Third Party Peer Review Comments (November 2013)

## B.1 Preamble

Cardno has been commissioned by the Department of State Development, Infrastructure and Planning (DSDIP) to undertake a review of previous stormwater-related reporting in relation to the Caloundra South project, including the following reports (by BMT WBM):

- "*Caloundra South Development: Integrated Water Management Plan*" (May 2012).
- "*Precinct 1, Caloundra South Development: Stormwater Quality Management Plan*" (December 2012).
- "*Precinct 2, Caloundra South Development: Stormwater Quality Management Plan*" (March 2013).
- "*Precincts 3 to 5, Caloundra South Development: Stormwater Quality Management Plan*" (March 2013).
- "*Caloundra South Precincts 6 to 10 & 16: Stormwater Quality Management Plan*" (August 2013).

In correspondence 26th November 2013 (to DSDIP) Cardno have provided a list of the items that that they consider require attention prior to the finalisation of approvals for the stormwater management strategy for the Caloundra South project.

## B.2 Responses to Comments

Items requiring attention (as outlined in the aforementioned correspondence) are given below in *black italics*, whilst responses from BMT WBM to these items are provided below in blue text.

### B.2.1 Item 1: Overarching Report

*While the modelling detailed in the ROL application (Precincts 2-5 and 7-10) is generally acceptable, the modelling only deals with the precincts under consideration. Given the changes to the modelling that have occurred since the preparation of the previous site wide report, it is necessary to prepare an overarching report for the whole site that demonstrates that development can occur without unacceptable impacts to satisfy the condition of approval.*

This report constitutes the requested overarching report for the whole site.

### B.2.2 Item 2: Western Detention Basin

*In lieu of an approval from Council in relation to the construction of the western detention basin, it will be necessary to demonstrate that development of the site can occur without producing unacceptable flood impacts if the Western Basin is not in place. The approval can then allow for the construction of the basin when approval has been received from council.*

*Further, the modelling of the western basin will need to include appropriate provision for those areas where is not to pond freely drain.*

Inclusion of the basin is not a requirement from a flood risk management strategy perspective; it is simply a potential enhancement to the flood risk management strategy. The Western Detention Basin has not been considered in this report. A separate flooding assessment for the Western Detention Basin is being prepared to support an application to Council.

### B.2.3 Item 3: Future Lake Area

*Modelling of the future lake area on Bells Creek South will need to include provision for the area to be free draining and a description of the measures required to support the adopted ground slope in the period prior to approval and construction of the lakes provided.*

The lake is located in an area of lowered ground for provision of additional flood storage. This ground lowering slopes towards the river corridor (approximately 1m drop over 1km). The model assumes that the future lake area is full prior to a flood event. Therefore, the lake does not provide additional flood storage and is not part of the flood risk management strategy. As such, this comment is not relevant to the flood risk management strategy.

### B.2.4 Item 4: Water Quality Treatment Devices in Waterway Corridor

*As noted in the comments provided in relation to the flood modelling, any water quality treatment devices (and the level of bunding proposed to protect the devices from frequent inundation) will need to be included in the hydraulic model. Based on advice from BMT WBM it is understood that this modelling has indicated that the impact of the treatment devices minimal and acceptable.*

*It is also noted that the acceptance of flood modelling completed on the basis is based on the assumption that the stormwater management (water quality) report will contain justification for the nominated immunity level and that the infrastructure agreement being reached with Council is also based on the level. The stromwater management report will also need to detail the flow velocities and depths calculated to occur within the treatment devices during minor and major flood events to confirm the level if impact to the treatment device (eg scour, removal of collected material) during such events. Commentary and justification is to be provided in relation to flow velocities that are in excess of excess of those nominated in Healthy Waterways Guidelines.*

The treatment devices have been included in the hydraulic model with a flood immunity of 1 year ARI. Velocities are illustrated in the mapping in this report in Appendix E.

### B.2.5 Item 5: Bells Creek North

*An increase in flood level is predicted to occur in Bells Creek North within the PDA external to the upstream boundary of the site. The report will need to include justification that the increase, if it cannot be reasonable be reasonably removed, does not result in an actionable nuisance or reduce the development potential of the affected land.*

See Section 7.1.

### B.2.6 Item 6: Flood Hazard

*The flood hazard work completed with respect to the BMT WBM report Precincts 2-5 and 7-10; Caloundra South: Flood Risk Management Study (Version 2, January 2013) provides the basis fo the work to be included in the overarching document do the site. This will include:*

- *Section 3.4 of the January 2013 report to confirm that the development will not impact on flood warning times for external developments and comply with Condition 34b (vii).*
- *Section 3.3 of the January 2013 report to provide flood hazard mapping to comply with Condition 34b (viii)*

# Appendix C Model Methodology

This Appendix outlines the flood modelling methodology for the Caloundra South site.

## C.1 Previous Studies

A number of previous flooding investigations of the Caloundra South region have been completed including:

- Caloundra South Informal Land Use Investigation Flooding Assessment - Supporting Technical Study no.5 (Cardno MBK, 1999);
- Caloundra South 2 Hydrological & Hydraulic Analysis Supplementary Report - Supporting Technical Study no.17 (Cardno MBK, 2000);
- Caloundra City Storm Tide Study – Development Report (Connell Wagner, 2003a);
- Caloundra City Storm Tide Study – Counter Disaster Planning Report (Connell Wagner, 2003b);
- Lamerough Creek and Duckholes Creek Flood Study and Stormwater Management Plan; Volumes 1, 2 & 3 (Cardno MBK, 2003);
- Joint Probability Assessment – Storm Tide and Freshwater Flooding, Caloundra City and Maroochy Shire Councils, in Draft (Connell Wagner, 2005);
- Caloundra South Flood Study – Caloundra Local Growth Management Strategy (SKM, 2006);
- Caloundra South Development: Flood Risk Management Strategy (BMT WBM, 2011a);
- Bellvista II Development Reconfiguration of a Lot Application: Flood Impact Assessment (BMT WBM, 2011b);
- Precincts 2-5 and 6-10 and 16, Caloundra South: Flood Risk Management Strategy (BMT WBM, 2013);
- Caloundra South Development: Flood Risk Management Strategy (BMT WBM 2014b); and
- Caloundra South: Flood Risk Management Strategy – September 2014 Update (BMT WBM, 2014c).

Apart from the recent BMT WBM studies, the SKM study is the most recent flooding investigation and includes a review of all the aforementioned investigations. The study area of the SKM study included the Bells Creek and Lamerough Creek catchments (the catchments in which the Caloundra South site is located). The study was undertaken as part of the development of a Local Growth Management Strategy for Caloundra City, and used hydrological and hydraulic models to investigate flooding characteristics of seven coastal catchments that discharge into Pumicestone Passage. This study formed the basis of the BMT WBM studies that followed.

# C.2 Flood Modelling Overview

## C.2.1 Data Summary

### *C.2.1.1 Digital Elevation Model*

A three dimensional Digital Elevation Model (DEM) of the terrain across the site and surrounding catchment is essential for development of hydrological and hydraulic models. The DEM used in this assessment was derived from two sources:

- A Light Detection and Ranging (LiDAR) survey flown in November 2012 that covers the Caloundra South PDA. This LiDAR survey was processed and issued by RPS, who also verified the LiDAR by ground survey in selected areas across the site.
- In portions of the catchment beyond the 2012 LiDAR coverage, the SKM flood study (SKM 2006) DEM was used.

SKM developed the DEM, which has a grid resolution of 5m, using the following:

- AAM Hatch undertook a LiDAR survey for the SKM flood study. The vertical and horizontal accuracy of this data was reported as ±0.11m and 0.35m respectively. SKM triangulated and converted this survey to a grid with 5m resolution. This data is the primary survey used to develop the DEM. The lasers used for LiDAR survey do not penetrate water. Hence, additional assumptions and survey were used in inundated areas (see below).
- Pre-existing cross section data were extracted from an existing 1D hydraulic model (MIKE11). These cross-sections covered Bells Creek North, Bells Creek South, Bells Creek and Lamerough Creek east of the Bruce Highway. This data was used to inform bathymetry data for Bells Creek.
- A bed level of -3.0mAHD was used through the Pelican Waters canals.

Figure 2-2 illustrates the DEM of the existing terrain used in the assessment. For the proposed development, a proposed DEM for the development was provided by Stockland's civil design consultants. This was supplemented with terrain modifications based on the conceptual layout of the development.

### *C.2.1.2 Land Use Mapping*

Aerial photography was used to digitise different land use classes across the catchment. This land use data were used to inform the roughness and percentage impervious parameters for the hydrological and hydraulic modelling. The aerial photography was obtained from NearMap, and relates to May 2011. Figure C-1 illustrates the existing land use mapping used in the assessment.

Land use mapping for the proposed development were provided by Stockland's civil design consultants.

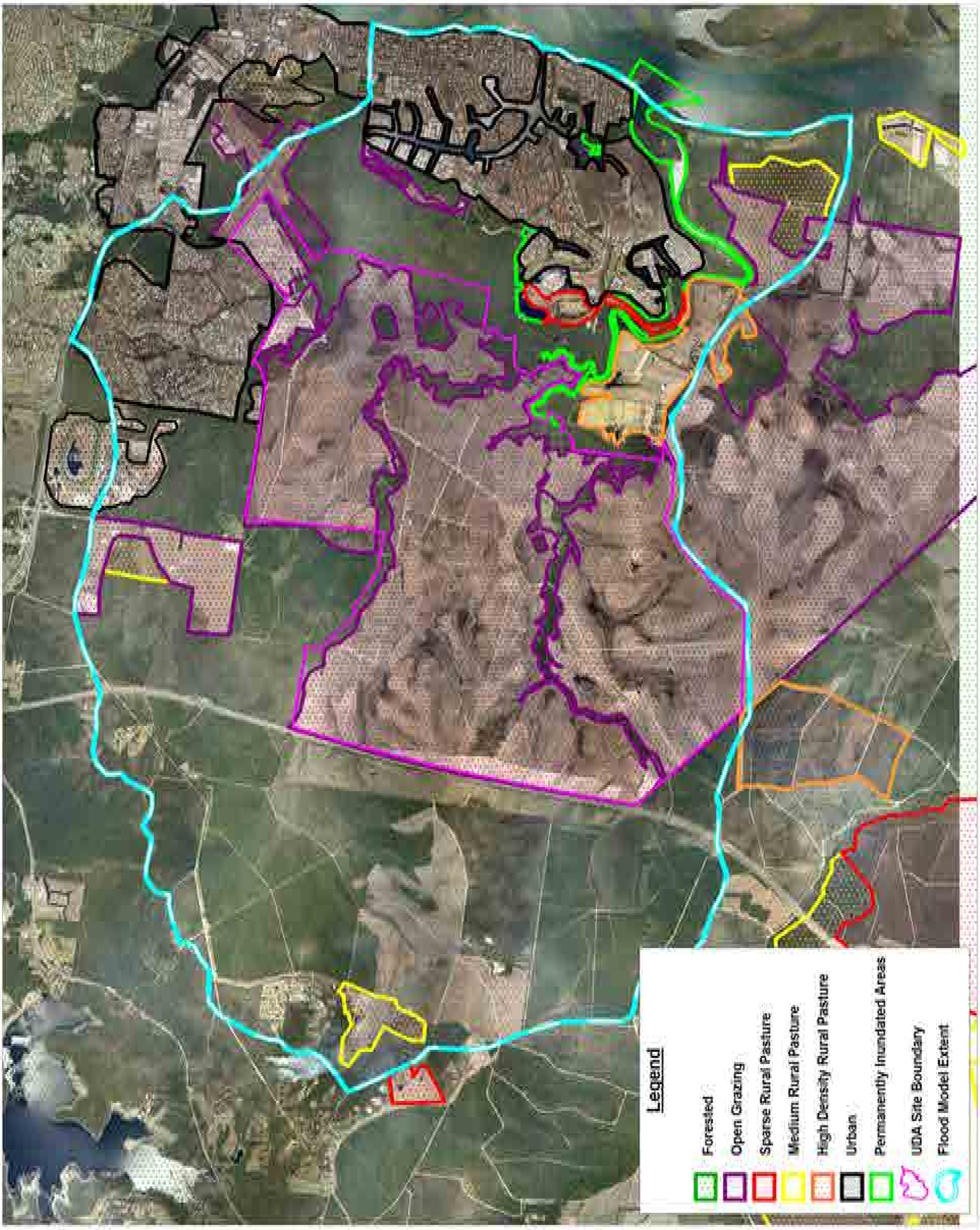
### *C.2.1.3 Existing Structures*

The Bruce Highway forms a significant obstruction to natural flow patterns across the highway. The highway embankment was inserted as a breakline in the topography of the model to ensure it was accurately represented in the model. The elevations used in the breakline were interrogated from the DEM.

To accurately represent drainage through the existing Bruce Highway road embankments, culvert crossings were incorporated as one-dimensional structures in the TUFLOW model and dynamically linked to the 2D model domain at the inlet and outlet. Surveys were conducted to determine the length, location and dimensions of the culvert crossings. These surveys were undertaken by RPS and the culvert dimensions are presented in Table C-1. The locations of the Bruce Highway structures are shown in Figure C-7. Structures in the vicinity of Bells Reach were captured by incorporating the modelling undertaken for the Bells Reach ROL application (BMT WBM 2011b).

**Table C-1 Bruce Highway Culvert Dimensions**

| Culvert ID | Type | Length | Upstream Invert | Downstream Invert | Width or Diameter | Height | Number |
|---|---|---|---|---|---|---|---|
| BH19 | Box Culvert | 21.7 | 11.064 | 10.854 | 2.4 | 3 | 3 |
| BH20 | Box Culvert | 21.6 | 10.854 | 10.836 | 2.6 | 3.8 | 3 |
| BH36_037 | Circular Culvert | 42.4 | 12.097 | 11.949 | 1.3 | N/A | 3 |
| BH38 | Box Culvert | 40 | 10.758 | 10.607 | 3.3 | 3.2 | 3 |
| BH40 | Circular Culvert | 18.2 | 23.997 | 23.667 | 0.825 | N/A | 4 |
| BH41 | Circular Culvert | 22.2 | 23.667 | 23.369 | 0.85 | N/A | 4 |
| BH42_43 | Box Culvert | 37.6 | 24.234 | 24.108 | 2.1 | 1.5 | 3 |
| BH21 | Circular Culvert | 27 | 12.831 | 12.646 | 0.75 | N/A | 1 |
| BH22 | Circular Culvert | 26.6 | 12.646 | 12.474 | 0.75 | N/A | 1 |
| BH_BCS6_1 | Circular Culvert | 18 | 13.7 | 13.5 | 1.3 | N/A | 5 |
| BH_BCS6_2 | Circular Culvert | 18 | 13.5 | 13.3 | 1.3 | N/A | 5 |




Title:

**Existing Land Use Mapping**

Figure: **C-1**

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Approx. Scale

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### C.2.2 Modelling Approach

The flood modelling undertaken in this study builds upon flood modelling developed during previous BMT WBM studies, which, in turn, are based on flood modelling developed during the SKM study.

The SKM study employed RAFTS-XP for the hydrological modelling and the MIKE FLOOD software for developing 1D-2D hydraulic models. BMT WBM subsequently re-established the SKM models using RAFTS-XP for the hydrological modelling and TUFLOW for the hydraulic modelling (BMT WBM 2011c). This work was done to enable BMT WBM to develop a preliminary flood risk management strategy for the Caloundra South PDA.

BMT WBM have also completed a flood study for a Stockland development that lies adjacent to the Caloundra South PDA in the vicinity of Bellvista, called Bells Reach (previously called Bellvista II) (BMT WBM 2011b). This modelling has been incorporated into the flood model. It should be noted that the Bells Reach development does not form part of the current application, and approval has already been granted.

## C.3 Hydrological Model Development

### C.3.1 Model Schematisation

The RAFTS-XP model includes the following catchments, Bells Creek North, Bells Creek South, Lamerough Creek and Duck Holes Creek. The sub-catchment delineation is presented in Figure C-2 and Figure C-3 for the existing and developed cases respectively.

The adopted percent impervious and Manning's n values for existing land use types are presented in Table C-2. The land use delineation for the 'existing case' RAFTS-XP model is shown in Figure C-2.

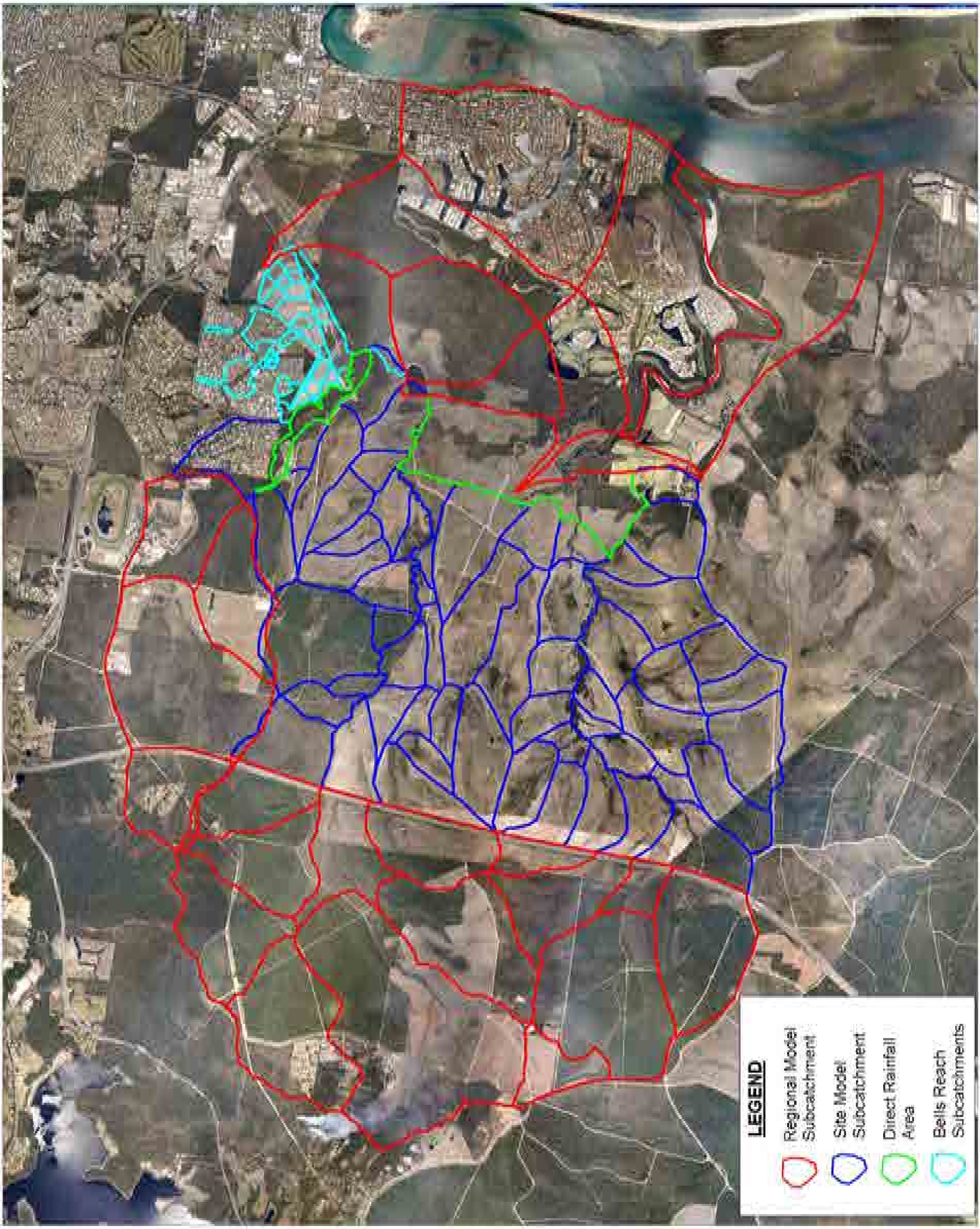
The existing case RAFTS-XP model formed the basis of the developed case hydrological model; sub-catchment roughness, pervious area and percentage impervious were adjusted to reflect the proposed development. Percent impervious for developed land use types was based on land use and density data provided by Stockland. Manning's 'n' for developed land use types has been estimated using typical industry values.

The pervious Manning's 'n', and impervious and pervious areas for each of the sub-catchments for the 'existing case' and 'developed case' RAFTS-XP models are presented in Table C-2.

**Table C-2 Pervious Percent and Manning's 'n' for Existing Land Use Types**

| Land Use Type | Percent Pervious | Pervious Manning's 'n' |
|---|---|---|
| Sparse Rural Pasture | 100% | 0.050 |
| Medium Rural Pasture | 100% | 0.060 |
| Very High Dense Rural Pasture | 100% | 0.080 |
| Permanently Inundated Areas | 0% | - |
| Forested | 100% | 0.100 |

| Land Use Type | Percent Pervious | Pervious Manning's 'n' |
| --- | --- | --- |
| Urban | 40% | 0.025 |
| Sparse Urban | 90% | 0.035 |
| Open Grazing | 100% | 0.05 |

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**Existing Case Hydrological Modelling Extents and Sub-Catchment Delineation**

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C-2

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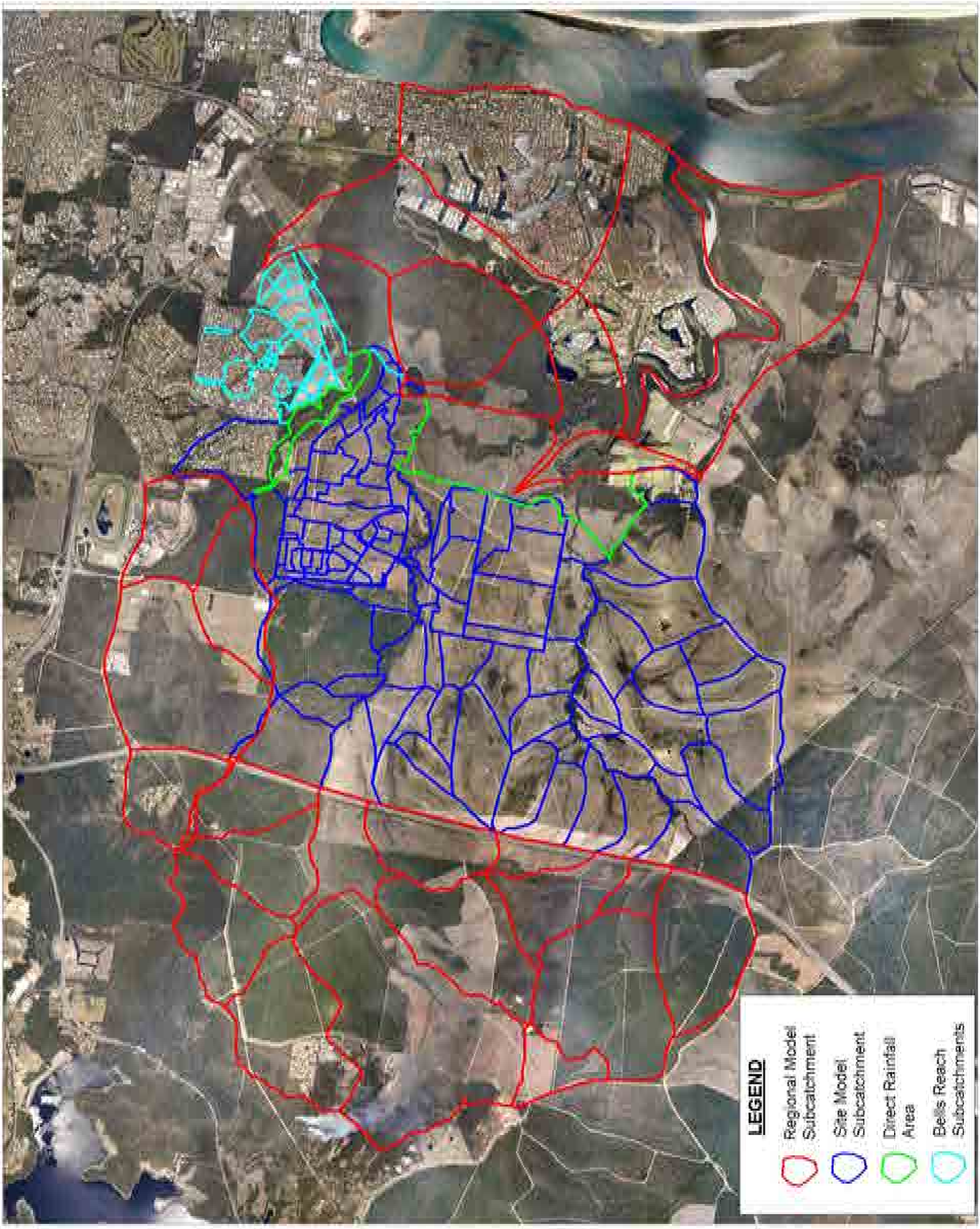


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**Developed Case Hydrological Modelling Extents and Sub-Catchment Delineation**

Figure: C-3

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N

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Approx. Scale

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## C.3.2 Hydrological Design Conditions

### *C.3.2.1 Design Rainfall Intensities*

The CRC-Forge method was used to estimate design rainfall intensities. CRC-Forge and AR&R rainfalls were compared in the Caloundra South Flood Study (SKM, 2006) and the CRC-Forge was found to result in slightly higher design rainfall depths. The design rainfall intensities adopted in this study are presented in Table C-3.

**Table C-3 Design Rainfall Intensities (mm/hr)**

| Event Duration | Average Recurrence Interval (years) | | | | |
|---|---|---|---|---|---|
| | 5 | 10 | 20 | 50 | 100 |
| 3 hours | 33.0 | 37.7 | 43.8 | 52.1 | 59.7 |
| 6 hours | 21.5 | 24.9 | 29.3 | 35.2 | 40.3 |
| 12 hours | 14.0 | 16.4 | 19.5 | 23.8 | 27.3 |

### *C.3.2.2 Areal Reduction Factors*

In contrast to the Caloundra South Flood Study (SKM, 2006), no areal reduction was used in this investigation (i.e. an areal reduction factor of 1 was adopted). This is a conservative approach. The areal reduction factors used in the Caloundra South Flood Study varied between 0.98 and 1 (SKM, 2006).

### *C.3.2.3 Design Rainfall Depths*

The CRC-Forge method was used to derive design rainfall depths up to the 2000 year design storm.

The Probable Maximum Precipitation (PMP) was used to derive the PMF event. The theoretical definition of the PMP is “the greatest depth of precipitation for a given duration that is physically possible over a given storm area at a particular geographical location at a certain time of year” (World Meteorological Organisation, 1986). The ARI of a PMP/PMF event ranges between $10^4$ and $10^7$ years and is beyond the “credible limit of extrapolation”. That is, it is not possible to use rainfall depths determined for the more frequent events (100 year ARI and less) to extrapolate the PMP.

The PMP design rainfall depths and temporal patterns were derived from the Bureau of Meteorology’s Generalised Short Duration Method (GSDM) for storm durations up to and including 6 hours and the Revised Generalised Tropical Storm Method (GTSMR) for storm durations equal to and greater than 24 hours. The design rainfall depth estimate for the 12 hour storm duration was interpolated from the GSDM 6 hour and GTSMR 24 hour design rainfall estimates.

The design rainfall depths used in the study are listed in Table C-4.

**Table C-4 Design Rainfall Depths (mm)**

| Event Duration | Average Recurrence Interval (years) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 5 | 10 | 20 | 50 | 100 | 200 | 500 | 2000 | PMP |
| 3 hours | 99.0 | 113.0 | 131.5 | 156.4 | 179.1 | 203.4 | 237.8 | 295.9 | 600.0 |
| 6 hours | 128.9 | 149.1 | 175.5 | 211.3 | 242.0 | 274.8 | 321.3 | 399.9 | 800.0 |
| 12 hours | 168.1 | 197.0 | 234.5 | 286.1 | 327.6 | 372.0 | 435.0 | 541.3 | 1070.0 |

#### *C.3.2.4 Design Temporal Rainfall Pattern*

Design temporal rainfall patterns from Australian Rainfall and Runoff (AR&R, 2000) Zone 3 were used in this investigation. This is consistent with the Caloundra South Flood Study (SKM, 2006). Both the GSDM and GTSMR temporal patterns were adopted independently for the 12 hour storm duration and the GSDM temporal pattern was used for the 6 hour PMP.

#### *C.3.2.5 Runoff Losses*

The rainfall losses used in the SKM study for pervious areas were 10mm initial loss and 5mm continuing loss. This was based on the dominant land-use in the catchment being forested. In this study, however, the rainfall losses have been reduced to an initial loss of 0mm and continuing loss of 2.5mm for the following two reasons:

- In this study, design storm bursts are being modelled, which are theoretically preceded by lower intensity rainfall. It is typical, therefore, to assume that the catchment is relatively saturated at the start of the storm burst; and
- The portion of the catchment where the development is proposed was covered by pine plantation at the time that the SKM study was undertaken. However, this plantation has been cleared, which has led to lower infiltration rates within the proposed development area east of the Bruce Highway.

Water sensitive urbane design measures will occupy approximately 4.5% of the developed area, and will typically store 0.25m depth of water for a few hours after any rainfall event. This equates to an additional initial loss of 0.011m across the site. This conservatively ignores the additional influence of the more than 20,000 rainwater tanks that will eventually be deployed across the site. However, to be conservative, the initial water losses within the site associated with water sensitive urban design measures has not been considered in the flood modelling.

### C.3.3 Proposed Works Affecting Runoff Behaviour

The proposed development includes changes to the characteristics of the catchment. The majority of the catchment is currently undeveloped. The development of the catchment will increase impervious surfaces and reduce catchment 'roughness' (i.e. decrease Manning's 'n') with the addition of roads, houses and other developments (except in area where revegetation is proposed). Both of these changes will increase peak runoff rates. The approximate proposed development footprint is presented in Figure 5-1.

The pervious Manning's 'n', and impervious and pervious areas, for each of the sub-catchments in the RAFTS-XP model are detailed in Table C-2.

## C.3.4 Hydrological Modelling Results

The relatively flat nature of the site means that runoff in the existing case is comparatively slow to respond. The increase in impervious area and reduced Manning's 'n' in the developed case mean that the affected catchments respond more quickly to rainfall. This can be seen in the existing and post-development runoff hydrographs (100 year ARI, 6 hour event) for sub-catchment BCN1 (Bells Creek North) and BCS1 (Bells Creek South); which are both located just downstream of the development area (refer Figure C-4 and Figure C-5 respectively).

Peak flows at each sub-catchment for the 5, 50 and 100 year ARI events (existing and developed) are provided in Appendix F. The peak flows for the climate change events are also provided in Appendix F.

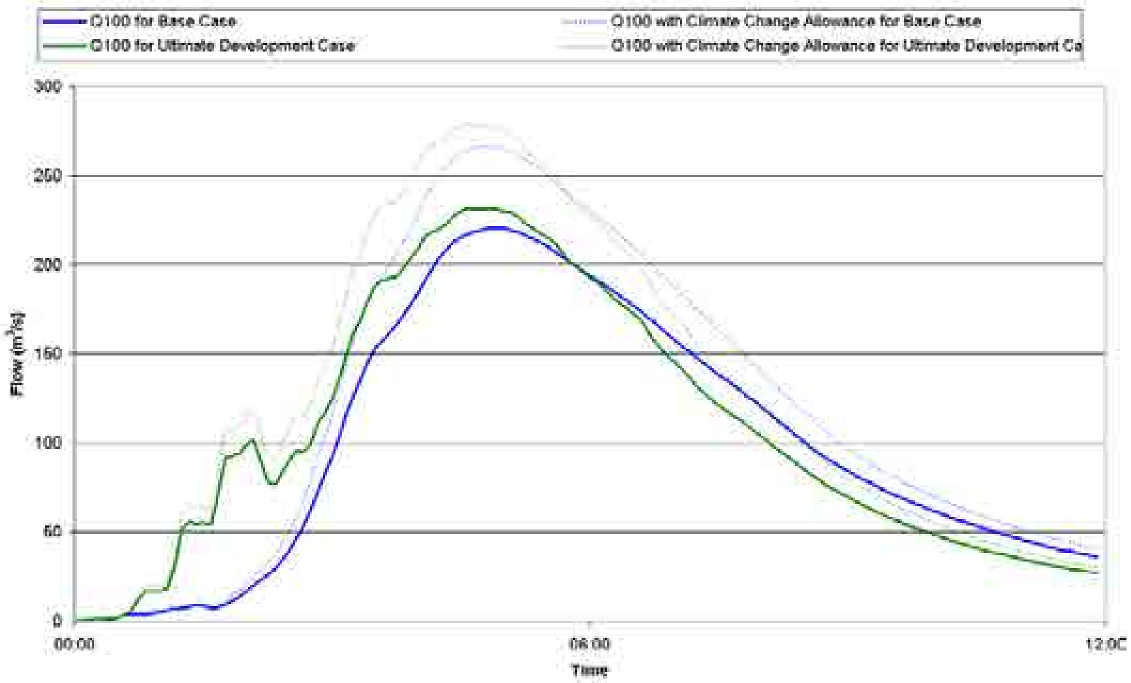



**Figure C-4 Modelled RAFTS-XP Flow Hydrographs at Sub-catchment BCN1**

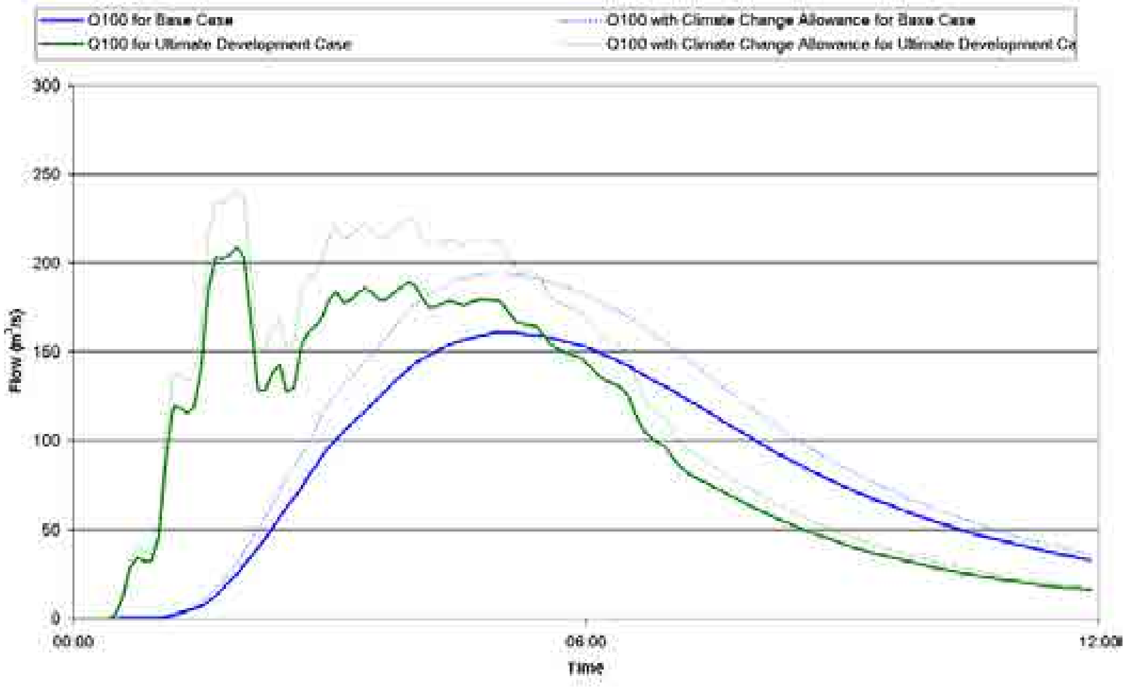



**Figure C-5 Modelled RAFTS-XP Flow Hydrographs at Sub-catchment BCS1**

## C.3.5 Hydrological Model Verification

The SKM study verified the adopted hydrological modelling assumptions against a regional flood frequency analysis and a historical rainfall event (March/April 1989) in the nearby Upper Mooloolah River catchment.

Further verification of the flows has not been possible due to the lack of available data in the area. As such, an indicative check of the flow was undertaken comparing the Rational Method approach against the existing case broader hydrologic model developed for the MCU application (BMT WBM, 2011a). This check was undertaken on the Bells Creek North catchment, which encompasses an area of approximately 2,270ha. Table C-5 shows the design flows and the rational method check for a storm event with a duration of 12 hours.

**Table C-5 Design Flow Check for Bells Creek North**

| Event | Design Flow (m3/s) | Rational Method Flow (m3/s) |
|---|---|---|
| 5 year ARI | 120 | 90 |
| 50 year ARI | 220 | 180 |
| 100 year ARI | 260 | 210 |

The Rational Method approach predicts flows that are 18% to 25% lower than the RAFTS-XP model, which has been considered conservative and acceptable for the purposes of this study, and the RAFTS model has been adopted in this study without further adjustment to the model assumptions. The sub-catchment delineation has been refined since this work, to capture more detail in the catchment run-off for the RoL applications.

### C.3.6 Flood Modelling of Increased Rainfall Intensities

To investigate the impacts of increased extreme rainfall intensities due to climate change, the RAFTS-XP hydrological model was run with increased rainfall intensities. The design rainfall depths as determined by CRC-FORGE (Table C-3) were increased by an additional 20%.

The RAFTS-XP model results for the developed case with climate change allowance (refer to Appendix F) suggest that the peak inflows may increase by about 25% on average as a result of climate change impacts.

