PARSONS BRINCKERHOFF

KEMPSEY TO EUNGAI
UPGRADING THE PACIFIC HIGHWAY

ENVIRONMENTAL ASSESSMENT
SUPPLEMENTARY FLOODING REPORT

MAY, 2007

WEBB, McKEOWN & ASSOCIATES PTY LTD

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Webb, McKeown & Associates Pty Ltd
Level 2, 160 Clarence Street, SYDNEY 2000
Telephone: (02) 9299 2855
Facsimile: (02) 9262 6208
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Prepared by: **E.Askew**

Verified by: **M.Babister**

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1. INTRODUCTION

As part of the Government's initiative to upgrade the Pacific Highway between Hexham and the Queensland border, the Roads and Traffic Authority (RTA), is developing a project to upgrade the highway alignment between Kempsey and Eungai, a total distance of 40.5km. The proposed route of the highway Upgrade passes to the east of Kempsey, crossing the Macleay River floodplain near Frederickton.

The lower Macleay floodplain has a long history of flooding and the issue rates highly among local priorities. Kempsey experienced two large floods in 1949 and 1950 and these are still well remembered. Consequently, significant flood mitigation works have been carried out including the construction of a series of levees and a floodway through the middle of the urban area.

While large floods are a concern in the rural areas downstream of Kempsey, of similar importance are smaller but more frequent floods. These inundate large tracts of fertile land used for dairy and beef cattle raising, causing significant damage to pastures due to the slow draining of floodwaters. The Kempsey Shire Council and local residents have invested considerable time and money in a system of levees, floodgates and warning gauges in an effort to regulate this flooding and minimise damages.

The proposed Upgrade would be a major structure across the floodplain with a perceived potential to raise flood levels at Kempsey and to redistribute flows in the lower Macleay floodplain. The RTA has therefore commissioned a series of studies to examine the flood impacts of route options and has used the results of these studies as major criteria in selecting the preferred option and developing the project design. An overview of the study area is provided on Figure 1.

The "*Kempsey to Eungai Upgrading of the Pacific Highway, Project Application Report, Supporting Information – Flood Investigation"* was completed in July 2006. The report examined the impacts of various combinations of bridges and embankments for the crossing of the main floodplain, together with a proposed flood levee at Frederickton. The report also considered the design for the crossing of Pola Creek.

An outcome of the July 2006 report was the identification of a preferred bridging and embankment option. Option 2.1 proved to be the most cost effective in terms of flooding impact and other considerations such as property impact management, and was therefore adopted as the preferred bridge option. The adopted bridging configuration and locations are shown on Figure 2 and identified as Main River, Middle Bridge, and South Bridge.

Following review of the July 2006 report by the Department of Natural Resources, some clarification and further information on key aspects was required. These aspects included:

- the potential for a significant increase in impacts on properties for events above the 100 year ARI where the preferred bridging option embankment would be overtopped,
- the sensitivity of flood levels and impacts to pre-settlement or pre-loading of the preferred bridging option embankment height,
- the sensitivity of flood levels and impacts to road guard rails which are installed above the embankment height and may potentially impede floodwaters overtopping the embankment, and
- confirmation of the March 2001 event modelling.

This report addresses these aspects with regard to the preferred bridging option (known as Option 2.1) and is a supplement to the July 2006 report. All locations, design criteria and the hydraulic model defined in the July 2006 report are the same as those referred to in this report.

This supplementary report should only be read in conjunction with the *Kempsey to Eungai Upgrading the Pacific Highway, Project Application Report, Supporting Information – Flood Investigations, July 2006* and is not intended as a stand alone document.

2. COMPUTER MODELLING

2.1. Calibration

The Macleay catchment and floodplain have been subjected to intensive computer based modelling of flooding since the late 1980's. Full details of the history of these investigations and details of the modelling that was carried out is provided in the *"Kempsey to Eungai Upgrading the Pacific Highway Project Application Report, Supporting Information – Flood Investigation",* July 2006. The immediate study area modelled for the study is shown on Figure 3.

The SOBEK model has been calibrated against reported results for both the RUBICON and RMA-2 hydraulic models previously established for the proposed embankment. The RUBICON hydraulic model was originally calibrated against recorded levels from the 1963 flood and further verified against the floods of 1949 and 1980.

The calibration and verification of the RUBICON model confirmed that it is able to replicate the flood gradient across the floodplain for a range of floods. The performance of the SOBEK model was therefore validated against the existing RUBICON model.

To achieve this calibration, three Manning's "n" roughness zones were applied across the floodplain, main river, and urban areas. The adopted Manning's "n" values were adjusted until the SOBEK model reproduced reported RUBICON values at key locations.

A comparison between the models at key locations across the floodplain is provided in Table 1.

Table 1: Comparison of Model Results – 100 year ARI Existing Conditions

Location (1)	Peak Flood Level (mAHD)	
	RUBICON	SOBEK
North Frederickton	n/a	5.6
u/s Bridge Right Bank	5.9	5.8
Pola Creek	8.2	8.1
Glenrock Drain	7.7	7.9
u/s Frederickton	7.1	7.0
Frederickton	6.7	6.6
d/s Frederickton	6.5	6.3
South West Rocks Road	5.9	5.9
Frogmore	5.9	5.9
Old Station Road	6.6	6.6
East Kempsey Wetland	n/a	6.6

Note: (1) refer Figure 3 for location of results.

2.2. Current Approach

As part of ongoing work for Kempsey Shire Council, hydrology for the March 2001 event has been revised in light of further recorded information becoming available. The hydrologic model established as part of previous work did not accurately reproduce the catchment response during the March 2001 event. This was highlighted during calibration to recorded flood levels at Kempsey Traffic Bridge. The main cause was due to the available recorded rainfall information being spatially sparse, with most information being concentrated in the upper and lower catchment. Recently further rainfall information in the middle catchment became available. This required a review of the temporal and spatial patterns to be undertaken. Inflows to the SOBEK model for the March 2001 event were based on this revised hydrology.

Hydrologic and hydraulic models were established as part of the July 2006 report and used to simulate flood behaviour for both existing (i.e. without the proposed upgrade) and proposed conditions, under the 20y, 100y ARI and March 2001 events. As part of this supplementary report a series of design floods, including the 200y, 500y ARI and the PMF events have been modelled together with the revised historical flood of March 2001. The March 2001 flood was approximately a 13y ARI event at Kempsey Traffic Bridge.

Figures 4 to 7 show peak water levels during existing conditions for the 200y, 500y ARI, PMF events as well as the revised March 2001 flood.

Results for these events are presented and discussed in the following sections.

3. HYDRAULIC IMPACTS

The impacts of the preferred option were examined by comparing the existing and proposed conditions for the 200y ARI, 500y ARI, PMF events and revised March 2001 (13y ARI) flood. The tables below summarise the key results at twelve locations on the Macleay River and floodplain between Kempsey and Frederickton. The locations are shown on Figure 3.

3.1. Afflux

Afflux is the increase in water levels caused by changes to the flow behaviour.

Table 2 shows the 200y ARI flood levels under existing conditions and the afflux caused by the proposed upgrade.

Table 2: 200y ARI Flood Level Impacts

	Location	200y ARI Existing Conditions (mAHD)	Afflux
			Option 2.1 (m)
Railway Bridge	River	10.98	0.01
Traffic Bridge	River	9.56	0.02
Pola Creek	River	8.81	0.03
Glenrock Drain	River	8.49	0.04
Upstream Frederickton	River	7.47	0.08
Frederickton	River	7.02	0.10
Downstream Frederickton	River	6.60	0.11
East Kempsey Wetland	Floodplain	7.44	0.15
Old Station Road	Floodplain	7.40	0.15
Frogmore	Floodplain	6.44	0.27
South West Rocks Road	Floodplain	6.33	0.19
Upstream Bridge Right Bank	Floodplain	6.32	0.24

Minor afflux was shown to occur across the floodplain during the 200y ARI as a result of Option 2.1. The most significant afflux of 0.27 m occurred on the floodplain at Frogmore immediately adjacent to the proposed embankment.

Table 3 shows flood levels and afflux for the 500y ARI event. Afflux is slightly more but comparable to that for the 200y ARI flood.

Table 3: 500y ARI Flood Level Impacts

	Location	500y ARI Existing Conditions (mAHD)	Afflux Option 2.1 (m)
Railway Bridge	River	11.71	0.01
Traffic Bridge	River	10.20	0.03
Pola Creek	River	9.34	0.04
Glenrock Drain	River	8.99	0.05
Upstream Frederickton	River	7.86	0.11
Frederickton	River	7.35	0.14
Downstream Frederickton	River	6.87	0.14
East Kempsey Wetland	Floodplain	8.04	0.15
Old Station Road	Floodplain	8.00	0.15
Frogmore	Floodplain	6.84	0.31
South West Rocks Road	Floodplain	6.69	0.23
Upstream Bridge Right Bank	Floodplain	6.66	0.30

Table 4 shows flood levels and the afflux for the revised March 2001 flood. Away from the immediate vicinity of the embankment there was little impact on levels for this size event. A slight increase in afflux was shown to occur in the immediate vicinity of the embankment at Frogmore, Old Station Road and South West Rocks Road for the revised March 2001 hydrology.

Table 4: Revised March 2001 Flood Level Impacts

Location	Area	March2001 Existing Conditions (mAHD)	Afflux Option 2.1 (m)
Railway Bridge	River	8.17	0.00
Traffic Bridge	River	7.48	0.00
Pola Creek	River	6.98	0.00
Glenrock Drain	River	6.75	0.00
Upstream Frederickton	River	6.22	0.01
Frederickton	River	6.04	0.01
Downstream Frederickton	River	5.86	0.01
East Kempsey Wetland	Floodplain	5.20	0.03
Old Station Road	Floodplain	5.15	0.04
Frogmore	Floodplain	4.90	0.05
South West Rocks Road	Floodplain	4.89	0.04
Upstream Bridge Right Bank	Floodplain	4.98	0.11

Table 5 shows flood levels and afflux for the PMF Impact.

Table 5: PMF Flood Level Impacts

Location	Area	PMF Existing Conditions (mAHD)	Afflux
			Option 2.1 (m)
Railway Bridge	River	16.29	0.03
Traffic Bridge	River	14.63	0.05
Pola Creek	River	13.18	0.09
Glenrock Drain	River	12.66	0.11
Upstream Frederickton	River	11.38	0.20
Frederickton	River	10.86	0.26
Downstream Frederickton	River	10.53	0.27
East Kempsey Wetland	Floodplain	12.23	0.12
Old Station Road	Floodplain	12.22	0.12
Frogmore	Floodplain	10.90	0.19
South West Rocks Road	Floodplain	10.69	0.21
Upstream Bridge Right Bank	Floodplain	10.61	0.47

Figures 8 to 11 show change in flood level for the 200y, 500y ARI, PMF and Revised March 2001 events.

3.2. Velocity

The proposed Upgrade would change flow behaviour within the floodplain causing velocities to increase around the bridge openings and decrease both upstream and downstream of the proposed embankments.

Tables 6 to 9 show changes in the velocity of floodwaters at the key locations for the 200y, 500y ARI, PMF and revised March 2001 events. Velocity changes for the whole study area are shown on Figures 12 to 15. These tables and figures demonstrate that the proposal locally increases velocities to a limited extent at the proposed openings but would have minimal impact elsewhere, including downstream at Smithtown and Gladstone.

Flood hazard is a reliable indicator of potential danger to people, vehicles and property. A comparison of flood hazard between existing and proposed conditions is shown in Figures 16 to 19 for the 200y, 500y ARI, PMF and Revised March 2001 events. A flood hazard greater than 1 is considered high, is likely to cause damage to buildings and is above the threshold at which evacuation can be safely undertaken.

Table 6: 200y ARI Flood – Change in Velocity

Location	Area	200y ARI Existing	Change in Velocity (m/s)
			Option 2.1
Railway Bridge	River	4.6	0.0
Traffic Bridge	River	5.0	0.0
Pola Creek	River	3.5	0.0
Glenrock Drain	River	3.1	0.0
Upstream Frederickton	River	3.1	-0.1
Frederickton	River	3.5	-0.1
Downstream Frederickton	River	3.9	-0.1
East Kempsey Wetland	Floodplain	1.6	0.0
Old Station Road	Floodplain	0.7	-0.1
Frogmore	Floodplain	0.8	0.0
South West Rocks Road	Floodplain	0.9	0.3
Upstream Bridge Right Bank	Floodplain	1.6	0.0

Table 7: 500y ARI Flood – Change in Velocity

Location	Area	500y ARI Existing	Change in Velocity (m/s)
			Option 2.1
Railway Bridge	River	4.9	0.0
Traffic Bridge	River	5.4	0.0
Pola Creek	River	3.6	0.0
Glenrock Drain	River	3.4	0.0
Upstream Frederickton	River	3.3	-0.1
Frederickton	River	3.8	-0.1
Downstream Frederickton	River	4.3	-0.1
East Kempsey Wetland	Floodplain	1.7	0.0
Old Station Road	Floodplain	0.7	-0.1
Frogmore	Floodplain	1.0	0.0
South West Rocks Road	Floodplain	1.0	0.3
Upstream Bridge Right Bank	Floodplain	1.6	0.0

Table 8: Revised March 2001 Flood – Change in Velocity

Location	Area	Revised March 2001 Existing	Change in Velocity (m/s)
			Option 2.1
Railway Bridge	River	3.1	0.0
Traffic Bridge	River	3.1	0.0
Pola Creek	River	2.7	0.0
Glenrock Drain	River	2.3	0.0
Upstream Frederickton	River	2.1	0.0
Frederickton	River	2.3	0.0
Downstream Frederickton	River	2.5	0.0
East Kempsey Wetland	Floodplain	1.1	0.0
Old Station Road	Floodplain	0.2	0.0
Frogmore	Floodplain	0.3	0.0
South West Rocks Road	Floodplain	0.5	0.1
Upstream Bridge Right Bank	Floodplain	1.2	-0.4

Table 9: PMF Change in Velocity

Location	Area	PMF Existing Conditions (mAHD)	Change in Velocity (m/s)
			Option 2.1
Railway Bridge	River	6.4	0.0
Traffic Bridge	River	7.0	0.0
Pola Creek	River	3.8	-0.1
Glenrock Drain	River	4.2	-0.1
Upstream Frederickton	River	4.1	-0.2
Frederickton	River	4.6	-0.3
Downstream Frederickton	River	5.1	-0.2
East Kempsey Wetland	Floodplain	1.4	0.0
Old Station Road	Floodplain	0.8	0.0
Frogmore	Floodplain	1.9	0.0
South West Rocks Road	Floodplain	2.0	0.2
Upstream Bridge Right Bank	Floodplain	2.1	-0.6

3.3. Flood Inundation

The proposed upgrade has the potential to influence both the extent and period of inundation. The extent of inundation is a function of flood levels. As shown in Figures 8 to 11, any impact on flood levels occurs near the embankments within the floodplain and is insignificant at the edges of the floodplain. Thus, the overall extent of inundation of any given flood would not be affected.

Figures 20 to 22 show stage hydrographs at three key points on the floodplain for the 200y, 500y ARI, PMF and Revised March 2001 floods. These indicate that the time of inundation due to flooding changes minimally.

3.4. Affected Properties

The proposed upgrade causes a minimal increase in flood levels upstream of the embankment and may potentially adversely impact on a number of dwellings, both in the town of Frederickton and in the rural areas. Table 10 lists the number of dwellings inundated during the 100y (previously reported), 200y and 500y ARI events.

Table 10: Houses Inundated

	100y	200y	500y
Inundated in Base Case	46	59	75
Inundated in Option 2.1	24	37	66
Previously Not Inundated	2	4	1
Protected by Frederickton Levee	24	26	10

3.5. Flood Level Sensitivity

The design embankment height is based on the 100y ARI flood level in the majority of locations, a small section between the bridges has been designed to the 20y ARI flood level. However, the embankment is initially constructed to a slightly higher level and surcharged in order to accelerate settlement prior to construction of the pavement. Should a major flood event occur during this time, there may be a slight increase in the afflux experienced across the floodplain. While there is a slight risk of this occurring it is likely that the risk would only be present for a period between 6 to 12 months.

Traffic safety barriers or guard rails are installed along the edges of roadways and embankments for the safety of drivers. These safety barriers may present a potential obstruction during a flood event which overtops the roadway. The design for the proposed upgrade would likely incorporate wire rope safety fence. This type of barrier would be more acceptable than the alternatives from the perspectives of likely flood and visual impacts. There is the potential however that in the event of a large flood, the wire rope fence may catch floating debris at isolated locations or that at some time in the future prevailing conditions may result in alternative barriers being installed.

In order to determine any potential afflux should a flood event occur prior to completion surcharging to accelerate embankment settlement, or the guard rail obstructing overflow, the embankment height was raised by 300 mm for a set of sensitivity model runs. In addition to the settlement/pre-loading scenario there is a potential for the installed safety barriers, or a future replacement, to obstruct the overflow of the embankment barrier. Sensitivity assessment was undertaken for the 100y, 200y, 500y ARI and PMF events.

Tables 11 to 14 show the sensitivity of the proposed flood levels to the embankment height. Changes in flood level are relative to the proposed Option 2.1 flood levels reported previously in Section 3.1. A comparison between peak flood level for the existing, proposed and proposed with increased embankment height scenarios is provided on Figures 23 to 26 for the 100y, 200y, 500y ARI and PMF events. Figures 27 to 30 show flood level impact of the embankment height increase when compared to the proposed embankment. A comparison between peak flood velocity and hazard for the existing, proposed and proposed with increased embankment height scenarios is provided on Figures 31 to 38 for the 100y, 200y, 500y ARI and PMF events.