The revised RAFTS-XP inflow hydrographs were then used as inflow boundaries in the TUFLOW model. In the simulations of the climate change scenarios (increased rainfall intensities), a constant water level of 1.25 mAHD was used as a downstream boundary condition. This water level represents a predicted mean high water spring level at Pumicestone Passage in 2100.

## C.4 Hydraulic Model Development

### C.4.1 Introduction

The SKM MIKE-FLOOD model was not made available to BMT WBM by Sunshine Coast Regional Council for use in the BMT WBM studies. However, a Digital Elevation Model (DEM) of the study area together with the peak flood levels for the three design flood events modelled in the Caloundra South Flood Study was obtained. Furthermore, the Caloundra South Flood Study report was used to obtain further information in relation to the Caloundra South MIKE-FLOOD model.

On the basis of the information obtained, a TUFLOW model of the Bells Creek and Lamerough Creek catchments was developed during the previous BMT WBM flooding assessment for the Caloundra South development. This formed the basis of the hydraulic model developed for this flood assessment. Furthermore, the model was updated to run on recent version of TUFLOW (version 2013-12-AD double precision).

### C.4.2 Model Area

The modelled area covers the entire Bells Creek and Lamerough Creek catchments, extending from Pumicestone Passage in the east to upstream of the Glasshouse Mountains Road in the west. The extent of the TUFLOW model is shown in Figure C-6.

The floodplain area and watercourses within the model area have been represented within a 2D model domain. The 2D model domain covers an area of approximately 67.5 km2. To the west of the Bruce Highway and in the lower reaches of Bells North and South, adjecnt to Pelican Waters, the model uses a 15m grid resolution. A finer scale 5m by 5m square grid is used around the Bellvista area (based on BMT WBM, 2011b) and throughout the central section of the model domain, which was dynamically linked to the 15m grid domains using a 2D domain linking technique. Each square grid element contains information on ground topography (sampled from a DEM), surface resistance to flow (Manning's 'n' roughness coefficient) and initial water level.

The ground topography of the TUFLOW model was sampled from the DEM. The topography of the Caloundra South area is presented in Figure 2-2.

Linear features that potentially influence the flow behaviour, such as natural gullies and creeks, levees and embankments, were incorporated into the model using 3D 'breaklines' to ensure that these were contained within the model grids and accurately represented in the model.

### C.4.3 Hydraulic Structures

The Glasshouse Mountains Road and the Bruce Highway form significant obstructions to natural flow patterns and convey flood waters at numerous bridge and culvert crossings.

To accurately represent drainage through existing embankments, bridge and culvert crossings were incorporated as one-dimensional structures in the TUFLOW model and dynamically linked to the 2D model domain.

Surveys were conducted to determine the length, location and dimensions of the culvert crossings. These surveys were undertaken by RPS (formerly Conics Ltd). Invert levels and loss coefficients were based on information provided in the Caloundra South Flood Study. Details on the exiting hydraulic structures included in the TUFLOW model are provided in Table C-1. Their locations are shown in Figure C-7.

A series of culverts have ben modelled at the downstream end of the proposed Bells Creek South detention basin to serve as an outlet control mechanism. Culvert dimensions are presented in Table C-6 and culvert locations are shown in Figure C-7.

**Table C-6 Bells Creek South Basin Culvert Dimensions**

| Culvert ID | Type | Length | Upstream Invert | Downstream Invert | Width or Diameter | Height | Number |
|---|---|---|---|---|---|---|---|
| Culv_01 | Box | 50 | 2.15 | 1.4 | 3 | 0.9 | 3 |
| Culv_02 | Box | 50 | 2.3 | 2 | 3 | 0.9 | 5 |
| KD1 | Circular | 80 | 2.95 | 0.88 | 0.9 | N/A | 2 |

A waterway opening optimisation assessment was carried out on all bridge crossings associated with the proposed development. An iterative approach was adopted in this regard whereby the peak flood water surface level, associated with a trial opening width, was assessed. If the trial opening width resulted in an unacceptable outcome in terms of peak water levels, either within the development boundary or external to the site, the effective opening was adjusted accordingly. The final waterway opening widths are presented in Table C-7 and their locations shown on Figure C-7.

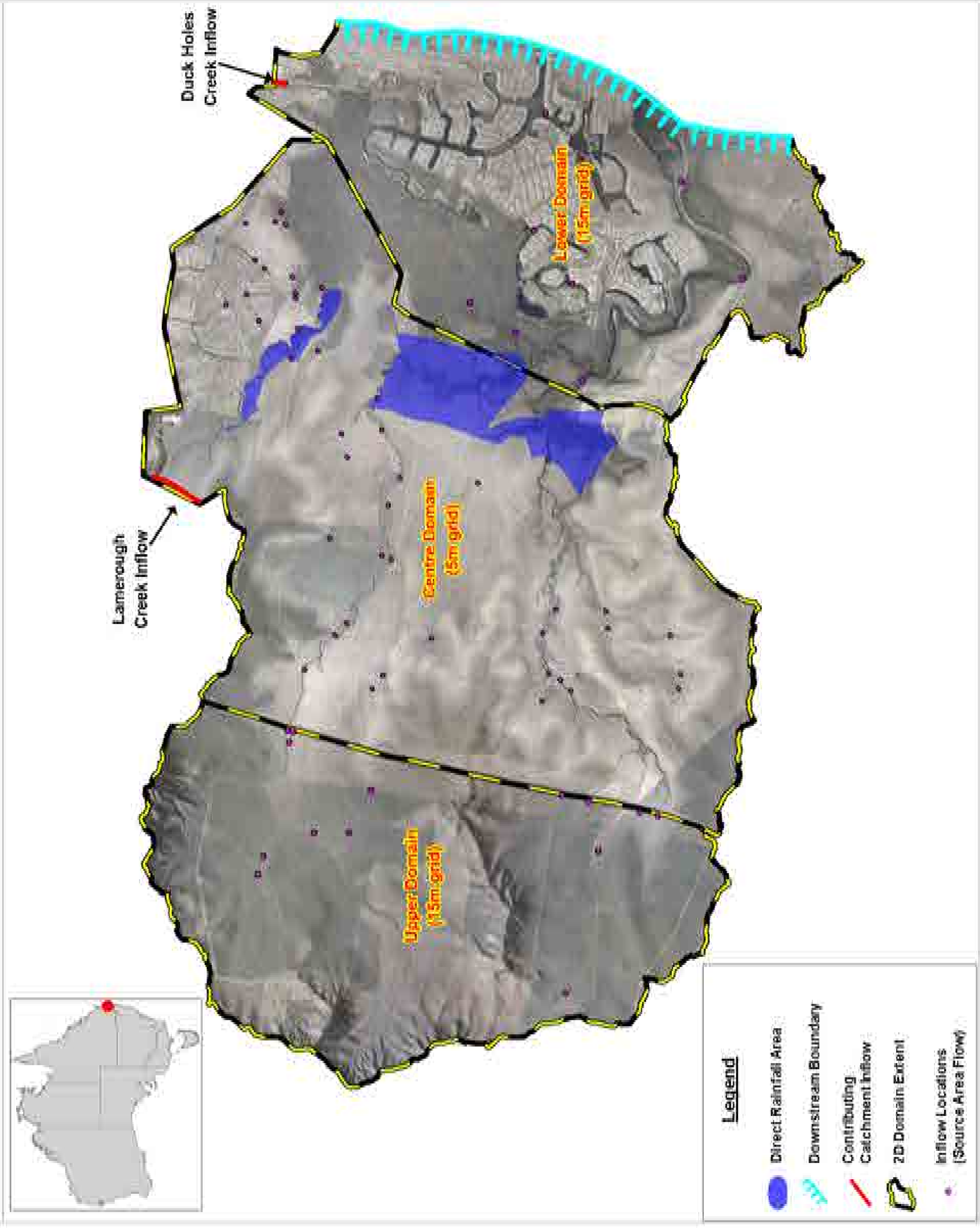
**Table C-7 Waterway Crossings Open Widths**

| Crossing ID | Waterway Opening Width (m) | Description |
|---|---|---|
| BCN_EW | 120 | Bells Creek North East West Link Road Crossing |
| BCN_US | 60 | Bells Creek North Upstream Crossing |
| LC_EW | 70 | Lamerough Creek East West Link Road Crossing |
| BCS_EW | 40 | Bells Creek South East West Link Road Crossing |
| BCS_US | 40 | Bells Creek South Upstream Crossing |

| Crossing ID | Waterway Opening Width (m) | Description |
|---|---|---|
| BCN_KA | 100 | Bells Creek North Bells Creek Arterial Crossing |
| | 50 | Lamerough Creek Bells Creek Arterial Crossing |

The waterway crossings listed above were supplemented with the culverts listed in Table C-8.

| Location | Type | Length | Upstream Invert | Downstream Invert | Width or Diameter | Height | Number |
|---|---|---|---|---|---|---|---|
| Bells Creek Arterial over Lamerough Creek | Circular | 44 | 6.2mAHD | 6.017mAHD | 0.9m | | 2 |
| East-West Link over Lamerough Creek | Circular | 50 | 2.6mAHD | 2.55mAHD | 0.9m | | 3 |
| East-West Link over Bells Creek North | Box | 54 | 6.5mAHD | 6.3mAHD | 2.1m | 1.5m | 20 |

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**TUFLOW Model Setup**

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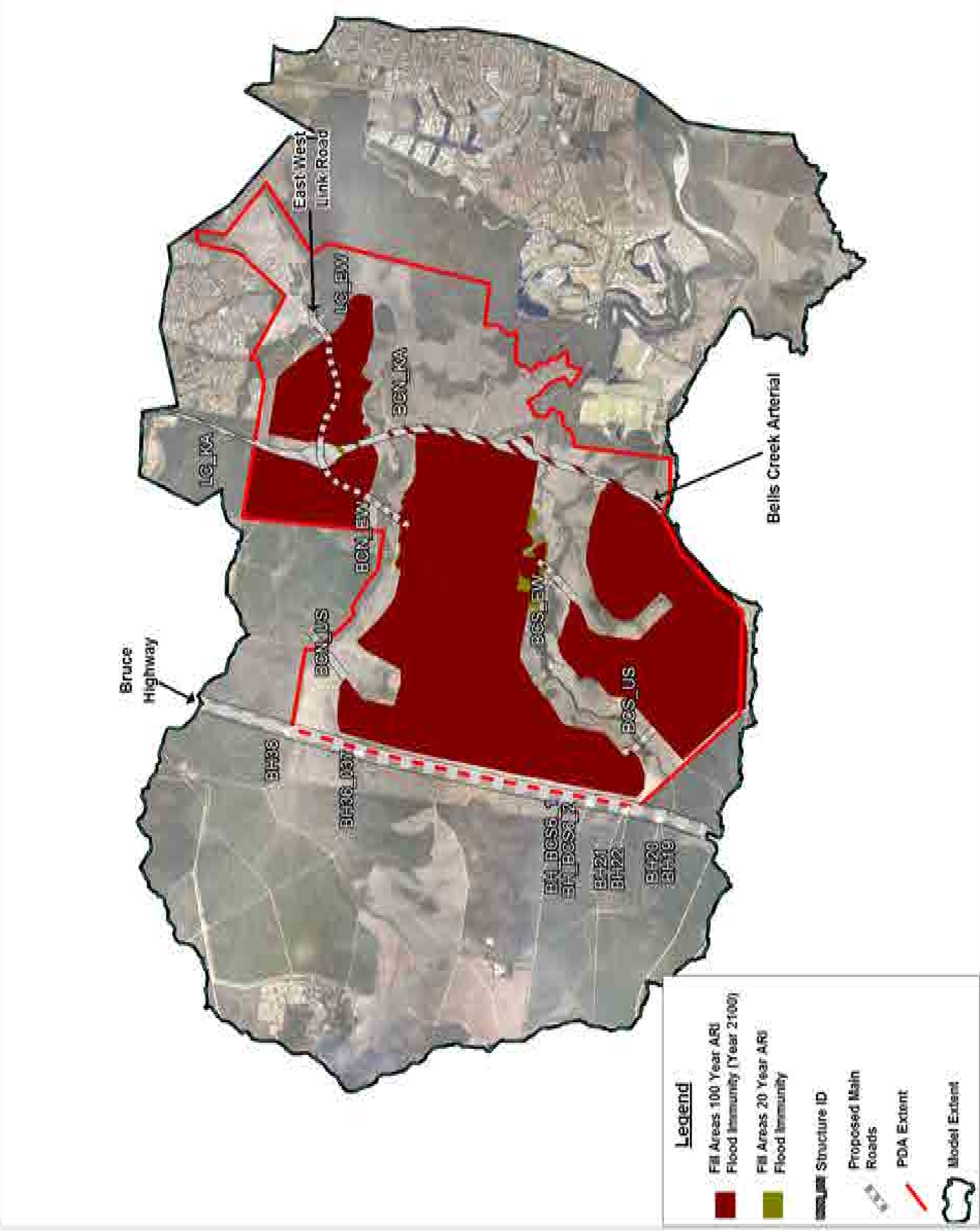


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**Structure Locations**

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### C.4.4 Hydraulic Roughness

Roughness coefficients represent the resistance to flood flows in channels and floodplains. In the hydraulic model, the adopted Manning's 'n' roughness coefficients were based on the Caloundra South Flood Study. The adopted Manning's 'n' roughness coefficients for the land uses within the proposed development are also listed in Table C-8. The land use delineation of the Base Case model is based on aerial photography and presented Figure C-1.

**Table C-8 Adopted Manning's 'n' Roughness Coefficients in TUFLOW Model**

| Land Use | Manning's 'n' Coefficients |
|---|---|
| ***Existing Land Uses*** | |
| Forested | 0.120 |
| Very high dense rural | 0.100 |
| Urban | 0.090 |
| Medium rural pasture | 0.050 |
| Permanently inundated areas | 0.045 |
| Sparse rural pasture | 0.040 |
| ***Proposed Land Uses*** | |
| Forested | 0.120 |
| Urban | 0.100 |
| Conservation and open space | 0.080 |
| Roads | 0.020 |
| Maintained parkland / playing fields | 0.045 |

### C.4.5 Water Quality Treatment Devices

An extensive series of water quality treatment devices are planned to be incorporated into the Caloundra South development. The purpose of these is to ensure the proposed development meets its obligations with regard to stormwater runoff water quality. To this end, a number of treatment devices, such as bioretention systems and wetlands are proposed to be constructed within the drainage corridors of Bells Creek South and Bells Creek North.

There are 2 design requirements that may influence flooding considerations, namely that devices remain immune in a 1 year ARI event and that flow velocities do not exceed 1m/s in a 100 year ARI event. The hydraulic model topography has been modified to ensure elevations at the devices are marginally greater than the predicted 1 Year ARI flood level (see Figure 5-1). As such, the treatment devices are flood immune in the 1 year ARI event. Furthermore, the results also indicate that peak flood flow velocities in the 100 year ARI event do not exceed 1m/s within treatment devices.

## C.4.6 Boundary Conditions

The TUFLOW model includes various inflow boundaries and a downstream water level boundary. The boundary conditions used in the TUFLOW model are discussed below. The inflow boundaries applied in the TUFLOW model are shown in Figure C-6.

### *C.4.6.1 Local Inflow Boundaries*

RAFTS-XP local inflows from the sub-catchments within the Bells Creek and Lamerough Creek catchments were specified as 'source-area' inflow boundaries in the TUFLOW model. These boundaries distribute inflows over the 2D domain, and are based on the sub-catchments from the RAFTS-XP model. The initial drainage locations for the source-area inflows for the base case are shown in Figure C-6.

### *C.4.6.2 Lamerough Creek Inflow Boundary*

The hydraulic model does not include the upper catchment of Lamerough Creek. The upstream model extent on Lamerough Creek is in the vicinity of the Bells Creek Arterial crossing. Therefore, it was necessary to derive flow hydrographs to simulate flow into Lamerough Creek at the upstream boundary.

A single 12m 2D domain version of the existing case hydraulic model that included the full extent of the Lamerough Creek catchment was run for all design runs. Flows at the location corresponding to the upstream boundary on Lamerough Creek in the multi-domain model were extracted from the single domain model results, and applied as upstream boundary conditions in the multi-domain model.

### *C.4.6.3 Duck Holes Creek Inflow Boundary*

The inflows from the Duck Holes Creek catchment were applied as an inflow hydrograph in the TUFLOW model. The inflows were based on the RAFTS-XP total flow results at the outlet of Duck Holes Creek.

### *C.4.6.4 Downstream Boundary Condition*

At the downstream end of the TUFLOW model, a static water level boundary condition was specified. The water level specified represents the tide within Pumicestone Passage. The water levels used are discussed below.

### *C.4.6.5 Downstream Water Levels during Freshwater Flood Events*

Based on SKM (2006), storm tide events and freshwater flood events have been considered to be statistically independent and it has been assumed that there is a minimal correlation between storm tide events and freshwater flood events. Consequently, for the modelling of freshwater flood events, ocean levels are not assumed to be affected by storm surge. For the modelling of freshwater flood events, a constant water level of 0.45mAHD was used as a downstream boundary condition. This water level represents a mean high water spring level at Golden Beach (from the Tide Tables and Boating Safety Guide (MSQ, 2007)).

#### C.4.6.6 Storm Tide Levels

The flood risk at the low lying land adjacent to Pumicestone Passage is dominated by inundation due to storm surge events. To assess the flood risk of these parts of the site, design storm levels at the proposed development site have been assessed. As discussed above, storm tide events have been assumed to be statistically independent of catchment flooding. A present-day 100 year ARI design storm tide level of 1.65mAHD has been adopted based on the "*Sunshine Coast Storm Tide Study*" (Aurecon, 2013).

### C.4.7 Model Verification

As part of a previous BMT WBM flood assessment of the Caloundra South development (in 2009), the TUFLOW model was simulated using the same design flood events and assumptions as per the SKM 2006 *Caloundra South Flood Study*. The results of the Caloundra South TUFLOW model were compared with results from the Caloundra South Flood Study MIKE-FLOOD model.

Overall, the results showed a relatively high level of consistency, with differences in modelled peak flood levels on-site generally within 0.1m for all design events modelled. This is considered to be a good comparison. However, there were some areas where model results deviated.

The differences in flood extent were likely to be related to the different approach adopted for applying the RAFTS-XP sub-catchment inflows. In the MIKE-FLOOD model, inflow boundaries were applied as source points at the centre point of the sub-catchment, whilst in the TULFOW model the inflows were distributed over wetted areas of the sub-catchment. The adopted approach in the TUFLOW model is considered to be more appropriate.

Differences in predicted peak flood levels upstream of the Bruce Highway were likely to be related to differences in culvert structures in the TUFLOW and MIKE-FLOOD model. (Culverts in the TUFLOW model were based on structure survey.) In addition, the RAFTS-XP sub-catchment at the highway, BCS5, was divided into two sub-catchments in the refined BMT WBM RAFTS-XP model.

The Caloundra South Flood Study MIKE-FLOOD model was not calibrated to historical flood events due to the absence of reliable data. Consequently, this analysis simply demonstrates that the previous TUFLOW model was predicting similar results to the un-calibrated MIKE-FLOOD model.

The current TUFLOW model that has been used in this study is a refined and updated version of the previous TUFLOW models, with changes to the underlying land use classification, more contemporary topographic data and refined model detail.

## C.5 Sensitivity Analysis

### C.5.1 Overview

In ungauged catchments, where it is not possible to undertake model calibration, it is prudent to undertake a sensitivity analysis to understand how sensitive the model is to the assumptions and uncertainty in the modelling. For the purposes of this assessment, the following parameters have been tested:

(1) Sensitivity of flood levels to inflow and downstream boundary conditions (as per climate change);

(2) Sensitivity of flood levels to Manning's n; and

(3) Sensitivity of flood levels to structure blockage.

It should be noted that the differences reported in the following sections are due to changes in the parameters tested and not as a result of the proposed development.

### C.5.2 Boundary Conditions

The results of the climate change assessment have been compared to the current climate results to quantify the sensitivity of the developed case model to the selected boundary conditions. Thus, this assessment assumes a 20% increase in rainfall depth and a 0.8m increase in the downstream boundary level. The differences on peak flood levels for the 100 year ARI flood event are shown in Figure C-8.

Downstream of the development, where the terrain is relatively low lying and flat, flood levels have increased by approximately 0.2m. Within the Pelican Waters canal, flood levels are particularly sensitive to the downstream boundary, and have increased by approximately 0.4m.

On Bells Creek North and Bells Creek South the flood levels are less sensitive; levels have increased by less than 0.1m. Lamerough Creek is slightly more sensitive, with levels increasing by approximately 0.15m.

Areas where flood waters are attenuated behind a structure, such as the Bells Creek South detention basin, upstream of the Bells Creek Arterial, the East-West Link Road and the Bruce Highway, are most sensitive to the increased rainfall depths with increases of 0.56m in the detention basin.

### C.5.3 Manning's n

The sensitivity of the developed case model to the assumed hydraulic roughness assumptions has been tested by increasing Manning's n values by 20% for the 100 year ARI flood event. The change in peak flood level is shown in Figure C-9.

The increase in Manning's n generally increases flood levels by less than 0.1m. The detention basin areas are not sensitive to Manning's n. Increases in flood levels do not impact on the flood extent within the proposed development. Thus, flood level uncertainties related to hydraulic roughness are smaller in magnitude than the freeboard between the adopted fill levels and 100 year ARI flood level.

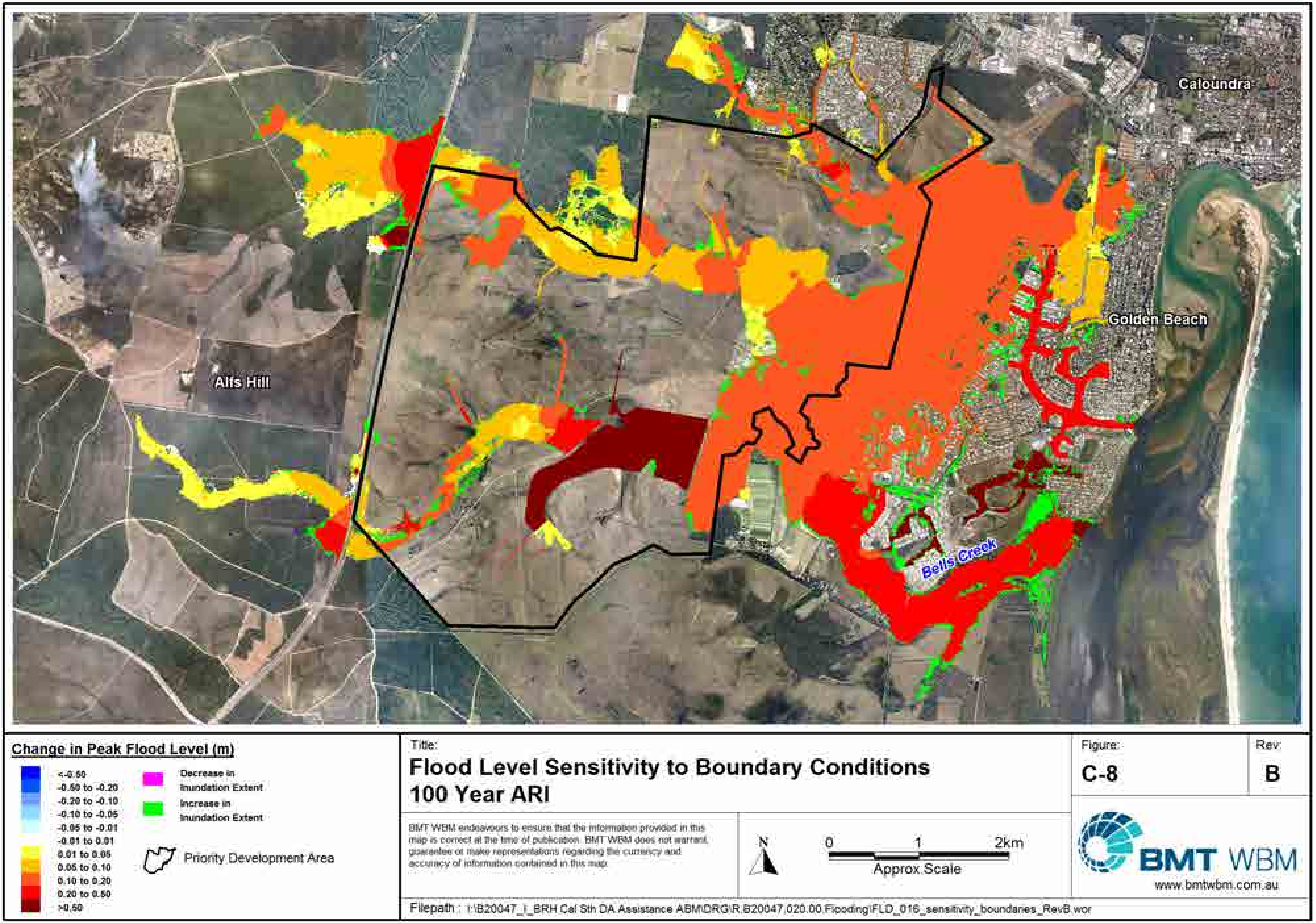
### C.5.4 Structure Blockage

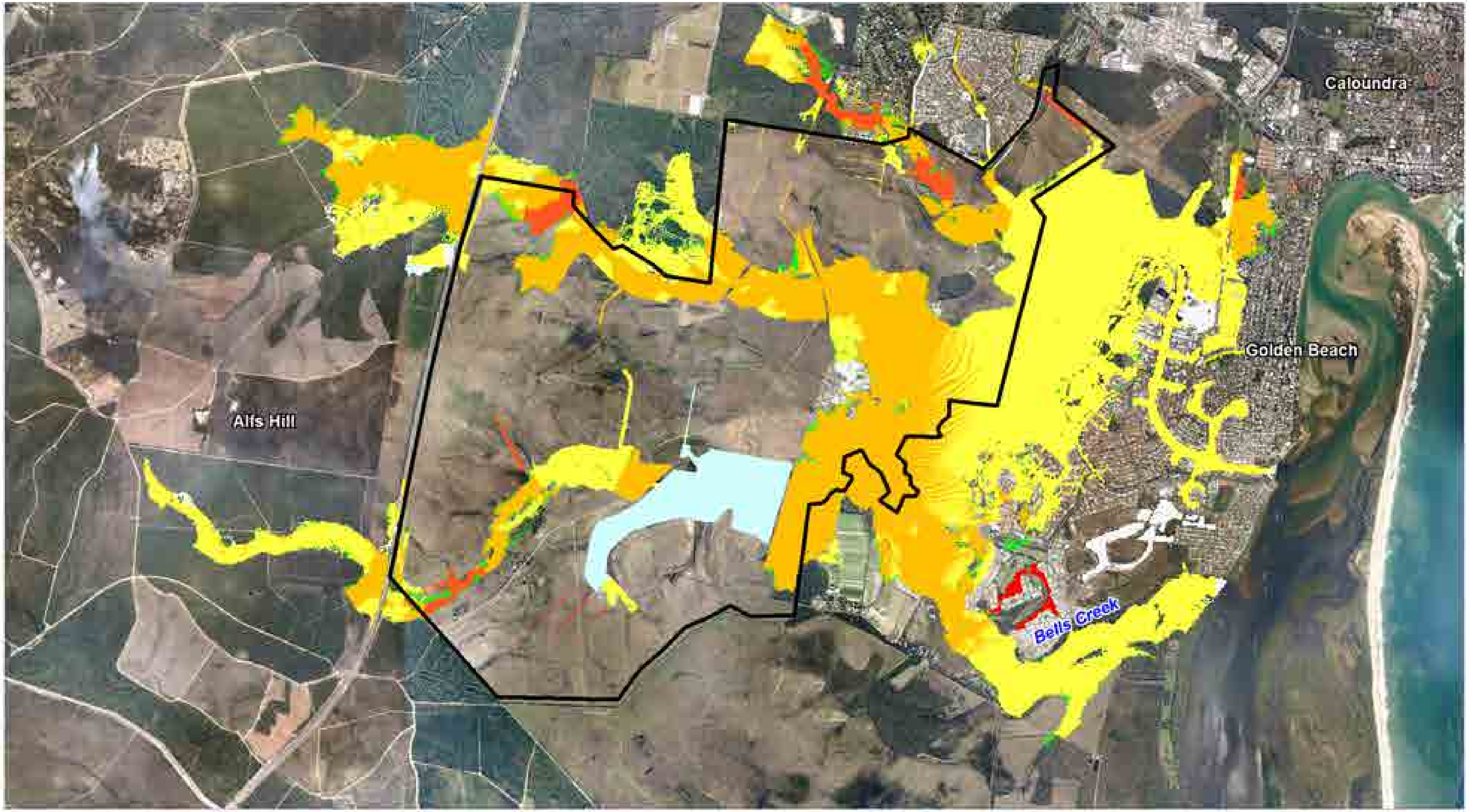
Structures in the model were assumed to be unblocked. The sensitivity of the developed case model to blockage of structures has been tested by applying a blockage to culvert structures for the 100 year ARI flood event. The percentage blockage has been selected based on *"AR&R Revision Project 11: Blockage of Hydraulic Structures"* (Weeks et al., 2013).

Based on the source area characteristics of the catchment, the debris potential is considered to be medium. For culverts, it has been assumed that the opening diameter/width is less than the length of the longest 10% of debris ($L_{10}$) and therefore a 50% blockage factor has been applied for culverts. For bridge openings, it has been assumed that the opening width is greater than 3 times the $L_{10}$ and therefore a 0% blockage factor has been applied. The existing culverts under the Bruce Highway were not blocked as this would attenuate flows into the Caloundra South PDA and mask potential increases in flood levels caused by blockages at proposed structures further downstream. The results of the analysis are shown in Figure C-10.

Flood levels in the detention basin outlet on Bells Creek South are highly sensitive to blockage. Here, flood levels have risen by 0.86m. This is 0.3m higher than the climate change level, and 0.05m below the Flood Planning Level. As such, the blockage is not expected to result in flooding to the proposed development. Nevertheless, the flood levels do get close to the Flood Planning Level and blockage mitigation measures, such as blockage prevention devices and overflows, should be incorporated in the detention basin outlet design during the detailed design stage.

The blockage of the culverts under the East-West Link Road on Bells Creek North has caused an increase in water levels upstream of the road crossing. The flood level increases by 0.12m immediately upstream of the road crossing.


Caloundra
Golden Beach
Alfs Hill
Bells Creek
Change in Peak Flood Level (m)
<-0.50
-0.50 to -0.20
-0.20 to -0.10
-0.10 to -0.05
-0.05 to -0.01
-0.01 to 0.01
0.01 to 0.05
0.05 to 0.10
0.10 to 0.20
0.20 to 0.50
>0.50
Decrease in Inundation Extent
Increase in Inundation Extent
Priority Development Area
Title:
Flood Level Sensitivity to Boundary Conditions
100 Year ARI
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
N
0
1
2km
Approx.Scale
Figure:
C-8
Rev:
B
BMT WBM
www.bmtwbm.com.au
Filepath : I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00.Flooding\FLD_016_sensitivity_boundaries_RevB.wor




**Change in Peak Flood Level (m)**

- <-0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- >0.50

Decrease in Inundation Extent

Increase in Inundation Extent

Priority Development Area

Title:

# Flood Level Sensitivity to Manning's n 100 Year ARI

Figure: C-9

Rev: B

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N

0 1 2km

Approx.Scale

BMT WBM

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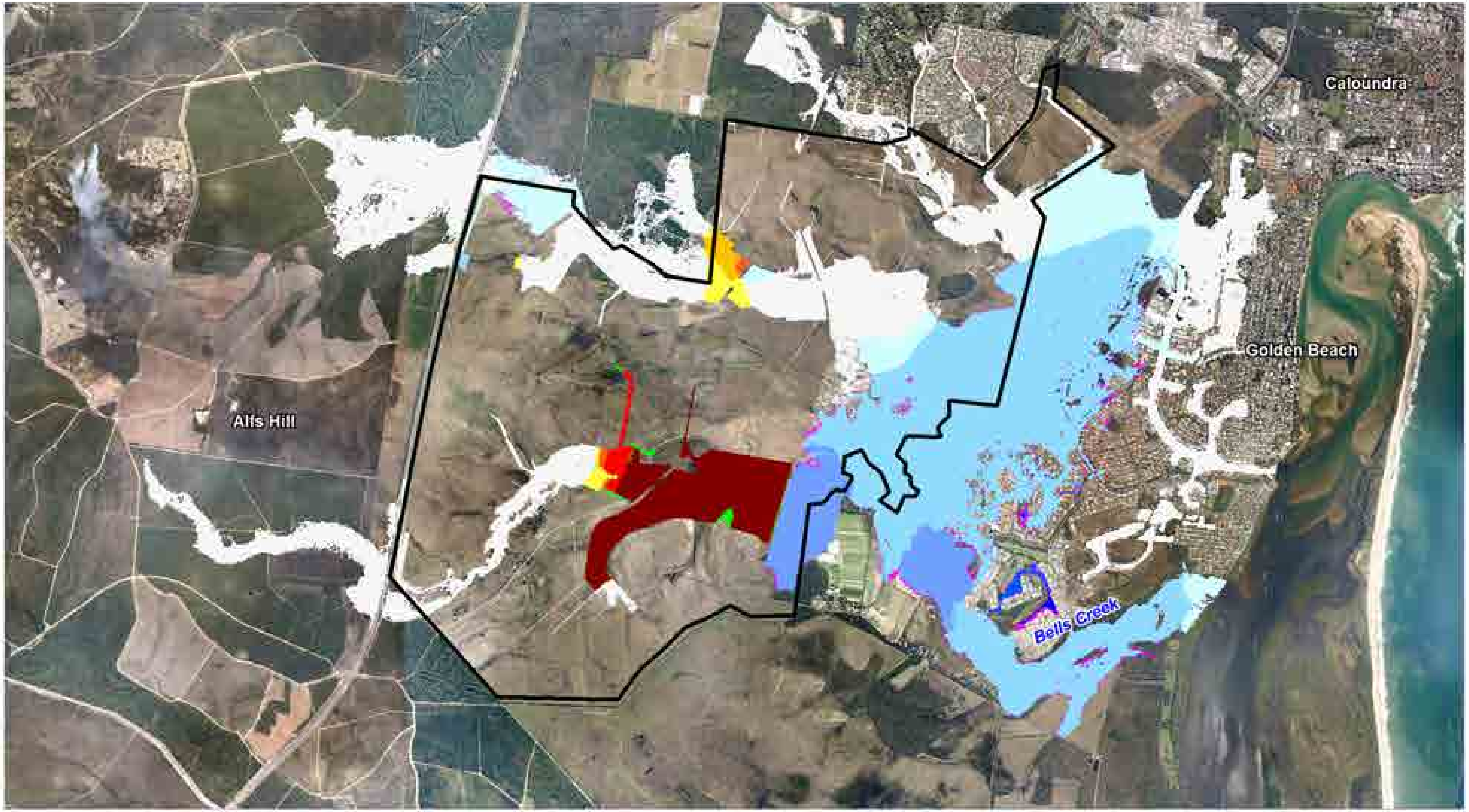
Filepath : I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00.Flooding\FLD_017_sensitivity_mannings_RevB.wor




**Change in Peak Flood Level (m)**

- <-0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- >0.50

Decrease in Inundation Extent

Increase in Inundation Extent

Priority Development Area

Title:

# Flood Level Sensitivity to Structural Blockage 100 Year ARI

Figure: C-10

Rev: B

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N

0 1 2km

Approx.Scale

BMT WBM

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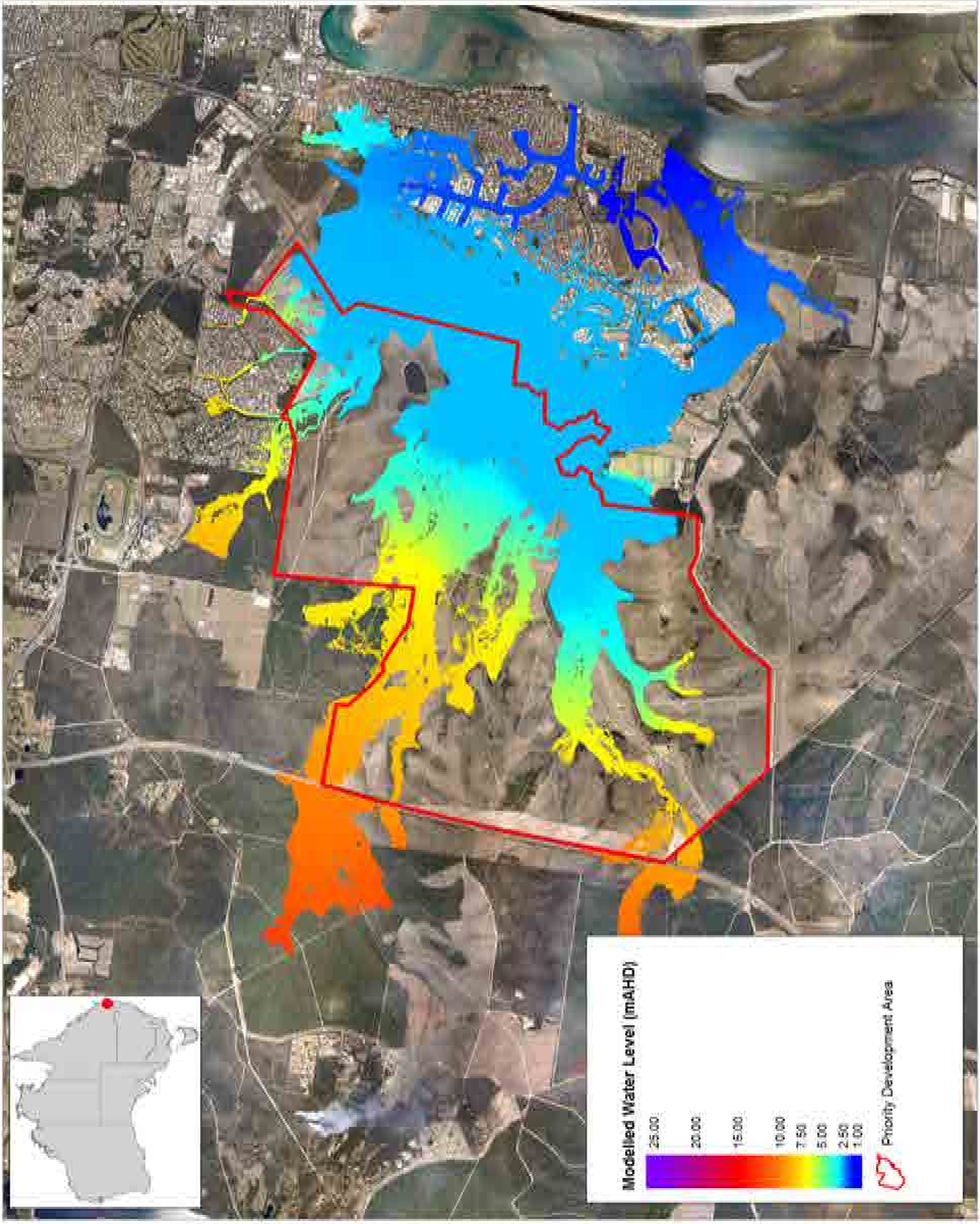
Filepath : I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00.Flooding\FLD_018_sensitivity_blockage_RevB.wor

# Appendix D Existing Case Results




Title:

**Existing Case Peak Fluvial 100 Year ARI Flood Level**

Figure: **D-1**

Rev: **-**



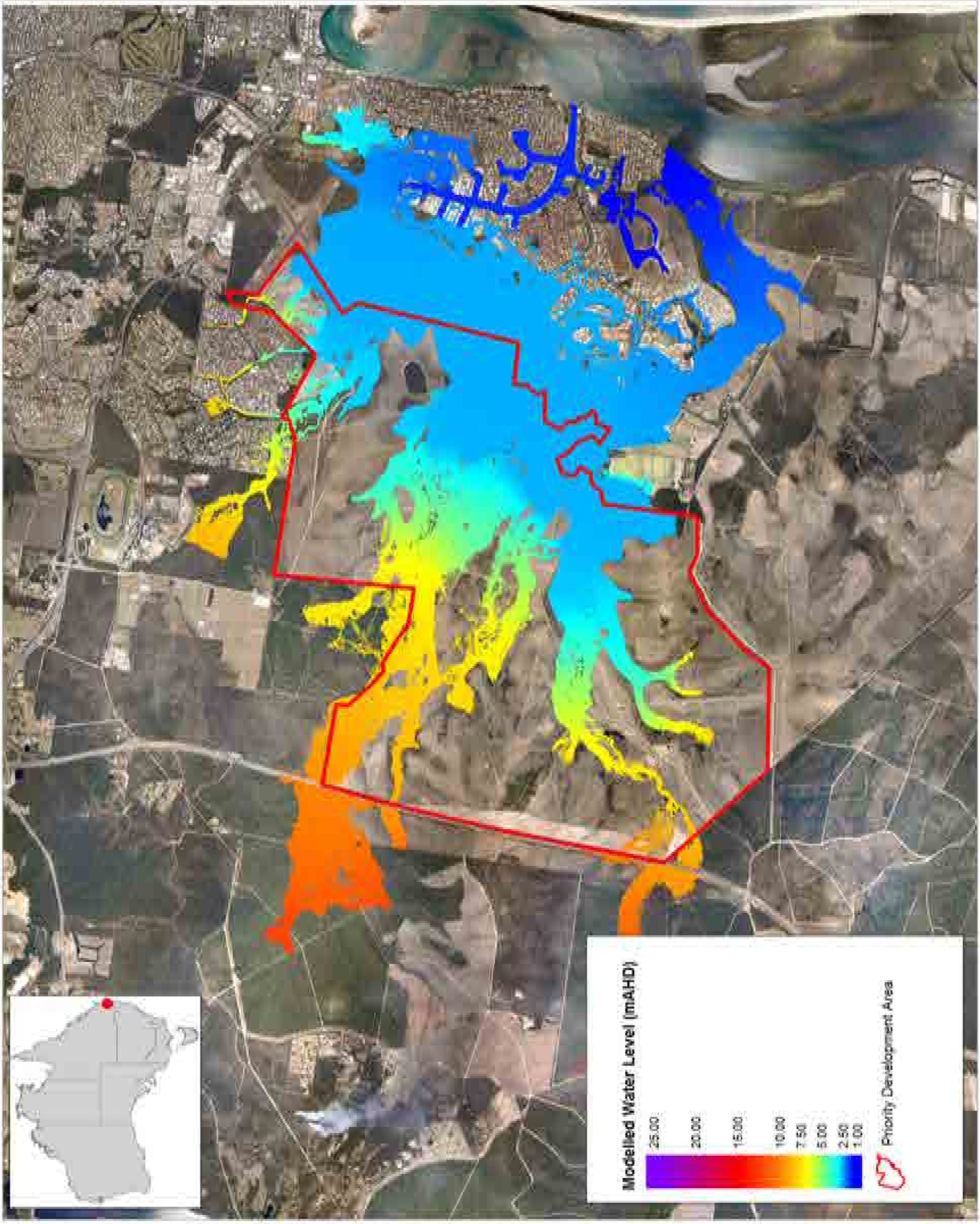
N

0 1.5 3km

Approx. Scale

www.bmtwbm.com.au

Filepath : "I:\B20047_I_BRH Cal 5th DA Assistance ABM\DRG\R.B20047.020.00.Flooding\Appendix\FLD_100_150813_Base_Q100_Levels.wor"




Title:

**Existing Case Peak Fluvial 50 Year ARI Flood Level**

Figure:

**D-2**

Rev:

**-**



N

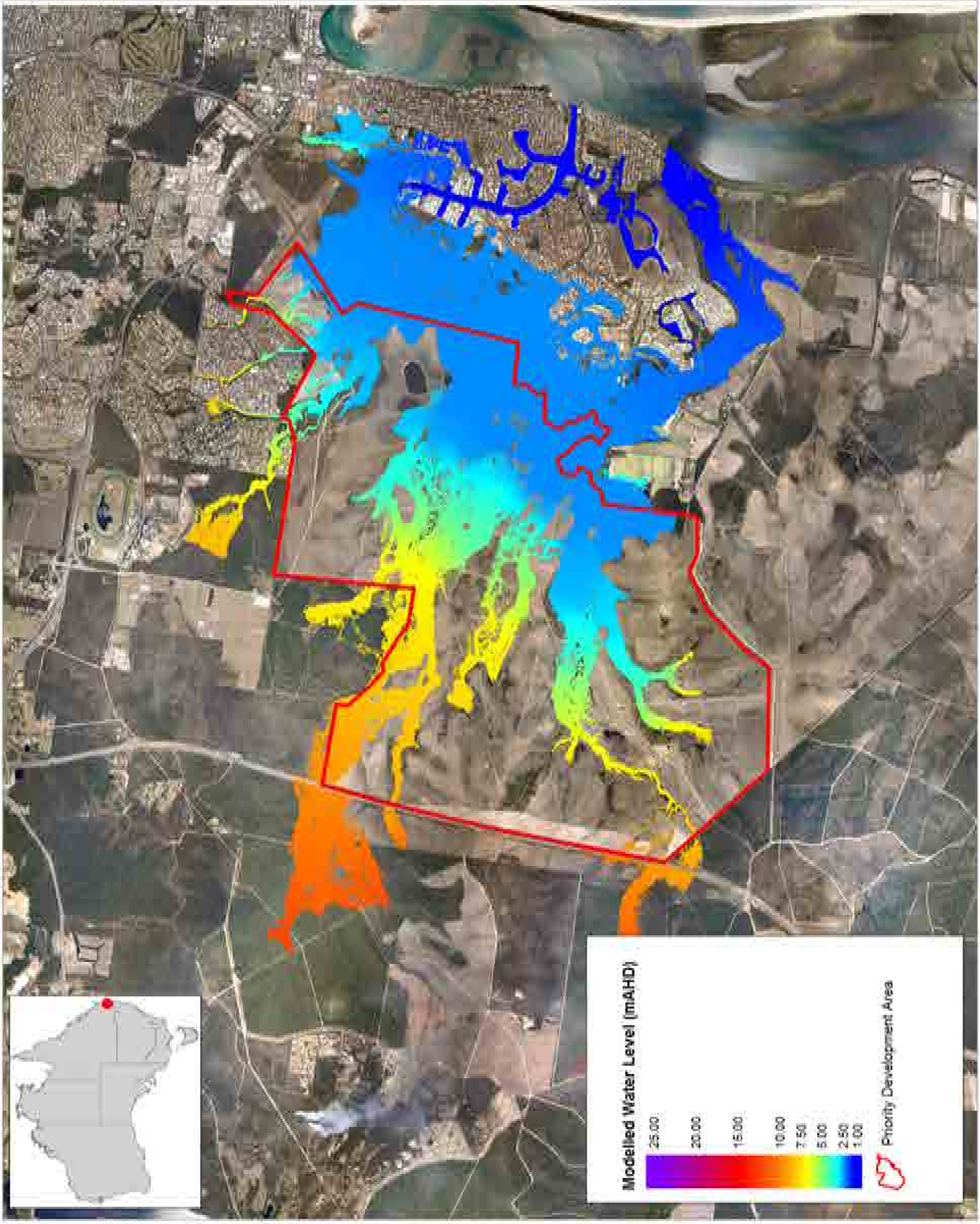
0 1.5 3km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B20047_I_BRH Cal 5th DA Assistance ABM\DRG\R.B20047.020.00.Flooding\Appendix\FLD_101_150813_Base_Q050_Levels.wor"




Title:

**Existing Case Peak Fluvial 10 Year ARI Flood Level**

Figure: D-4

Rev: -



N

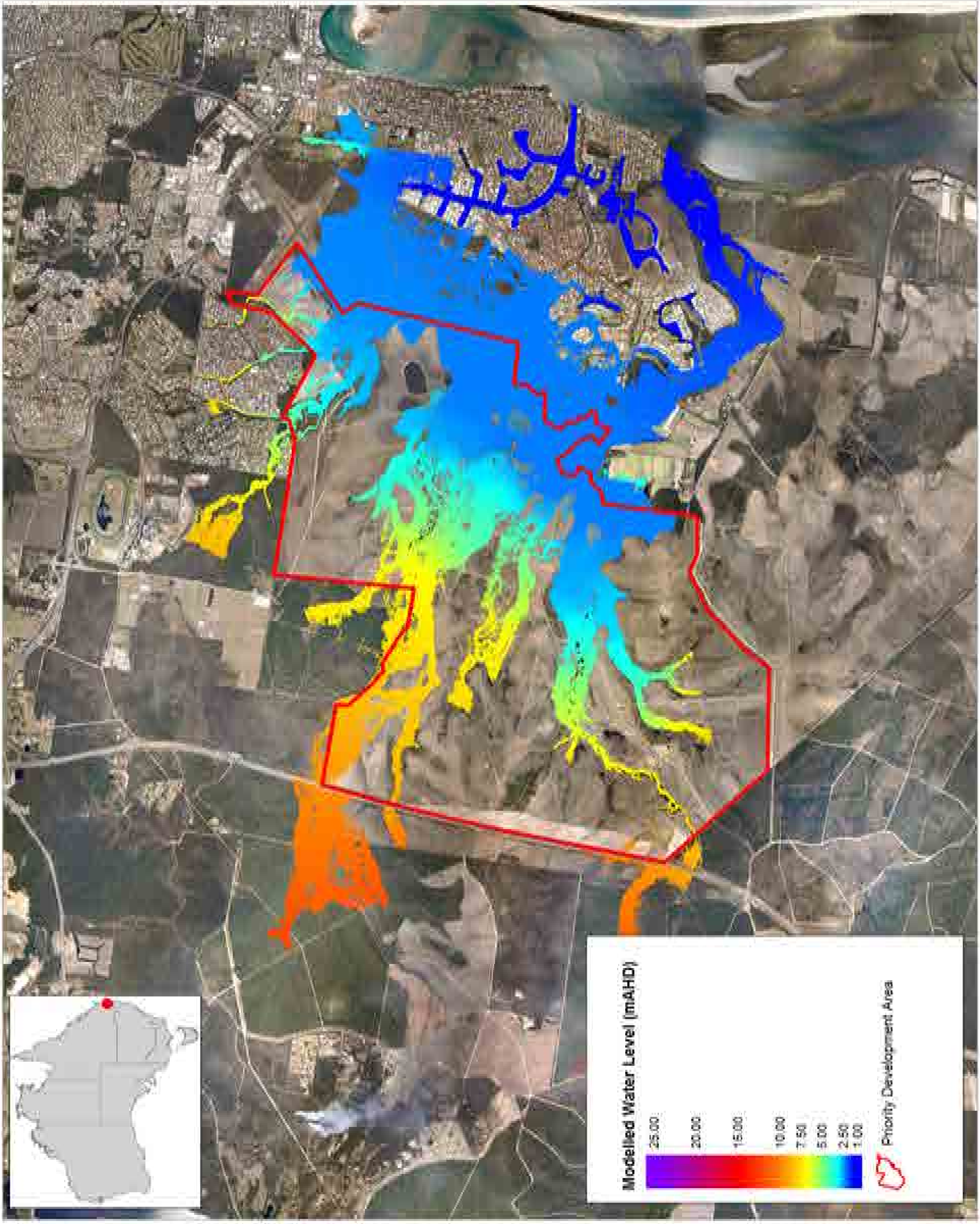
0 1.5 3km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00.Flooding\Appendix\FLD_103_150813_Base_Q010_Levels.wor"




Title:

**Existing Case Peak Fluvial 5 Year ARI Flood Level**

Figure: **D-5**

Rev: **-**



N

0 1.5 3km

Approx. Scale

BMT WBM

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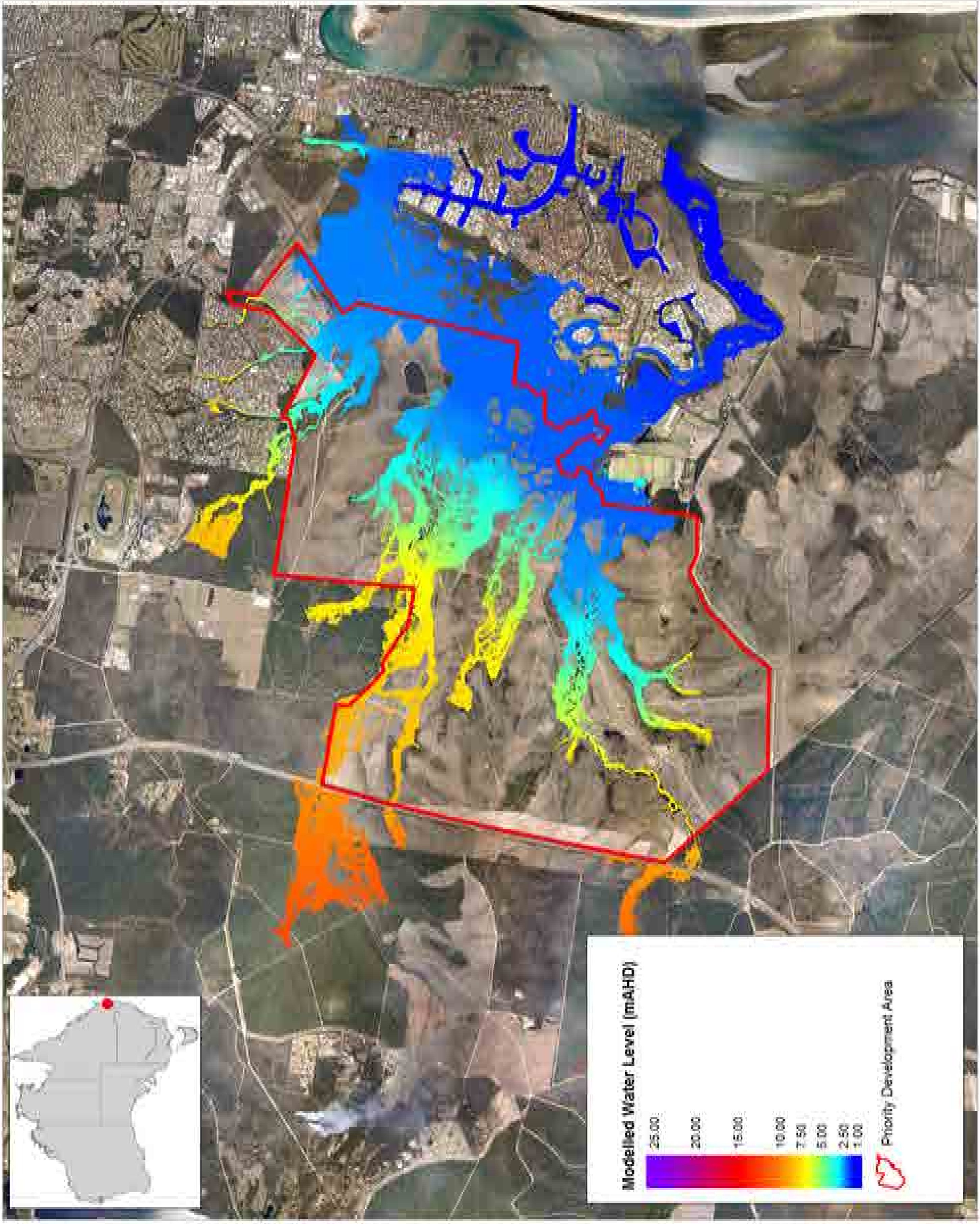
Filepath : "I:\B20047_I_BRH Cal 5th DA Assistance ABM\DRG\R.B20047.020.00.Flooding\Appendix\FLD_104_150813_Base_Q005_Levels.wor"




Title:

**Existing Case Peak Fluvial 2 Year ARI Flood Level**

Figure: D-6

Rev: -



N

0 1.5 3km

Approx. Scale

BMT WBM

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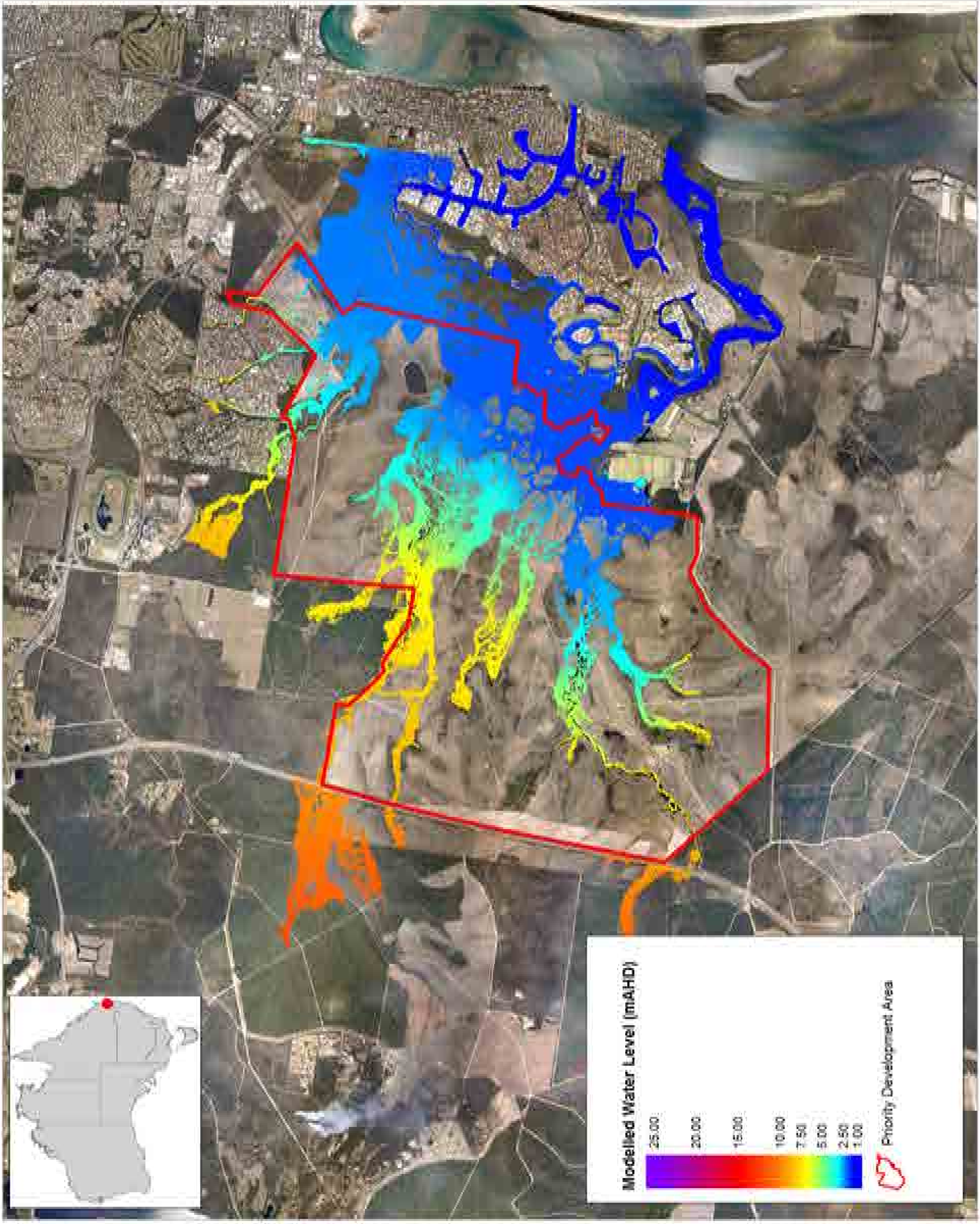
Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00.Flooding\Appendix\FLD_105_150813_Base_Q002_Levels.wor"




Title:

**Existing Case Peak Fluvial 1 Year ARI Flood Level**

Figure: D-7

Rev: -



N

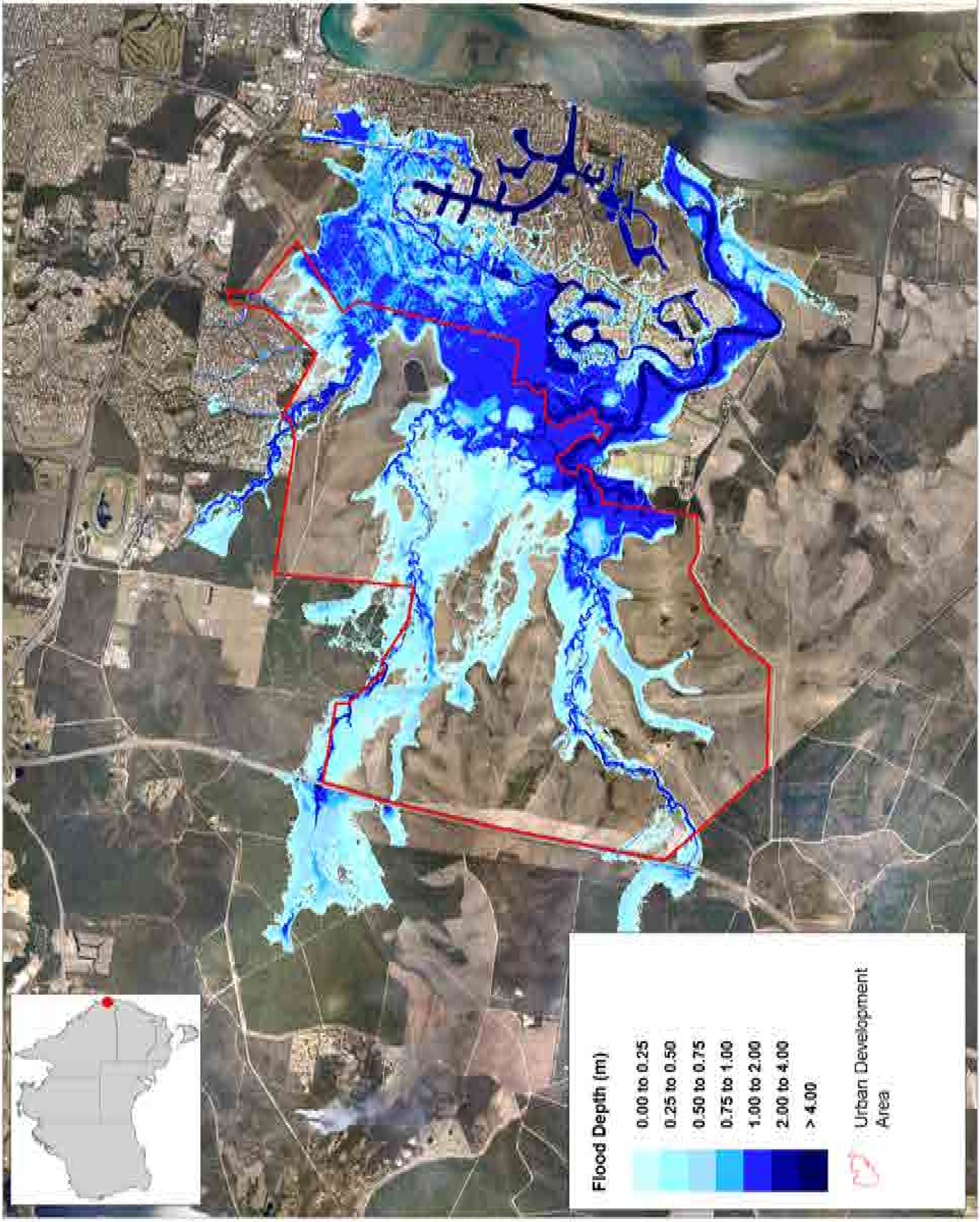
0 1.5 3km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B20047_I_BRH Cal 5th DA Assistance ABM\DRG\R.B20047.020.00.Flooding\Appendix\FLD_106_150813_Base_Q001_Levels.wor"




Title:

## Existing Case Peak 100 Year ARI Flood Depth

Figure:

**D-8**

Rev:

**-**



N

0 1.5 3km

Approx. Scale

BMT WBM

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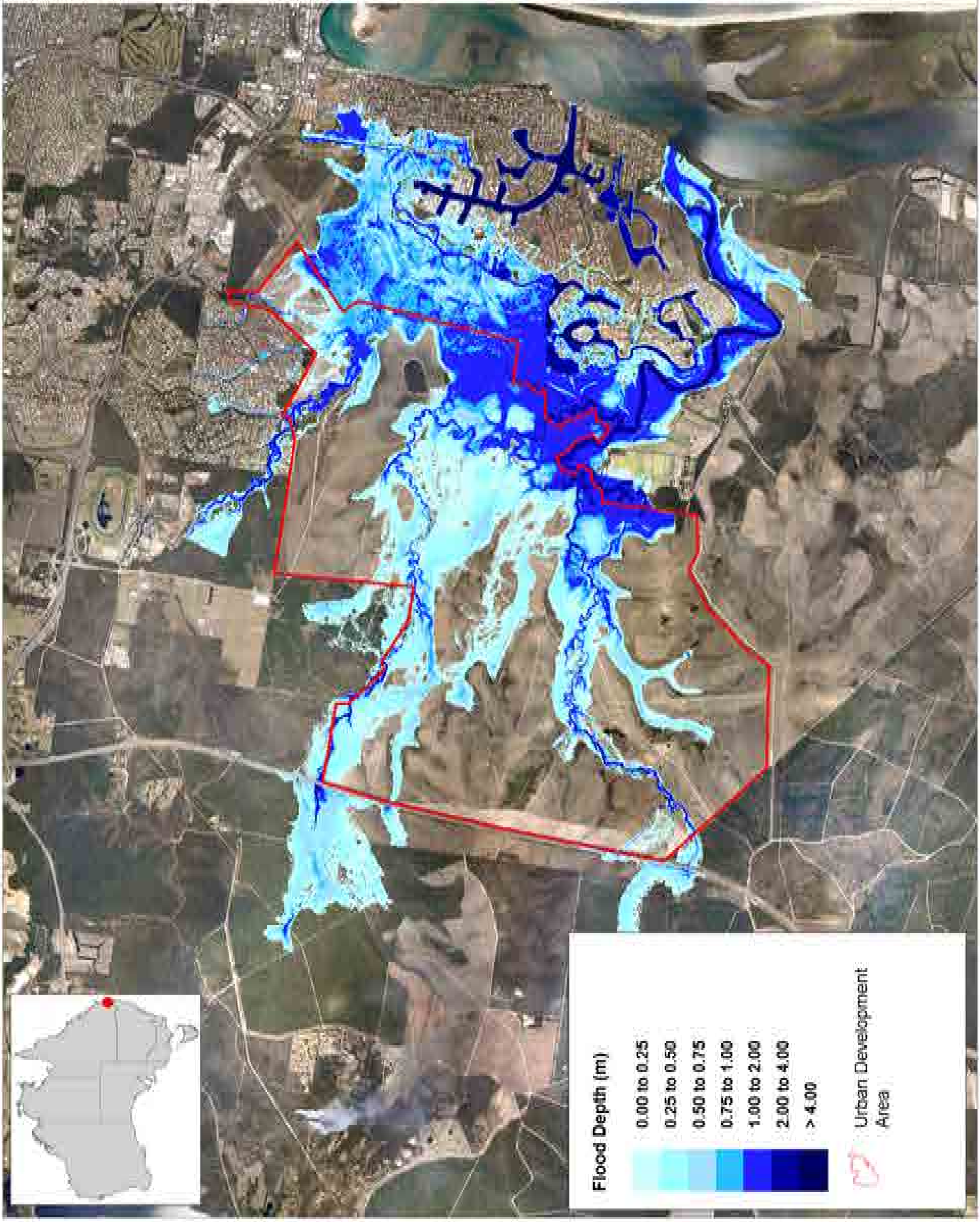
Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00 Flooding\Appendix\FLD_107_150813_Base_Q100_Depths.wor"




Title:

**Existing Case Peak 50 Year ARI Flood Depth**

Figure: **D-9**

Rev: **-**

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N

0 1.5 3km

Approx. Scale

BMT WBM

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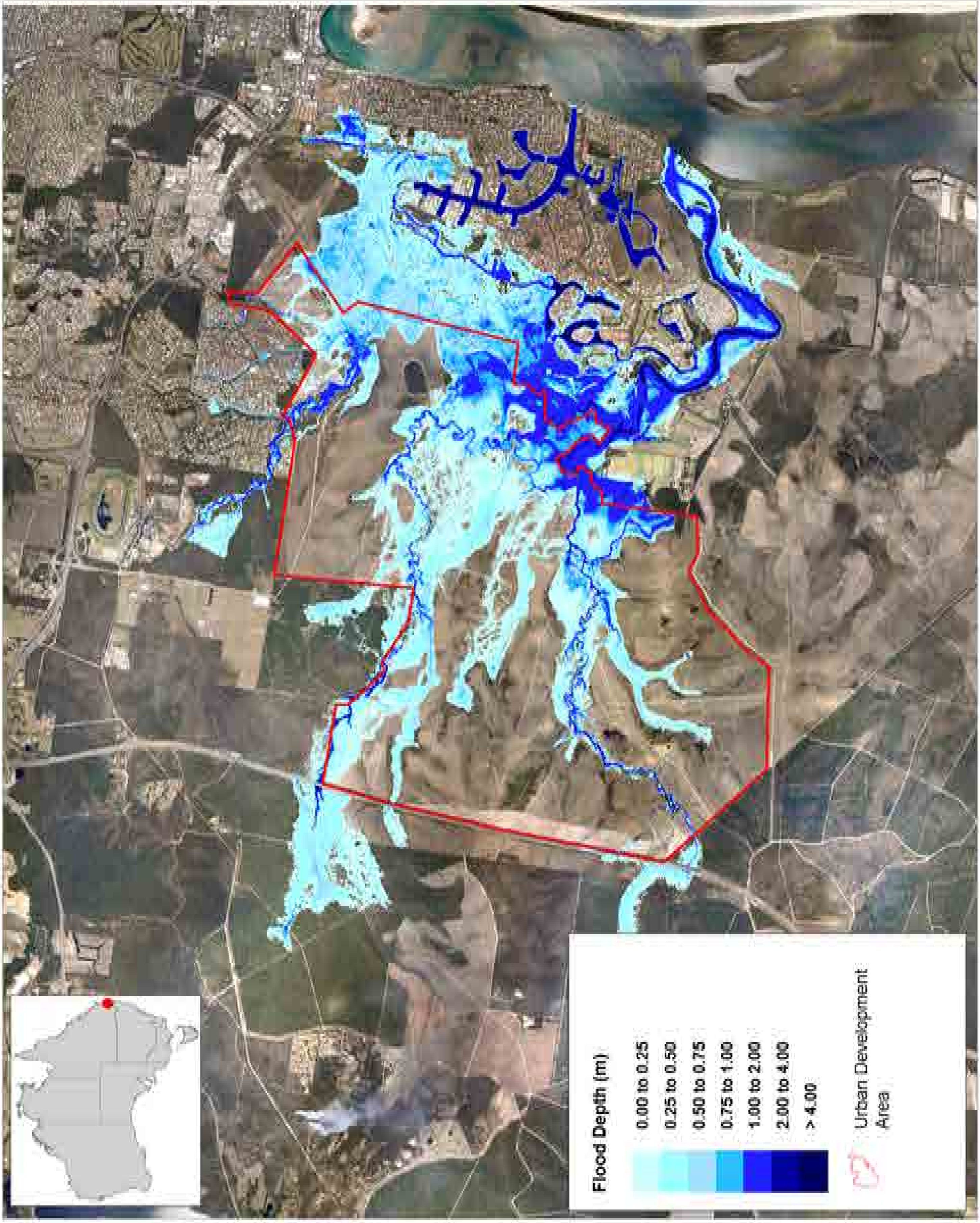
Filepath : "I:\B20047_I_BRH Cal 5th DA Assistance ABM\DRG\R.B20047.020.00 Flooding\Appendix\FLD_108_150813_Base_Q050_Depths.wor"




Title:

**Existing Case Peak 10 Year ARI Flood Depth**

Figure: D-11

Rev: -



N 0 1.5 3km Approx. Scale

BMT WBM
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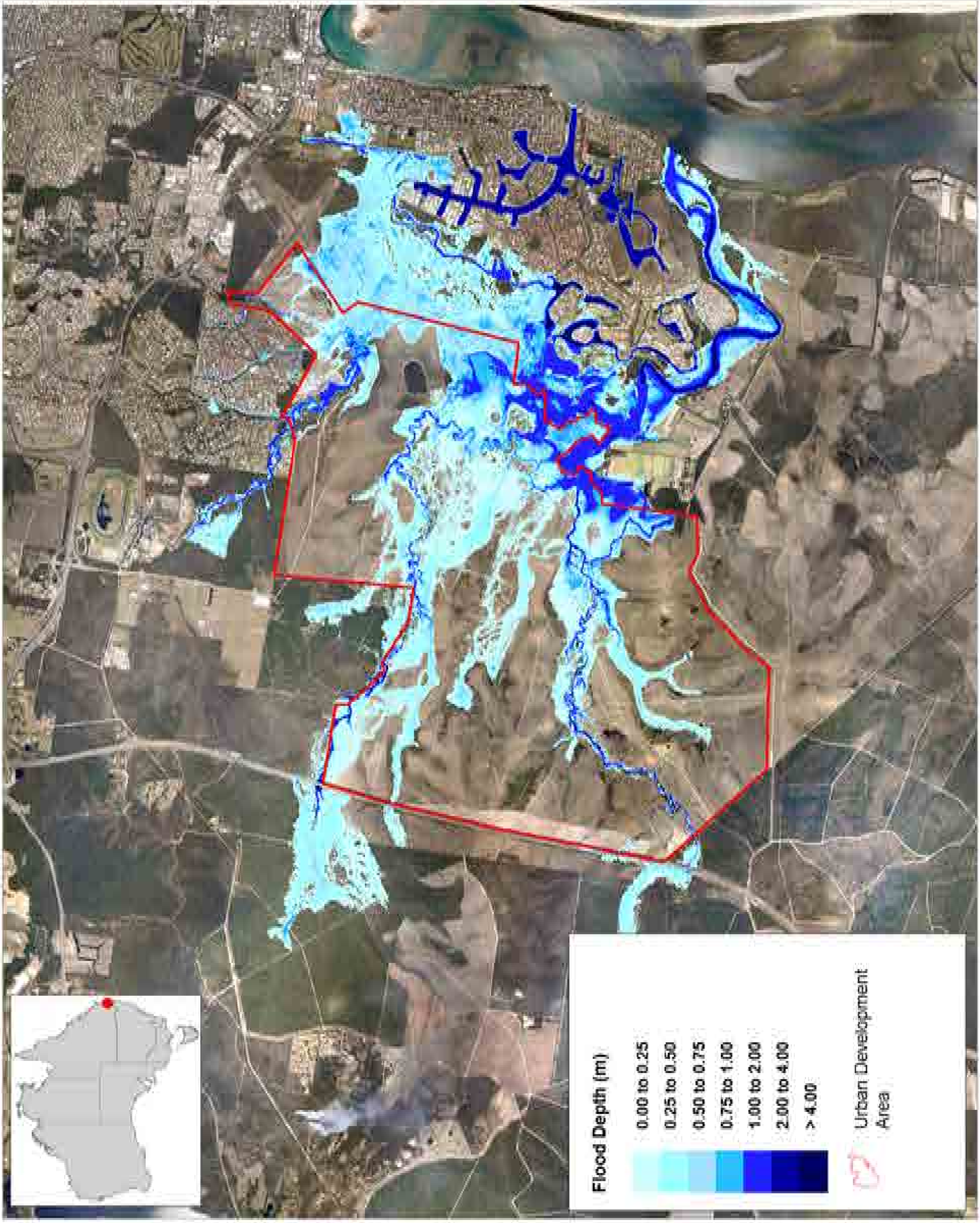
Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00 Flooding\Appendix\FLD_110_150813_Base_Q010_Depths.wor"