Table 11: 100y ARI Flood – Flood Level Sensitivity

Location	Area	Change in Flood Level (m)
		Embankment Height plus 300 mm
Railway Bridge	River	0.00
Traffic Bridge	River	0.00
Pola Creek	River	0.00
Glenrock Drain	River	0.00
Upstream Frederickton	River	0.00
Frederickton	River	-0.01
Downstream Frederickton	River	-0.01
East Kempsey Wetland	Floodplain	0.02
Old Station Road	Floodplain	0.02
Frogmore	Floodplain	0.01
South West Rocks Road	Floodplain	0.02
Upstream Bridge Right Bank	Floodplain	0.07

Table 12: 200y ARI Flood – Flood Level Sensitivity

Location	Area	Change in Flood Level (m)
		Embankment Height plus 300 mm
Railway Bridge	River	0.00
Traffic Bridge	River	0.00
Pola Creek	River	0.00
Glenrock Drain	River	0.00
Upstream Frederickton	River	0.00
Frederickton	River	0.00
Downstream Frederickton	River	0.00
East Kempsey Wetland	Floodplain	0.01
Old Station Road	Floodplain	0.01
Frogmore	Floodplain	0.02
South West Rocks Road	Floodplain	0.01
Upstream Bridge Right Bank	Floodplain	0.01

Table 13: 500y ARI Flood – Flood Level Sensitivity

Location	Area	Change in Flood Level (m)
		Embankment Height plus 300 mm
Railway Bridge	River	0.00
Traffic Bridge	River	0.00
Pola Creek	River	0.00
Glenrock Drain	River	0.00
Upstream Frederickton	River	0.01
Frederickton	River	0.01
Downstream Frederickton	River	0.01
East Kempsey Wetland	Floodplain	0.01
Old Station Road	Floodplain	0.01
Frogmore	Floodplain	0.03
South West Rocks Road	Floodplain	0.02
Upstream Bridge Right Bank	Floodplain	0.02

Table 14: PMF – Flood Level Sensitivity

Location	Area	Change in Flood Level (m)
		Embankment Height plus 300 mm
Railway Bridge	River	0.00
Traffic Bridge	River	0.01
Pola Creek	River	0.01
Glenrock Drain	River	0.01
Upstream Frederickton	River	0.02
Frederickton	River	0.02
Downstream Frederickton	River	0.02
East Kempsey Wetland	Floodplain	0.01
Old Station Road	Floodplain	0.01
Frogmore	Floodplain	0.02
South West Rocks Road	Floodplain	0.01
Upstream Bridge Right Bank	Floodplain	0.02

Tables 11 to 14 show that a minor increase in the embankment height has a minimal impact on flood levels in the surrounding floodplain. The most significant impacts occurred immediately adjacent to the embankment and were typically much less than 0.1 m.

4. FURTHER ISSUES IN RESPONSE TO COMMENTS

The following section provides clarification to issues raised during a review of the July 2006 report, which have not been addressed in the previous sections:

- **Stock Mounds.** Increased flood levels may impact on the safety of stock in the area immediately upstream of the proposed Upgrade. During major floods, farmers in Frogmore evacuate their cattle via South West Rocks Road to higher ground in the Hamden Hall area. Locating stock mounds along South West Rocks Road provides a cost effective strategy for stock evacuation.

  For short duration flood events, the mounds can provide temporary refuge areas for cattle until the floodwaters have receded. During major events they can provide a temporary safe area for livestock whilst also providing a mustering point to load cattle onto trucks for evacuation. It is essential that livestock owners are aware that stock mounds will only protect their stock up to a particular flood event and at some point the stock mounds will become inundated. As part of the detailed design phase consideration should be given to the development of a flood reference system for the stock mounds. For example, assigning each stock mound with a level with reference to the Kempsey Traffic Bridge gauge could give affected land owners an indication of the useability of the stock mound during a flood event. Stock mounds like earth levees have a tendency to settle over time and this effect is compounded by the normal actions of stock. Understand the need to periodically top up mound any reference system needs to take account of this. It is essential that landowners be made aware of the limitations of stock mounds with regard to larger flood events and that they will only provide temporary flood immunity during these events.

  The mounds would be located parallel to, but clear of the identified flow paths where possible to reduce potential impacts on local flood levels. Where possible mounds would also shadow each other in the principle direction of flow across South West Rocks Road to minimise the amount of flow area obstructed. The dimensions of stock mounds will need to be determined in consultation with landowners to allow appropriate sizing to accommodate the numbers of stock likely to use the mounds. However, mounds should be elongated in shape so that they provide sufficient area to fulfil their intended function while presenting as small obstruction to the flow of floodwaters as possible, thereby limiting any potential flood level impacts. Mound heights would be governed by the height of South West Rocks Road to allow access for loading stock into trucks for evacuation. In order to determine the likely impact of introducing stock mounds into the floodplain on the local flooding regime a preliminary assessment was undertaken. A potential stock mound was inserted into the topography within the SOBEK hydraulic model. The hydraulic model was then run for the 100y ARI event. The preliminary assessment showed that the likely local impact of stock mounds would be limited to the immediate vicinity and generally less than 0.001 m. It is essential that at final design stage all stock mounds should be properly designed and a full hydraulic assessment of

their combined impacts be undertaken.

- **Impact Line.** The impact line shown on all impact figures (Figures 8 to 11 from this report and Figures 7 to 9 from *Kempsey to Eungai Upgrading the Pacific Highway, Project Application Report, Supporting Information – Flood Investigations*, July 2006 represents the limit of impacts greater than 0.02 m resulting from the proposed embankment. As the size of the event increases this line moves closer towards the Kempsey CBD as a result of the proposed embankment.

- **Frederickton Levee.** Preliminary work to date has shown that conceptually a levee providing flood protection to Frederickton is achievable. This work has also shown that there are viable options for maintaining the passage of runoff from the local town catchment through the levee. However, further assessment will be required to confirm the viability of such options. This assessment will required further detailed design, in addition to further hydrologic and hydraulic assessments. Consideration would be given to the following options during this further assessment.
  - potential for a controlled spillway with a low level flood gated outlet structure,
  - design of a suitably sized flood gated outlet structure to manage local runoff, and
  - the potential to divert runoff from part of the local town catchment directly to the river.

5. SUMMARY AND CONCLUSIONS

This supplementary report details the results of an assessment of impact of the preferred Option 2.1 configuration for a range of additional flood events not previously addressed. In addition to other flood related aspects highlighted during DNR review of "*Kempsey to Eungai Upgrading of the Pacific Highway, Project Application Report, Supporting Information – Flood Investigation (July 2006)".*

Supplementary modelling showed that Option 2.1 caused minor afflux across the floodplain during the 200y, 500y ARI and PMF events. The most significant afflux was found to be 0.27 m, 0.31 m and 0.19 m for the 200y, 500y ARI and PMF events respectively. These impacts occurred immediately adjacent to the proposed embankment at Frogmore. During the PMF event up to 0.27 m of afflux was also shown to occur around Frederickton.

As part of this supplementary report, modelling of the March 2001 flood event was also undertaken based on revised hydrology. The results showed a slight increase in afflux immediately adjacent to the embankment when compared to previously reported March 2001 event results. The maximum increase in afflux of 0.03 m occurred at Frogmore and South West Rocks Road.

The model was also used to assess the potential impacts of varying the embankment height. The flood levels for the 100y, 200y, 500y ARI and PMF events were shown to not be sensitive to a 300 mm increase in the height of the embankment. This 300 mm increase represents pre-settlement conditions or a scenario where an alternative guard rail may be installed that could obstruct free overflow of the embankment. Under these conditions the most significant change in flood level occurred immediately adjacent to the embankment at Frogmore and adjacent to the Macleay River bridge. However, the additional afflux compared with those from the concept assessment of Option 2.1 was found to be a maximum of 0.07 m.

Option 2.1 will cause minimal impacts beyond the immediate vicinity of the new crossing. Within this area however, there are two main issues to be addressed related to increased flooding in Frederickton and stock evacuation. Preliminary assessments have shown that increased flooding in Frederickton can be mitigated by the construction of a levee with appropriate measures for local runoff. Provisions for stock evacuation can be addressed by the installation of appropriately designed stock mounds.

Further flood modelling will be required during the detailed design stage to confirm the impact of the final bridge design and embankment configuration on flood levels. Additional modelling will also be needed to assist in detailed design of any proposed mitigation measures. It is recommended that the existing modelling outcomes be reviewed should any more detailed topographic data be obtained in the area of interest.

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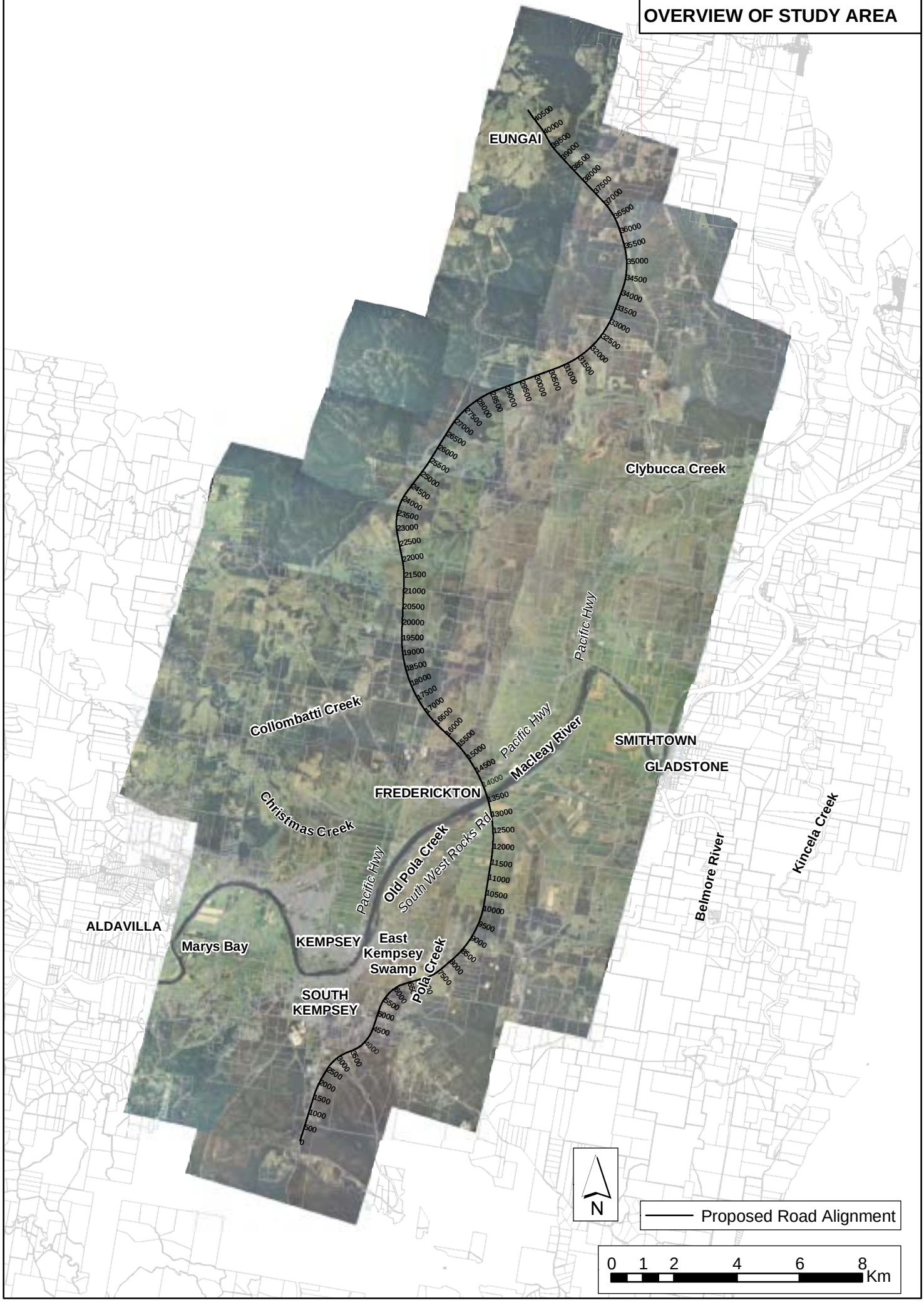
FIGURES

FIGURE 1

OVERVIEW OF STUDY AREA



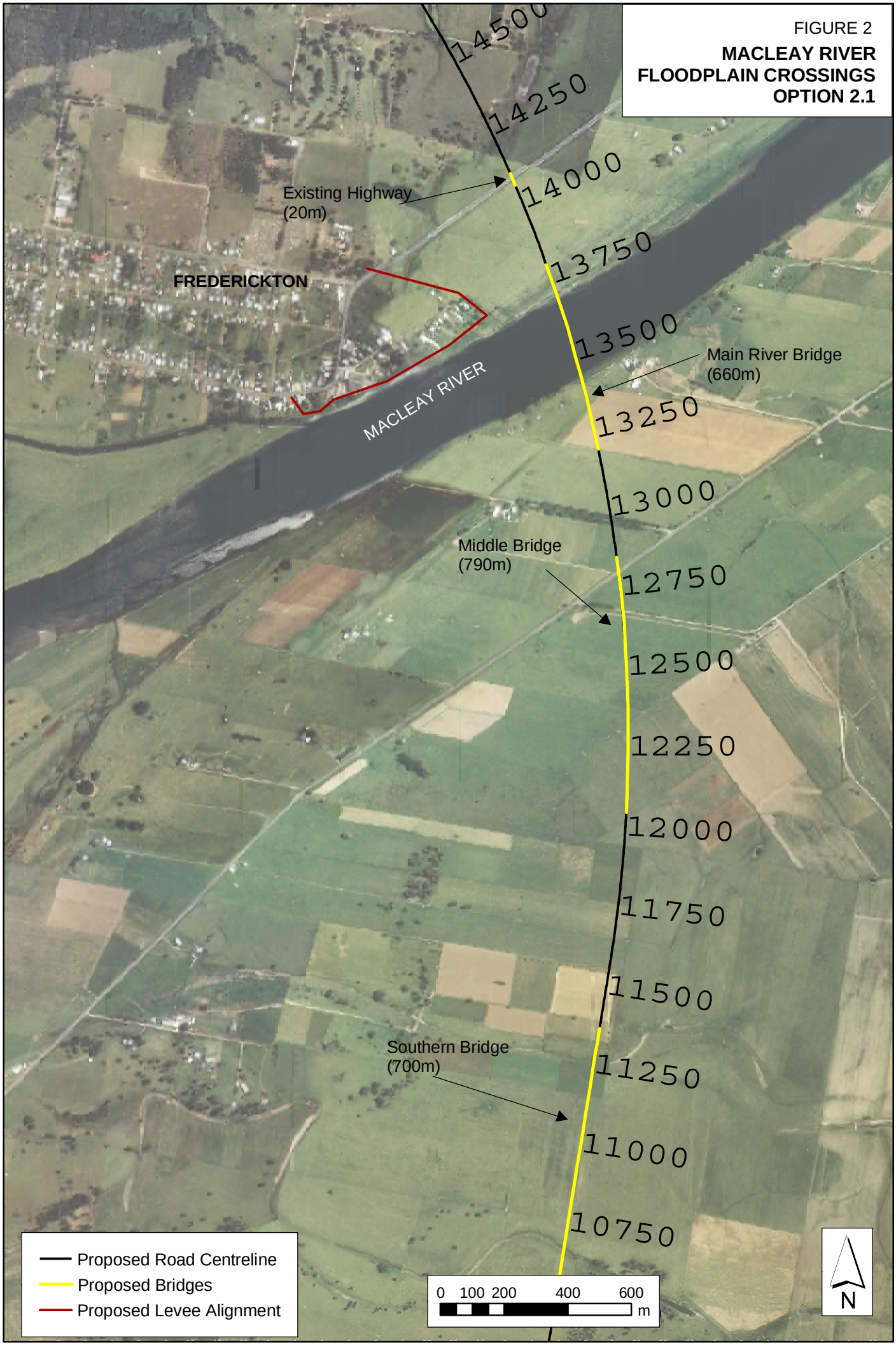


FIGURE 2
MACLEAY RIVER
FLOODPLAIN CROSSINGS
OPTION 2.1
14500
14250
14000
13750
13500
13250
13000
12750
12500
12250
12000
11750
11500
11250
11000
10750
Existing Highway
(20m)
FREDERICKTON
MACLEAY RIVER
Main River Bridge
(660m)
Middle Bridge
(790m)
Southern Bridge
(700m)
Proposed Road Centreline
Proposed Bridges
Proposed Levee Alignment
0 100 200 400 600
m
N