Title:

# Existing Case Peak 5 Year ARI Flood Depth

Figure:
**D-12**

Rev:
**-**



BMT WBM
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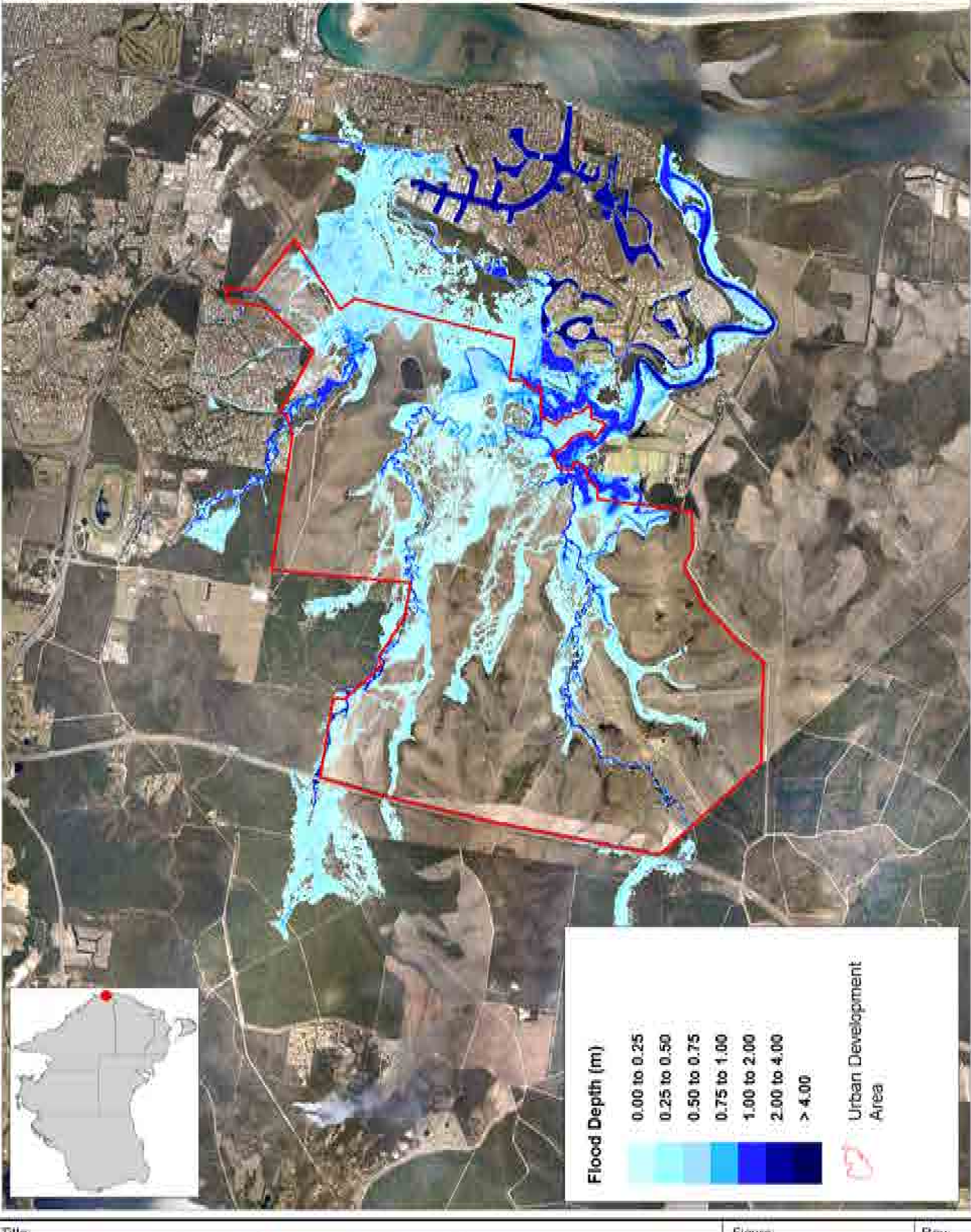
Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00 Flooding\Appendix\FLD_111_150813_Base_Q005_Depths.wor"




Title:

# Existing Case Peak 2 Year ARI Flood Depth

Figure:

**D-13**

Rev:

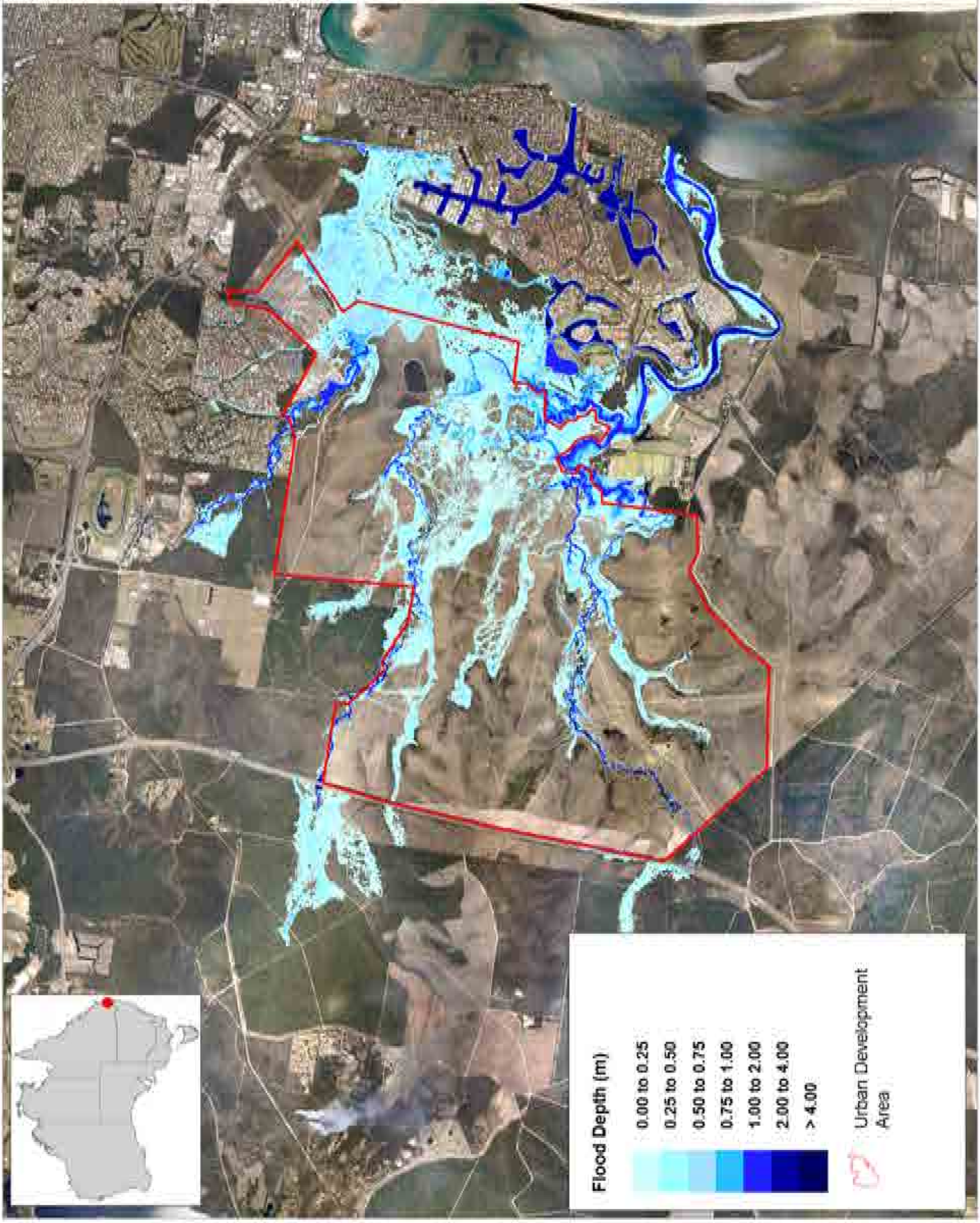
**-**



BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00 Flooding\Appendix\FLD_112_150813_Base_Q002_Depths.wor"




Title:
## Existing Case Peak 1 Year ARI Flood Depth

Figure: **D-14**

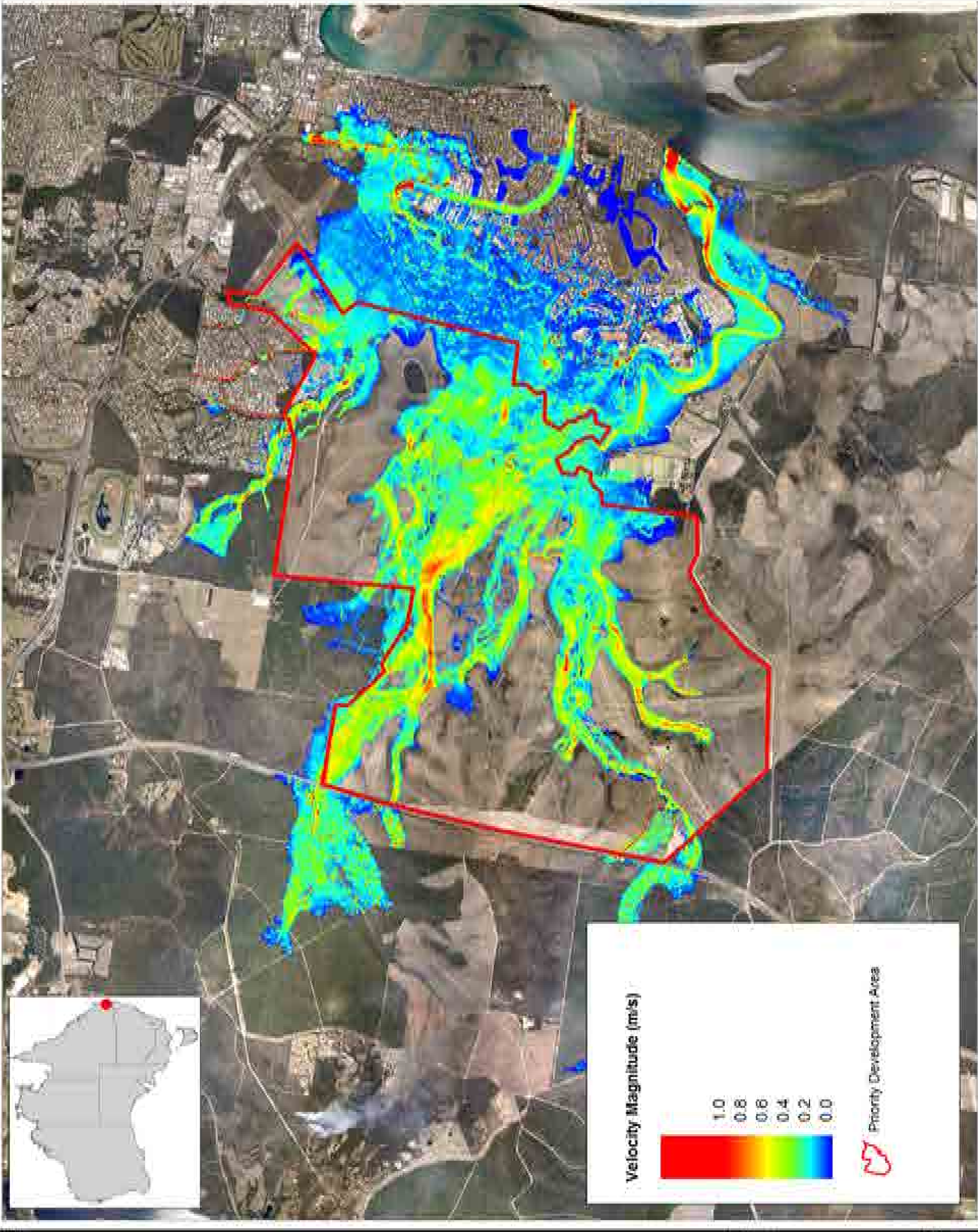
Rev: **-**



N 0 1.5 3km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00 Flooding\Appendix\FLD_113_150813_Base_Q001_Depths.wor"




Title:

# Existing Case Peak 100 Year Flow Velocity

Figure: **D-15**

Rev: **-**

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N 0 1.5 3km
Approx. Scale

BMT WBM
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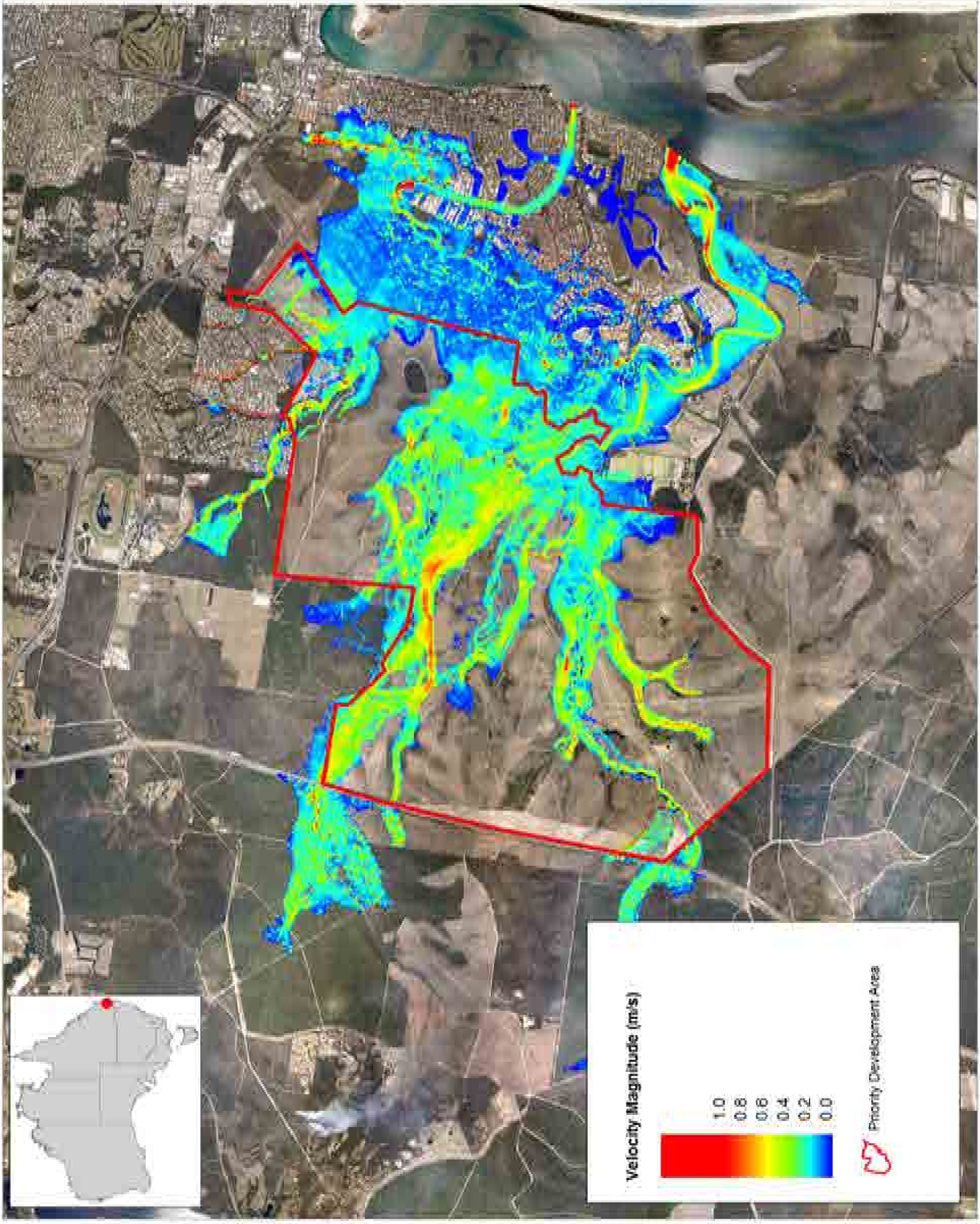
Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00.FloodingAppendix\FLD_114_150813_Base_Q100_Velocity.wor"




Title:

**Existing Case Peak 50 Year Flow Velocity**

Figure: D-16

Rev: -



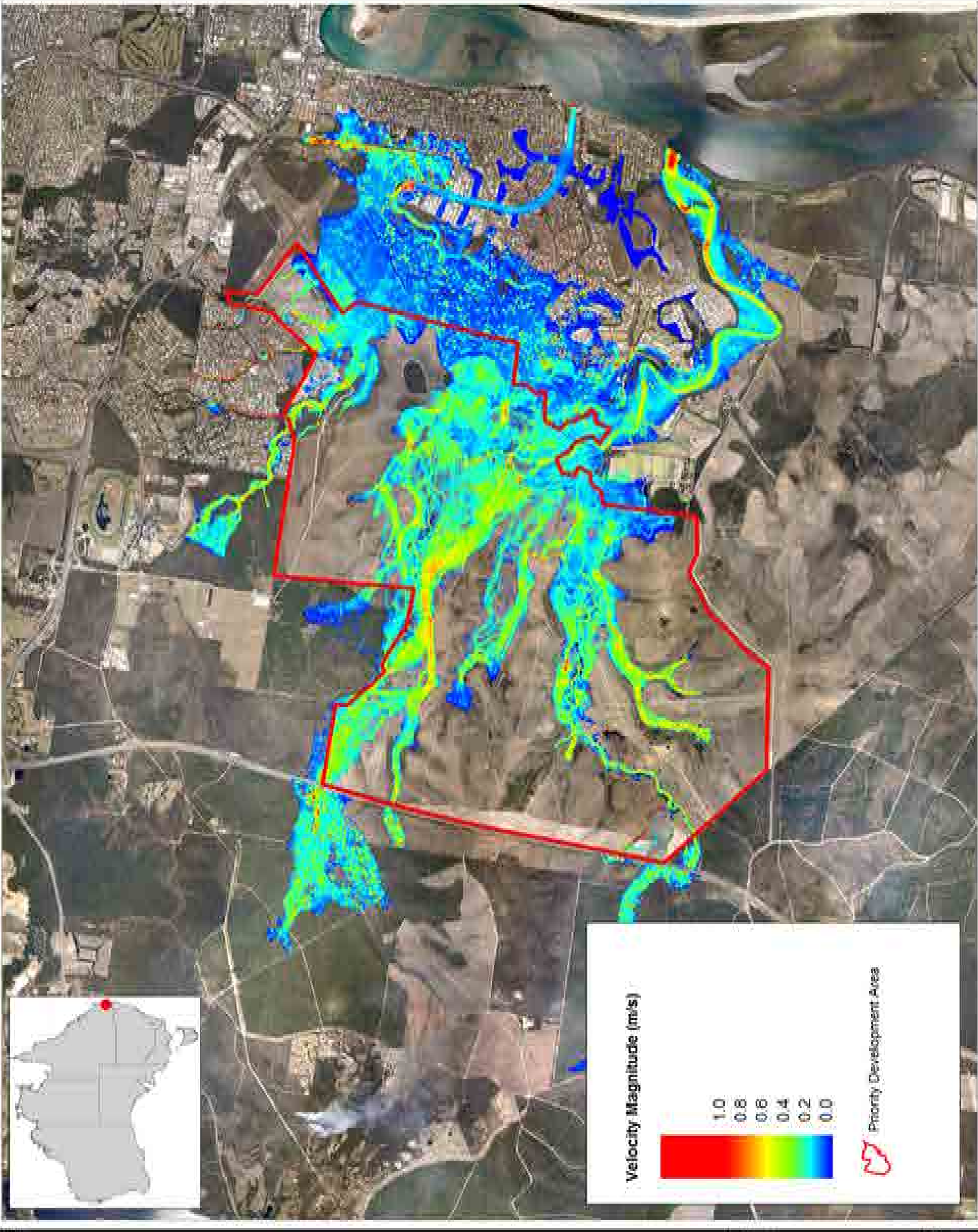
N 0 1.5 3km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00.Flooding\Appendix\FLD_115_150813_Base_Q050_Velocity.wor"




Title:

## Existing Case Peak 10 Year Flow Velocity

Figure: D-18

Rev: -



N

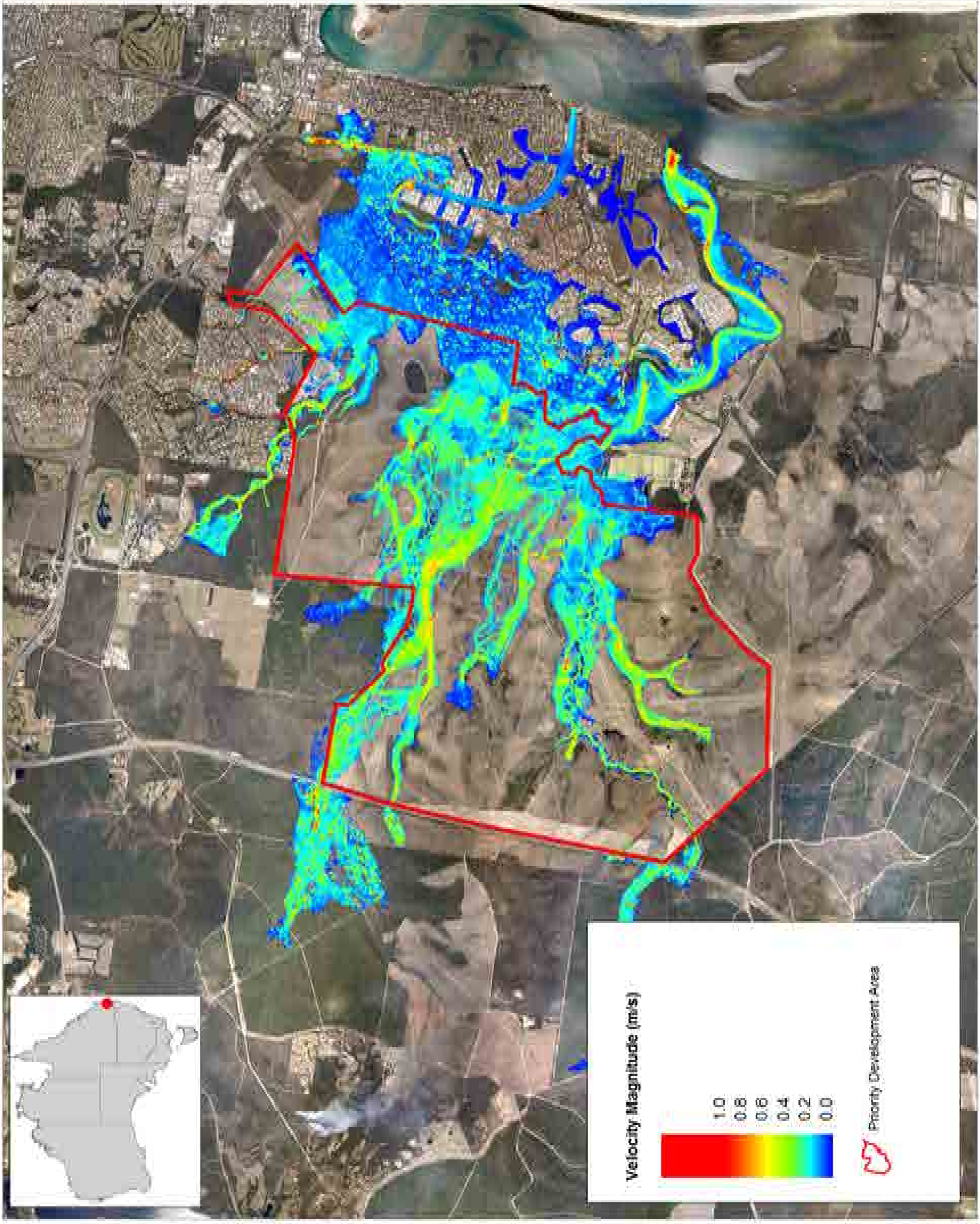
0 1.5 3km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00.Flooding\Appendix\FLD_117_150813_Base_Q010_Velocity.wor"




Title:

# Existing Case Peak 5 Year Flow Velocity

Figure:
**D-19**

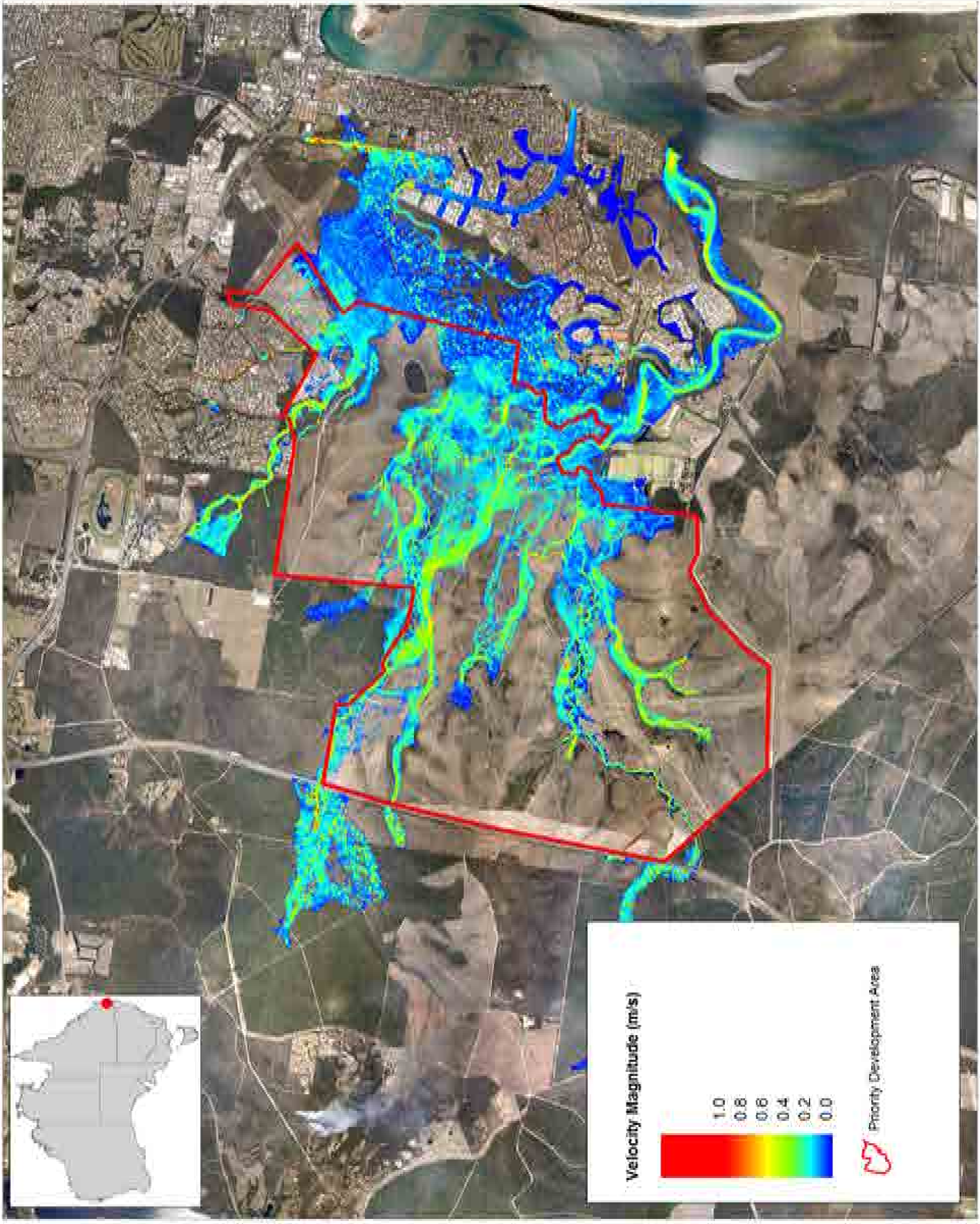
Rev:
**-**



N
0 1.5 3km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00.Flooding\Appendix\FLD_118_150813_Base_Q005_Velocity.wor"




Title:

**Existing Case Peak 2 Year Flow Velocity**

Figure: D-20

Rev: -



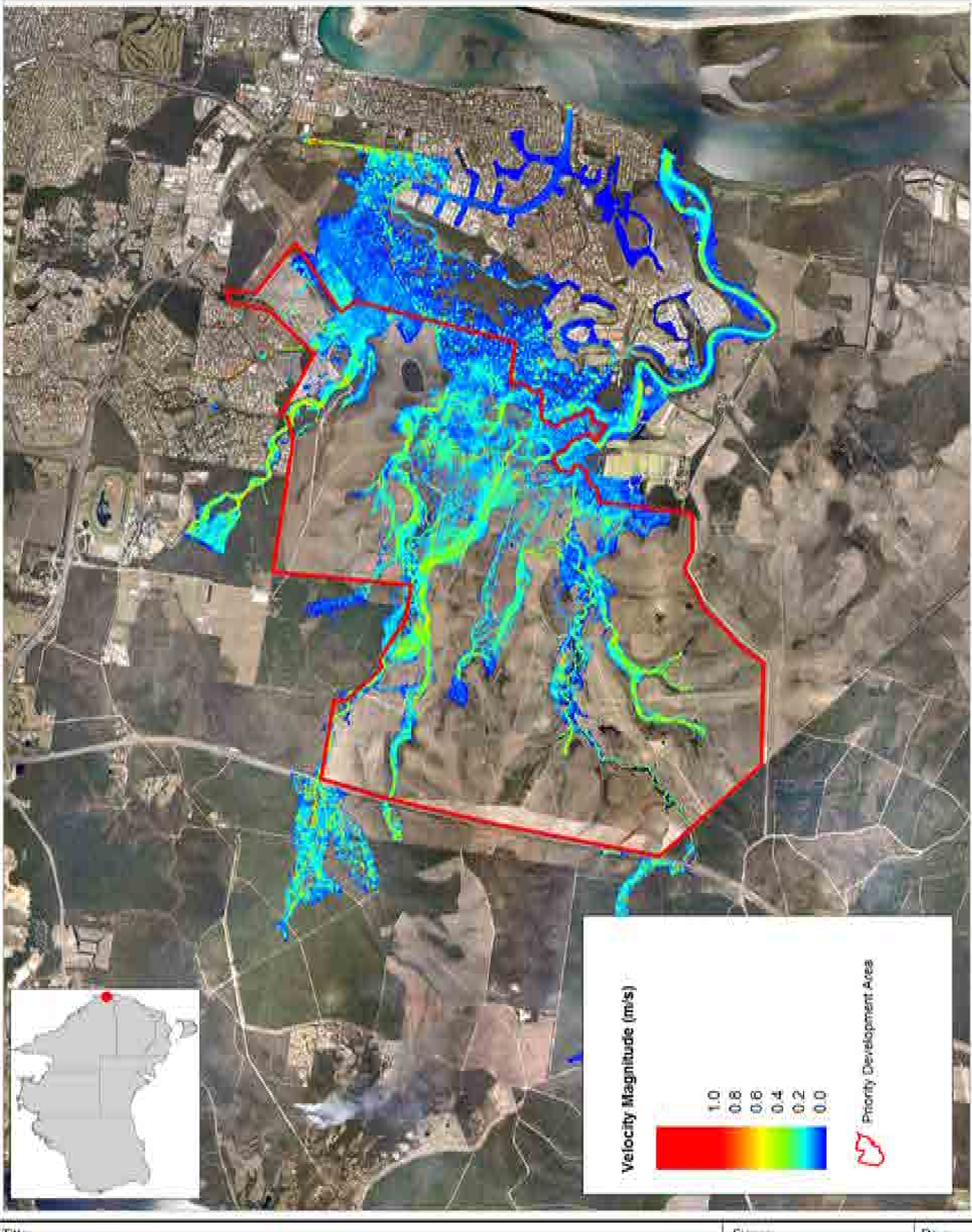
N 0 1.5 3km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00.Flooding\Appendix\FLD_119_150813_Base_Q002_Velocity.wor"




Title:

**Existing Case Peak 1 Year Flow Velocity**

Figure:

**D-21**

Rev:

**-**



N

0 1.5 3km

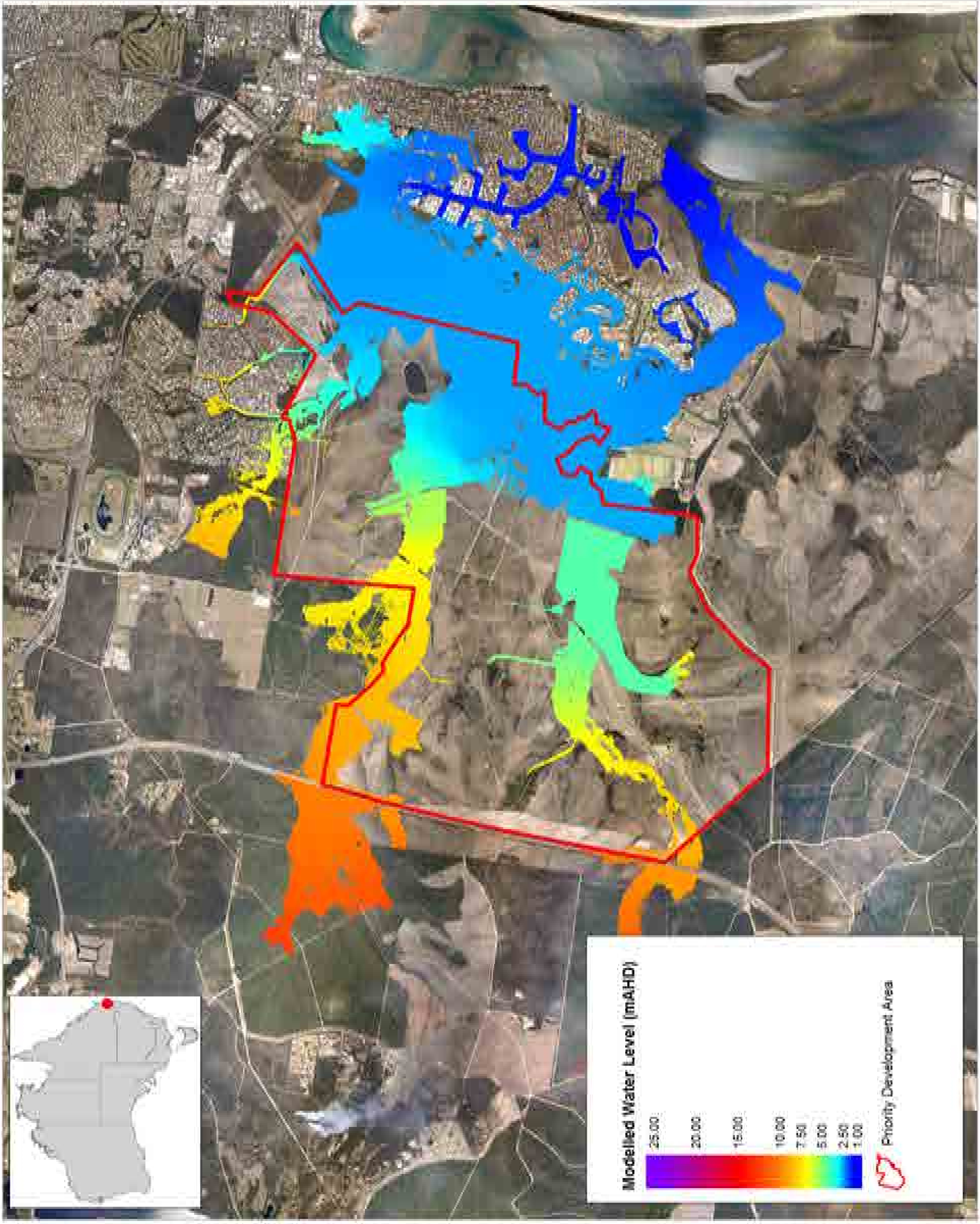
Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00.Flooding\Appendix\FLD_120_150813_Base_Q001_Velocity.wor"

# Appendix E Developed Case Results




Title:

**Developed Case Peak Fluvial 100 Year ARI Flood Level**

Figure: E-1

Rev: -



N

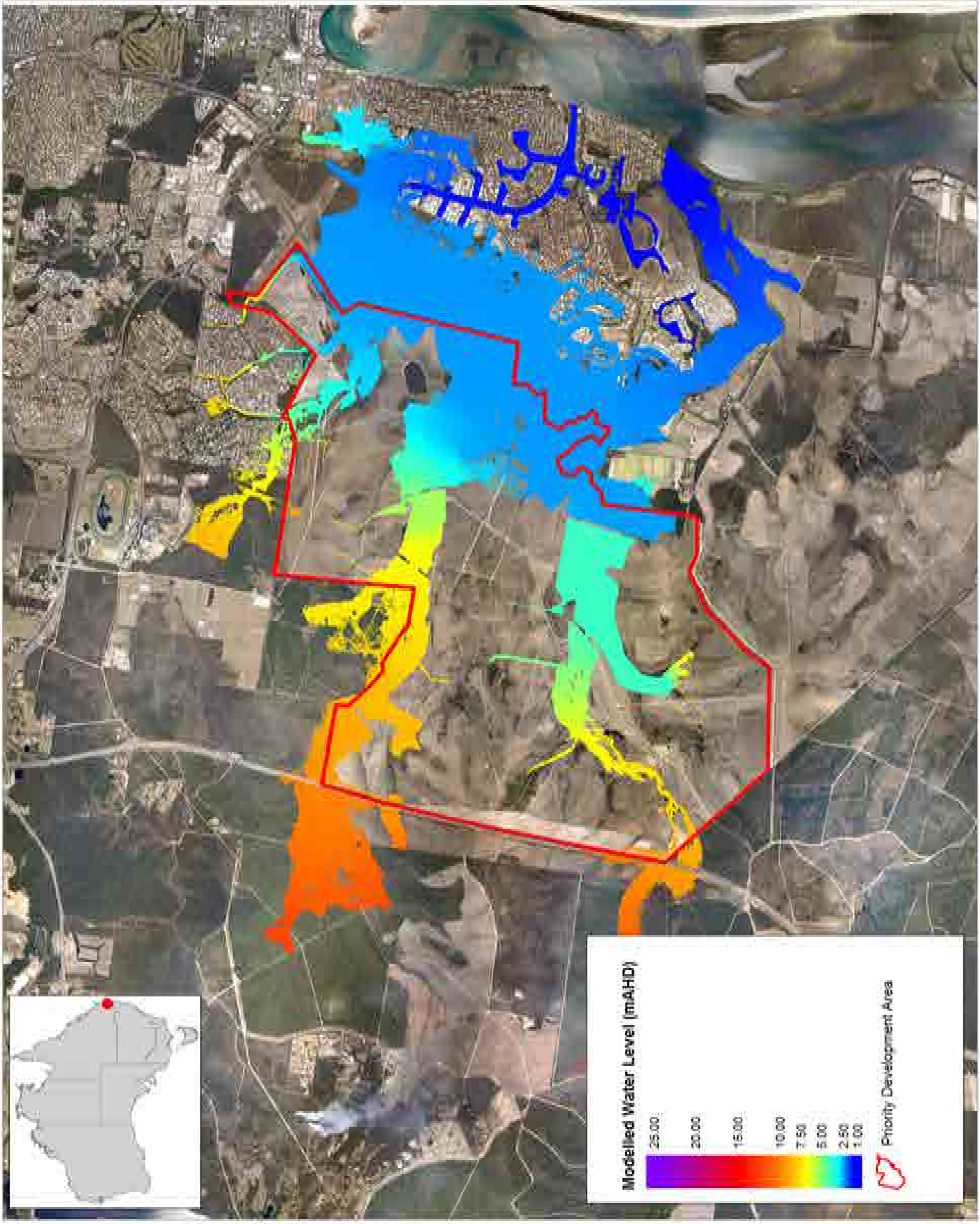
0 1.5 3km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00.Flooding\Appendix\FLD_150_150813_Dev_Q100_Levels.wor"




Title:

**Developed Case Peak Fluvial 50 Year ARI Flood Level**

Figure:

**E-2**

Rev.:

**-**

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N 0 1.5 3km

Approx. Scale

BMT WBM

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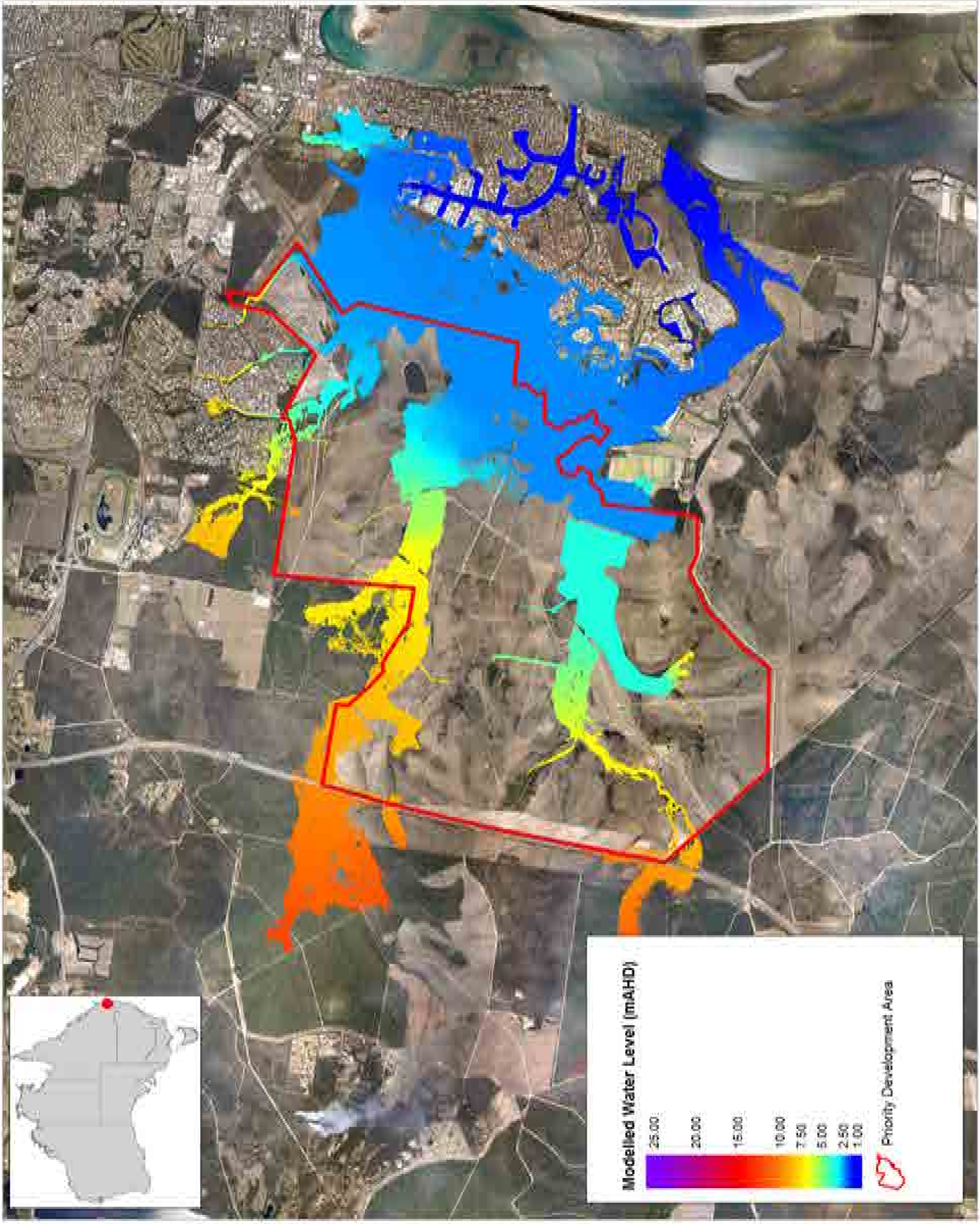
Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00.Flooding\Appendix\FLD_151_150813_Dev_Q050_Levels.wor"




Title:

**Developed Case Peak Fluvial 20 Year ARI Flood Level**

Figure: **E-3**

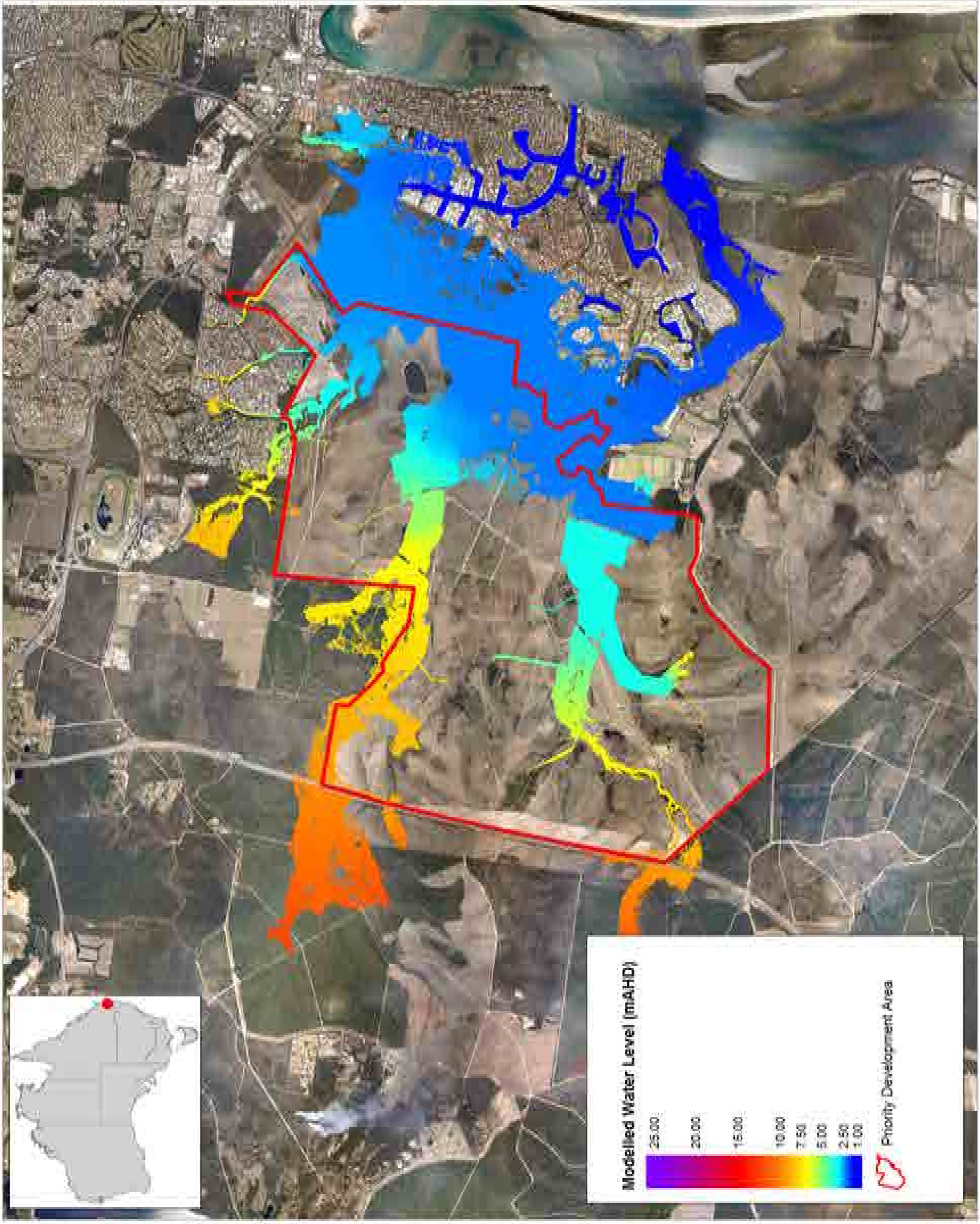
Rev: **-**



N 0 1.5 3km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00.Flooding\Appendix\FLD_152_150813_Dev_Q020_Levels.wor"




Title:

# Developed Case Peak Fluvial 10 Year ARI Flood Level

Figure: **E-4**

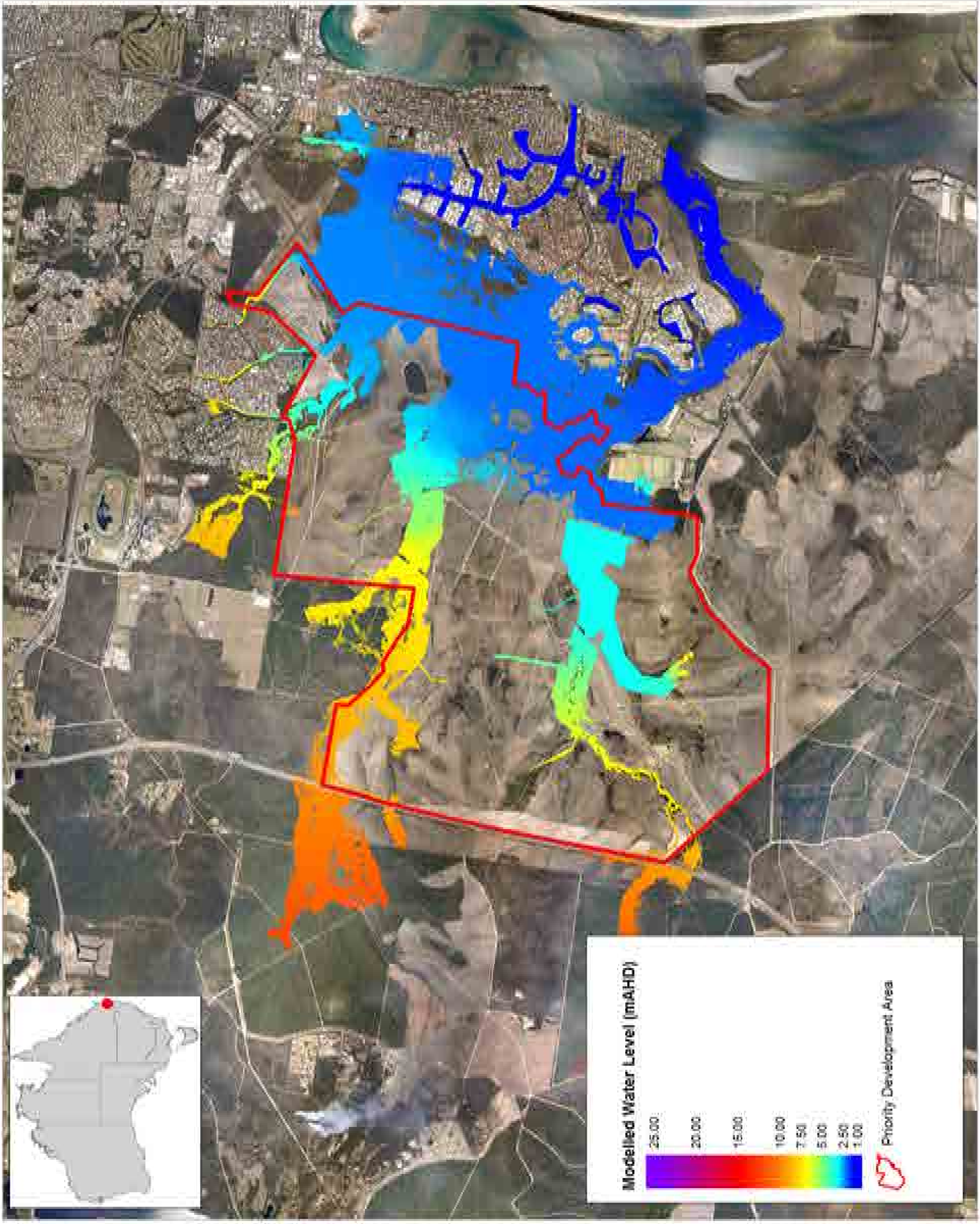
Rev: -



N 0 1.5 3km Approx. Scale

BMT WBM www.bmtwbm.com.au

Filepath : "I:\B20047_I_BRH Cal 5th DA Assistance ABM\DRG\R.B20047.020.00.Flooding\Appendix\FLD_153_150813_Dev_Q010_Levels.wor"




Title:

**Developed Case Peak Fluvial 5 Year ARI Flood Level**

Figure: E-5

Rev: -



N

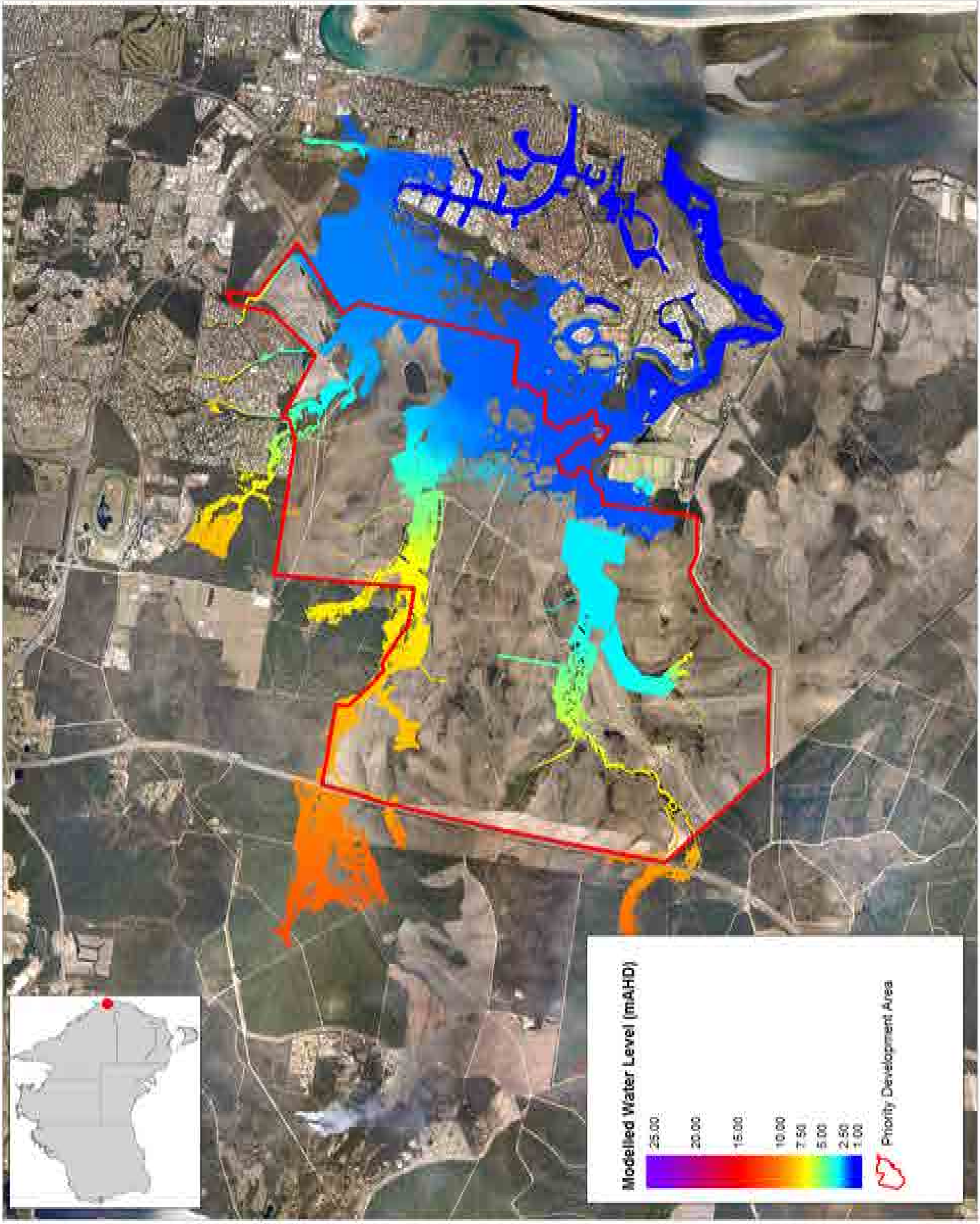
0 1.5 3km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00.Flooding\Appendix\FLD_154_150813_Dev_Q005_Levels.wor"




Title:

# Developed Case Peak Fluvial 2 Year ARI Flood Level

Figure: **E-6**

Rev: **-**

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N

0 1.5 3km

Approx. Scale

BMT WBM

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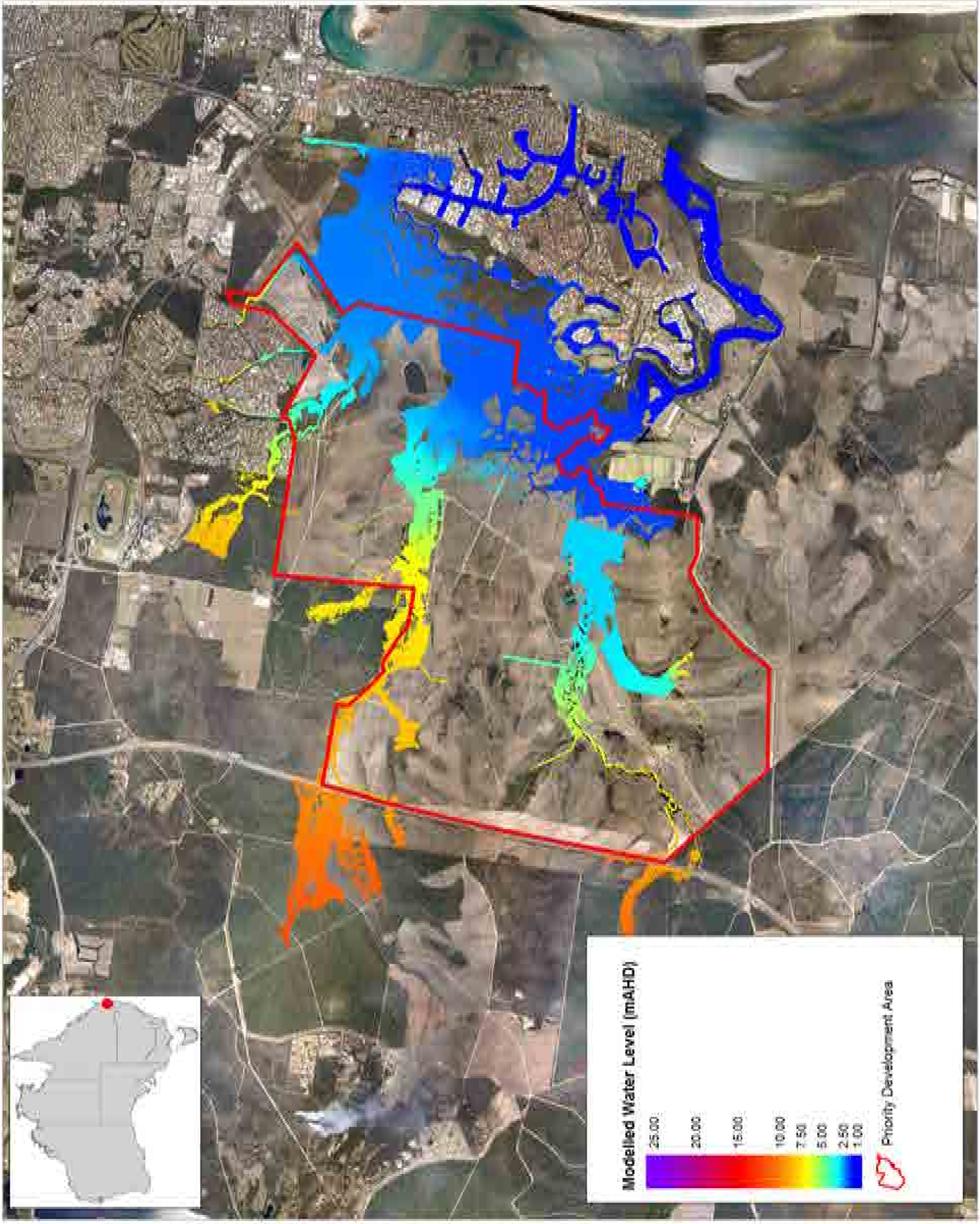
Filepath : "I:\B20047_I_BRH Cal 5th DA Assistance ABM\DRG\R.B20047.020.00.Flooding\Appendix\FLD_155_150813_Dev_Q002_Levels.wor"




Title:

**Developed Case Peak Fluvial 1 Year ARI Flood Level**

Figure:

**E-7**

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**-**



N 0 1.5 3km

Approx. Scale

BMT WBM

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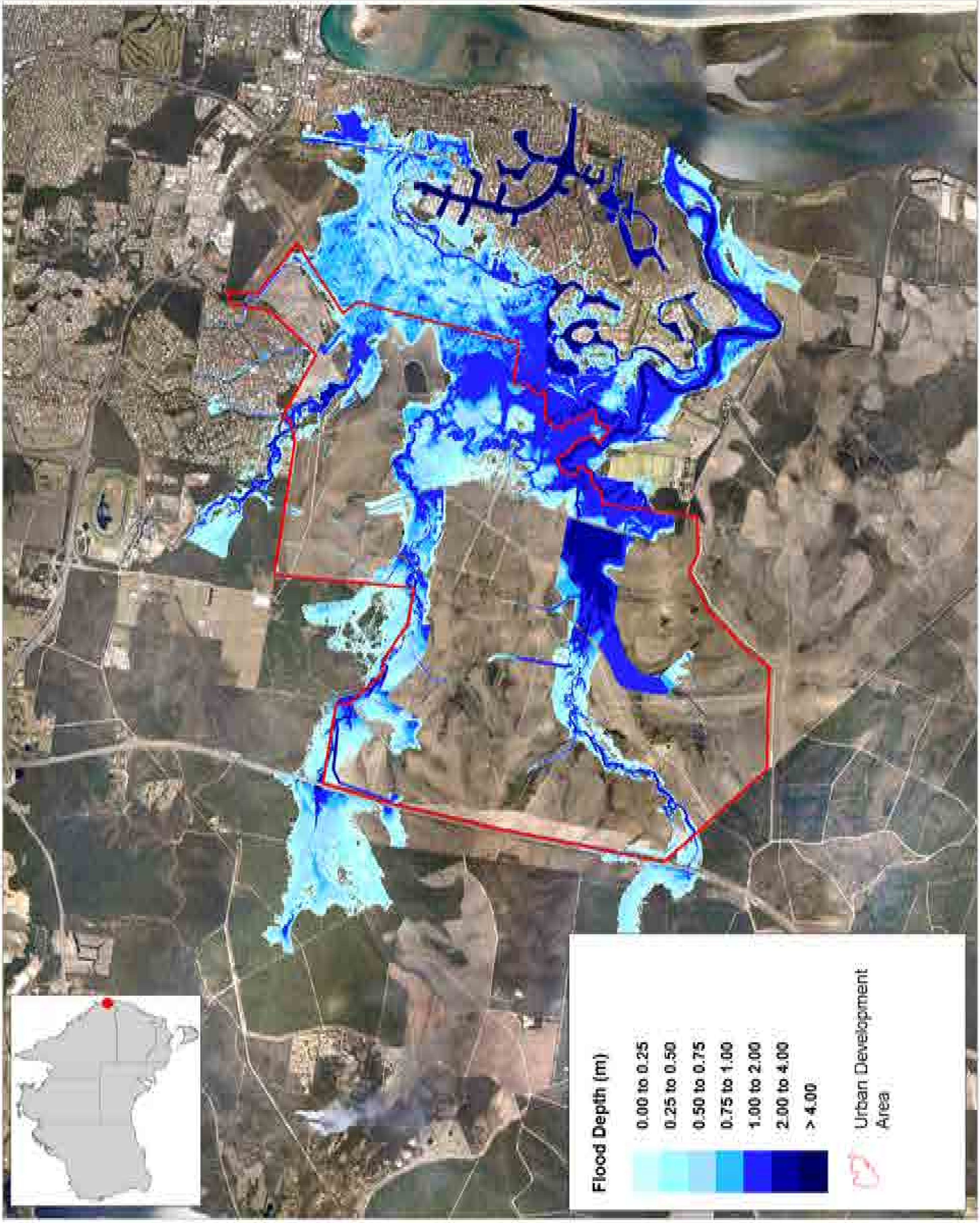
Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\FLD\B20047.020.00.Flooding\Appendix\FLD_156_150813_Dev_Q001_Levels.wor"




Title:

**Developed Case Peak 100 Year ARI Flood Depth**

Figure: **E-8**

Rev: **-**



N

0 1.5 3km

Approx. Scale

BMT WBM

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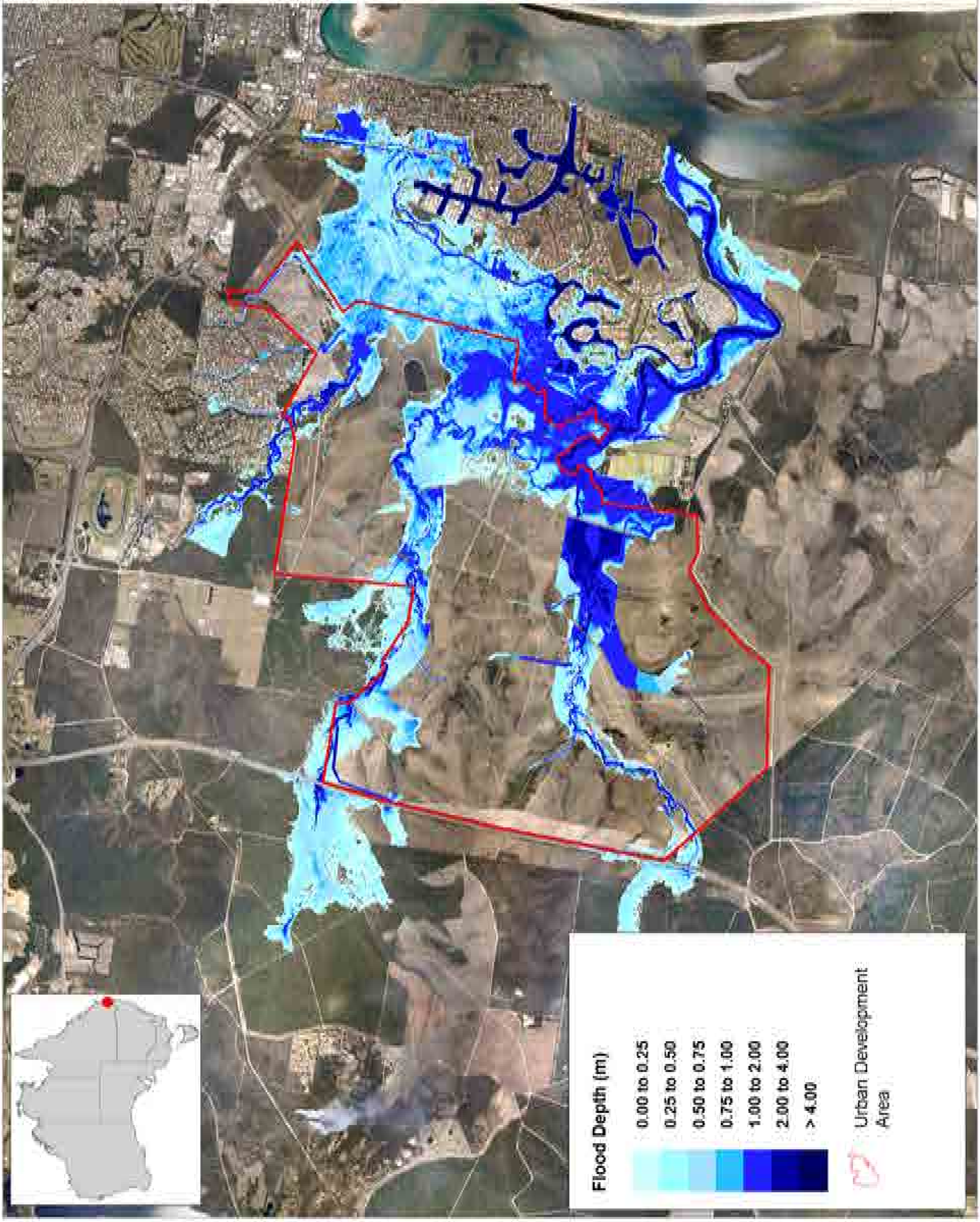
Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00 Flooding\Appendix\FLD_157_150813_Dev_Q100_Depths.wor"




Title:

**Developed Case Peak 50 Year ARI Flood Depth**

Figure: **E-9**

Rev: **-**

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N

0 1.5 3km

Approx. Scale

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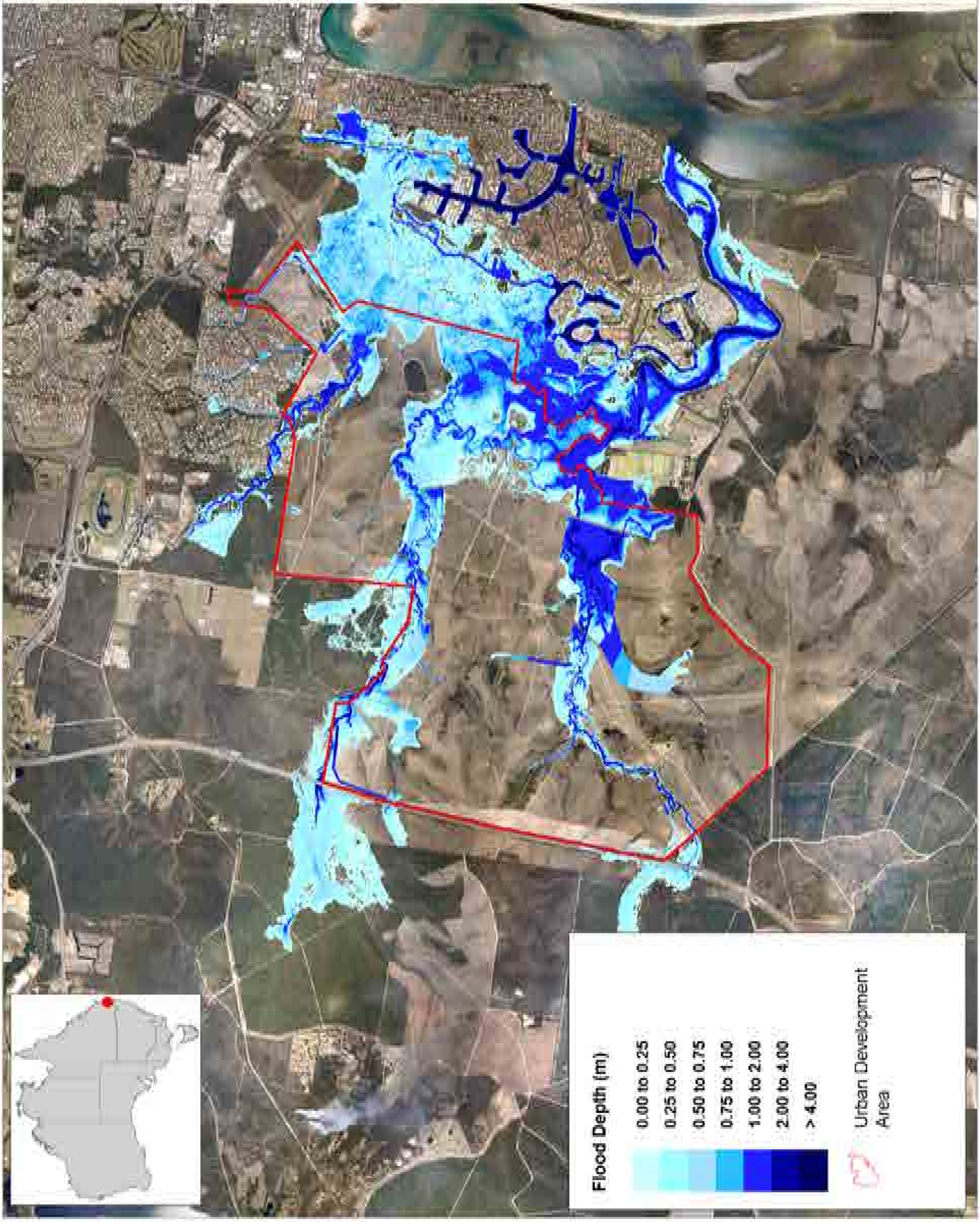
Filepath : "I:\B20047_I_BRH Cal 5th DA Assistance ABM\DRG\R.B20047.020.00 Flooding\Appendix\FLD_158_150813_Dev_Q050_Depths.wor"




Title:

**Developed Case Peak 20 Year ARI Flood Depth**

Figure: **E-10**

Rev: **-**



N

0 1.5 3km

Approx. Scale

BMT WBM

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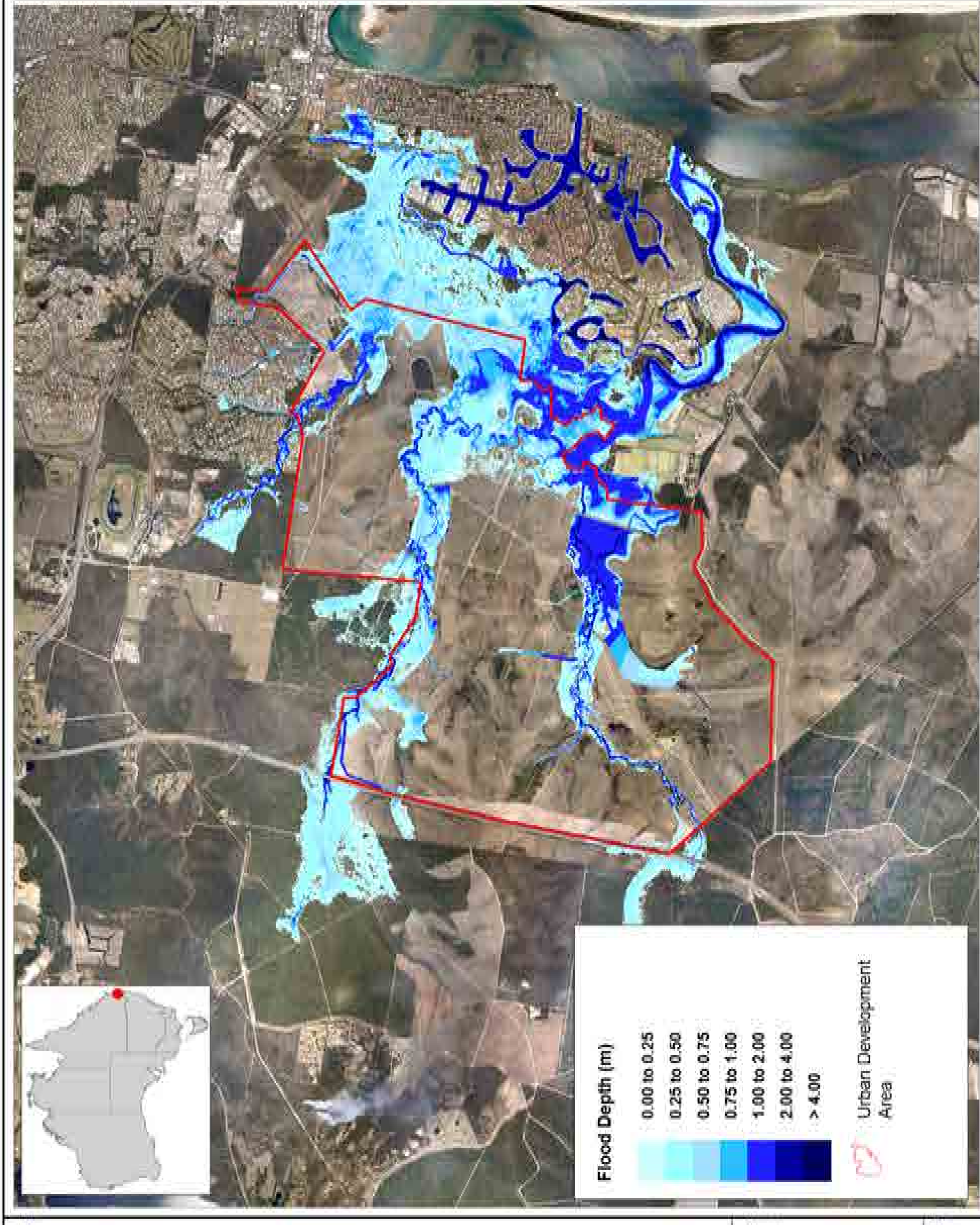
Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00 Flooding\Appendix\FLD_159_150813_Dev_Q020_Depths.wor"




Title:

**Developed Case Peak 10 Year ARI Flood Depth**

Figure:

**E-11**

Rev:

**-**



N

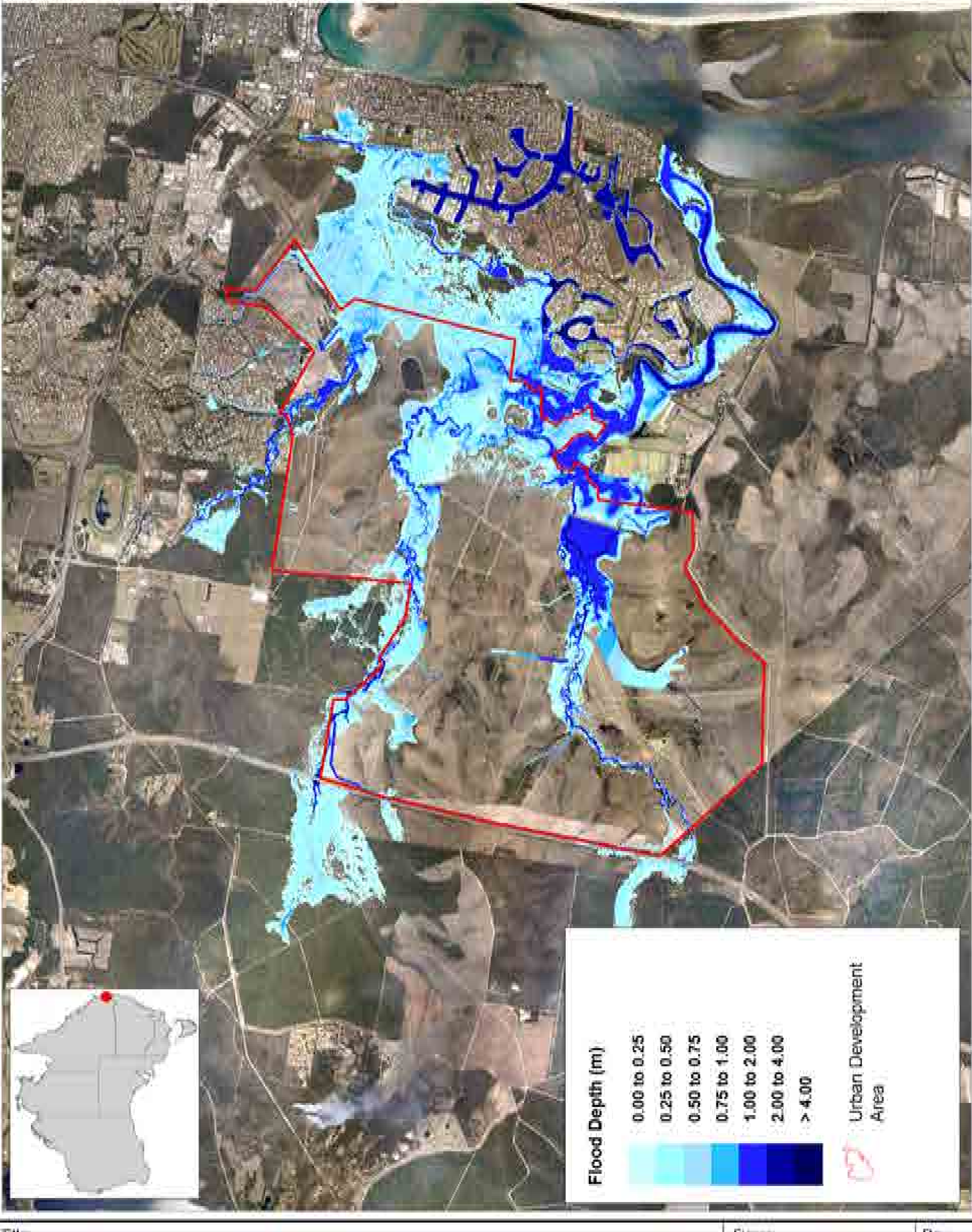
0 1.5 3km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B20047_I_BRH Cal 5th DA Assistance ABM\DRG\R.B20047.020.00 Flooding\Appendix\FLD_160_150813_Dev_Q010_Depths.wor"




Title:

**Developed Case Peak 5 Year ARI Flood Depth**

Figure: **E-12**

Rev: **-**



N

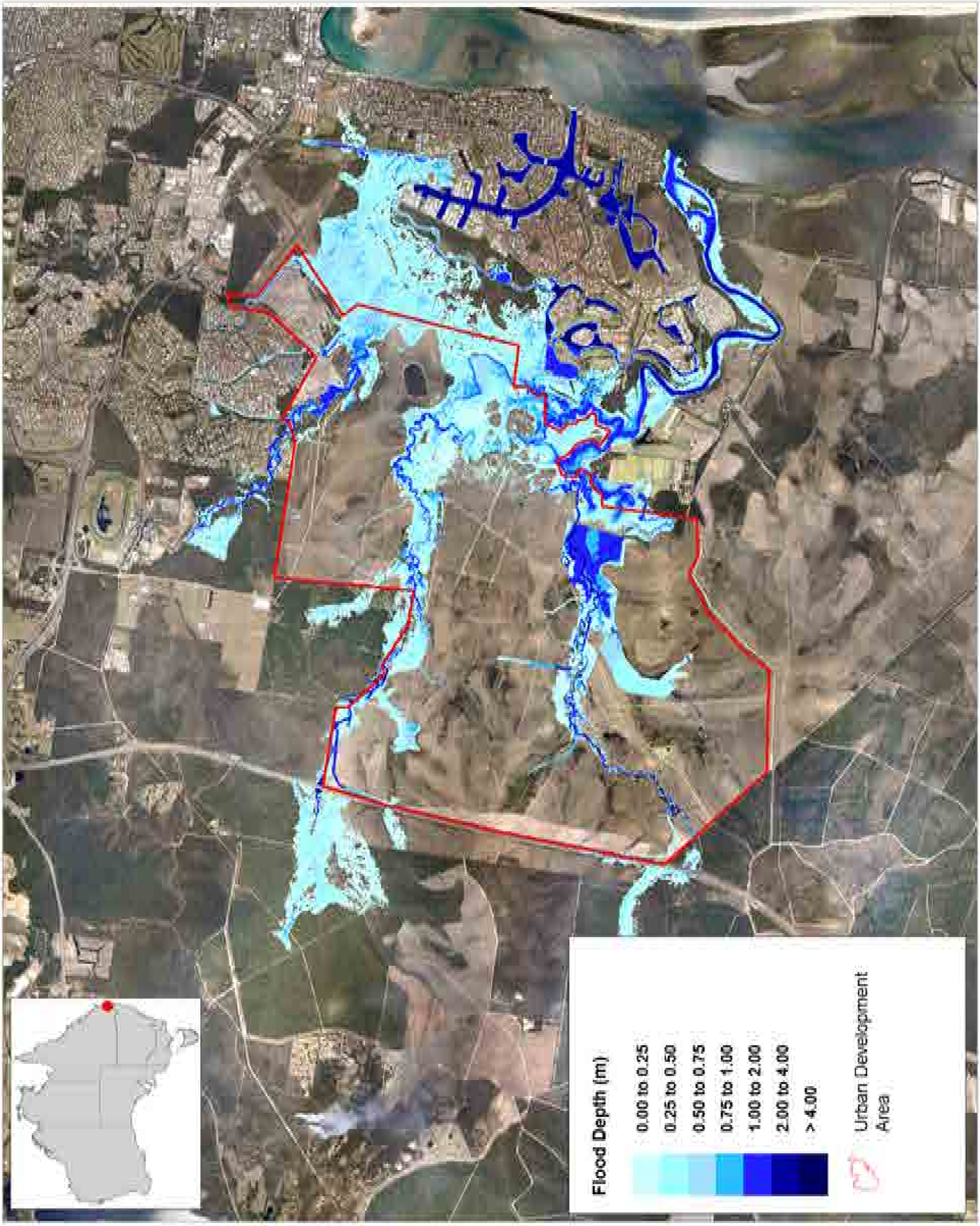
0 1.5 3km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00 Flooding\Appendix\FLD_161_150813_Dev_Q005_Depths.wor"




Title:

**Developed Case Peak 2 Year ARI Flood Depth**

Figure: **E-13**

Rev: **-**



N

0 1.5 3km

Approx. Scale

BMT WBM

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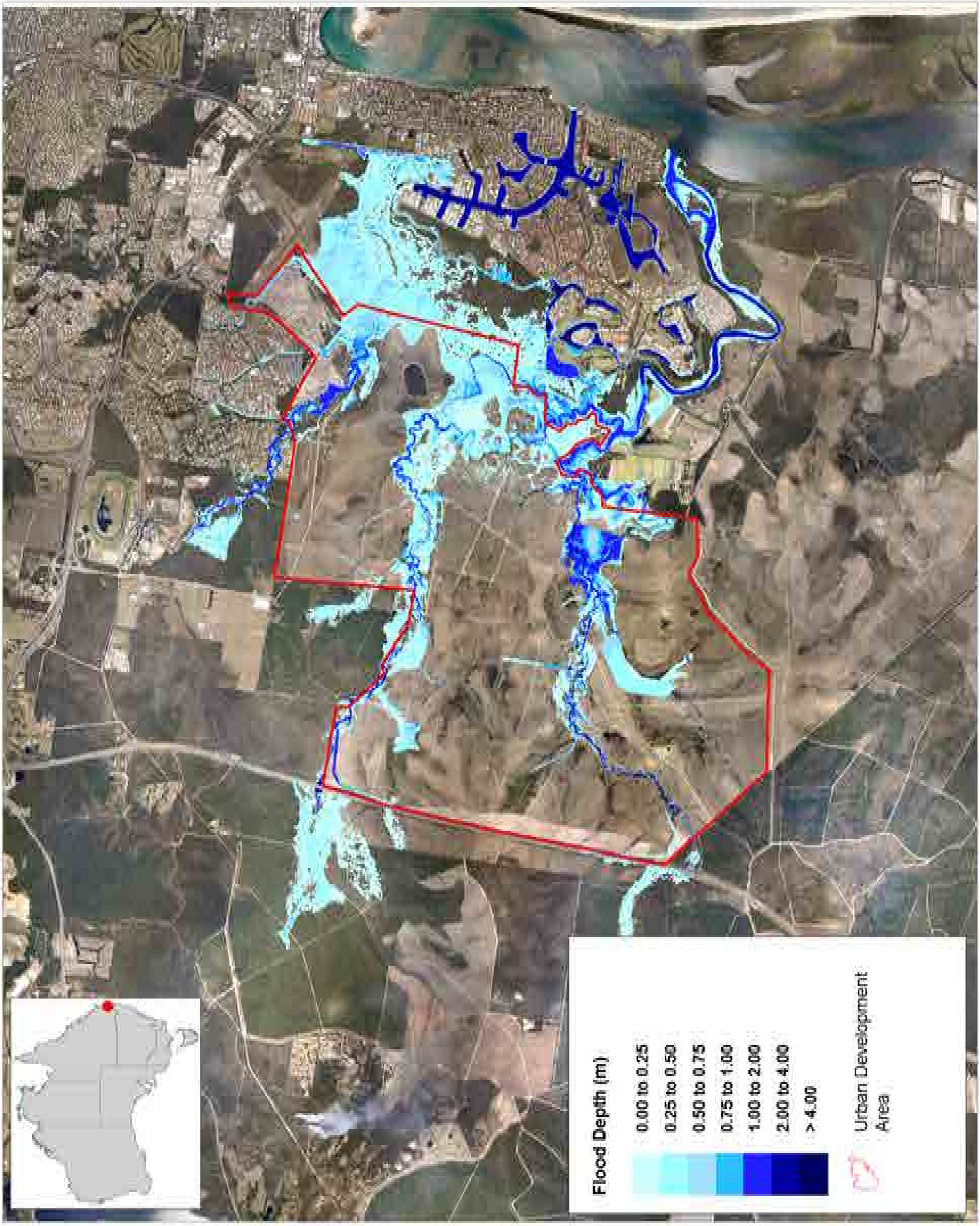
Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00 Flooding\Appendix\FLD_162_150813_Dev_Q002_Depths.wor"




Title:

**Developed Case Peak 1 Year ARI Flood Depth**

Figure: **E-14**

Rev: **-**



N

0 1.5 3km

Approx. Scale

BMT WBM

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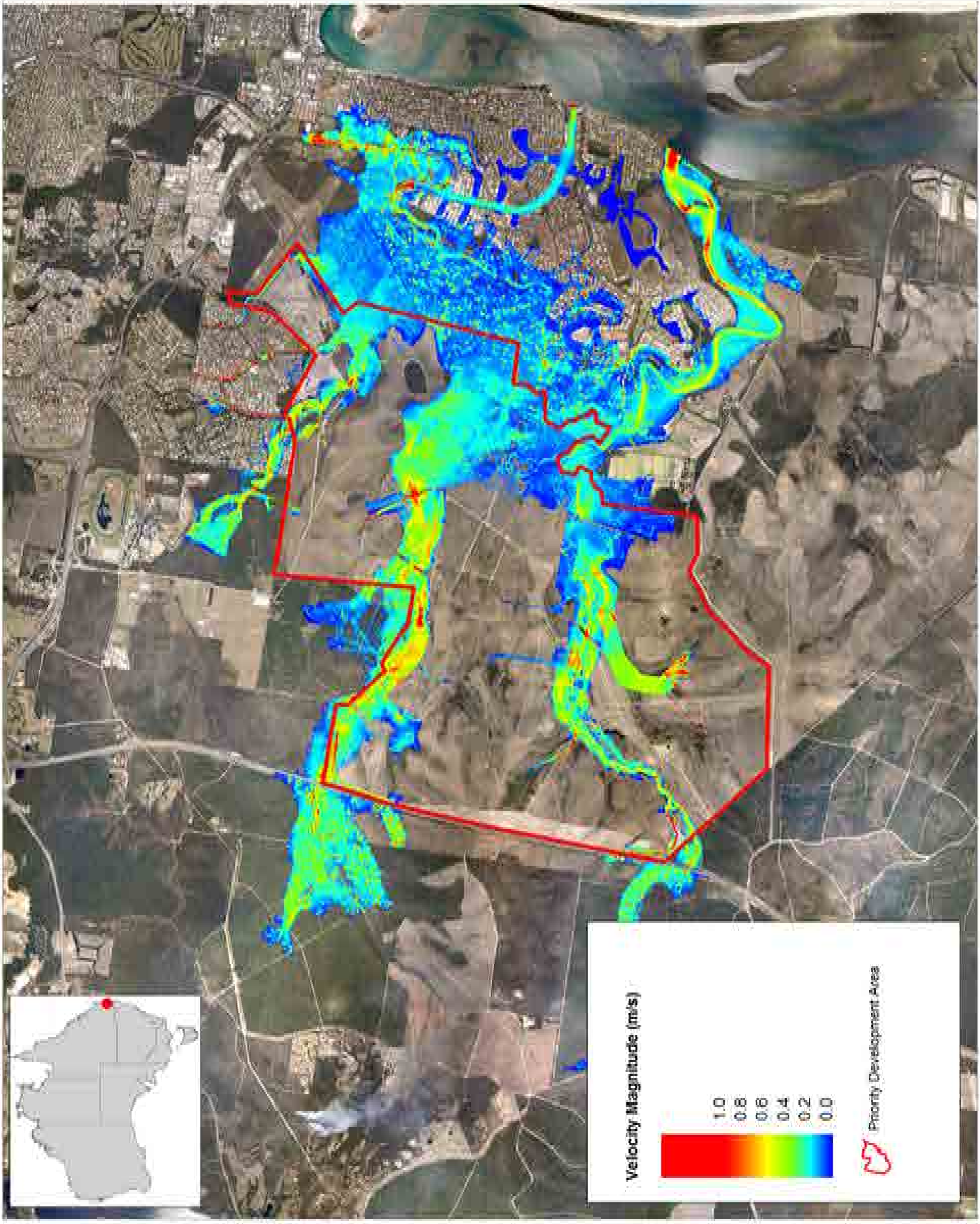
Filepath : "I:\B20047_I_BRH Cal 5th DA Assistance ABM\DRG\R.B20047.020.00 Flooding\Appendix\FLD_163_150813_Dev_Q001_Depths.wor"




Title:

**Developed Case Peak 100 Year Flow Velocity**

Figure: **E-15**

Rev: **-**

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N

0 1.5 3km

Approx. Scale

BMT WBM

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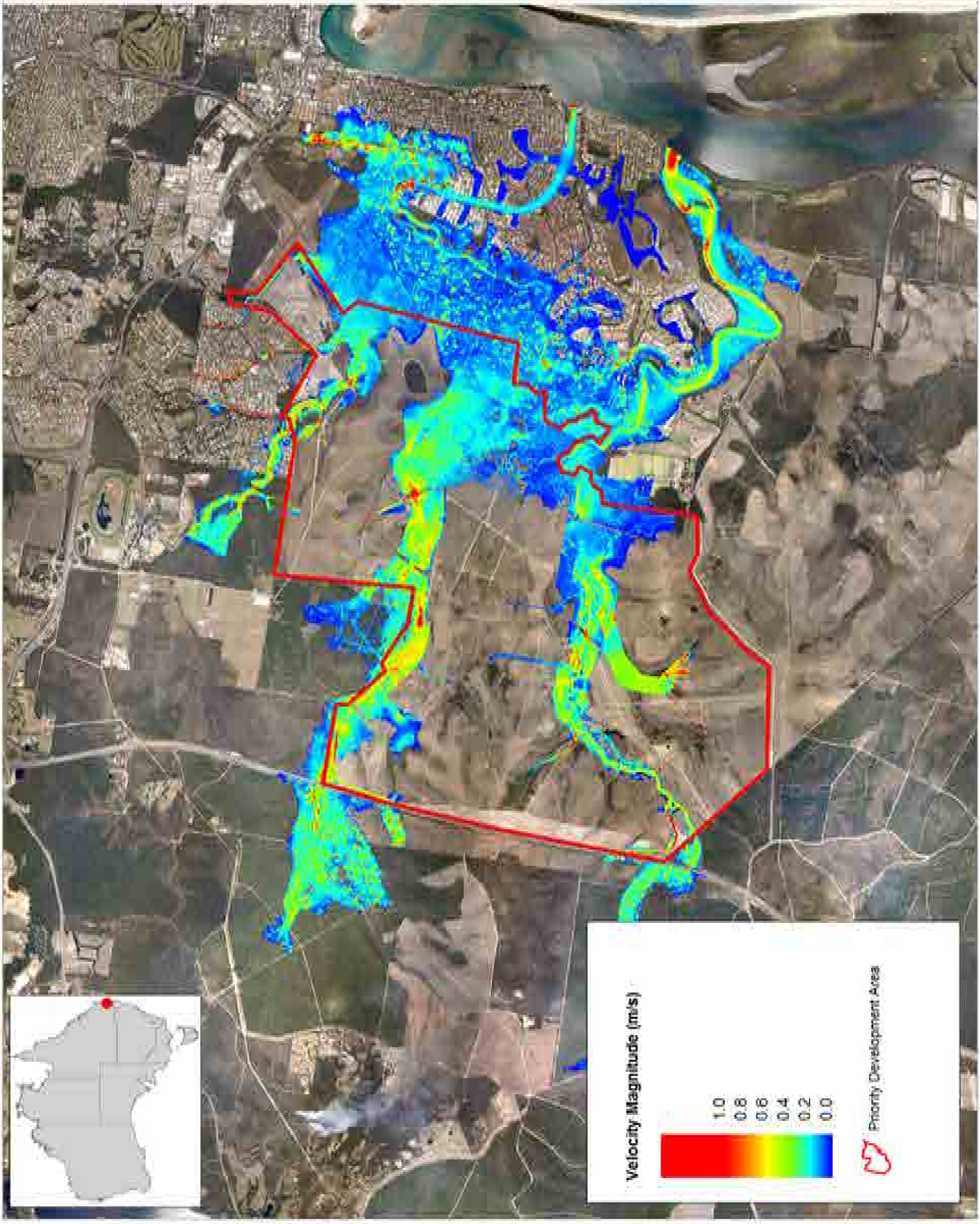
Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00.Flooding\Appendix\FLD_164_150813_Dev_Q100_Velocity.wor"




Title:

**Developed Case Peak 50 Year Flow Velocity**

Figure: **E-16**

Rev: **-**



N 0 1.5 3km
Approx. Scale

BMT WBM
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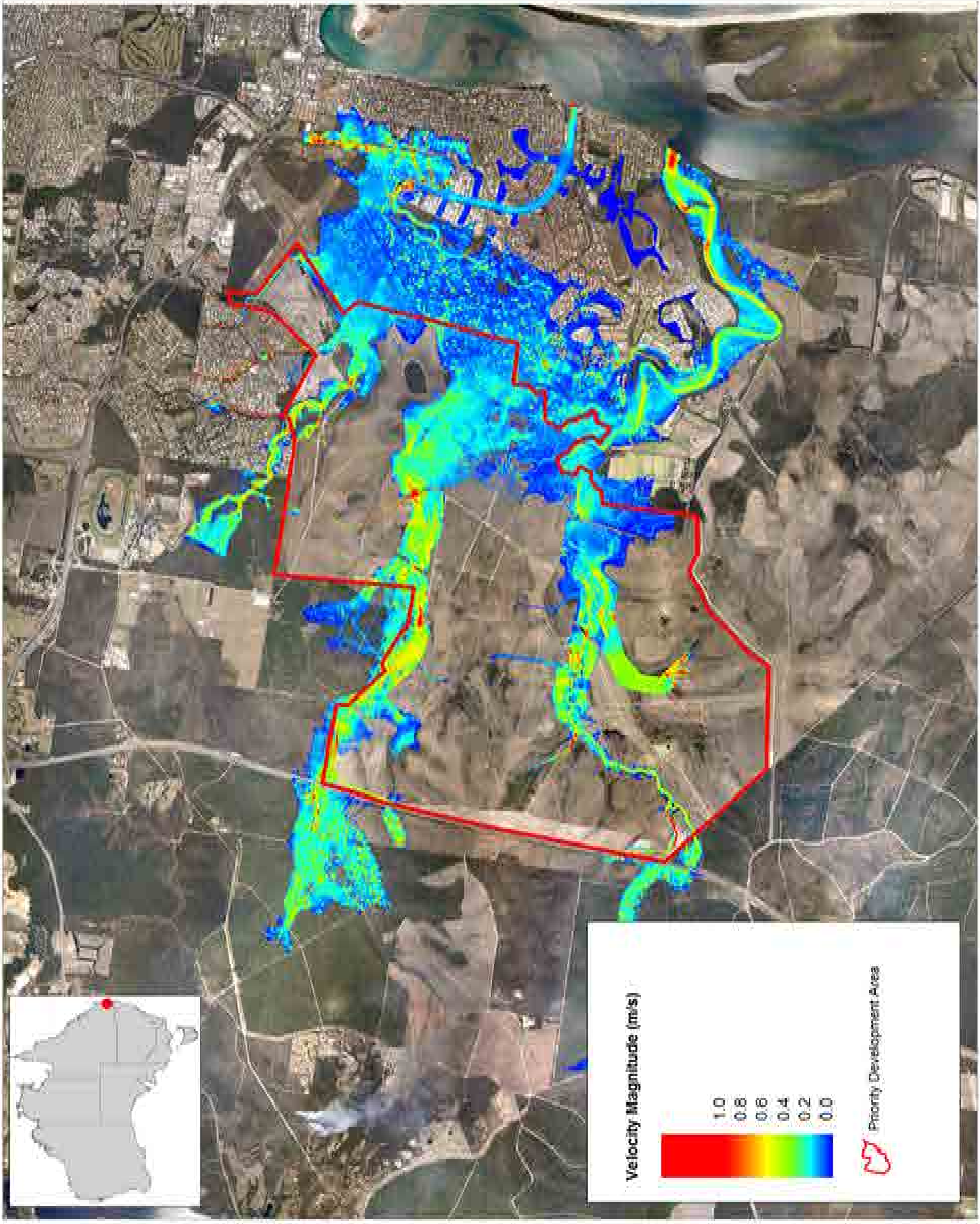
Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00.Flooding\Appendix\FLD_165_150813_Dev_Q050_Velocity.wor"




Title:

**Developed Case Peak 20 Year Flow Velocity**

Figure:

**E-17**

Rev:

**-**




BMT WBM

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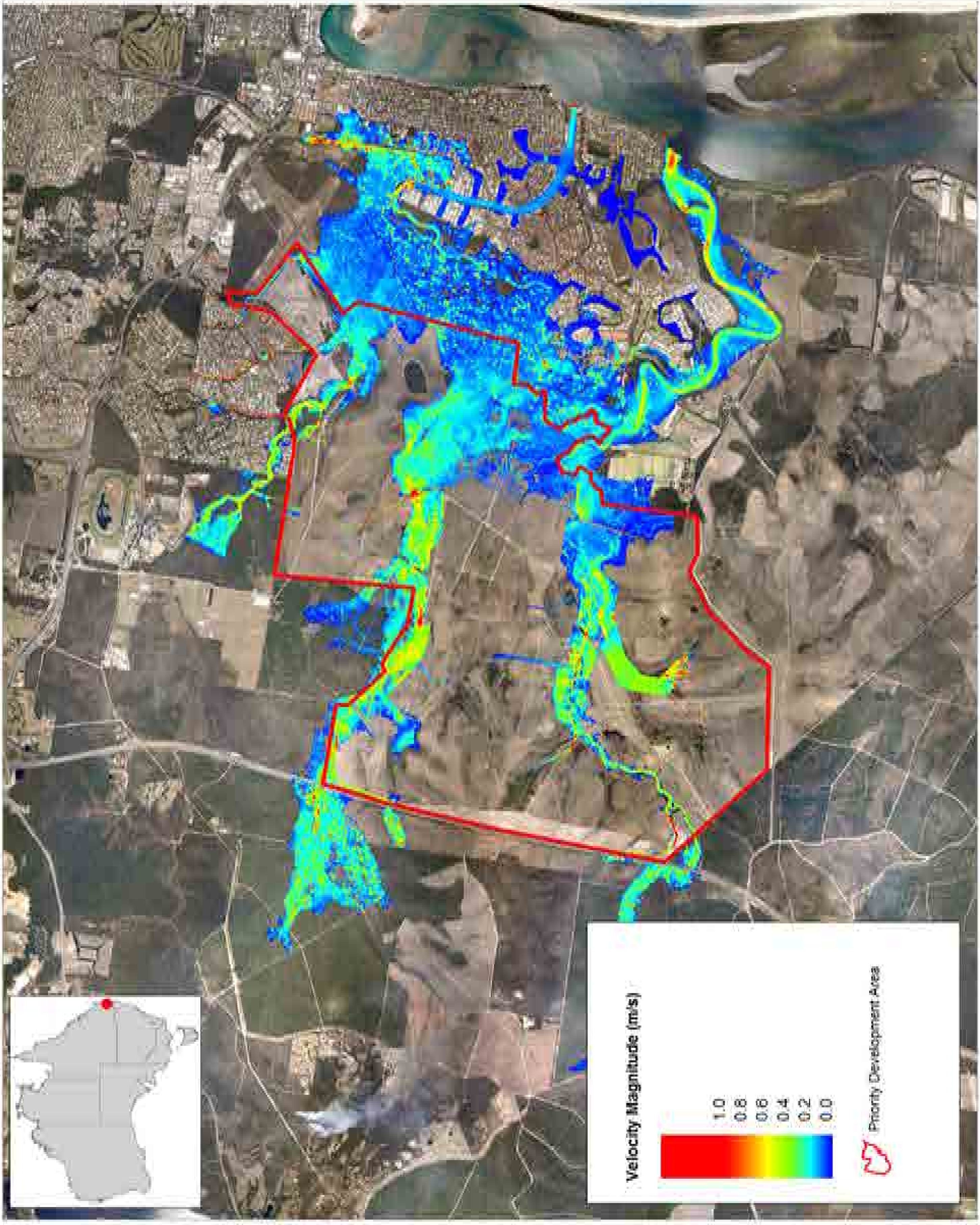
Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00.Flooding\Appendix\FLD_166_150813_Dev_Q020_Velocity.wor"




Title:

**Developed Case Peak 10 Year Flow Velocity**

Figure:

**E-18**

Rev:

**-**



0 1.5 3km

Approx. Scale

BMT WBM

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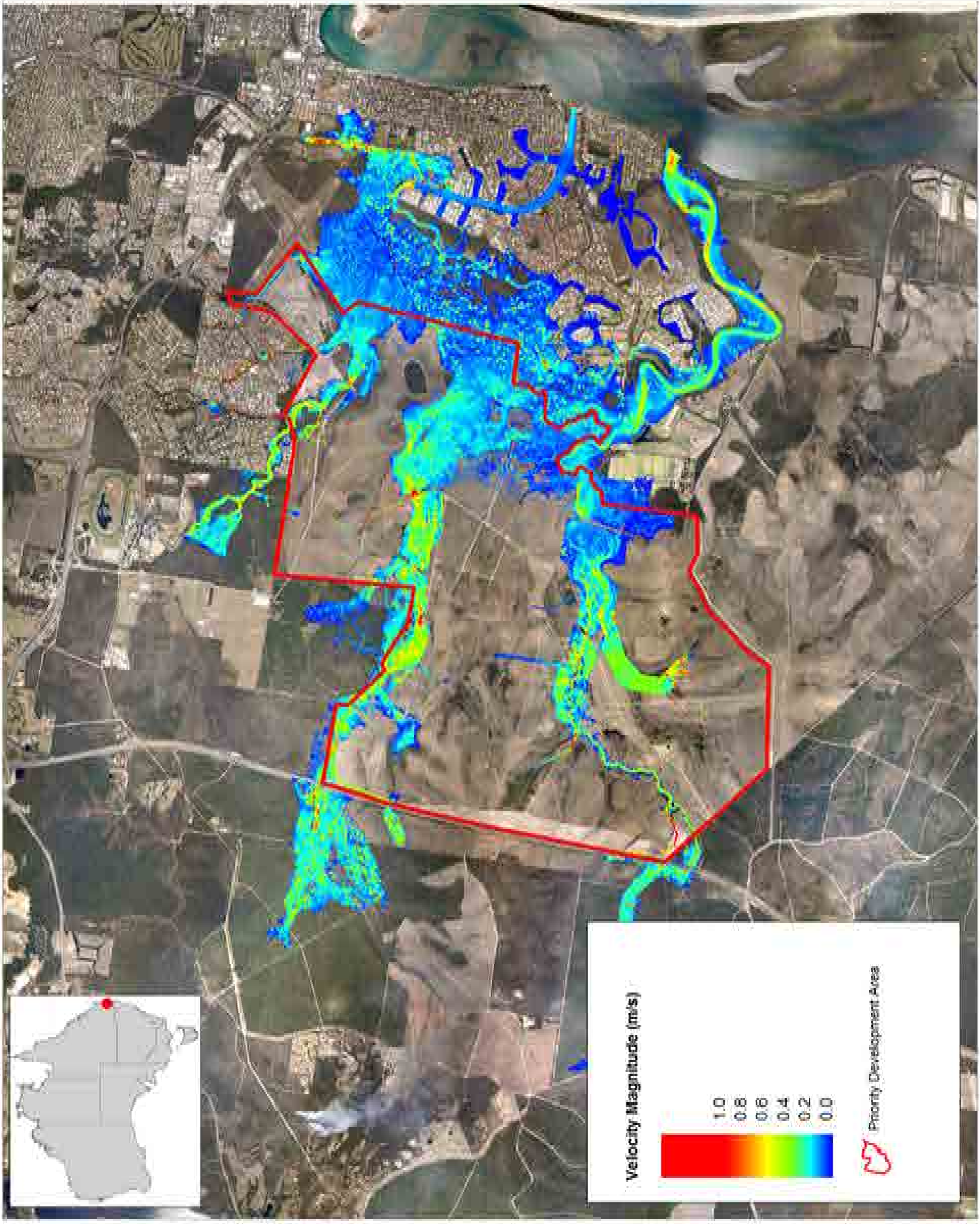
Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00.Flooding\Appendix\FLD_167_150813_Dev_Q010_Velocity.wor"




Title:

**Developed Case Peak 5 Year Flow Velocity**

Figure: **E-19**

Rev: **-**



N

0 1.5 3km

Approx. Scale

BMT WBM

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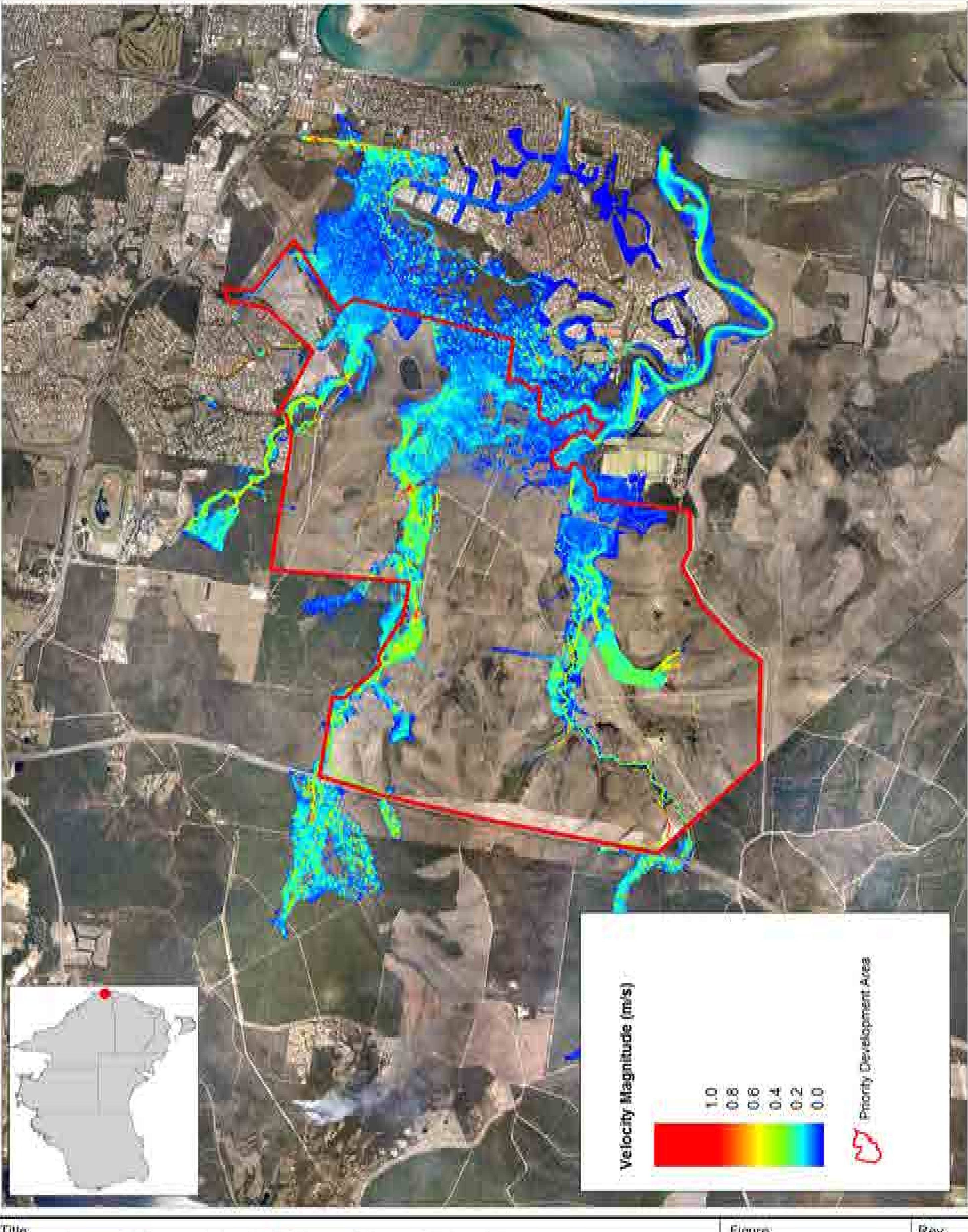
Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00.Flooding\Appendix\FLD_168_150813_Dev_Q005_Velocity.wor"