FIGURE 3

IMMEDIATE STUDY AREA

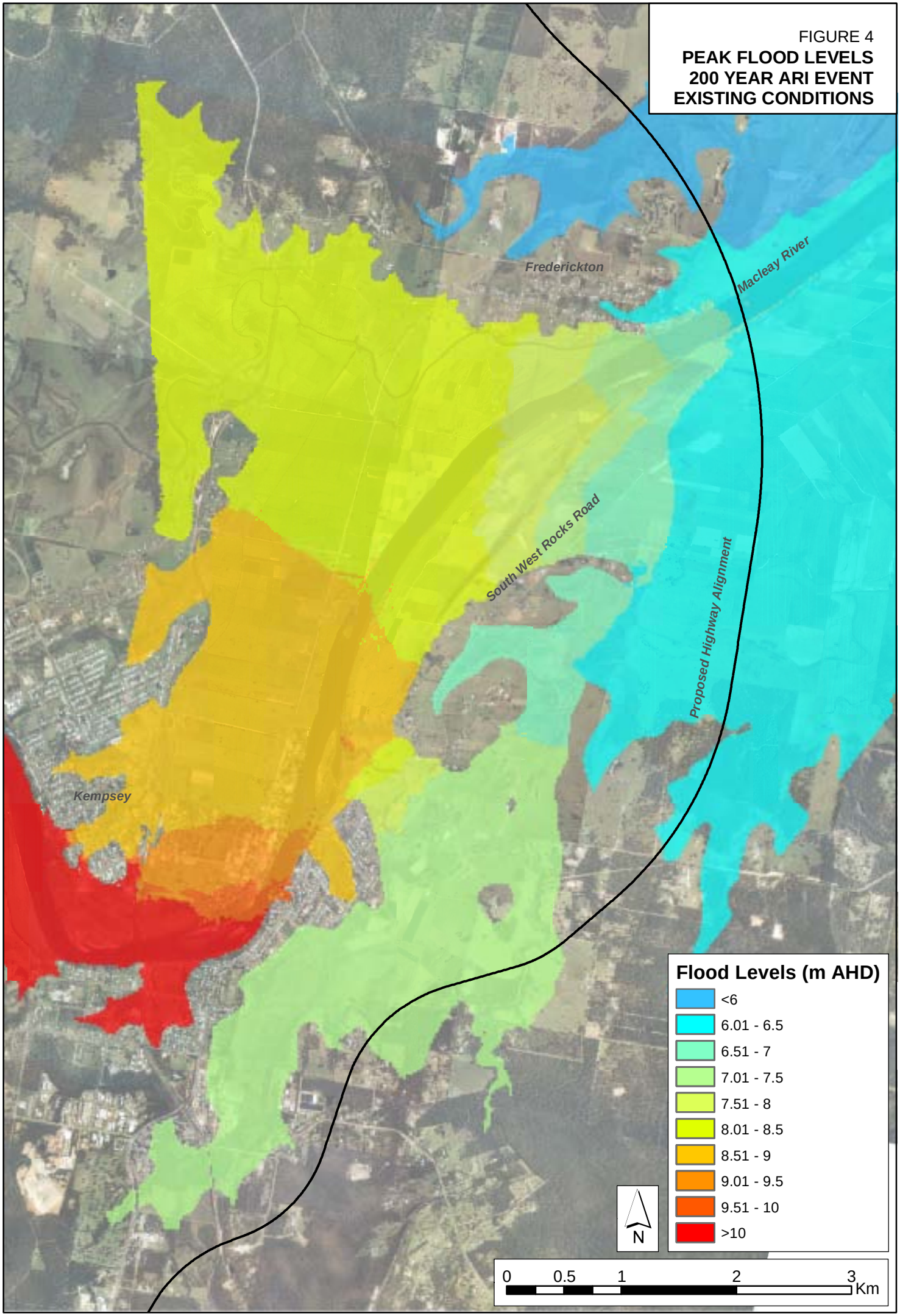


FIGURE 4
PEAK FLOOD LEVELS
200 YEAR ARI EVENT
EXISTING CONDITIONS
Fredericton
Macleay River
South West Rocks Road
Proposed Highway Alignment
Kempsey
Flood Levels (m AHD)
<6
6.01 - 6.5
6.51 - 7
7.01 - 7.5
7.51 - 8
8.01 - 8.5
8.51 - 9
9.01 - 9.5
9.51 - 10
>10
N
0
0.5
1
2
3
Km

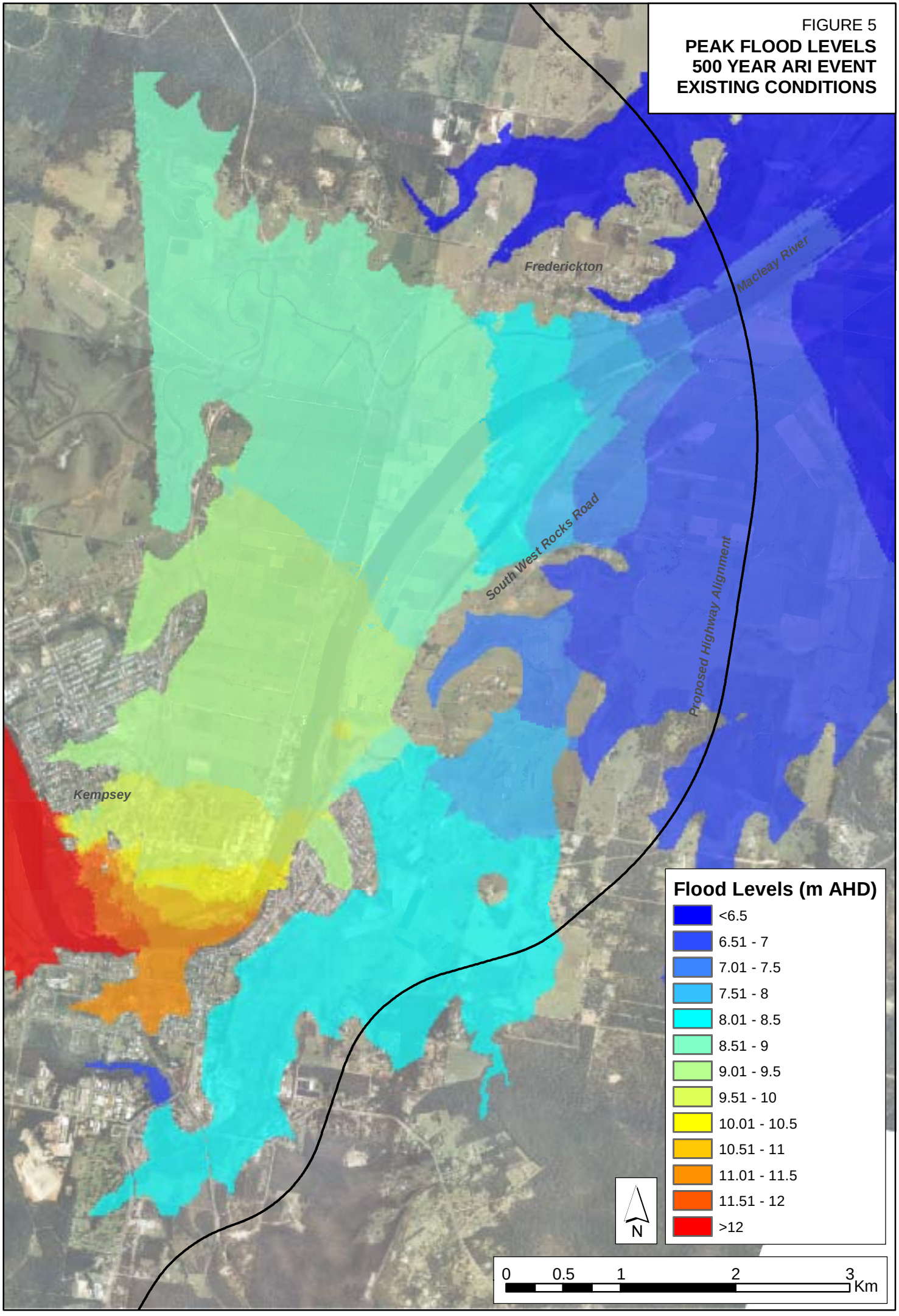


FIGURE 5
PEAK FLOOD LEVELS
500 YEAR ARI EVENT
EXISTING CONDITIONS
Frederickton
Macleay River
South West Rocks Road
Proposed Highway Alignment
Kempsey
Flood Levels (m AHD)
<6.5
6.51 - 7
7.01 - 7.5
7.51 - 8
8.01 - 8.5
8.51 - 9
9.01 - 9.5
9.51 - 10
10.01 - 10.5
10.51 - 11
11.01 - 11.5
11.51 - 12
>12
N
0
0.5
1
2
3
Km

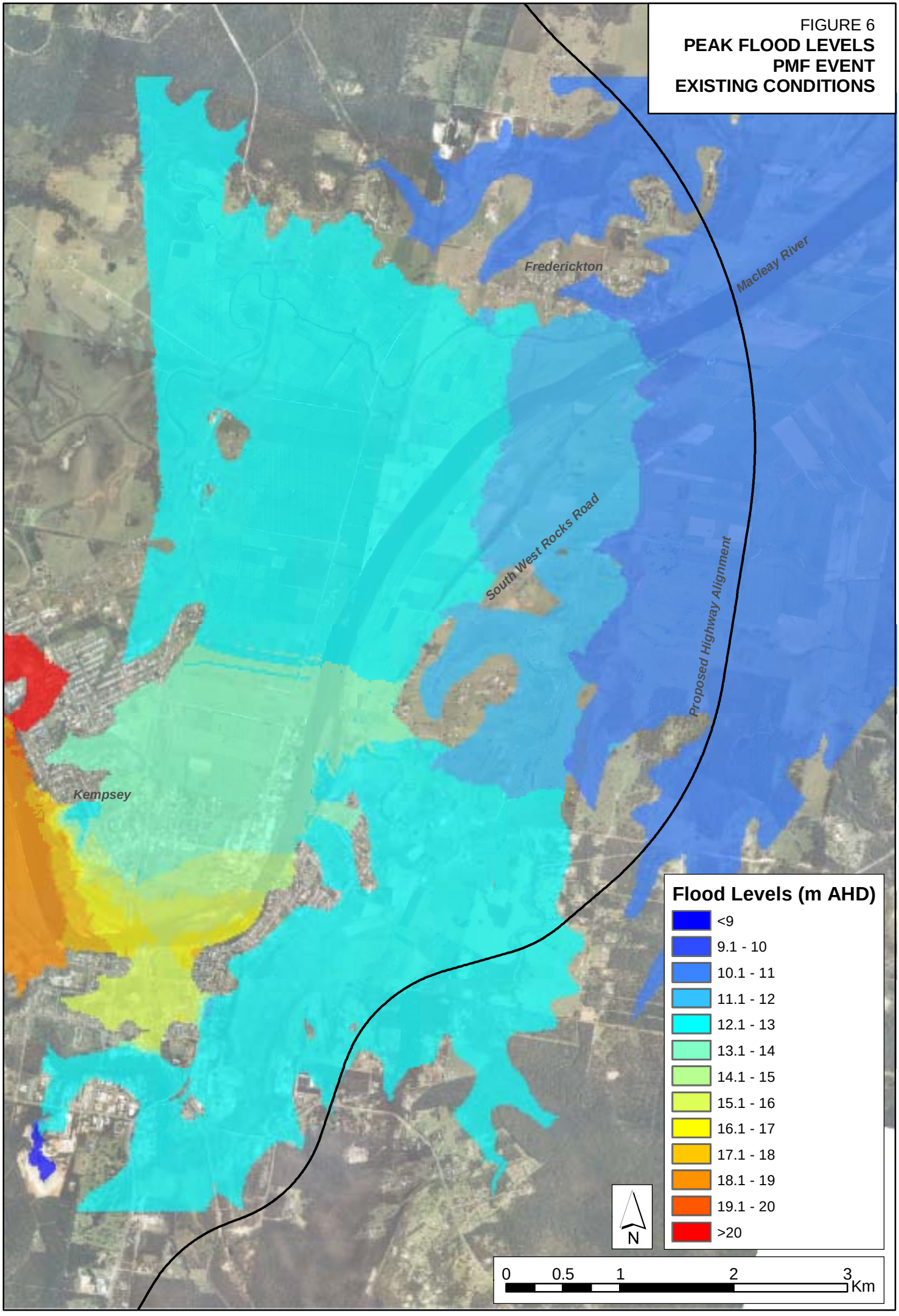


FIGURE 6
PEAK FLOOD LEVELS
PMF EVENT
EXISTING CONDITIONS
Fredericton
Macleay River
South West Rocks Road
Proposed Highway Alignment
Kempsey
Flood Levels (m AHD)
<9
9.1 - 10
10.1 - 11
11.1 - 12
12.1 - 13
13.1 - 14
14.1 - 15
15.1 - 16
16.1 - 17
17.1 - 18
18.1 - 19
19.1 - 20
>20
N
0
0.5
1
2
3
Km

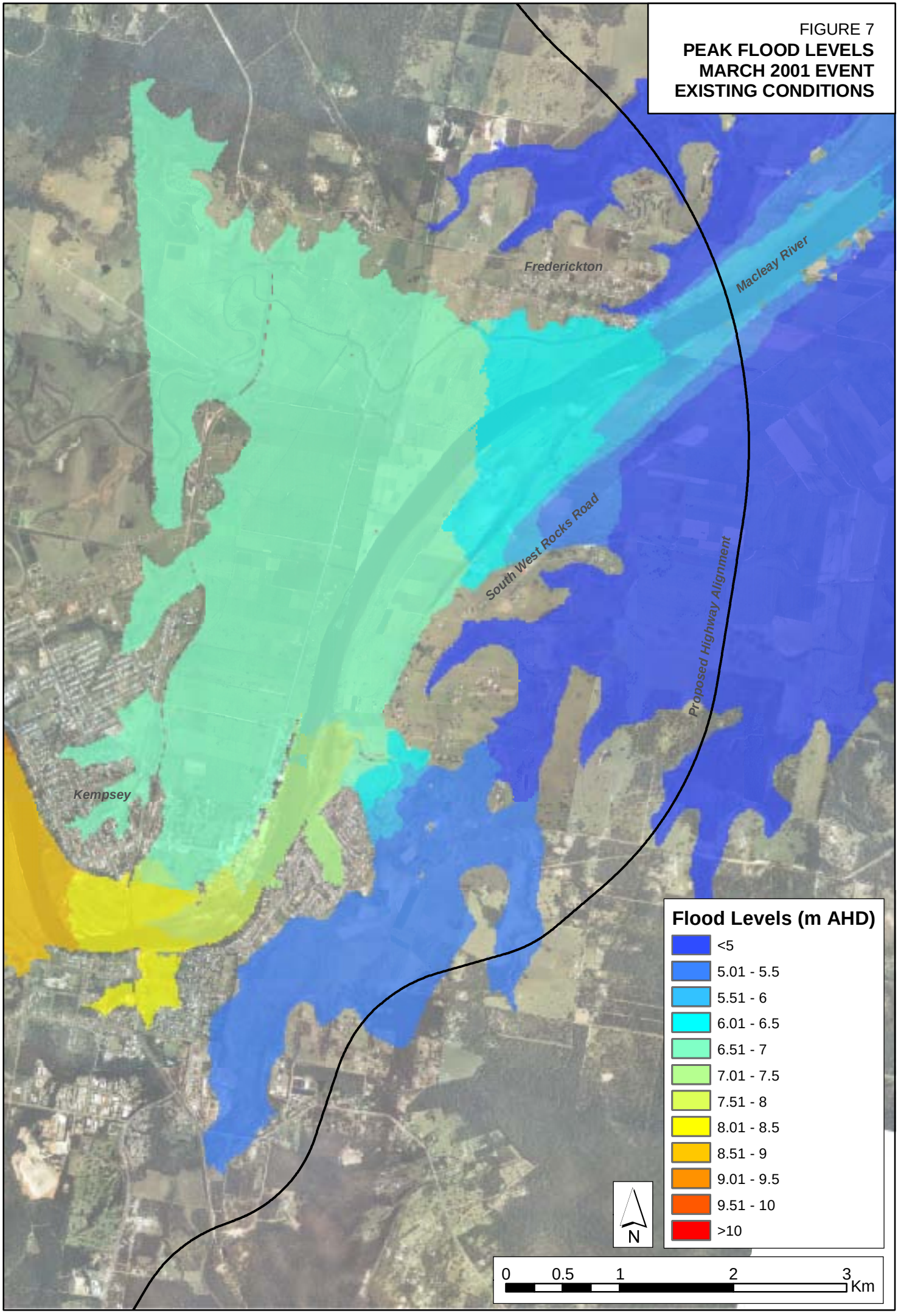


FIGURE 7
PEAK FLOOD LEVELS
MARCH 2001 EVENT
EXISTING CONDITIONS
Fredericton
Macleay River
South West Rocks Road
Proposed Highway Alignment
Kempsey
Flood Levels (m AHD)
<5
5.01 - 5.5
5.51 - 6
6.01 - 6.5
6.51 - 7
7.01 - 7.5
7.51 - 8
8.01 - 8.5
8.51 - 9
9.01 - 9.5
9.51 - 10
>10
N
0
0.5
1
2
3
Km

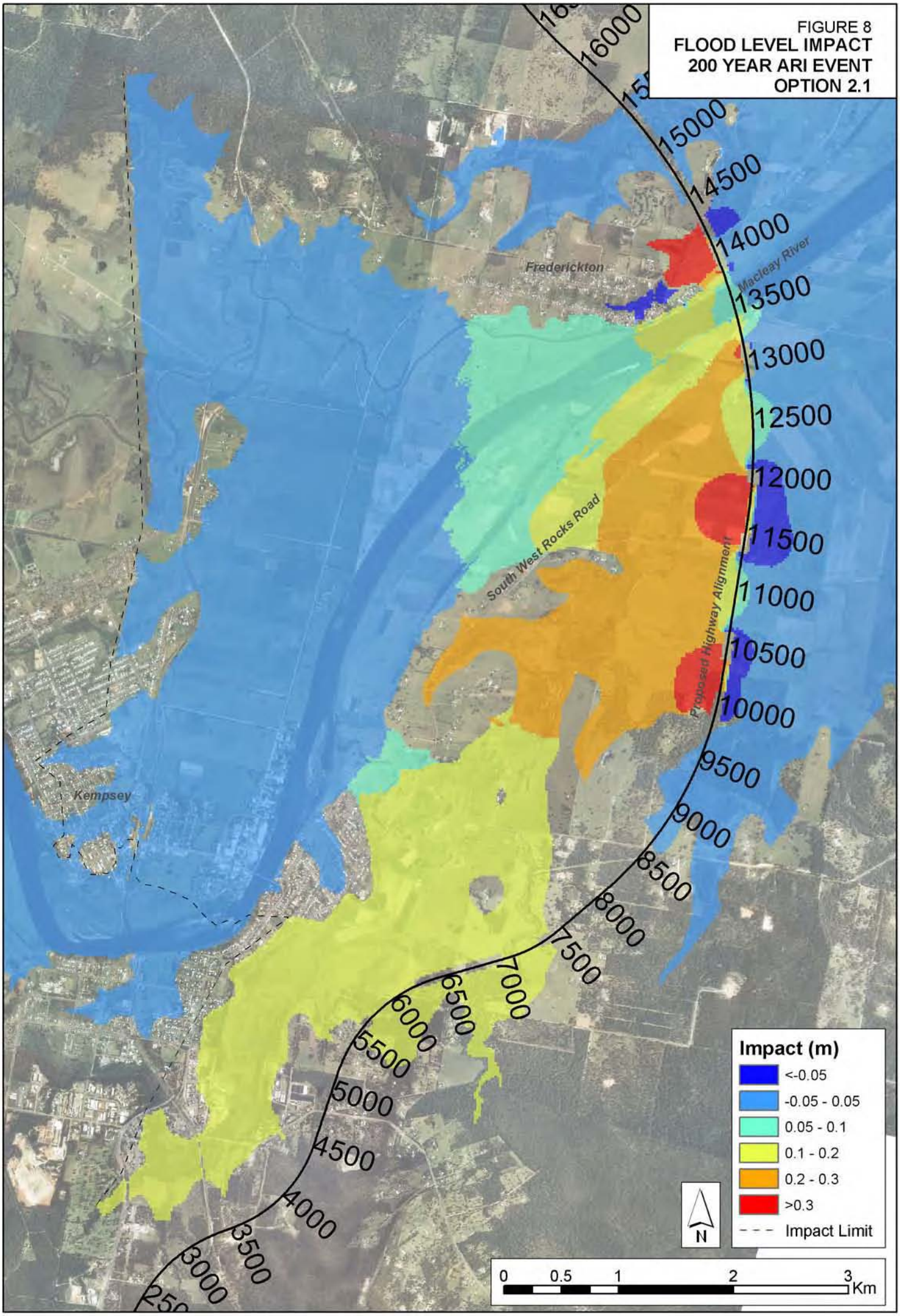


FIGURE 8
FLOOD LEVEL IMPACT
200 YEAR ARI EVENT
OPTION 2.1
16000
15000
14500
14000
13500
13000
12500
12000
11500
11000
10500
10000
9500
9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
Frederickton
Macleay River
South West Rocks Road
Proposed Highway Alignment
Kempsey
Impact (m)
<-0.05
-0.05 - 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
>0.3
Impact Limit
N
0
0.5
1
2
3
Km

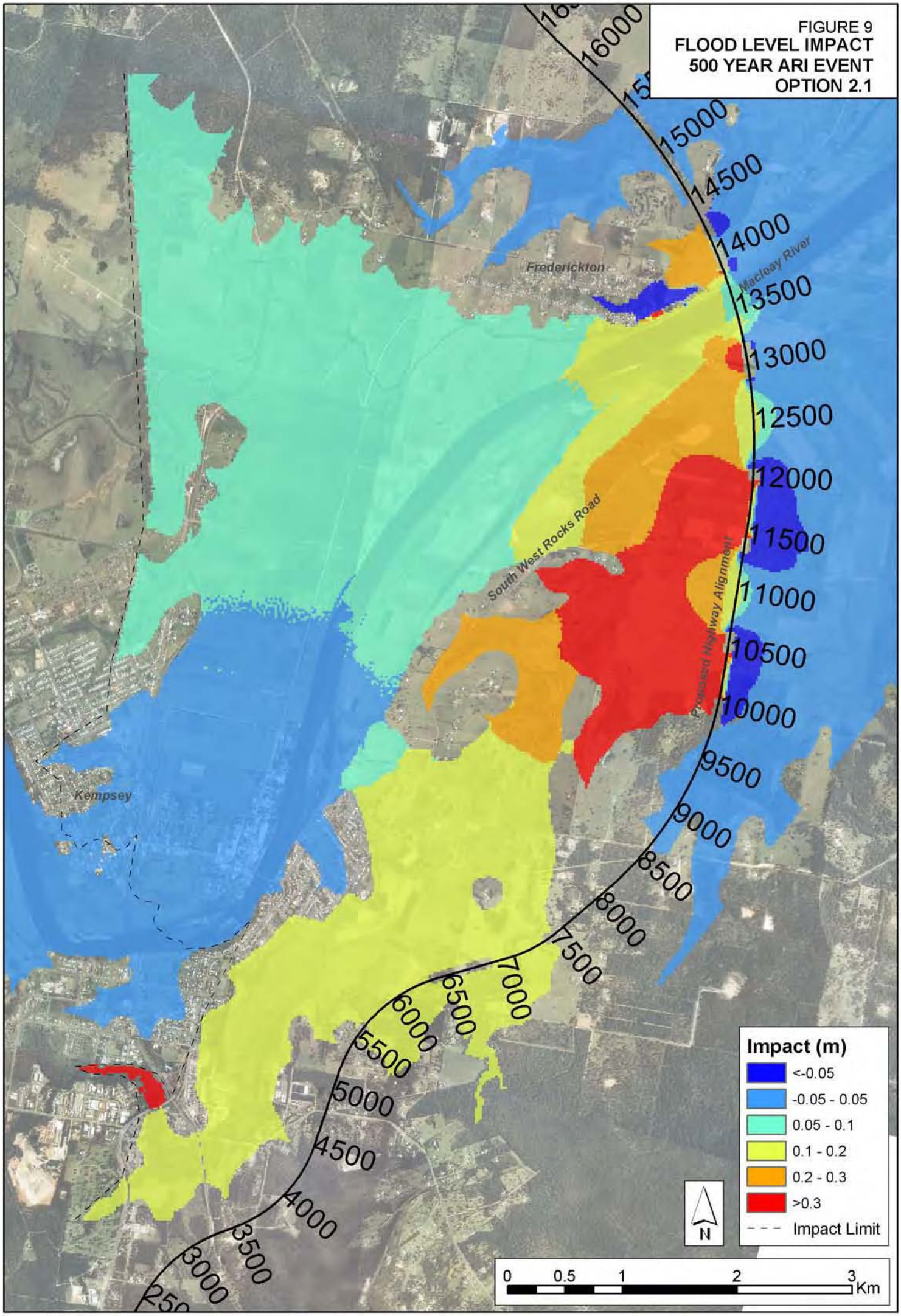


FIGURE 9
FLOOD LEVEL IMPACT
500 YEAR ARI EVENT
OPTION 2.1
16000
15000
14500
14000
13500
13000
12500
12000
11500
11000
10500
10000
9500
9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
Fredericton
Macleay River
South West Rocks Road
Proposed Highway Alignment
Kempsey
Impact (m)
<-0.05
-0.05 - 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
>0.3
Impact Limit
N
0
0.5
1
2
3
Km

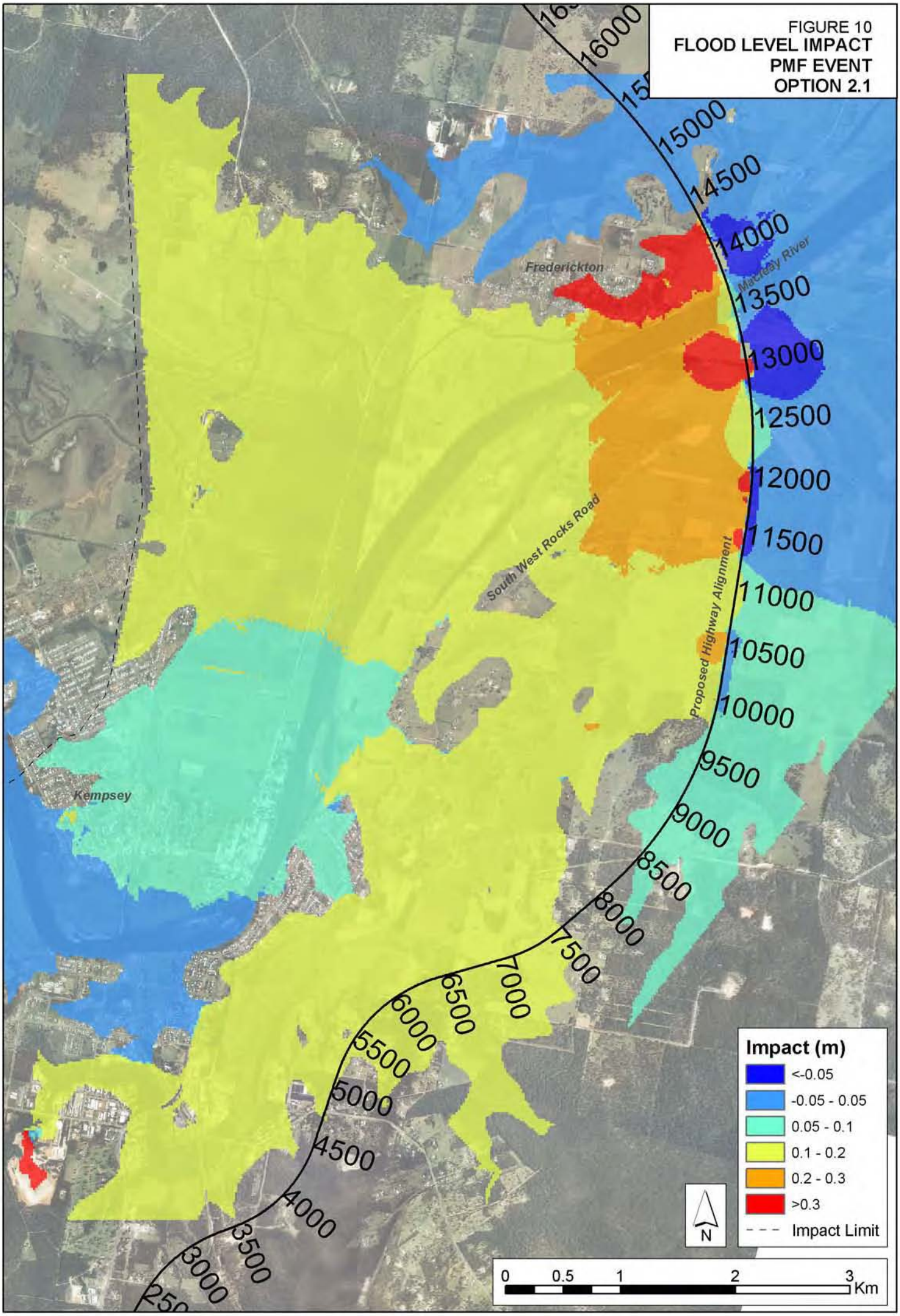


FIGURE 10
FLOOD LEVEL IMPACT
PMF EVENT
OPTION 2.1
16000
15000
14500
14000
13500
13000
12500
12000
11500
11000
10500
10000
9500
9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
Fredericton
Macleay River
South West Rocks Road
Proposed Highway Alignment
Kempsey
Impact (m)
<-0.05
-0.05 - 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
>0.3
Impact Limit
N
0
0.5
1
2
3
Km

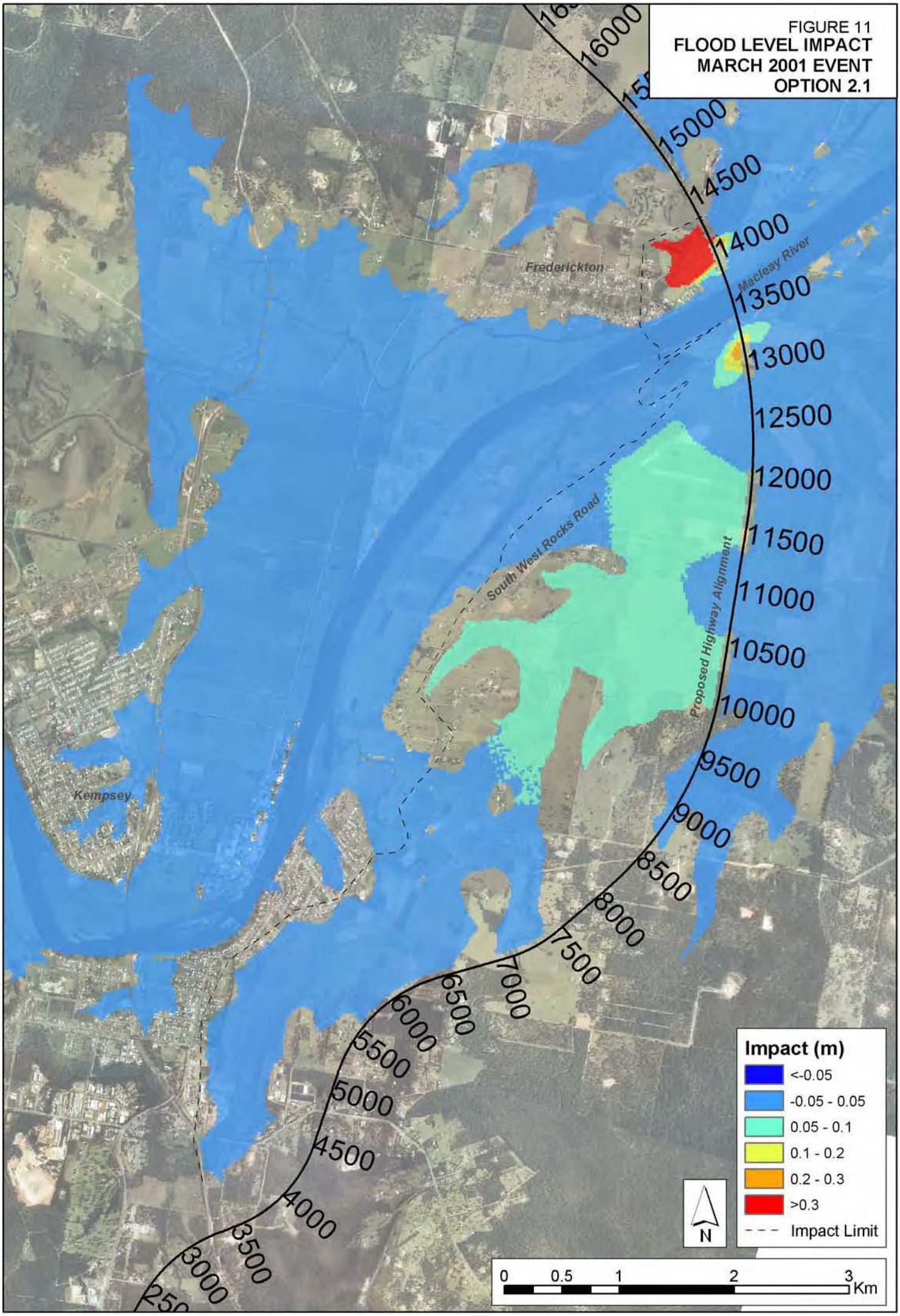
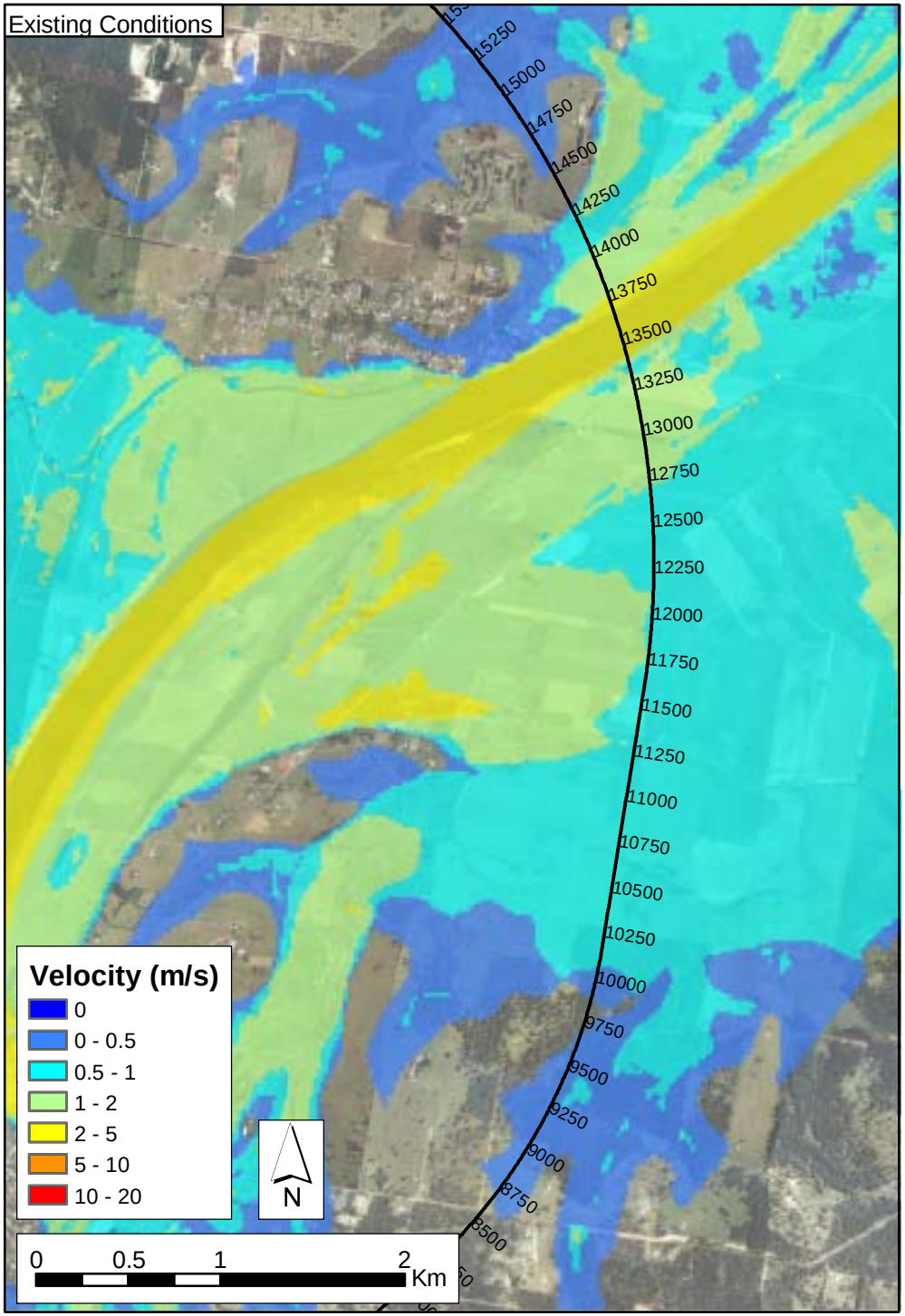


FIGURE 11
FLOOD LEVEL IMPACT
MARCH 2001 EVENT
OPTION 2.1
16000
15000
14500
14000
13500
13000
12500
12000
11500
11000
10500
10000
9500
9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
Fredericton
Macleay River
South West Rocks Road
Proposed Highway Alignment
Kempsey
Impact (m)
<-0.05
-0.05 - 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
>0.3
Impact Limit
N
0
0.5
1
2
3
Km