Title:

# Developed Case Peak 2 Year Flow Velocity

Figure: **E-20**

Rev: **-**

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N

0 1.5 3km

Approx. Scale

BMT WBM

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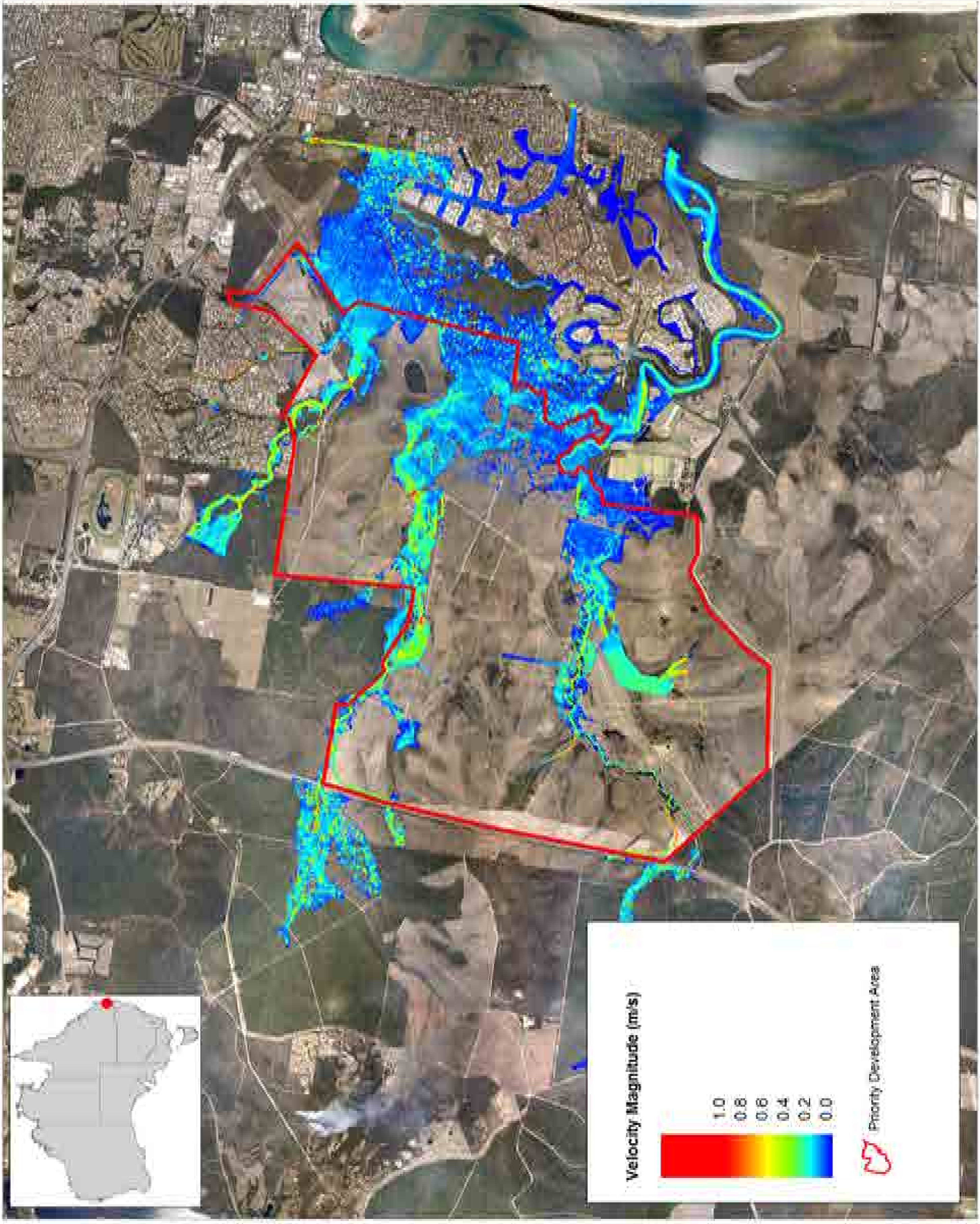
Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00.Flooding\Appendix\FLD_169_150813_Dev_Q002_Velocity.wor"




Title:

**Developed Case Peak 1 Year Flow Velocity**

Figure:

**E-21**

Rev:

**-**



N

0 1.5 3km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : "I:\B20047_I_BRH Cal Sth DA Assistance ABM\DRG\R.B20047.020.00.Flooding\Appendix\FLD_170_150813_Dev_Q001_Velocity.wor"

# Appendix F Rafts XP Peak Flow Summary

**Table F-1 RAFTS-XP Peak Inflows without Climate Change Allowance (m3/s)**

| Event Magnitude | 5 Year ARI | | | | 50 Year ARI | | | | 100 Year ARI | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Event Duration | 6 Hour Duration | | 12 Hour Duration | | 6 Hour Duration | | 12 Hour Duration | | 6 Hour Duration | | 12 Hour Duration | |
| Subcatchment ID | Base Case | Developed Case | Base Case | Developed Case | Base Case | Developed Case | Base Case | Developed Case | Base Case | Developed Case | Base Case | Developed Case |
| BC01 | 12 | 12 | 12 | 12 | 17 | 18 | 18 | 19 | 20 | 21 | 21 | 22 |
| BC02 | 7.8 | 8.7 | 8.6 | 9.2 | 17 | 17 | 20 | 20 | 21 | 21 | 24 | 25 |
| BCN1 | 3.5 | 3.5 | 3.6 | 3.6 | 5.4 | 5.4 | 5.7 | 5.7 | 6.3 | 6.3 | 6.6 | 6.6 |
| BCN2 | 1 | 1 | 1.2 | 1.2 | 2.4 | 2.4 | 3 | 3 | 2.9 | 2.9 | 3.7 | 3.7 |
| BCN3 | 13 | 37 | 14 | 38 | 30 | 56 | 33 | 59 | 37 | 65 | 41 | 68 |
| BCN4 | 9.7 | 24 | 10 | 24 | 22 | 37 | 22 | 38 | 27 | 42 | 26 | 44 |
| BCN5 | 11 | 11 | 11 | 12 | 22 | 22 | 23 | 25 | 26 | 26 | 28 | 30 |
| BCN6 | 29 | 29 | 30 | 30 | 57 | 57 | 61 | 61 | 68 | 68 | 73 | 73 |
| BCN7 | 29 | 29 | 31 | 31 | 54 | 54 | 59 | 59 | 65 | 65 | 71 | 71 |
| BCS1 | 0.81 | 0.81 | 0.95 | 0.96 | 2 | 2 | 2.4 | 2.4 | 2.4 | 2.4 | 2.9 | 2.9 |
| BCS2 | 7 | 37 | 7.8 | 39 | 17 | 55 | 18 | 58 | 21 | 63 | 22 | 67 |
| BCS3 | 14 | 57 | 15 | 59 | 33 | 85 | 35 | 90 | 41 | 98 | 43 | 100 |
| BCS4 | 12 | 38 | 13 | 39 | 27 | 57 | 26 | 60 | 33 | 67 | 32 | 69 |
| BCS5 | 24 | 24 | 23 | 23 | 46 | 46 | 48 | 48 | 56 | 56 | 58 | 58 |
| BCS6 | 8.3 | 8.8 | 9 | 10 | 16 | 17 | 17 | 19 | 19 | 20 | 20 | 22 |
| DC01 | 18 | 18 | 20 | 20 | 30 | 30 | 38 | 38 | 36 | 36 | 45 | 45 |
| DC02 | 11 | 11 | 11 | 11 | 20 | 20 | 20 | 20 | 24 | 24 | 23 | 23 |
| DC03 | 22 | 22 | 23 | 23 | 32 | 32 | 35 | 35 | 37 | 37 | 40 | 40 |
| K:\B17427.k.JGJ.CaloundraDowns_FIA\Hydrology\RAFTS_XP\OUTPUT\Summary\[Summary_Q_Loc_Exg_Dev_008.xls]Peak_Q_Summary_no_CC_008 | | | | | | | | | | | | |

| Event Magnitude | 5 Year ARI | | | | 50 Year ARI | | | | 100 Year ARI | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Event Magnitude | 5 Year ARI | | | | 50 Year ARI | | | | 100 Year ARI | | | |
| Event Duration | 6 Hour Duration | | 12 Hour Duration | | 6 Hour Duration | | 12 Hour Duration | | 6 Hour Duration | | 12 Hour Duration | |
| Subcatchment ID | Base Case | Developed Case | Base Case | Developed Case | Base Case | Developed Case | Base Case | Developed Case | Base Case | Developed Case | Base Case | Developed Case |
| LC01 | 37 | 37 | 37 | 37 | 56 | 56 | 58 | 58 | 65 | 65 | 67 | 67 |
| LC02 | 3.1 | 3.2 | 3.8 | 3.9 | 7.9 | 8 | 9.7 | 9.8 | 9.8 | 10 | 12 | 12 |
| LC03 | 2.1 | 2.1 | 2.5 | 2.5 | 5.1 | 5.1 | 6.6 | 6.6 | 6.4 | 6.4 | 8.2 | 8.2 |
| LC04 | 5.3 | 6.1 | 5 | 7 | 11 | 12 | 11 | 14 | 13 | 14 | 13 | 16 |
| LC05 | 5 | 14 | 4.4 | 14 | 10 | 21 | 9.7 | 22 | 13 | 25 | 12 | 26 |
| LC06 | 37 | 37 | 36 | 36 | 63 | 63 | 62 | 62 | 75 | 75 | 75 | 75 |
| LC07 | 23 | 25 | 23 | 25 | 38 | 41 | 38 | 41 | 45 | 48 | 45 | 49 |
| LC08 | 4.4 | 4.4 | 3.8 | 3.8 | 9.1 | 9.1 | 8.6 | 8.6 | 11 | 11 | 10 | 10 |
| LC09 | 5.8 | 5.8 | 5.8 | 5.8 | 11 | 11 | 12 | 12 | 14 | 14 | 15 | 15 |
| LC10 | 11 | 11 | 9.4 | 9.4 | 22 | 22 | 21 | 21 | 27 | 27 | 25 | 25 |
| LC11 | 9.1 | 9.1 | 8.1 | 8.1 | 17 | 17 | 17 | 17 | 21 | 21 | 20 | 20 |
| K:\B17427.k.JGJ.CaloundraDowns_FIA\Hydrology\RAFTS_XP\OUTPUT\Summary\[Summary_Q_Loc_Exg_Dev_008.xls]Peak_Q_Summary_no_CC_008 | | | | | | | | | | | | |

Table F-2 RAFTS-XP Peak Inflows with Climate Change Allowance (m3/s)

| Event Magnitude | 5 Year ARI | | | | 50 Year ARI | | | | 100 Year ARI | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Event Duration | 6 Hour | | 12 Hour | | 6 Hour | | 12 Hour | | 6 Hour | | 12 Hour | |
| Subcatchment ID | Base Case | Developed Case | Base Case | Developed Case | Base Case | Developed Case | Base Case | Developed Case | Base Case | Developed Case | Base Case | Developed Case |
| BC01 | 14 | 14 | 14 | 15 | 21 | 22 | 22 | 23 | 24 | 25 | 25 | 26 |
| BC02 | 10 | 11 | 12 | 12 | 23 | 23 | 26 | 26 | 28 | 28 | 31 | 32 |
| BCN1 | 4.3 | 4.3 | 4.4 | 4.4 | 6.6 | 6.6 | 6.9 | 6.9 | 7.7 | 7.7 | 8.0 | 8.0 |
| BCN2 | 1.4 | 1.4 | 1.7 | 1.7 | 3.2 | 3.2 | 4.0 | 4.0 | 3.9 | 3.9 | 4.9 | 5.0 |
| BCN3 | 18 | 45 | 19 | 46 | 40 | 69 | 43 | 71 | 49 | 80 | 52 | 83 |
| BCN4 | 13 | 29 | 14 | 29 | 28 | 45 | 28 | 46 | 35 | 52 | 33 | 54 |
| BCN5 | 15 | 15 | 15 | 17 | 28 | 28 | 29 | 32 | 33 | 33 | 36 | 38 |
| BCN6 | 38 | 38 | 41 | 41 | 72 | 72 | 78 | 78 | 86 | 86 | 93 | 93 |
| BCN7 | 38 | 38 | 41 | 41 | 69 | 69 | 75 | 75 | 82 | 82 | 89 | 89 |
| BCS1 | 1.1 | 1.2 | 1.3 | 1.3 | 2.6 | 2.6 | 3.1 | 3.1 | 3.2 | 3.2 | 3.7 | 3.7 |
| BCS2 | 10 | 45 | 11 | 46 | 22 | 66 | 24 | 70 | 27 | 76 | 29 | 80 |
| BCS3 | 20 | 69 | 21 | 71 | 44 | 103 | 45 | 108 | 53 | 119 | 54 | 125 |
| BCS4 | 17 | 46 | 17 | 47 | 35 | 70 | 33 | 73 | 43 | 81 | 40 | 84 |
| BCS5 | 31 | 31 | 31 | 31 | 59 | 59 | 62 | 62 | 70 | 70 | 75 | 75 |
| BCS6 | 11 | 12 | 12 | 13 | 20 | 21 | 21 | 23 | 23 | 25 | 25 | 27 |
| DC01 | 23 | 23 | 26 | 26 | 38 | 38 | 47 | 47 | 46 | 46 | 56 | 56 |
| DC02 | 15 | 15 | 14 | 14 | 25 | 25 | 25 | 25 | 30 | 30 | 30 | 30 |
| DC03 | 26 | 26 | 27 | 27 | 39 | 39 | 42 | 42 | 45 | 45 | 48 | 48 |

## Rafts XP Peak Flow Summary

| Event Magnitude | 5 Year ARI | | | | 50 Year ARI | | | | 100 Year ARI | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Event Duration** | **6 Hour** | | **12 Hour** | | **6 Hour** | | **12 Hour** | | **6 Hour** | | **12 Hour** | |
| **Subcatchment ID** | **Base Case** | **Developed Case** | **Base Case** | **Developed Case** | **Base Case** | **Developed Case** | **Base Case** | **Developed Case** | **Base Case** | **Developed Case** | **Base Case** | **Develope d Case** |
| LC01 | 45 | 46 | 45 | 45 | 69 | 69 | 71 | 71 | 79 | 79 | 82 | 82 |
| LC02 | 4.4 | 4.5 | 5.4 | 5.5 | 11 | 11 | 13 | 13 | 13 | 13 | 15 | 16 |
| LC03 | 2.9 | 2.9 | 3.5 | 3.5 | 6.8 | 6.9 | 8.8 | 8.8 | 8.7 | 8.7 | 11 | 11 |
| LC04 | 7.1 | 8.0 | 6.8 | 9.2 | 14 | 15 | 14 | 18 | 17 | 18 | 17 | 21 |
| LC05 | 6.7 | 17 | 6.1 | 17 | 13 | 26 | 13 | 27 | 16 | 31 | 16 | 32 |
| LC06 | 47 | 47 | 46 | 46 | 79 | 79 | 80 | 80 | 93 | 93 | 93 | 93 |
| LC07 | 29 | 31 | 29 | 31 | 48 | 51 | 48 | 51 | 56 | 60 | 57 | 61 |
| LC08 | 5.9 | 5.9 | 5.4 | 5.4 | 12 | 12 | 11 | 11 | 14 | 14 | 14 | 14 |
| LC09 | 7.7 | 7.7 | 8.0 | 8.0 | 14 | 14 | 16 | 16 | 17 | 17 | 19 | 19 |
| LC10 | 14 | 14 | 13 | 13 | 28 | 28 | 27 | 27 | 34 | 34 | 33 | 33 |
| LC11 | 12 | 12 | 11 | 11 | 22 | 22 | 22 | 22 | 26 | 26 | 26 | 26 |
| K:\B17427.k.JGJ.CaloundraDowns_FIA\Hydrology\RAFTS_XP\OUTPUT\Summary\[Summary_Q_Loc_Exg_Dev_008.xls]Peak_Q_Summary_inc_CC_008 | | | | | | | | | | | | |

# Appendix G Overland Flow Reconfiguration Assessment

# 1 Introduction

As part of the proposed Caloundra South master-planned community, Stockland is considering undertaking modifications to the structure of a section of the Bells Creek South corridor, comprising a modified low-flow/overflow channel configuration and the creation of some wetlands immediately south-west of the proposed Town Centre. The approximate extent of the reconfiguration is illustrated in Figure 1-1.


**Figure 1-1 Approximate Extent of Proposed Flow Path Reconfiguration**

The aim of this study is to undertake a hydraulic assessment of the proposed reconfiguration. Specifically, the assessment aims to determine if the proposed reconfiguration will:

- Cause any increase in flow velocities (and associated risk of scour/erosion) downstream of the proposed reconfiguration during the Q100 storm event
- Cause any change in maximum water level during the Q5 event that may impact on the habitat of the Wallum Sedgefrog.

# 2 Site Characteristics

The study area is located on Bells Creek South, approximately 2km upstream of the junction with Bells Creek North. Elevations within the study area vary from 1.5m AHD in the east to 7.6m AHD in the north-west.

Soils within the study site are expected to be consistent with those of the greater extend of the Caloundra South Development site. As outlined in '*Caloundra South Development: Groundwater Assessment*' (BMT WBM, 2014), shallow boreholes constructed on the site revealed soils with very sandy A horizons over clayey subsoil layers to a depth of 0.75m.

# 3 Methodology

BMT WBM has previously undertaken a number of flood assessments associated with the proposed Caloundra South Development. The regional Tuflow hydraulic model used in these assessments has a 5m resolution, and incorporates a model area of 7000 hectares. Technical details of the most recent assessment using this model are described in '*Caloundra South: Flood Risk Management Strategy – September 2014 Update'* (BMT WBM, 2014).

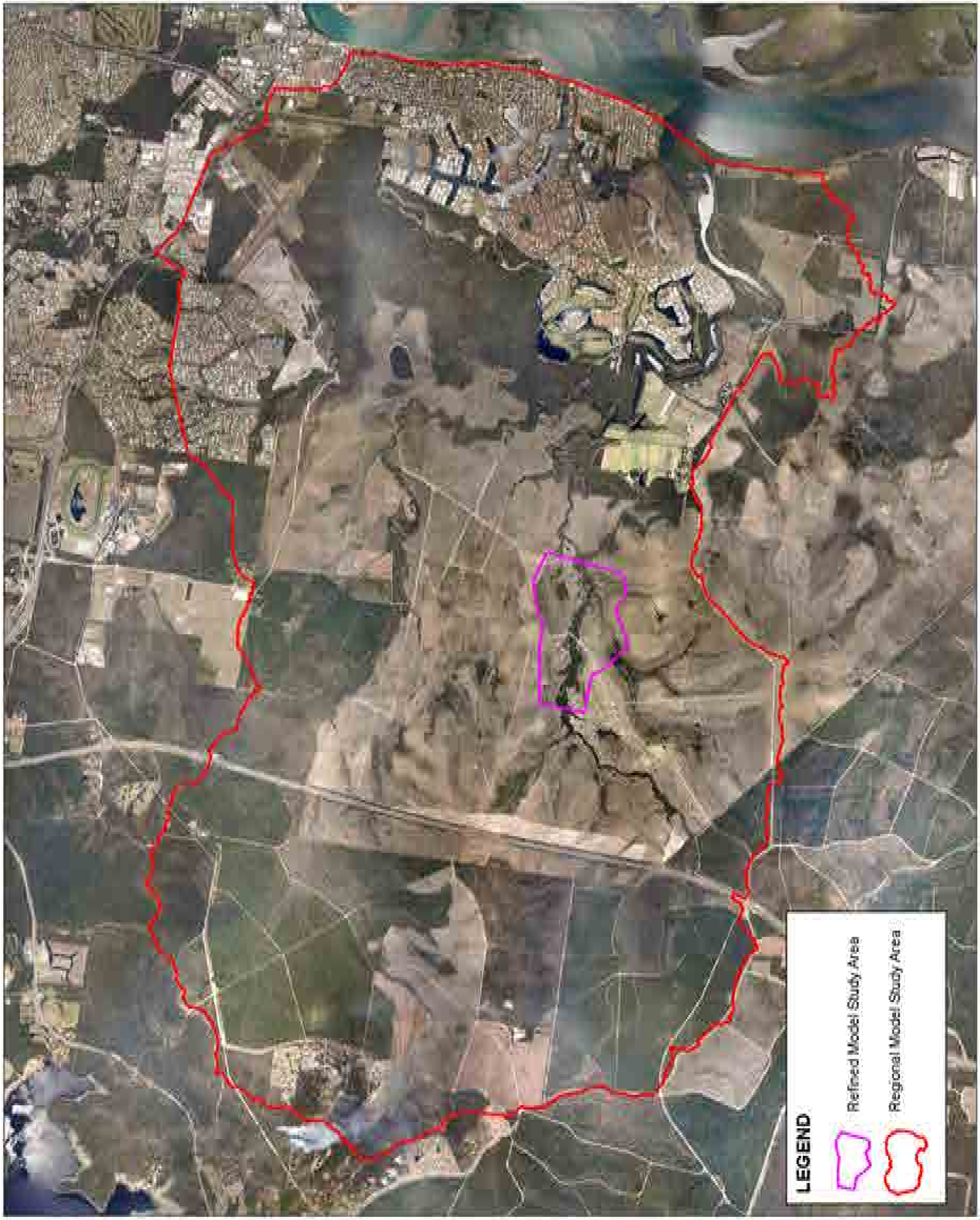
For this assessment, a refined Tuflow hydraulic model with a resolution of 2m was created using the latest 1m LiDar data supplied by RPS. The model extends 700m downstream, and 900m upstream from the proposed modified channel, and covers an area of 133 hectares. The extent of the model used in this study, and the regional model are presented in Figure 3-1.

Three scenarios were modelled during the study:

- Pre-development land usage with existing overland flow path
- Post-development land usage with existing overland flow path
- Post-development land usage with proposed modified overland flow path.

Digital elevation models of the three scenarios are presented in Figures 3-2 to 3-4.

For each of the scenarios, flood impacts were evaluated for the 1 in 5 year (Q5), and the 1 in 100 (Q100) ARI design storms. Inflow and downstream boundary conditions for these events were derived from the regional model.




Title:

**Comparison of Refined Model and Regional Model Area**

Figure: 3-1

Rev: A



N

0 300 600m
Approx. Scale

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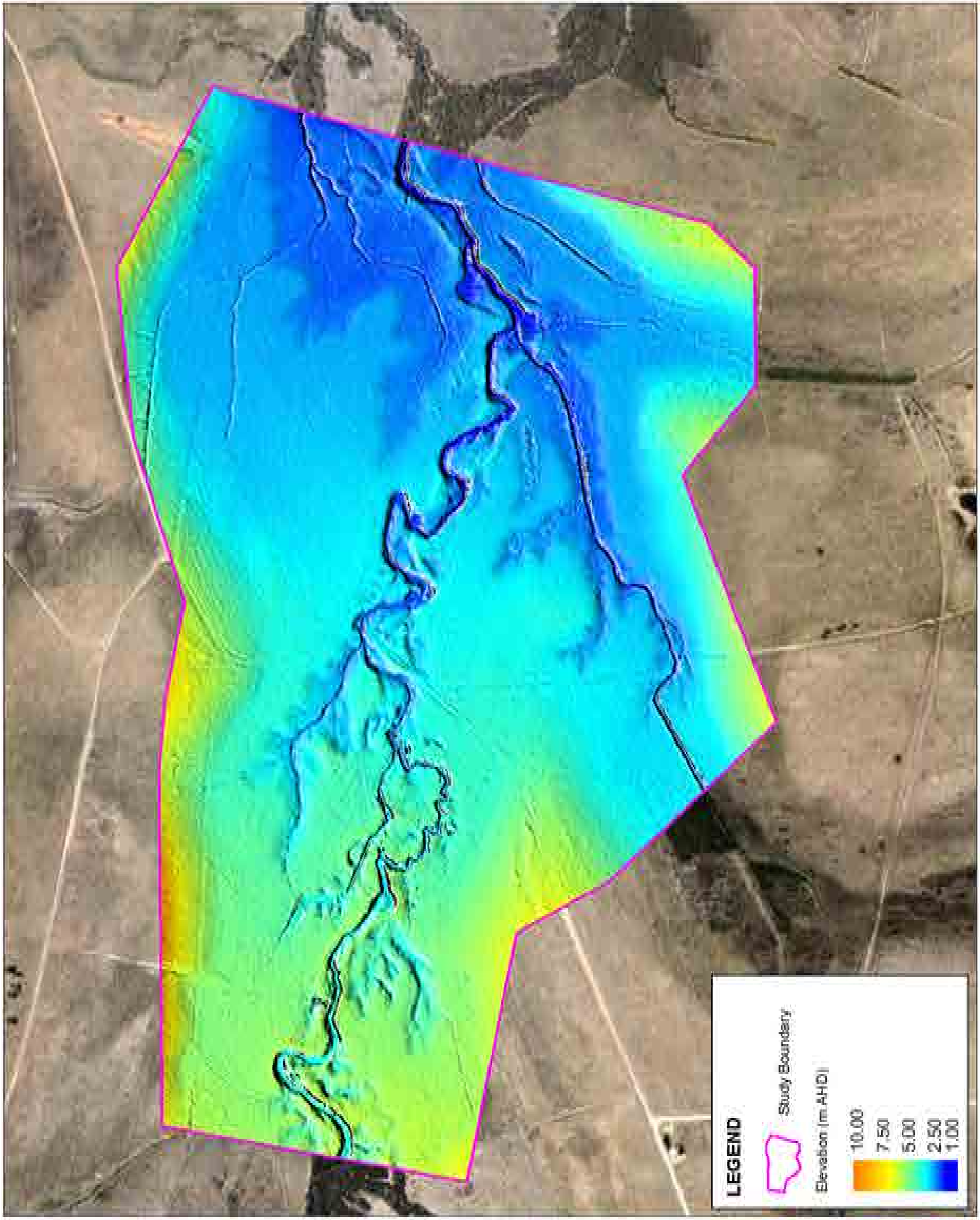


Title:

**Digital Elevation Model of Pre-Development with Existing Overland Flow Path**

Figure: 3-2

Rev: A

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N

0 100 200m
Approx Scale

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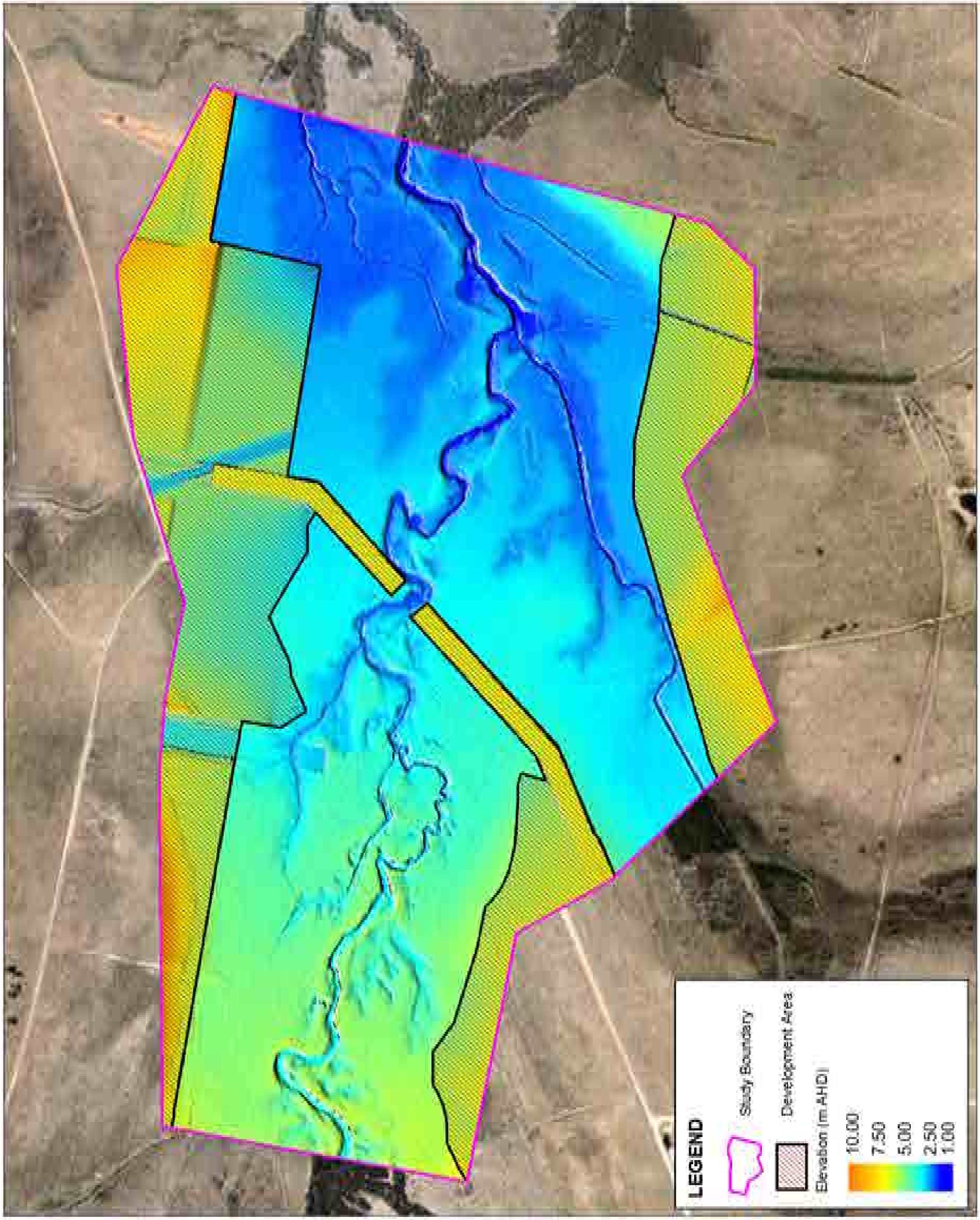
Filepath: K:\B20047.k.abm_Cal South DA Assistance\Flood_Modelling\Hydraulics\Creek_Modification\MapInfo\DRG\Figure 3-2 DEM Base Case.wor




Title:

**Digital Elevation Model of Post-Development with Existing Overland Flow Path**

Figure: 3-3

Rev: A

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N

0 100 200m

Approx Scale

BMT WBM

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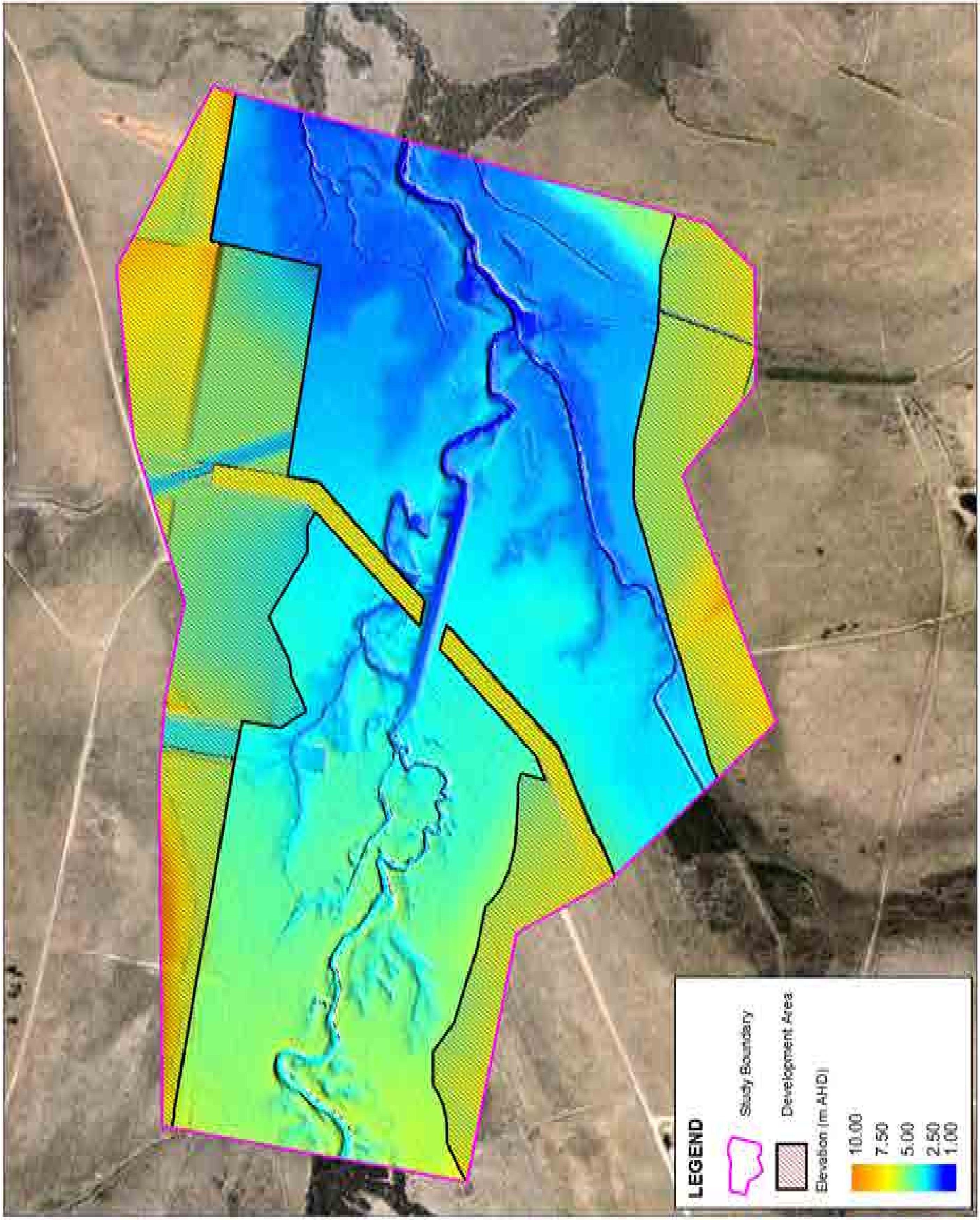
Filepath: K:\B20047.k.abm_Cal South DA Assistance\Flood_Modelling\Hydraulics\Creek_Modification\MapInfo\DRG\Figure 3-3 DEM Design1 Case.wor




Title:

**Digital Elevation Model of Post-Development with Proposed Overland Flow Path**

Figure: 3-4

Rev: A



N

0 100 200m

Approx. Scale

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Filepath: K:\B20047.k.abm_Cal South DA Assistance\Flood_Modelling\Hydraulics\Creek_Modification\MapInfo\DRG\Figure 3-4 DEM Design2 Case.wor

# 4 Design Parameters

As described in Section 1, key parameters in this assessment are:

- Velocity
- Water level.

## 4.1 Velocity

Maximum water velocity during the Q100 event was chosen as the key design parameter to determine the scour/erosion potential for each scenario.

From the Queensland Urban Drainage Manual (QUDM), a guideline value of 1.2m/s water velocity was chosen based on the soils in the channel being easily eroded, the bed slope less than 1%, and the channel having 50% vegetation cover.

## 4.2 Water Level

From the '*Caloundra South Public Environment Report Environmental Management Plan – Final Draft*' (BMT WBM, 2012), the Wallum Sedgefrog mitigation strategy include the conservation of existing habitats that are to be retained on site, and habitat creation and enhancement along identified frog movement corridors.

From the '*Caloundra South Public Environment Report Environmental Management Plan – Final Draft*' (BMT WBM, 2012), Wallum Sedgefrog habitat areas need to be above the Q5 flood level.