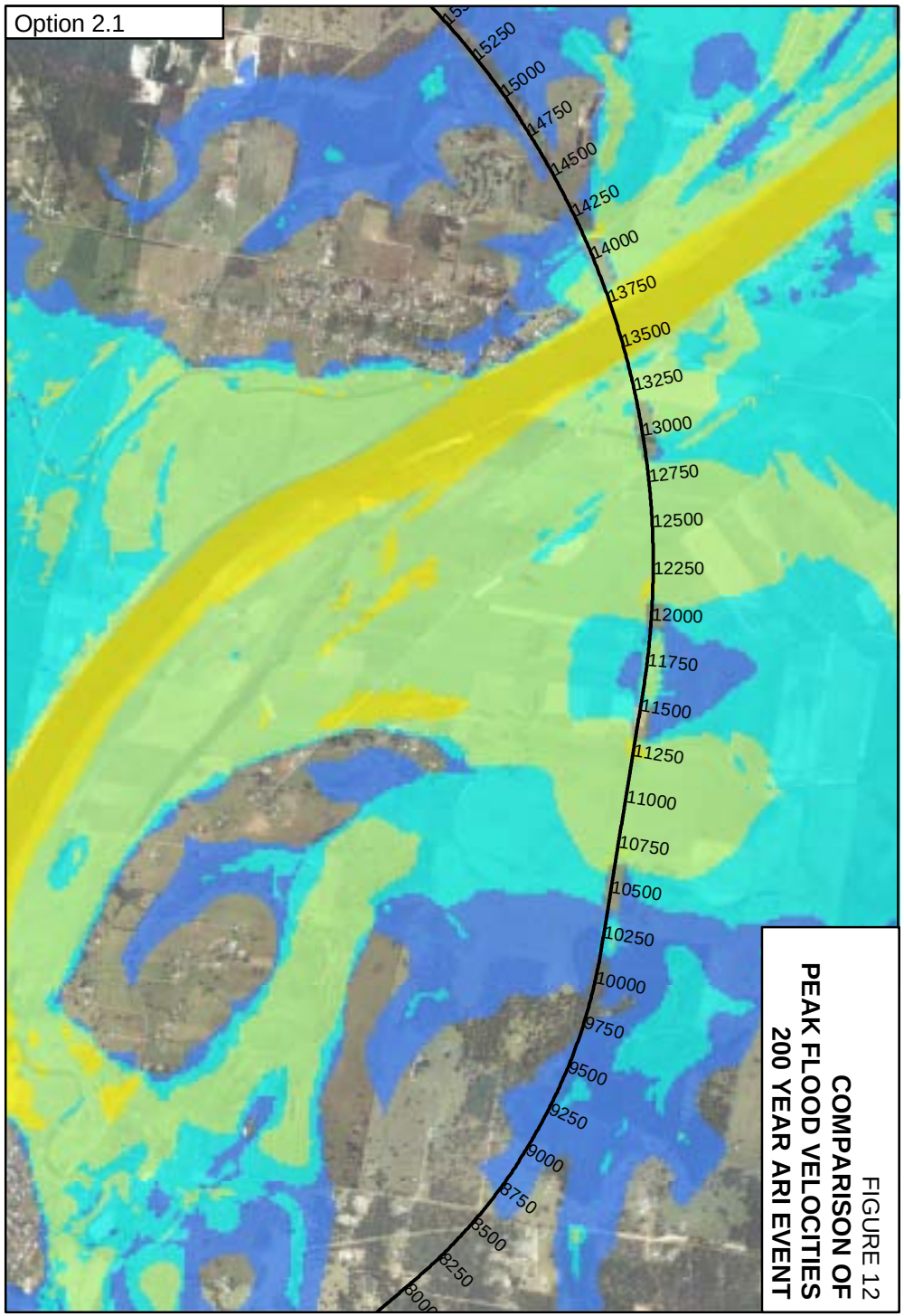
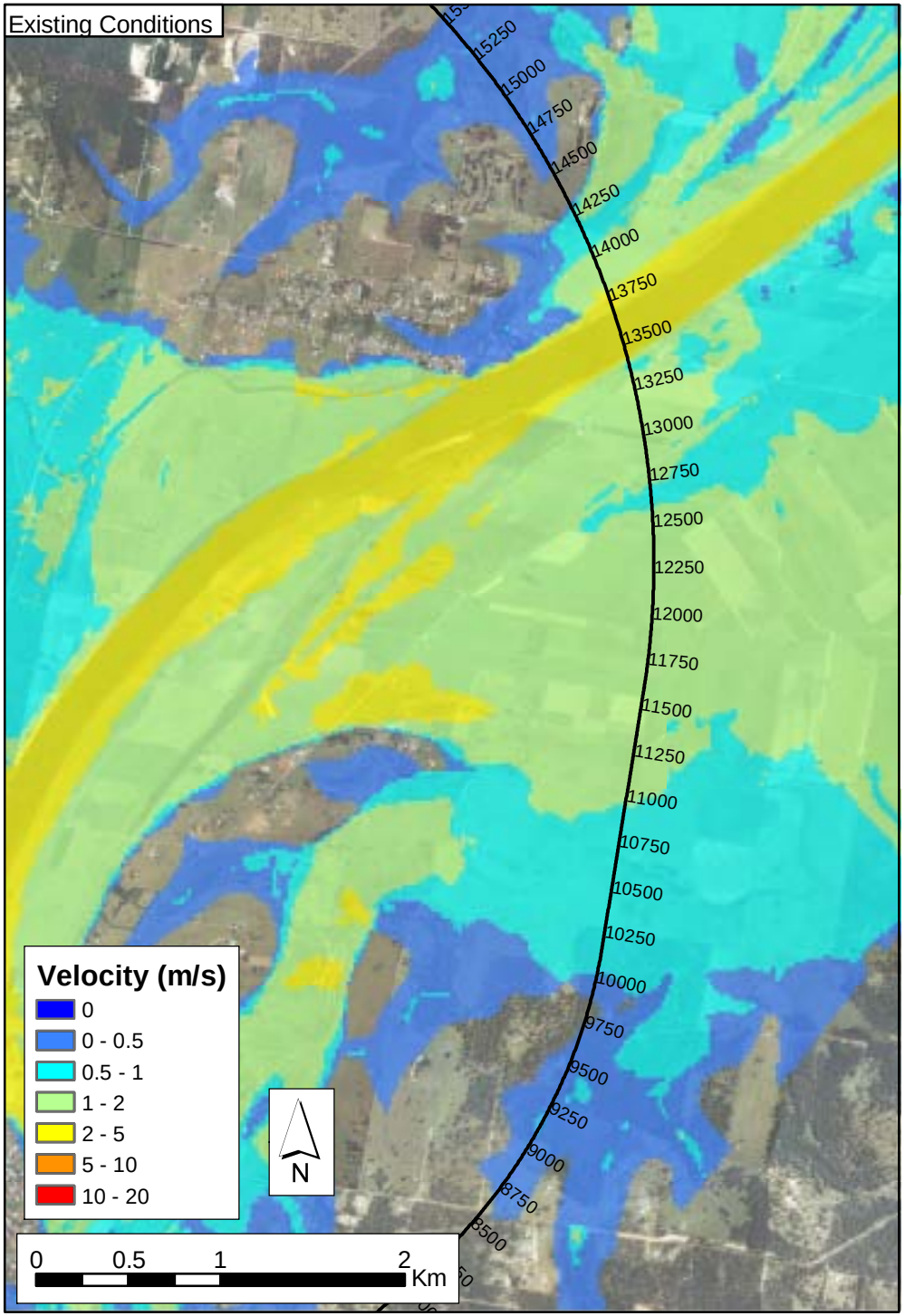


FIGURE 12
COMPARISON OF PEAK FLOOD VELOCITIES 200 YEAR ARI EVENT



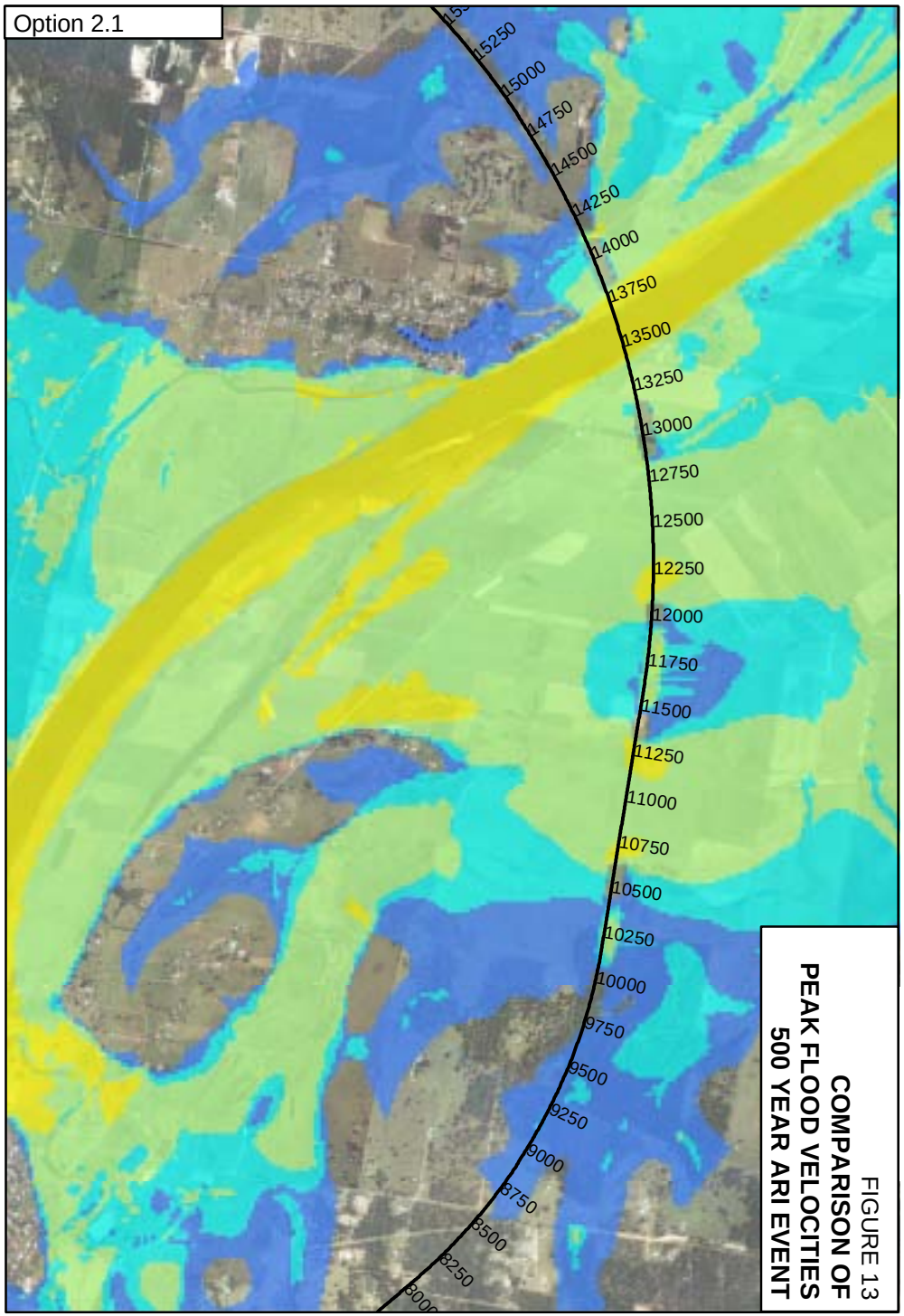
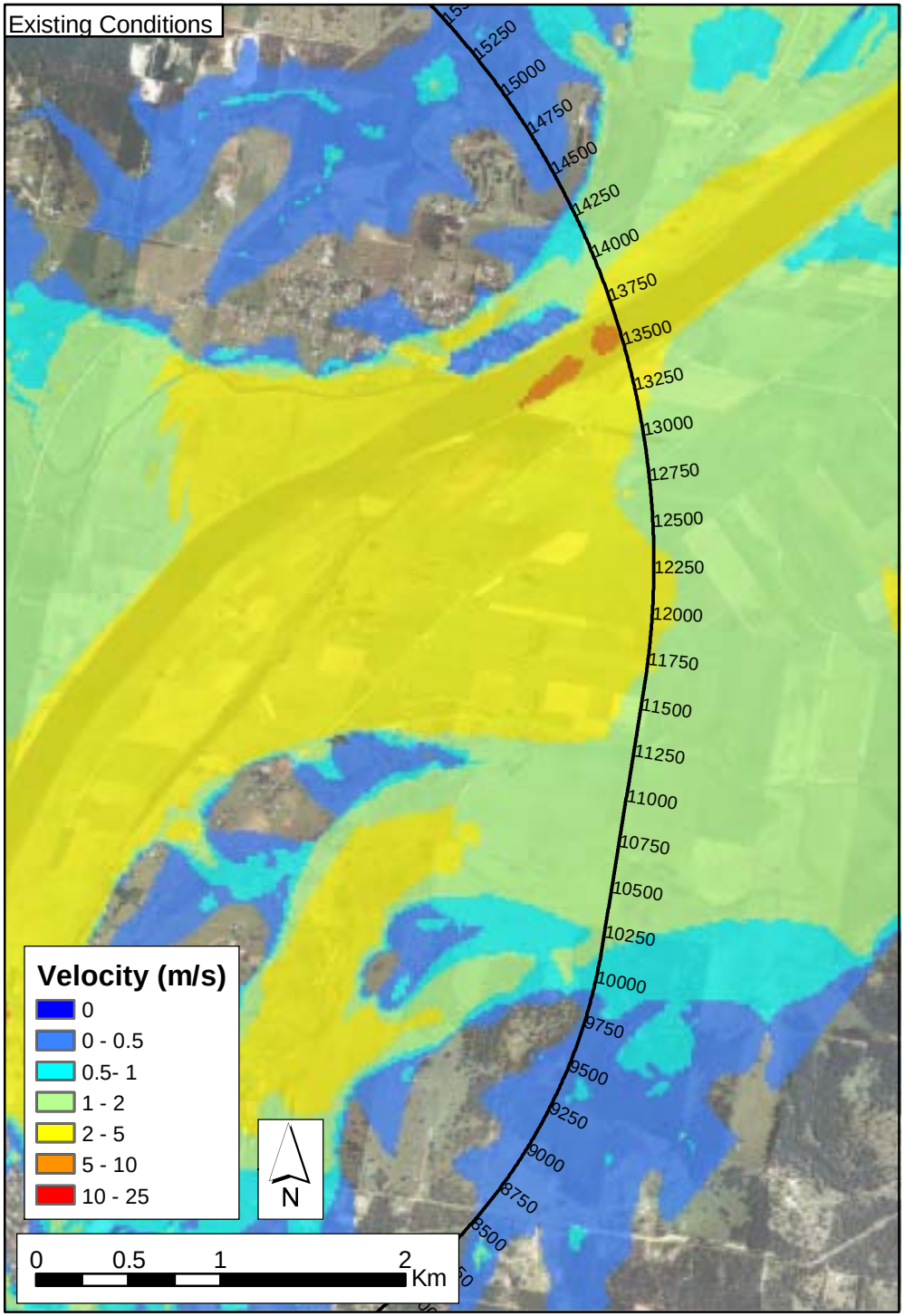


FIGURE 13
COMPARISON OF PEAK FLOOD VELOCITIES 500 YEAR ARI EVENT



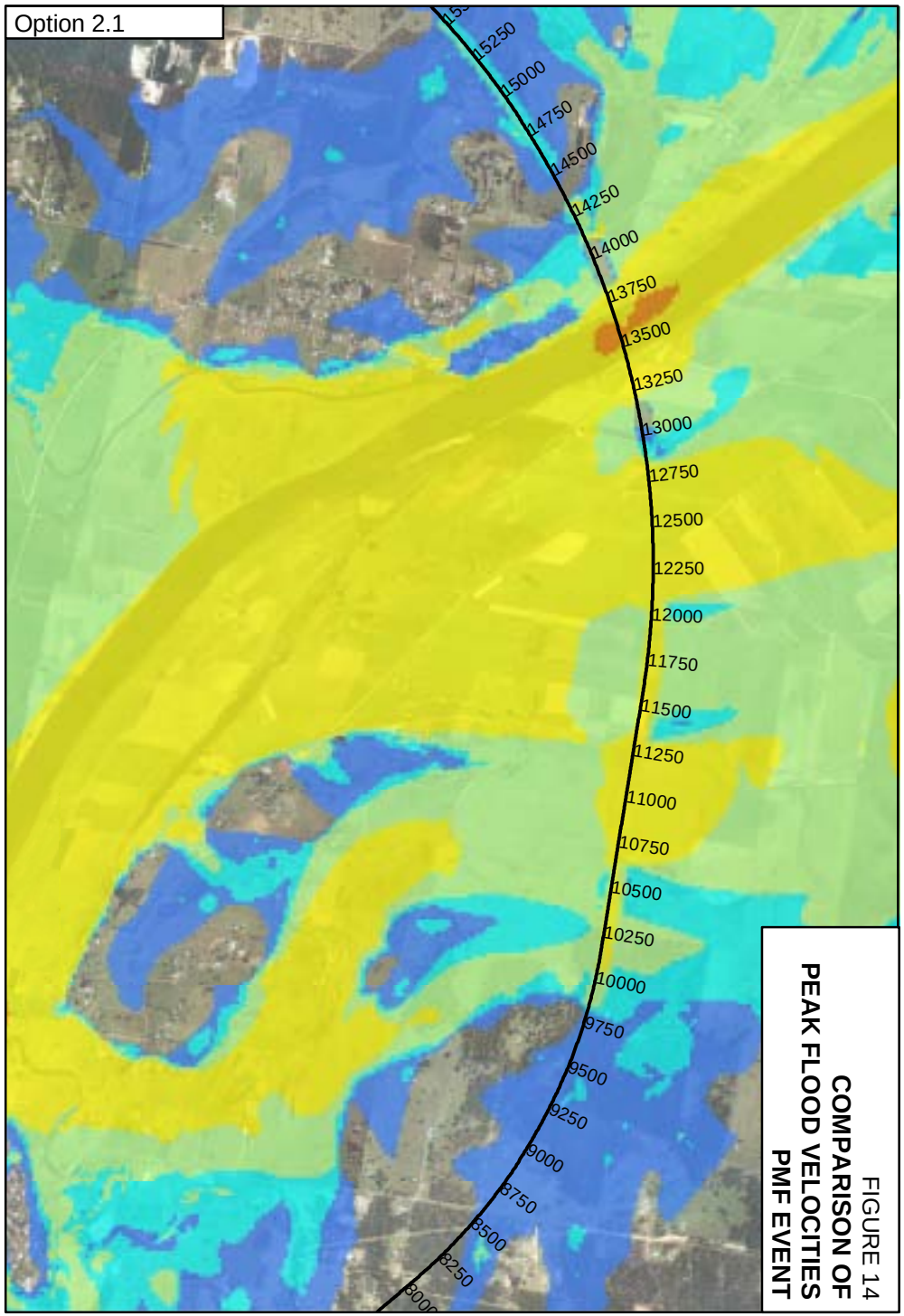


FIGURE 14
COMPARISON OF PEAK FLOOD VELOCITIES PMF EVENT

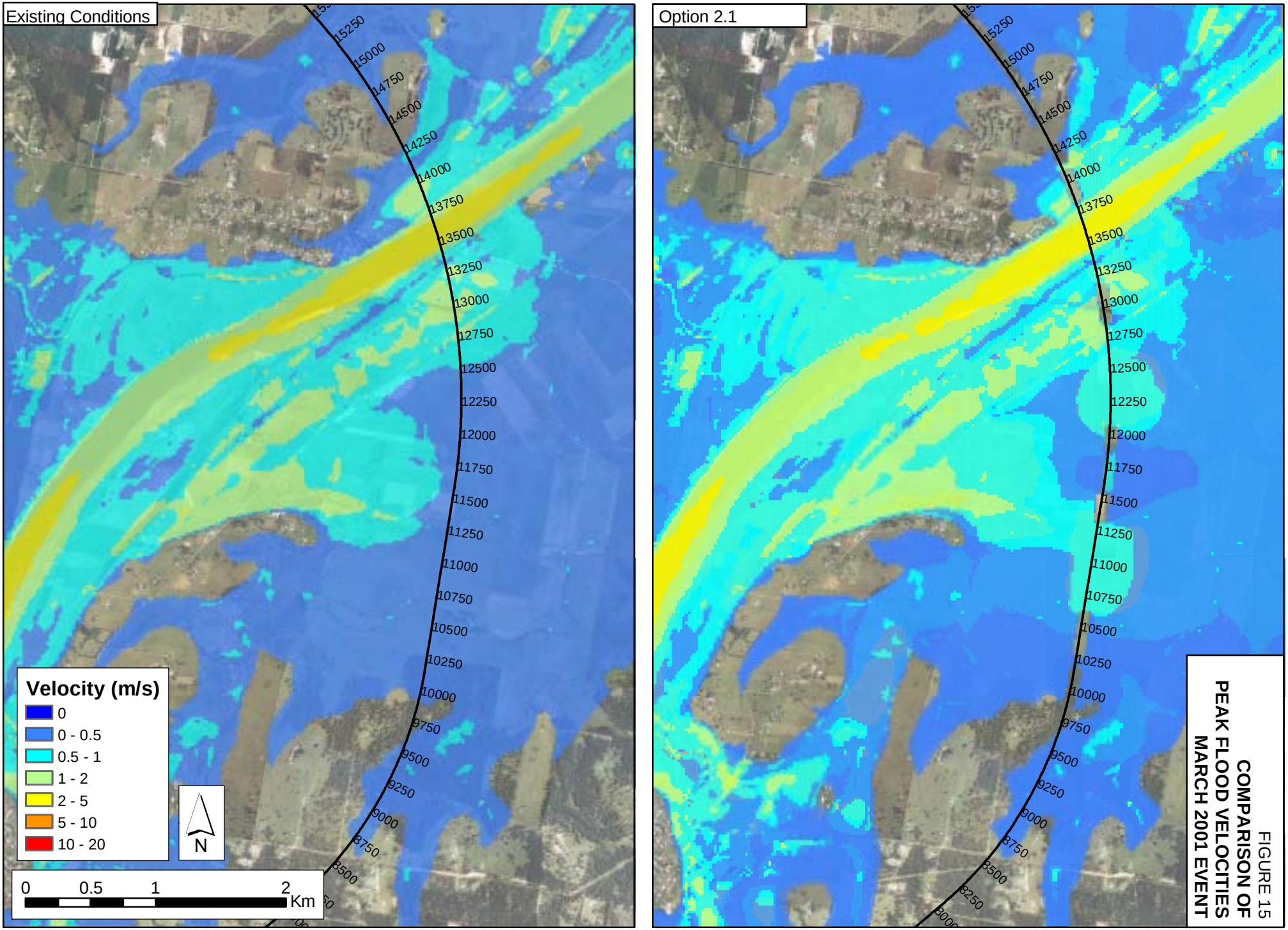
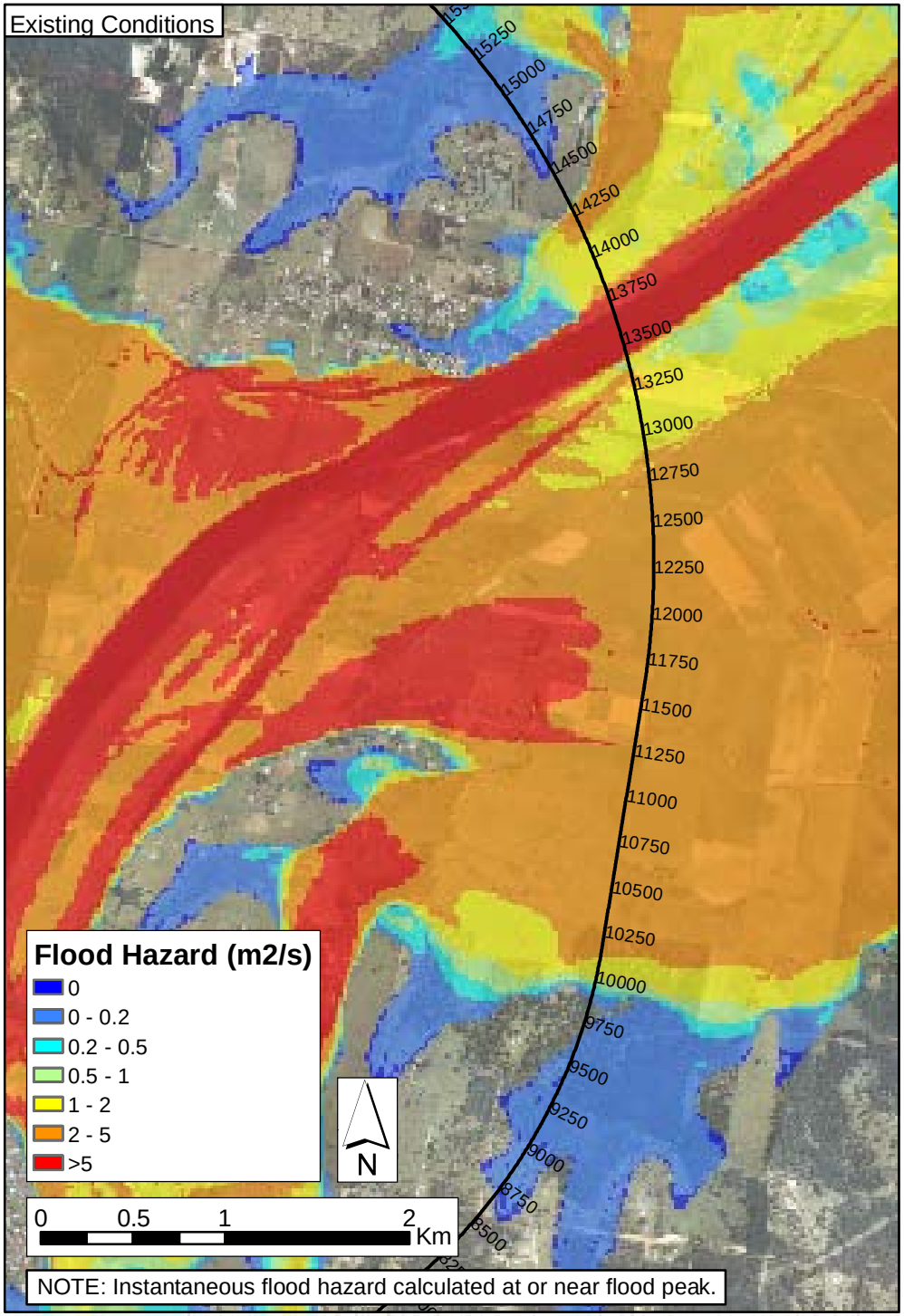
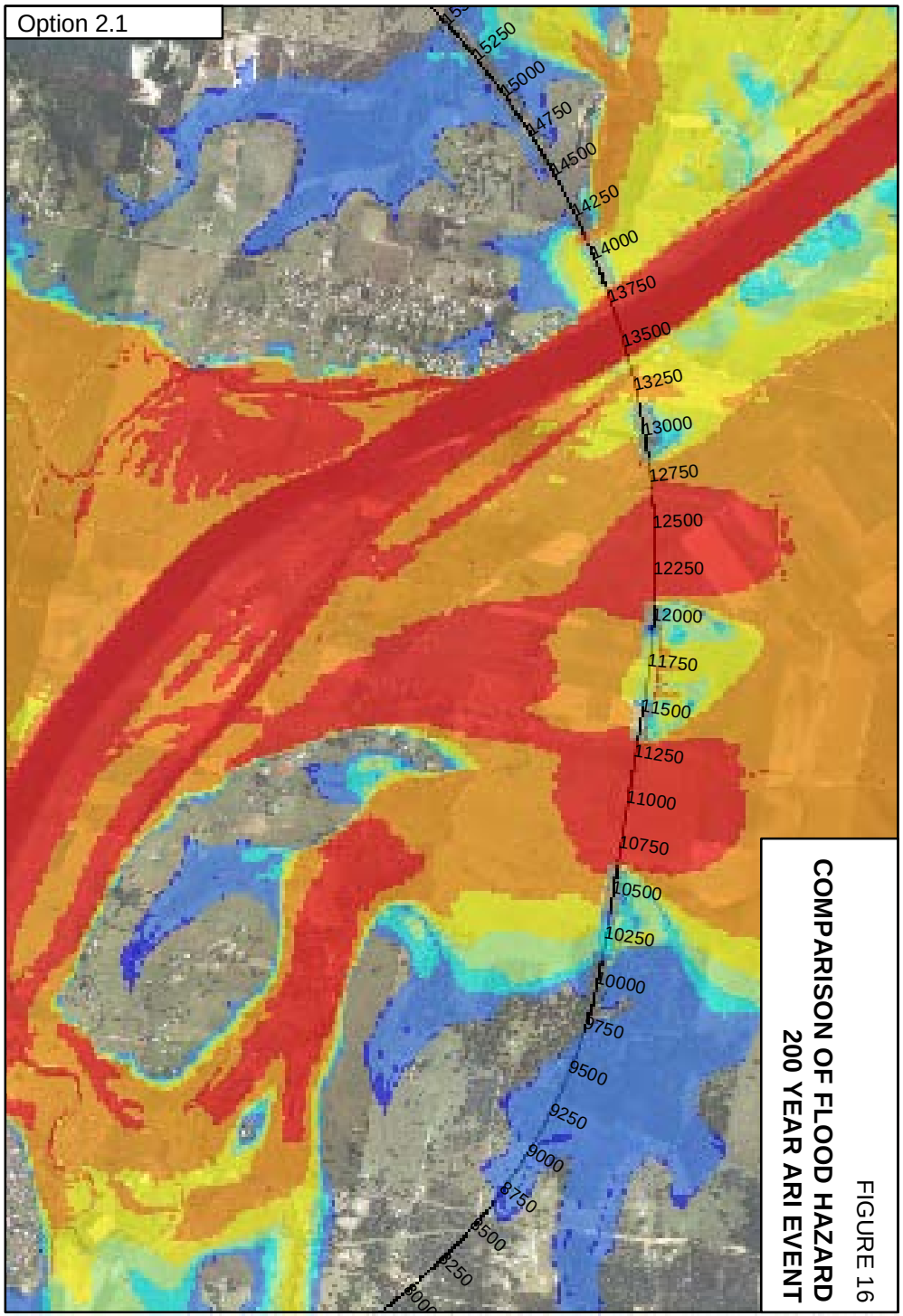