# 5 Results

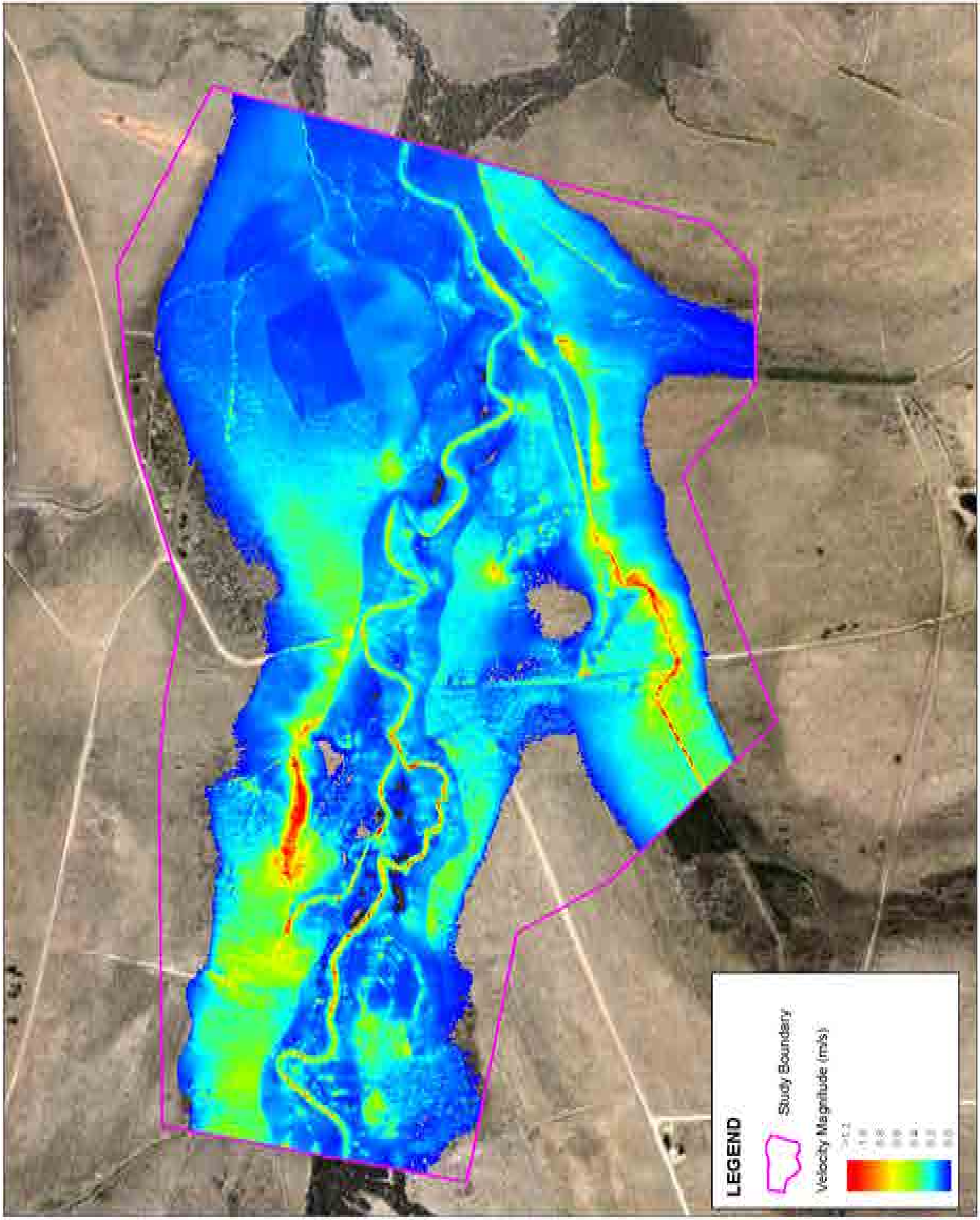
Figures 5-1, 5-3 and 5-5 provide Q100 water velocity plots for each modelled scenario, for the whole study area.

Figures 5-2, 5-4 and 5-6 provide Q100 water velocity plots with velocity vectors, for the area around the proposed overland flow path.

On each of the velocity plots, velocities equal to or above 1.2m/s are shown in red.

The change in peak water velocity between the proposed and existing overland flow path (both with post-development land usage) is shown in Figure 5-7 for the Q100 design storm event.

The change in peak water level between the proposed and existing overland flow path (both with post-development land usage) is shown in Figures 5-8 and 5-9 for the Q100 and Q5 design storm events.





Title:

**Peak Water Velocities for Pre-Development with Existing Overland Flow Path; Bells Creek South Q100**

Figure: 5-1

Rev: A



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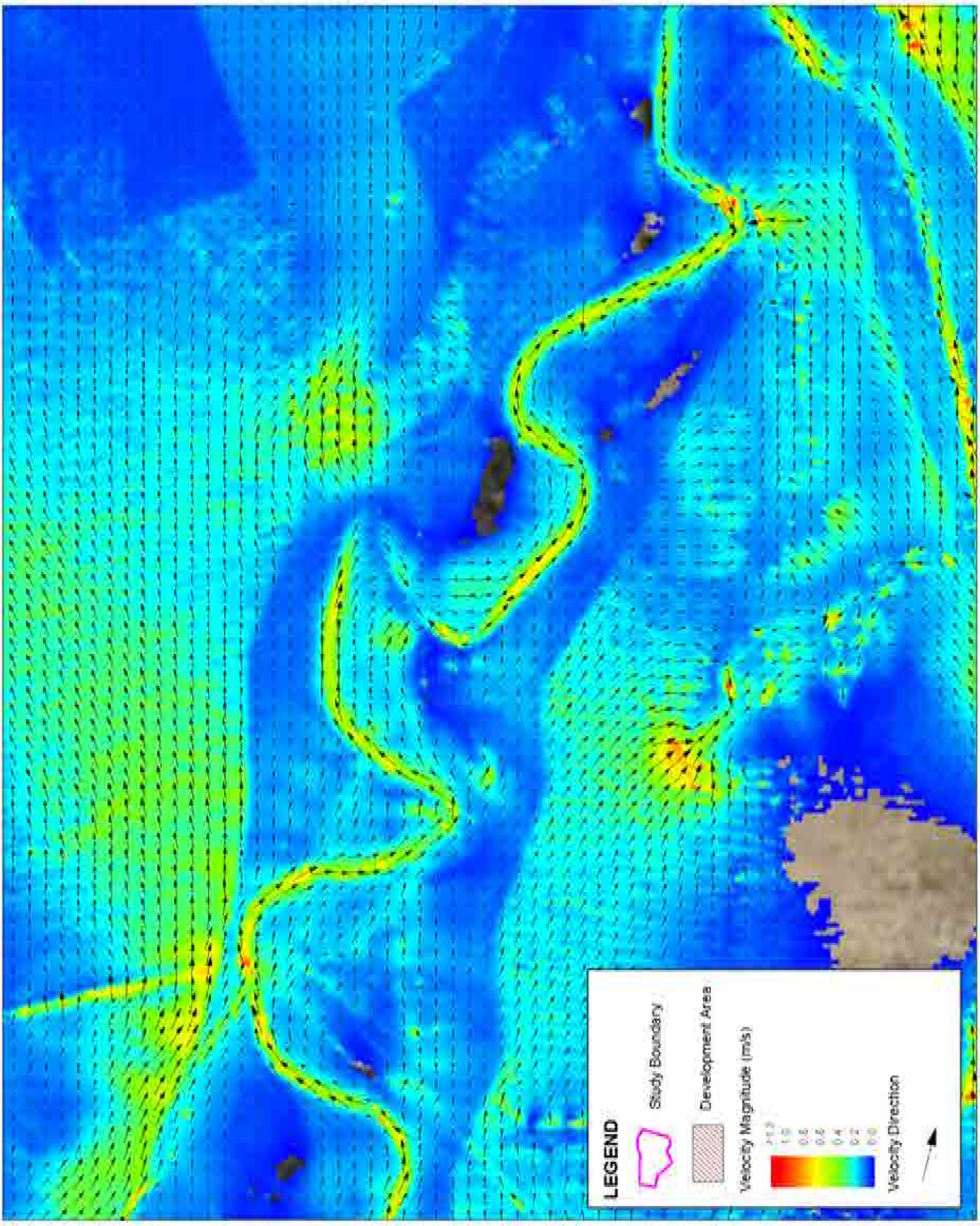
Filepath: K:\B20047.k.abm_Cal South DA Assistance\Flood_Modelling\Hydraulics\Creek_Modification\MapInfo\DRG\Figure 5-1 Vel Q100 Base Case.wor




Title:

**Peak Water Velocity Vectors Pre-Devellopment with Existing Overland Flow Path; Bells Creek South Q100**

Figure: **5-2**

Rev: **A**



N

Approx. Scale

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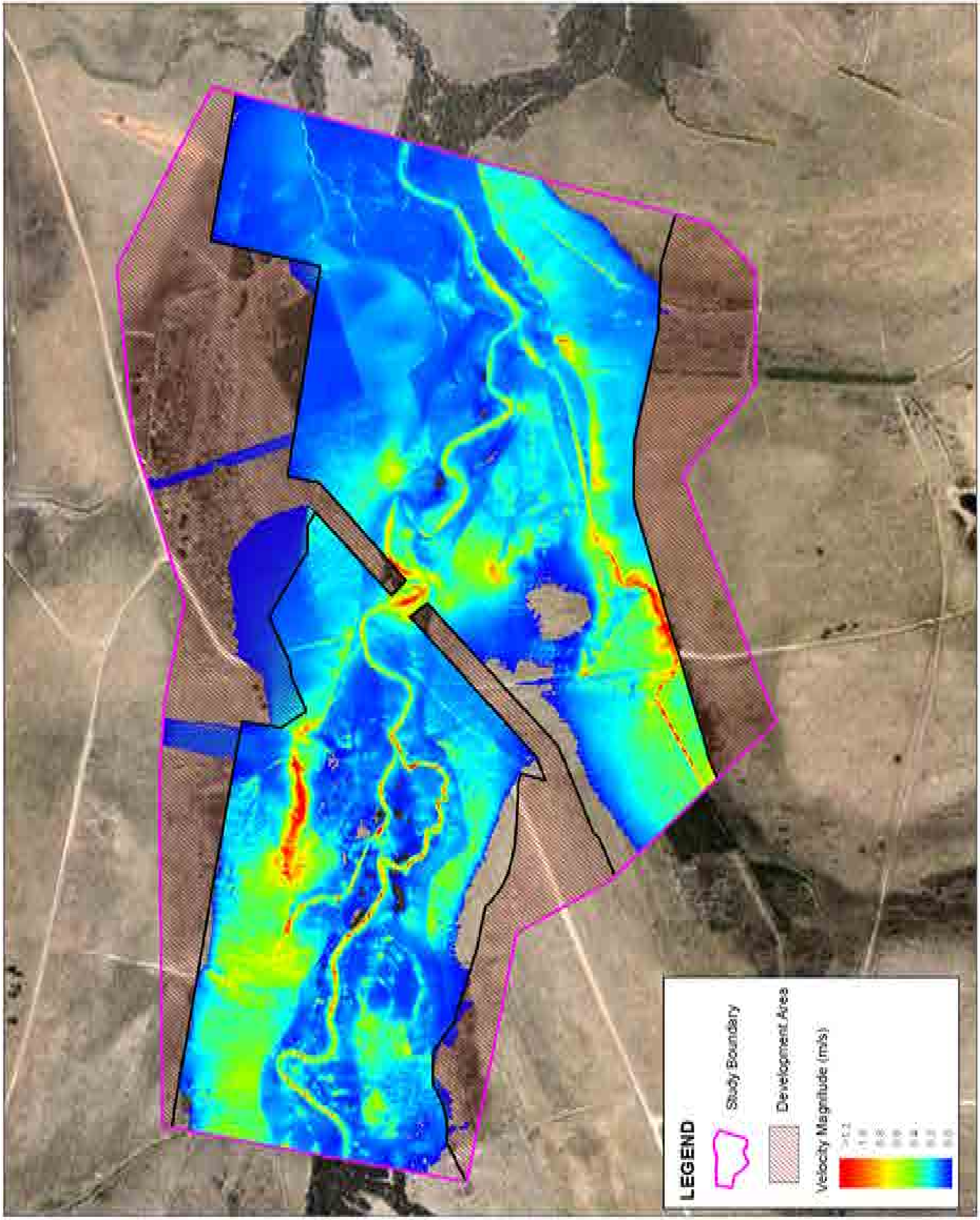
Filepath: K:\B20047.k.abm_Cal South DA Assistance\Flood_Modelling\Hydraulics\Creek_Modification\MapInfo\DRG\Figure 5-2 Vel Vectors Q100 Base.wor




Title:

**Peak Water Velocities for Post-Development with Existing Overland Flow Path; Bells Creek South Q100**

Figure: 5-3

Rev: A

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N

0 100 200m

Approx. Scale

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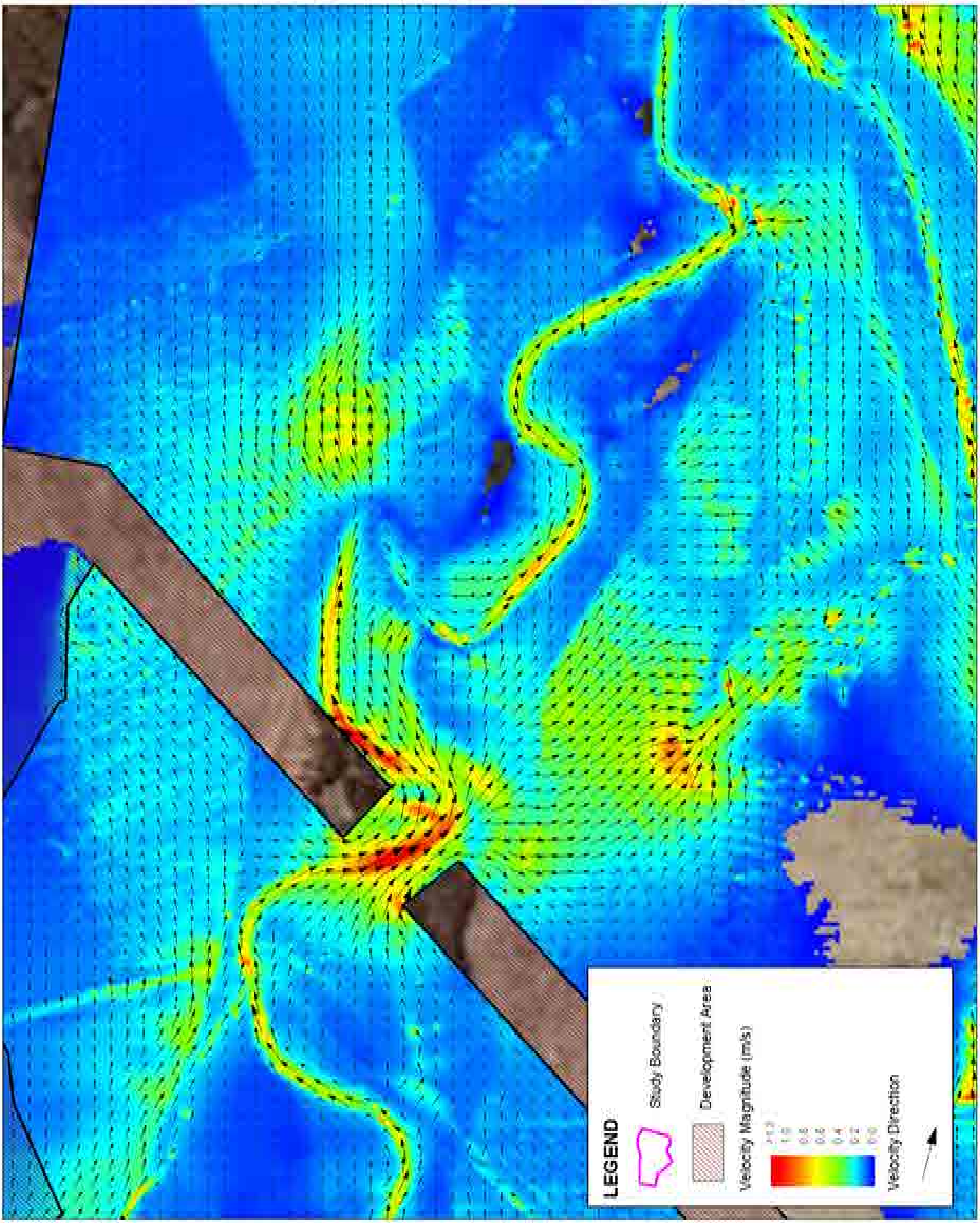


Title:

**Peak Water Velocity Vectors Post-Devellopment with Existing Overland Flow Path; Bells Creek South Q100**

Figure: **5-4**

Rev: **A**



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Approx. Scale

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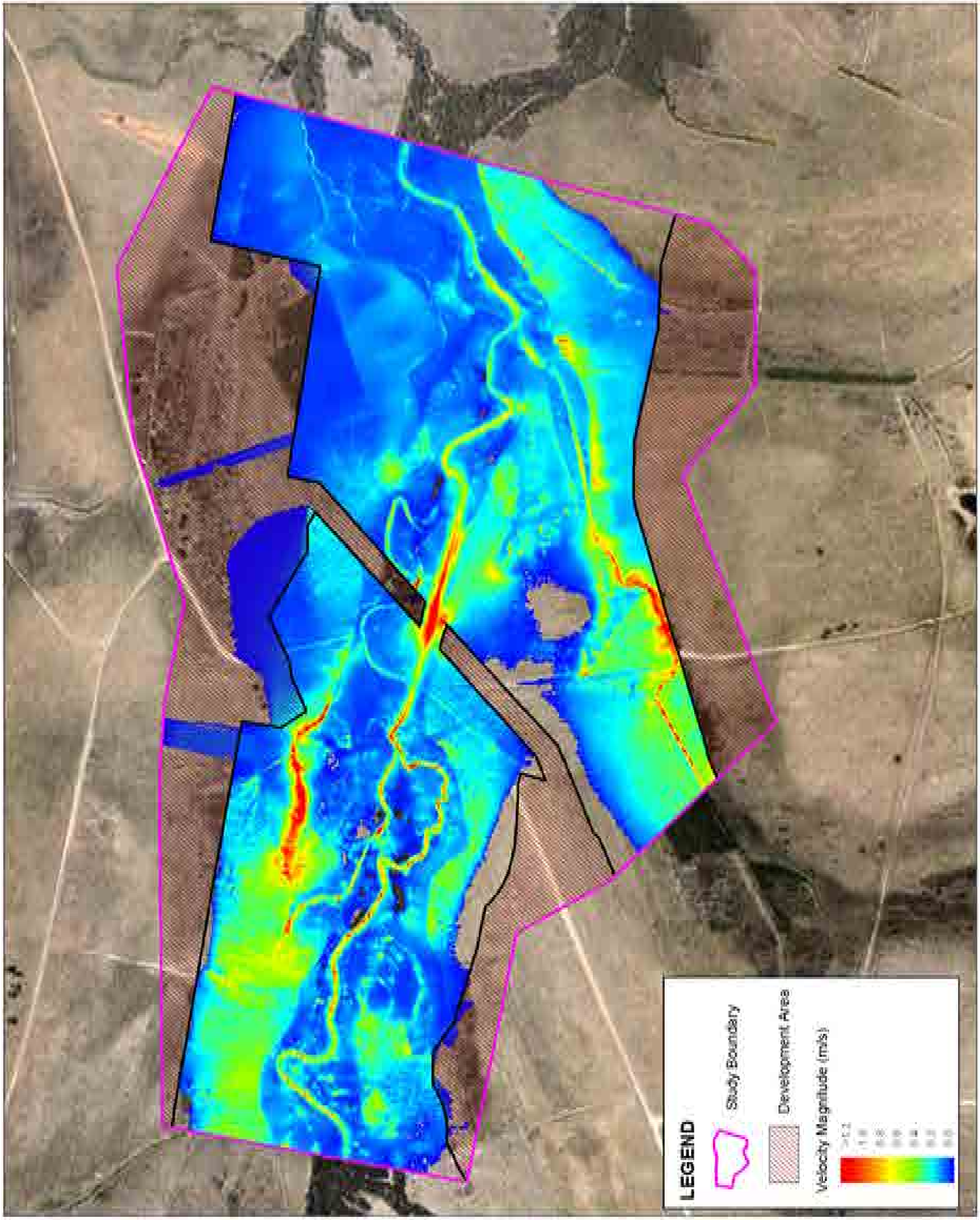


Title:

**Peak Water Velocities for Post-Development with Proposed Overland Flow Path; Bells Creek South Q100**

Figure:

**5-5**

Rev:

**A**



N

0 100 200m

Approx. Scale

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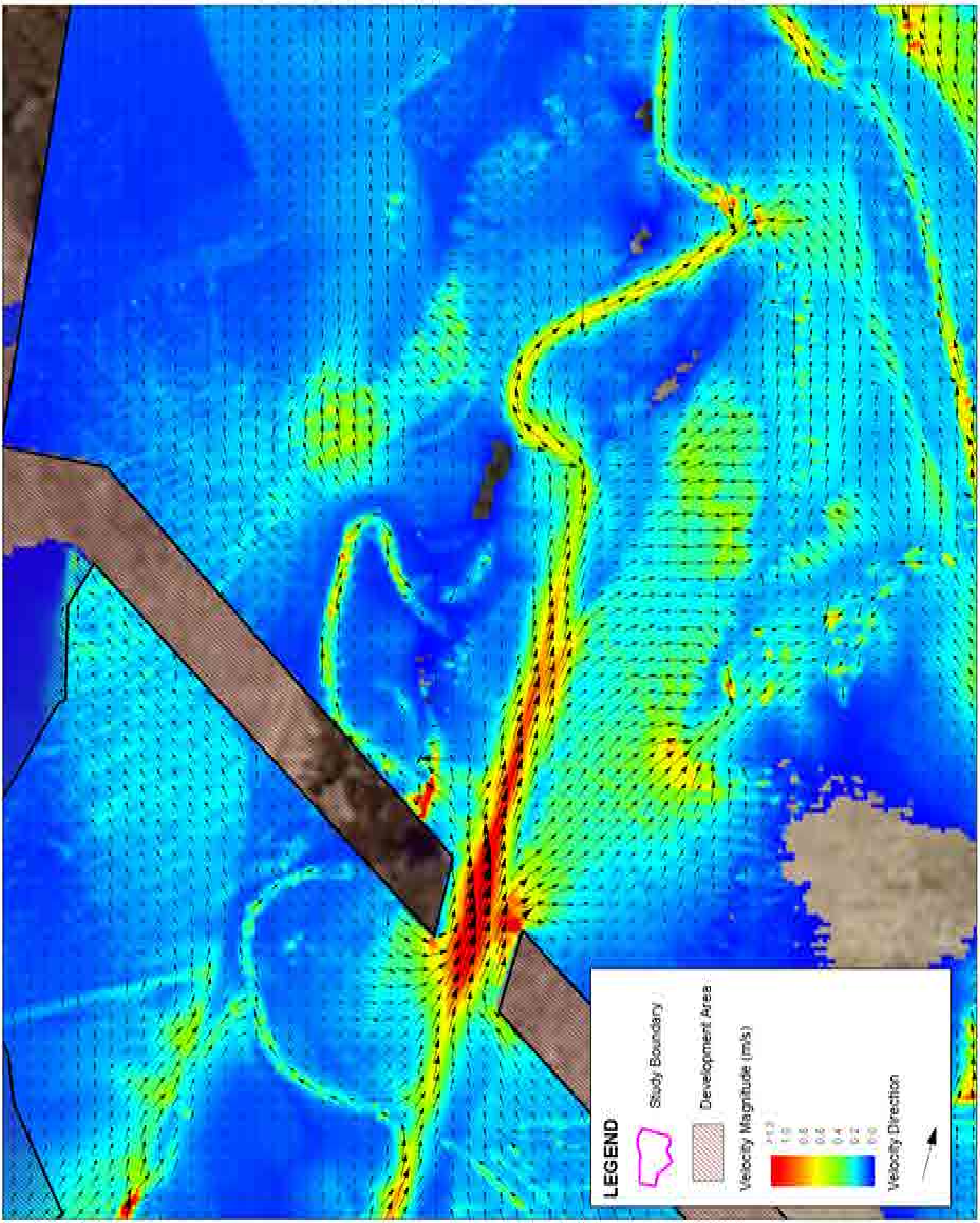


Title:

**Peak Water Velocity Vectors Post-Devellopment with Proposed Overland Flow Path; Bells Creek South Q100**

Figure: 5-6

Rev: A



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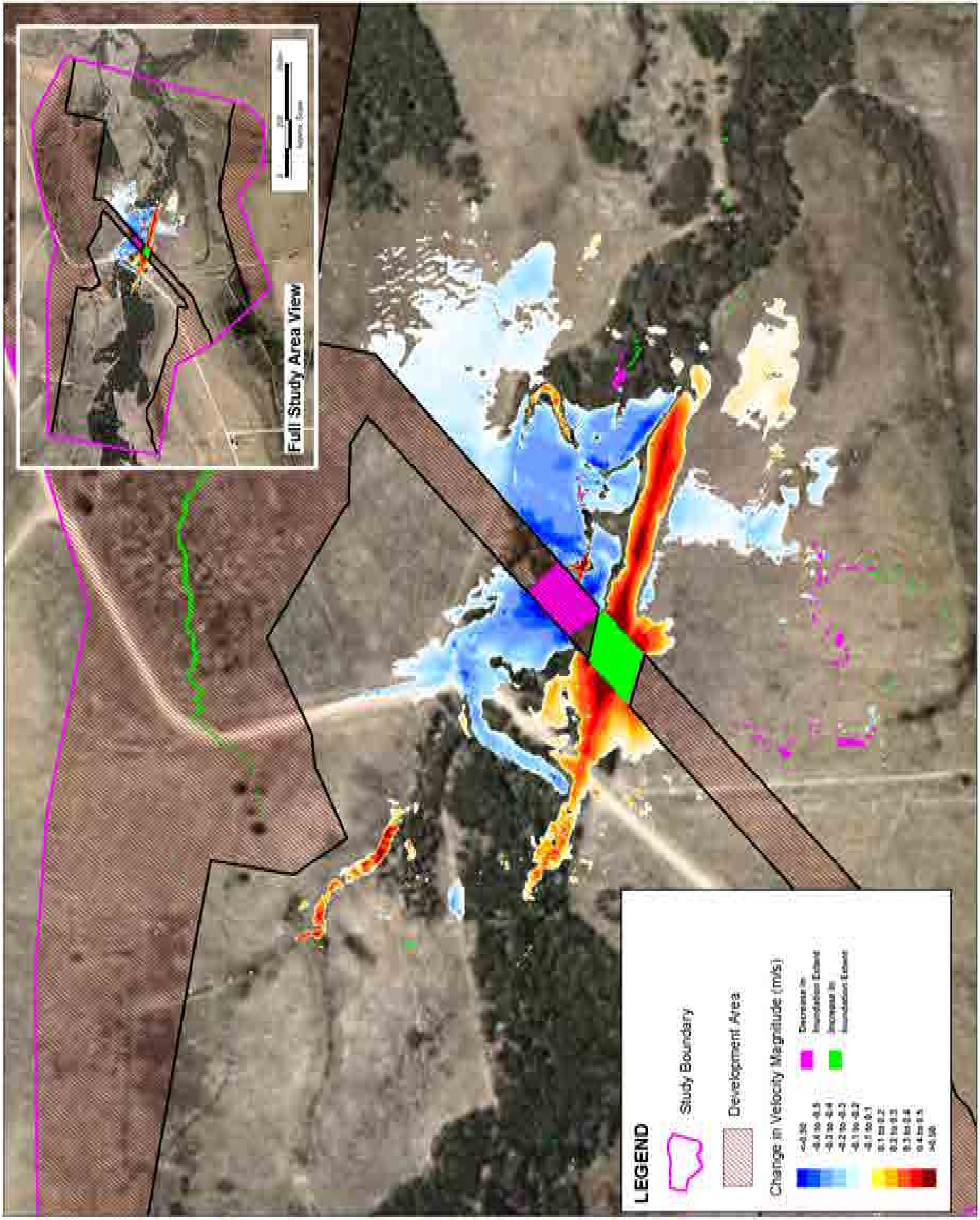


Title:

**Peak Water Velocity Impact between Existing and Proposed Overland Flow Path for Post-Development; Bells Creek South Q100**

Figure: 5-7

Rev: A



0 75m 150m

Approx.Scale

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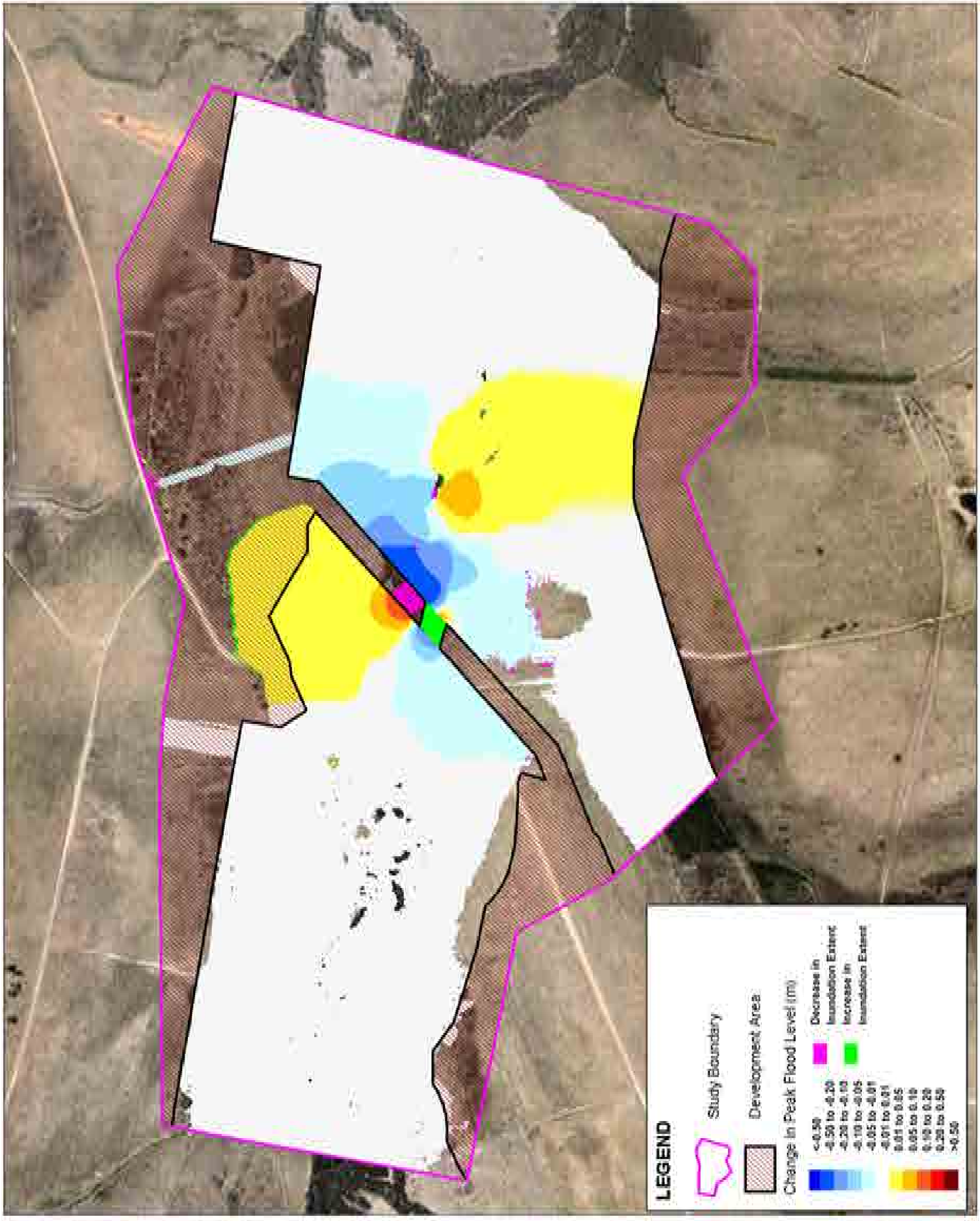
Filepath: K:\B20047.k.abm_Cal South DA Assistance\Flood_Modelling\Hydraulics\Creek_Modification\MapInfo\DRG\Figure 5-7 Vel Q100 Impact Design2 Design1.wor




Title:

**Peak Water Level Afflux between Existing and Proposed Overland Flow Path for Post-Development; Bells Creek South Q100**

Figure: **5-8**

Rev: **A**

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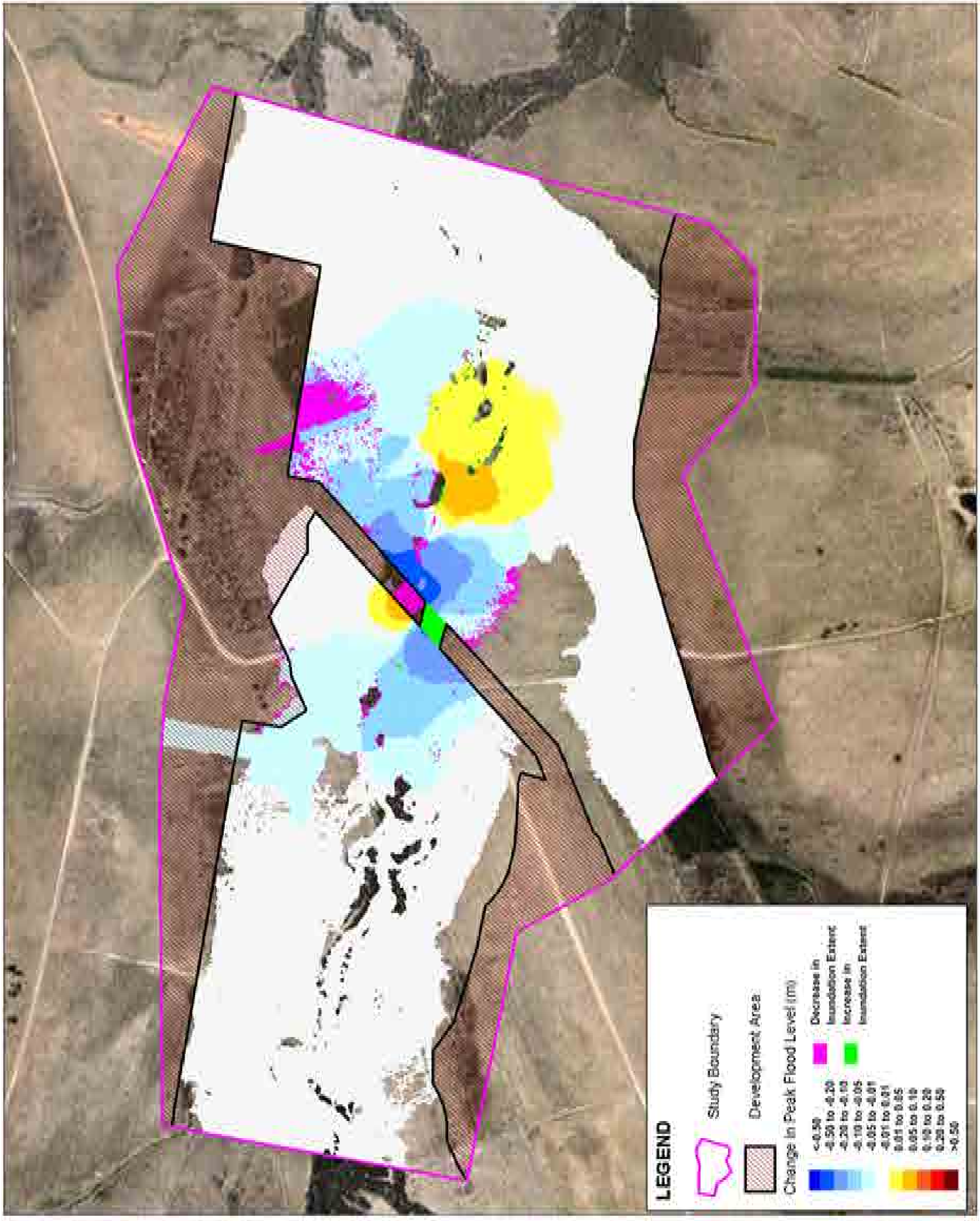


Title:
**Peak Water Level Afflux between Existing and Proposed Overland Flow Path for Post-Development; Bells Creek South Q5**

Figure:
**5-9**

Rev:
**A**

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0 100 200m
Approx Scale

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# 6 Discussion

## 6.1 Velocity

Key velocity-related findings from our assessment include the following:

- In all scenarios (including the pre-development scenario) there are areas of velocity above 1.2m/s during the Q100 event.
- Velocities at the bridge crossing (for both existing and proposed flow paths) experience velocities above 1.2m/s
- The impact plots indicate the proposed reconfiguration will not cause any significant increase in velocity (greater than 0.1m/s) downstream of the proposed reconfiguration. Some minor increases are shown upstream, with an isolated area to the north-west a result of a secondary flow path draining more efficiently causing a small area of increased velocity.
- Since there is no significant increase in water velocities above 1.2m/s, there is no significant risk of an increase in scour/erosion associated with modifying the overland flow path.

## 6.2 Peak Water Levels

Key water level-related findings from our assessment include the following:

- There is no significant change in the Q100 flood inundation extent associated with modifying the overland flow path.
- There is a slight reduction in the Q5 flood inundation extent associated with modifying the overland flow path.
- Since the Q5 inundation extent decreases with modifying the overland flow path, there is potential for an increase in Wallum Sedgefrog habitat.

# 7 Conclusion

Our hydraulic assessment has demonstrated:

- The proposed reconfiguration will not cause any increase in flow velocities (and associated risk of scour/ erosion) downstream of the proposed reconfiguration during the Q100 storm event
- The proposed reconfiguration will cause a slight decrease in the Q5 inundation extent, which may result in an increase in Wallum Sedgefrog habitat.

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