FIGURE 15
COMPARISON OF PEAK FLOOD VELOCITIES MARCH 2001 EVENT





COMPARISON OF FLOOD HAZARD
200 YEAR ARI EVENT

FIGURE 16

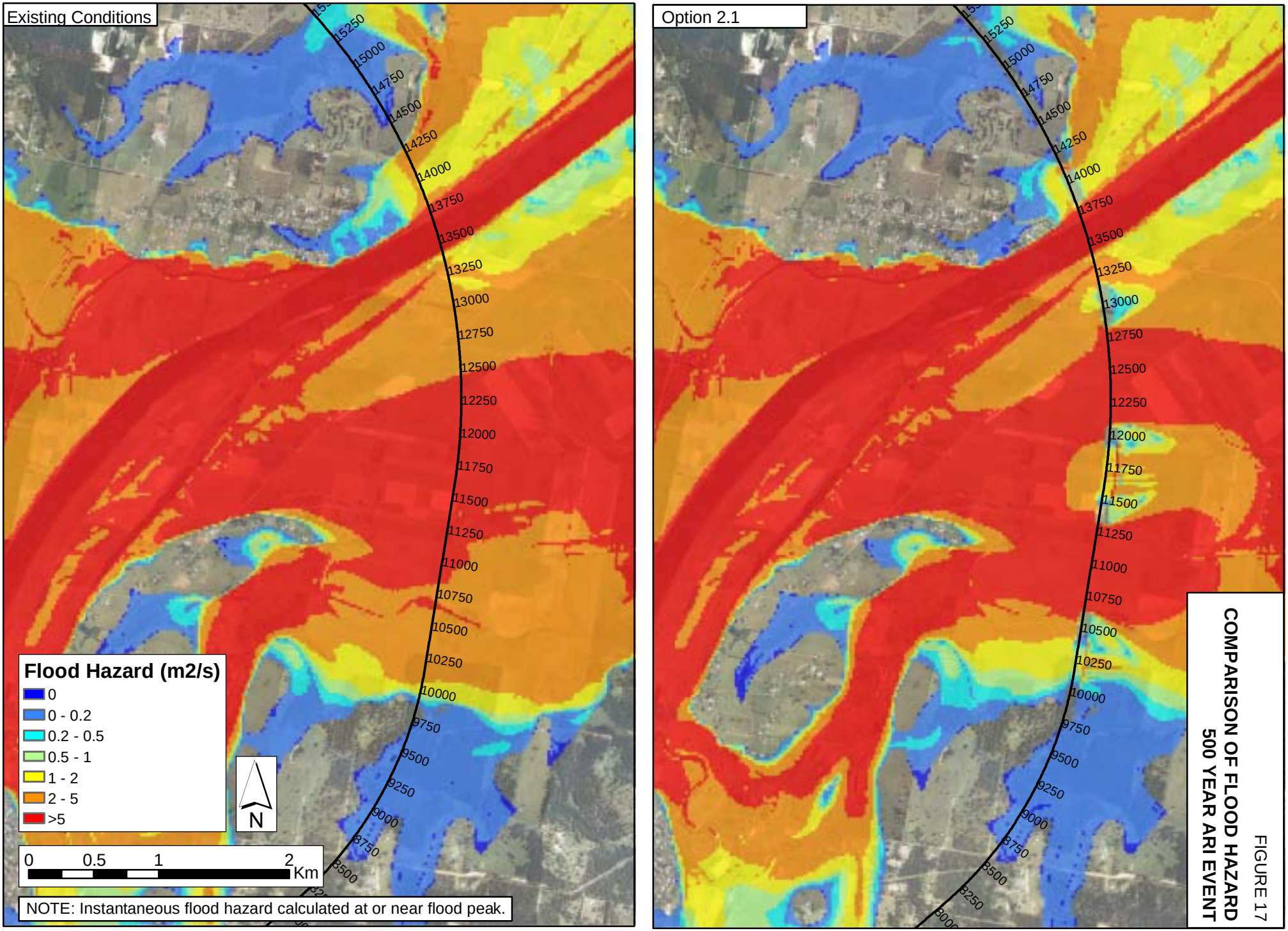
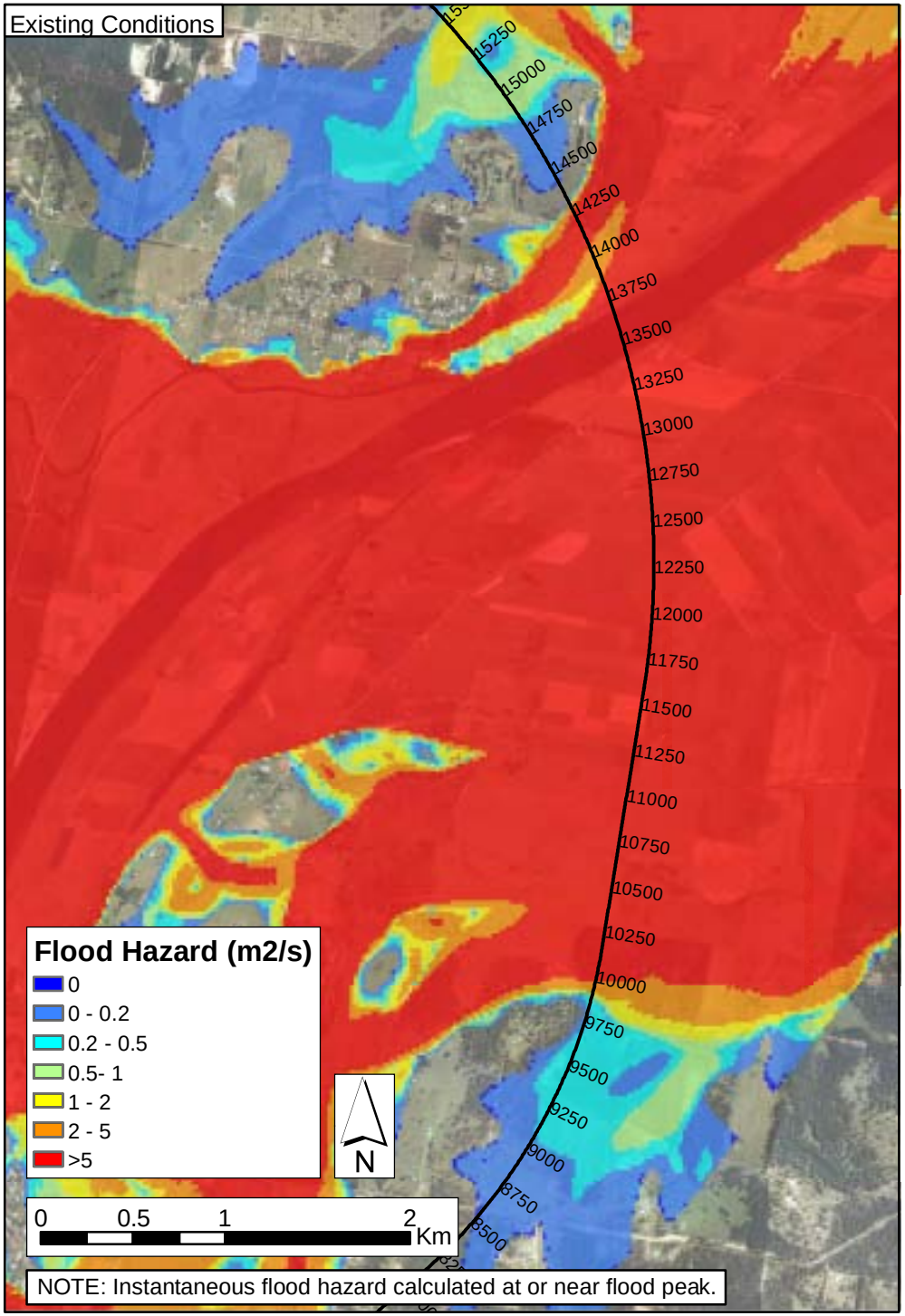
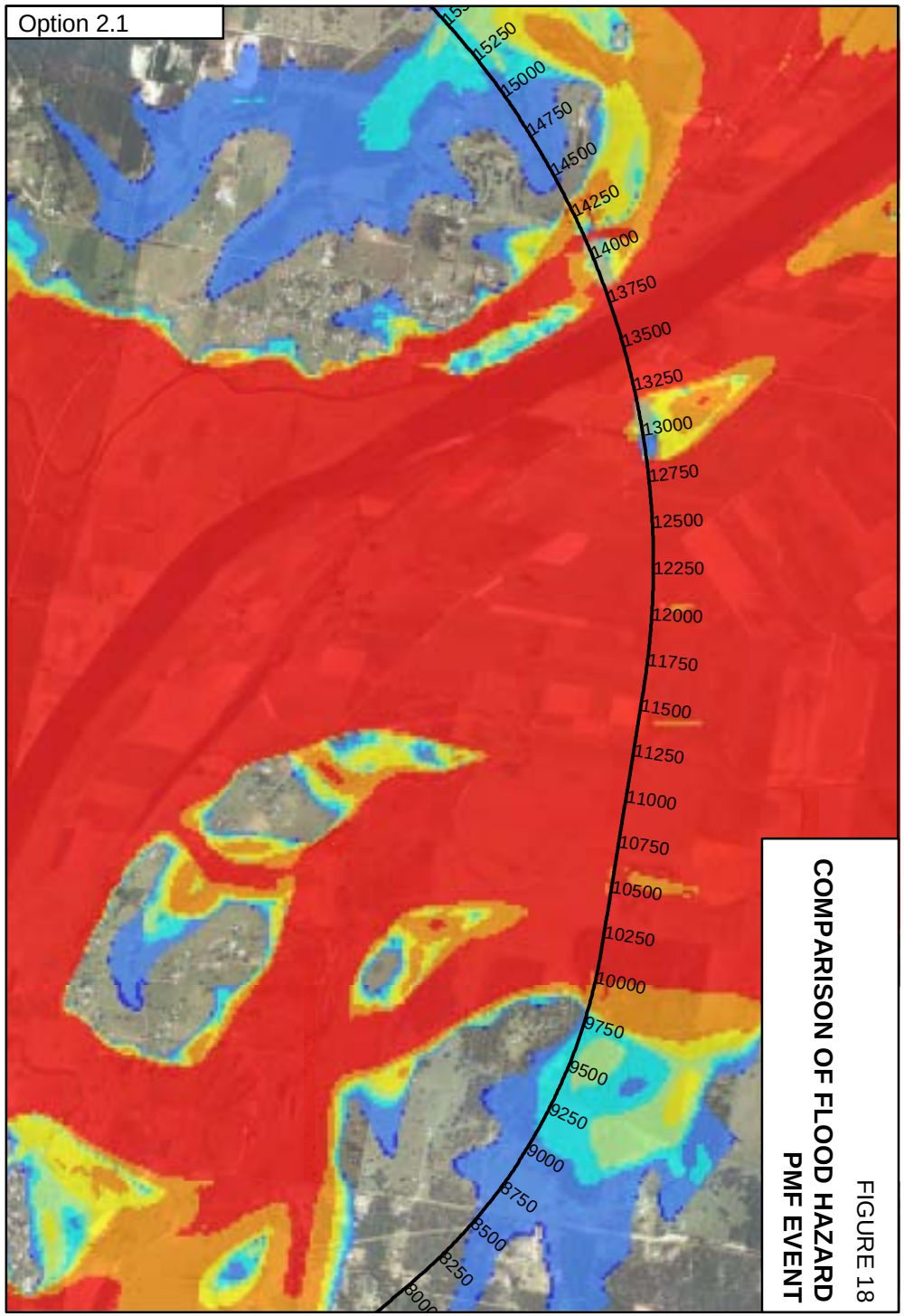


FIGURE 17

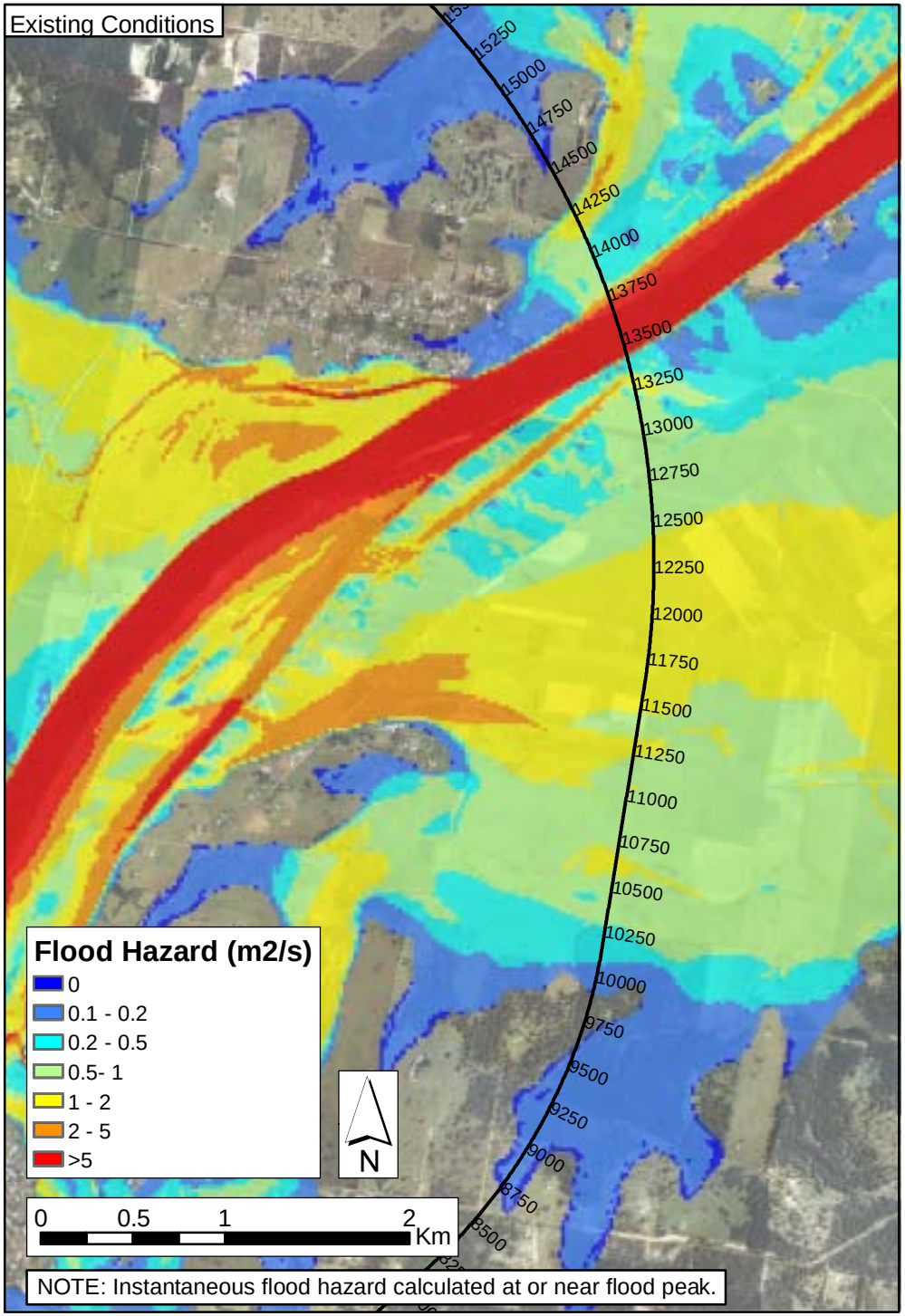
COMPARISON OF FLOOD HAZARD
500 YEAR ARI EVENT





COMPARISON OF FLOOD HAZARD
PMF EVENT

FIGURE 18



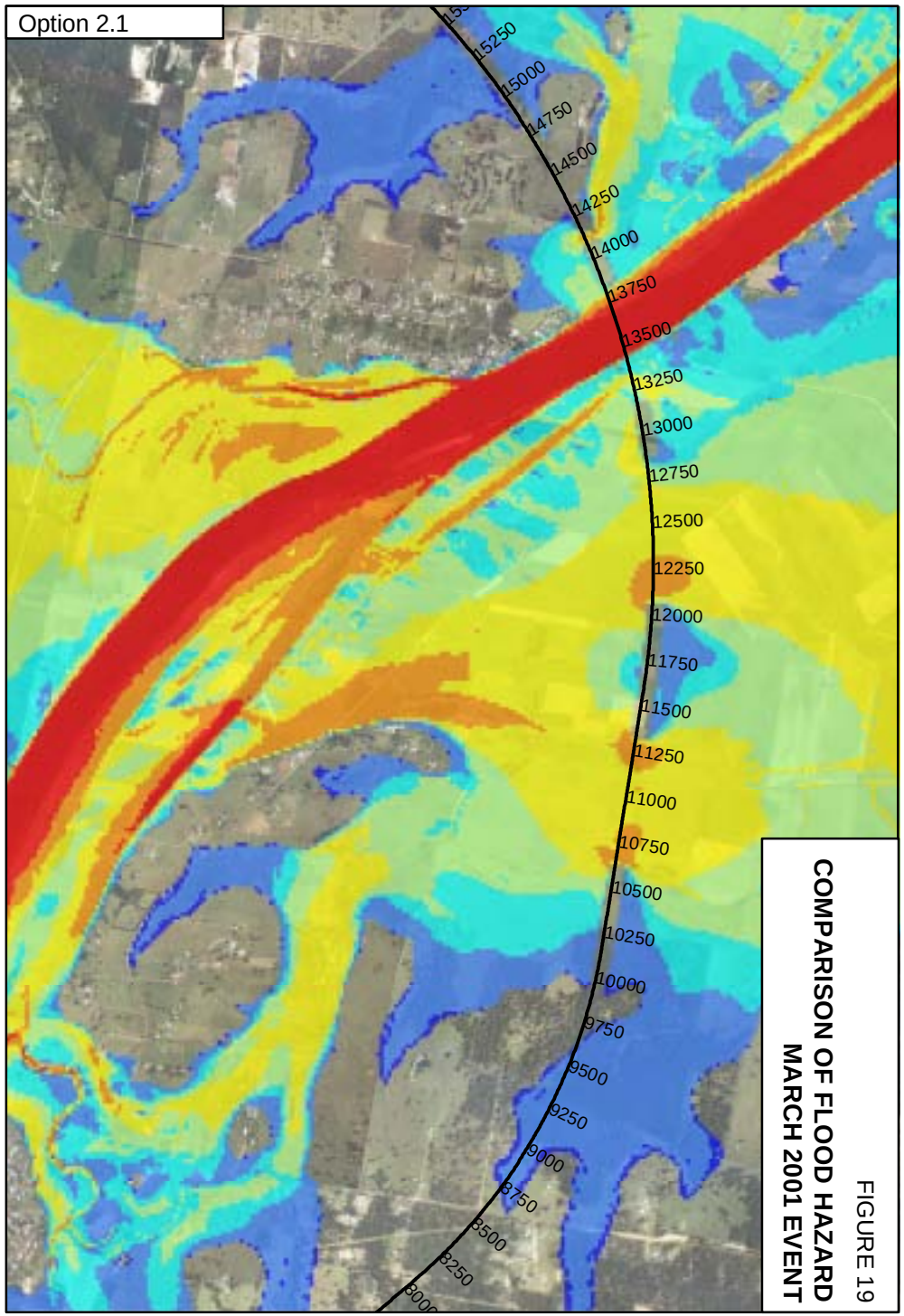
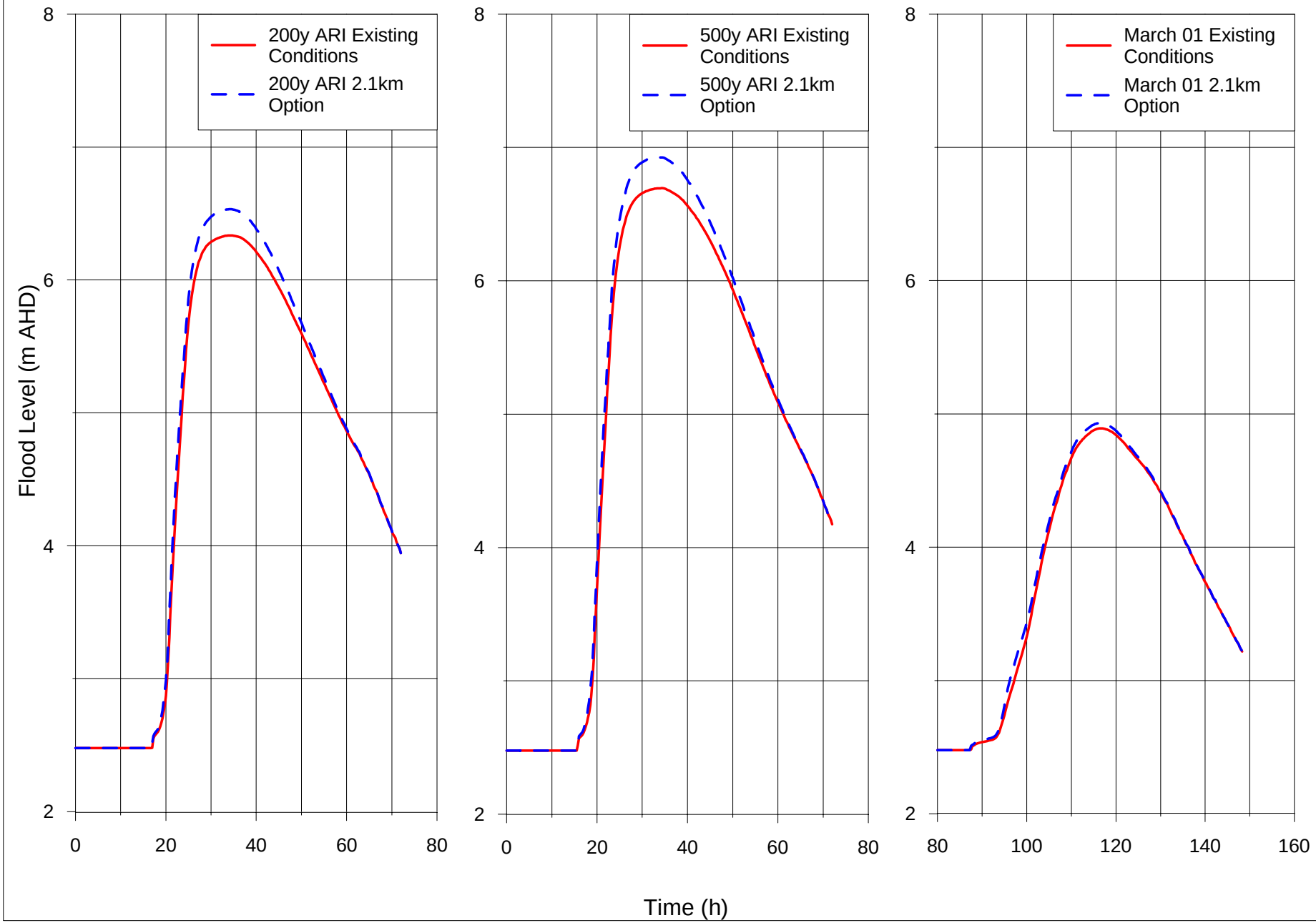


FIGURE 19

COMPARISON OF FLOOD HAZARD MARCH 2001 EVENT



STAGE HYDROGRAPHS
SOUTH WEST ROCKS ROAD AT RED HILL LANE
200 YEAR ARI, 500 YEAR ARI AND MARCH 2001 EVENTS

FIGURE 20

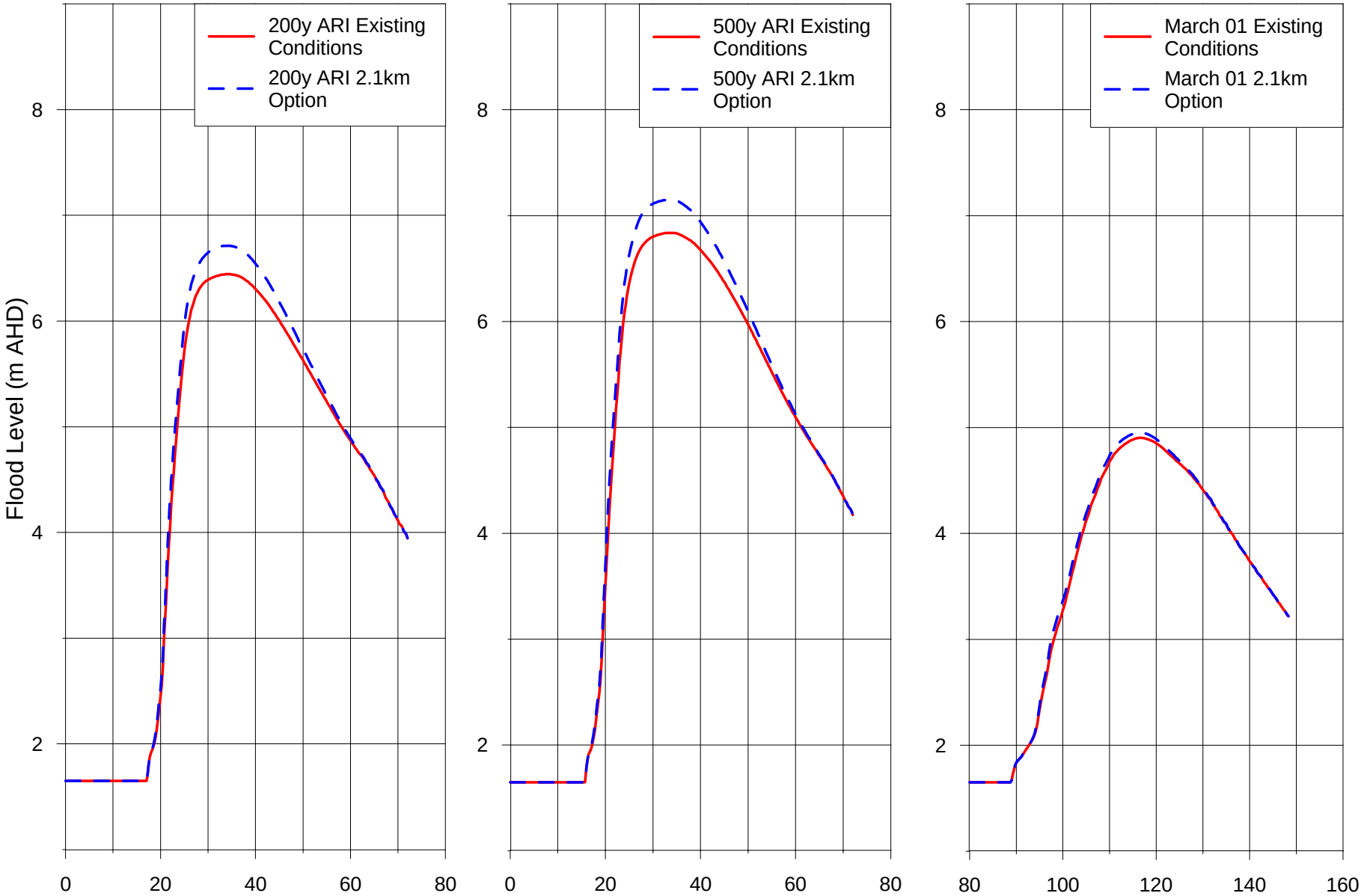
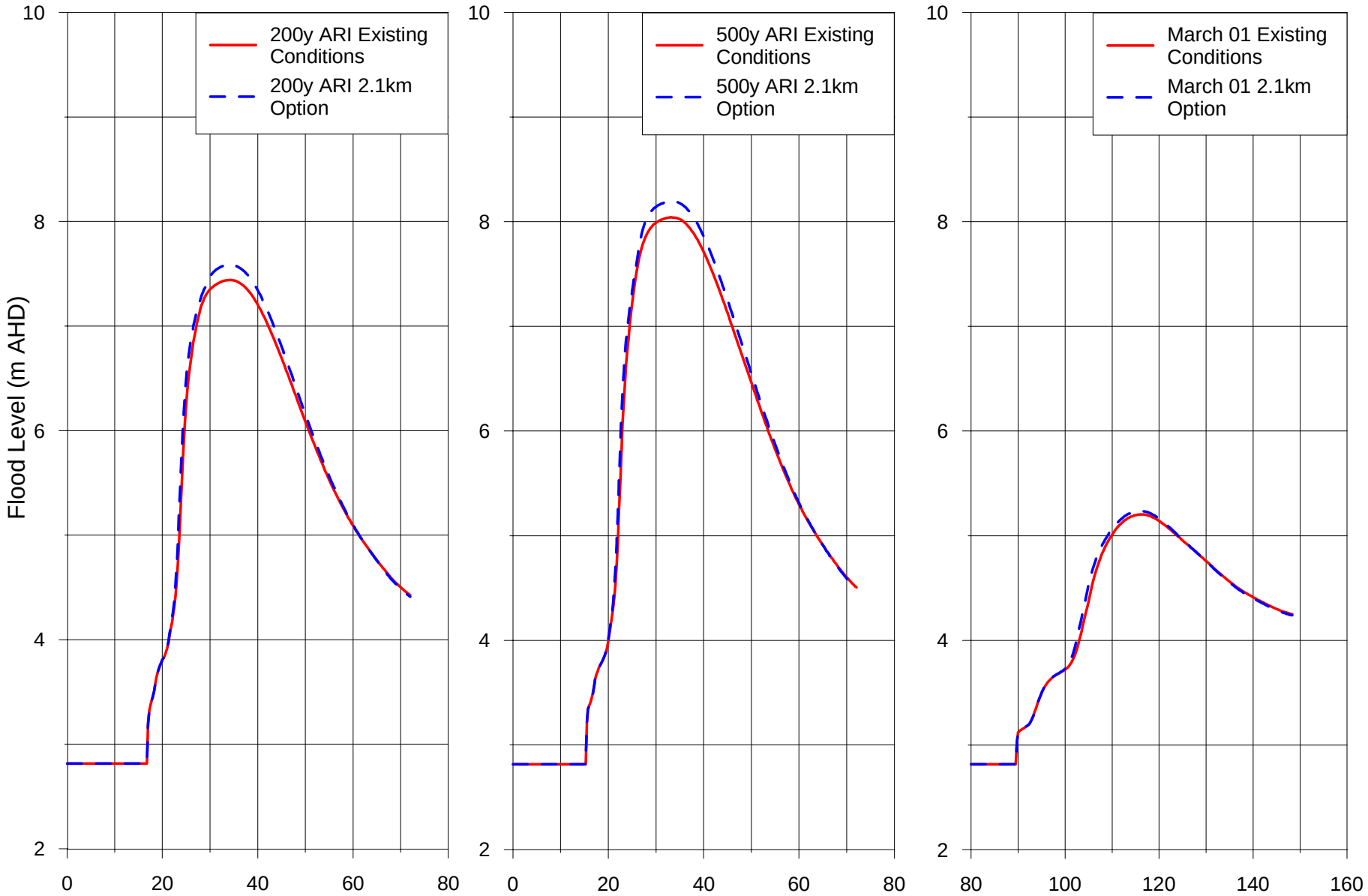


FIGURE 21

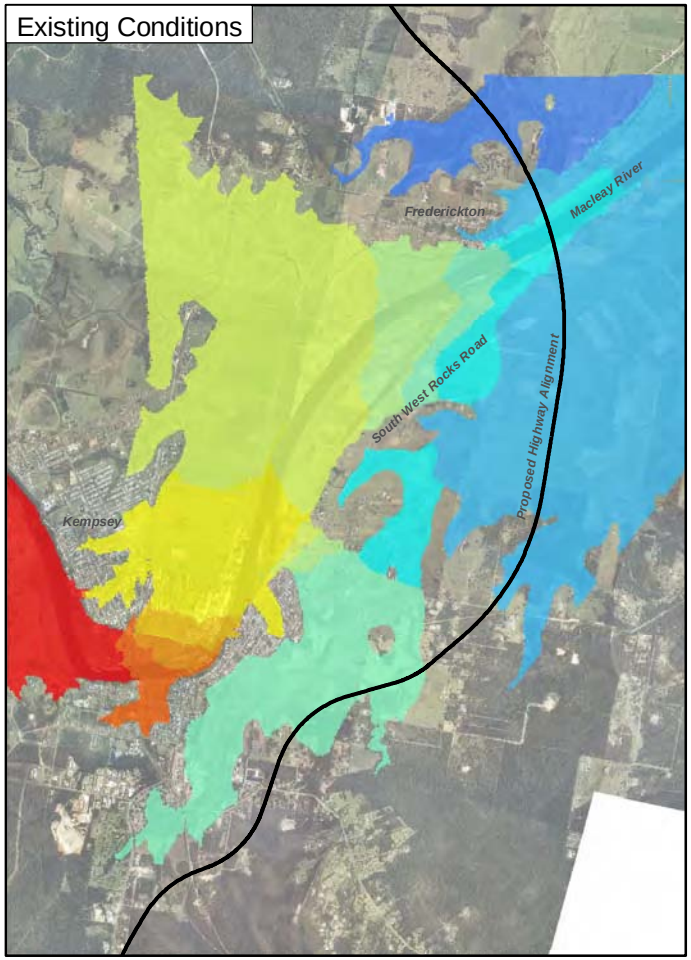
STAGE HYDROGRAPHS FROGMORE

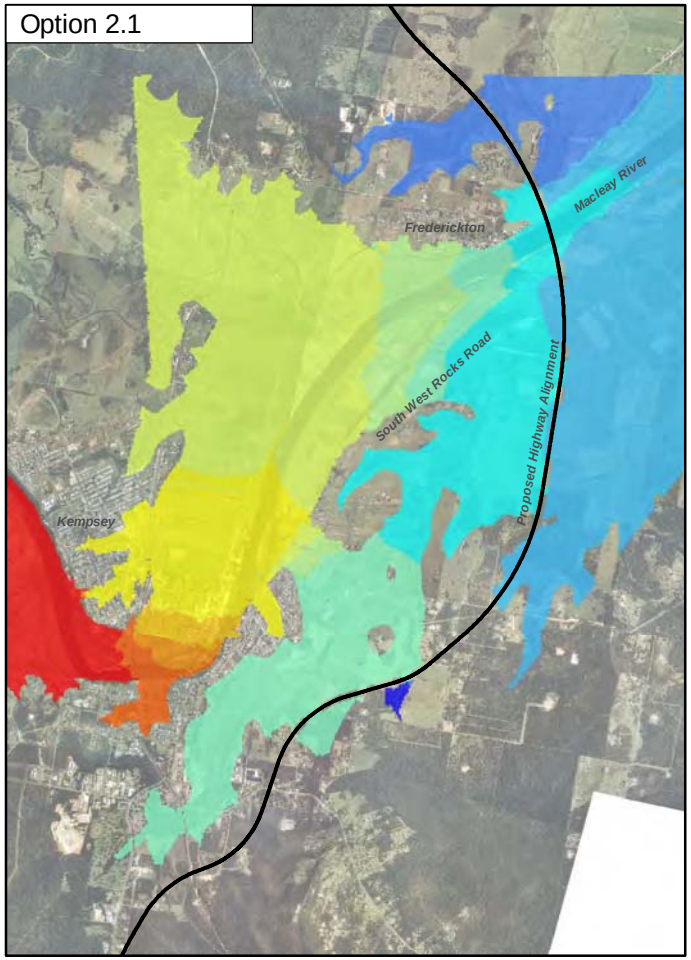
200 YEAR ARI, 500 YEAR ARI AND MARCH 2001 EVENTS

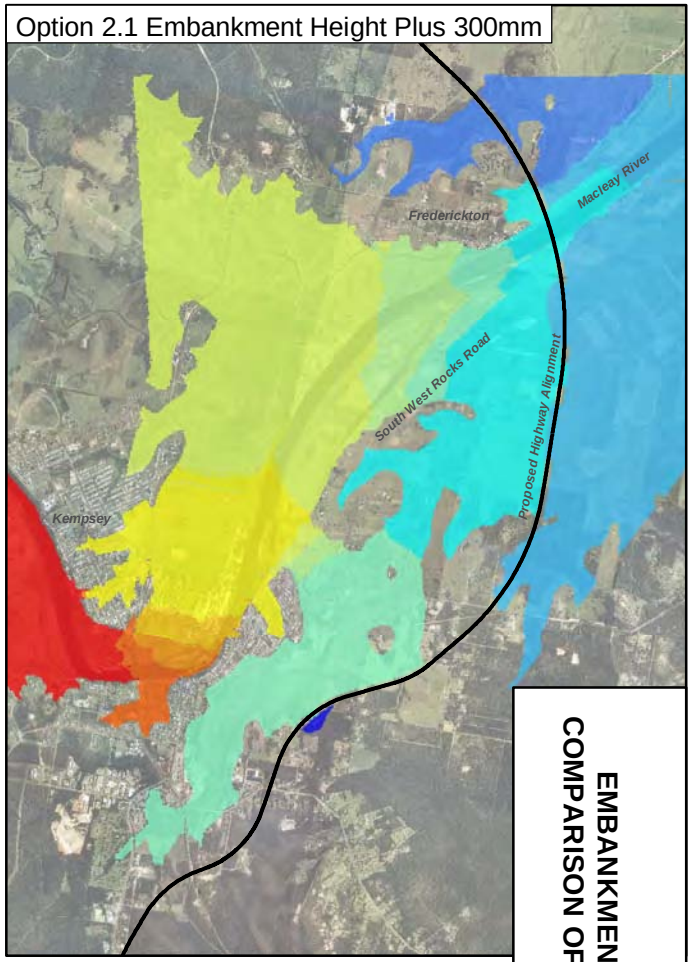


STAGE HYDROGRAPHS
EAST KEMPSEY WETLANDS
200 YEAR ARI, 500 YEAR ARI AND MARCH 2001 EVENTS

FIGURE 22







Flood Levels (m AHD)

<4.5	7.01 - 7.5
4.51 - 5	7.51 - 8
5.01 - 5.5	8.01 - 8.5
5.51 - 6	8.51 - 9
6.01 - 6.5	9.01 - 9.5
6.51 - 7	9.51 - 10
	>10

FIGURE 23

EMBANKMENT HEIGHT SENSITIVITY
COMPARISON OF PEAK FLOOD LEVELS
100 YEAR ARI EVENT

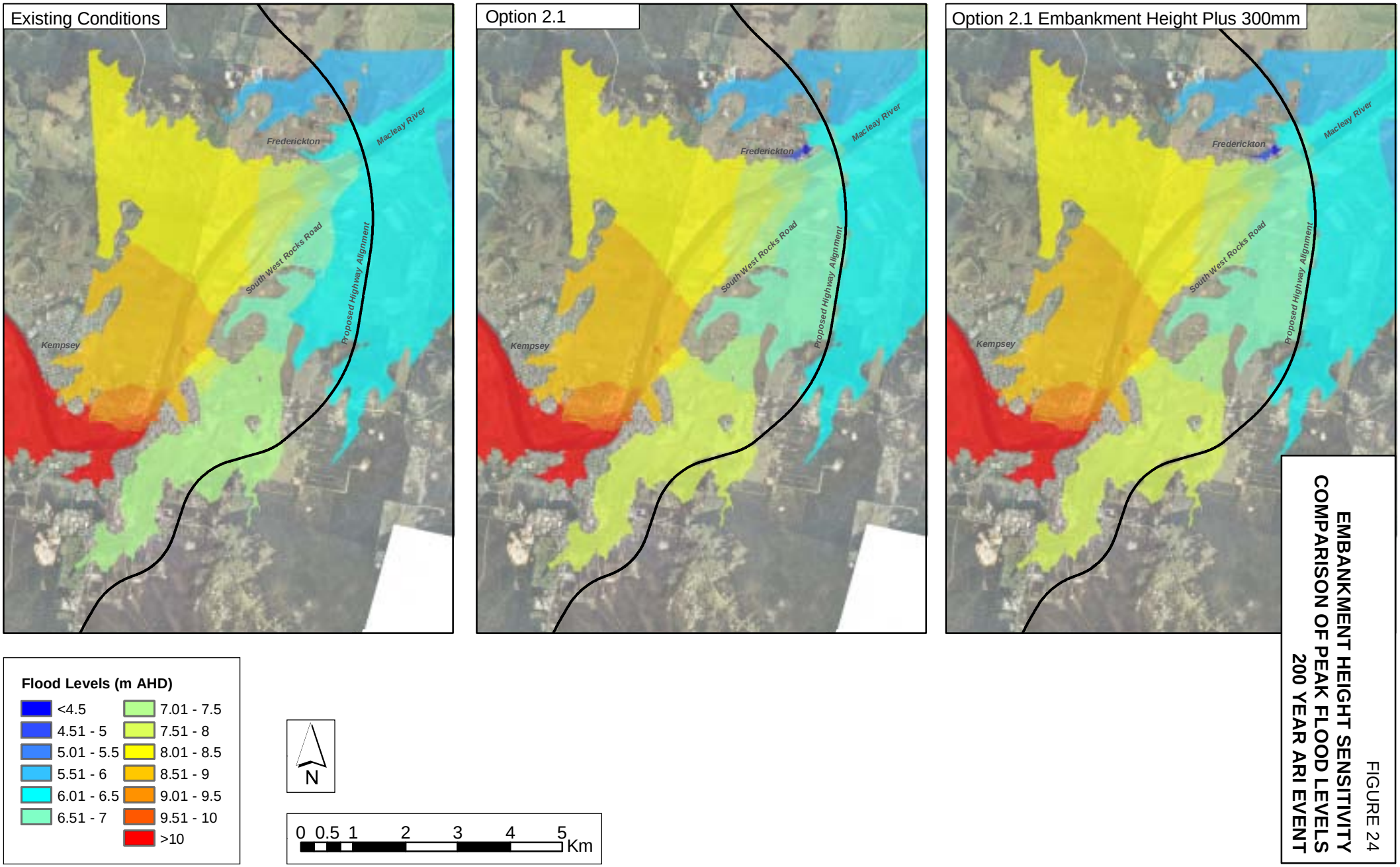
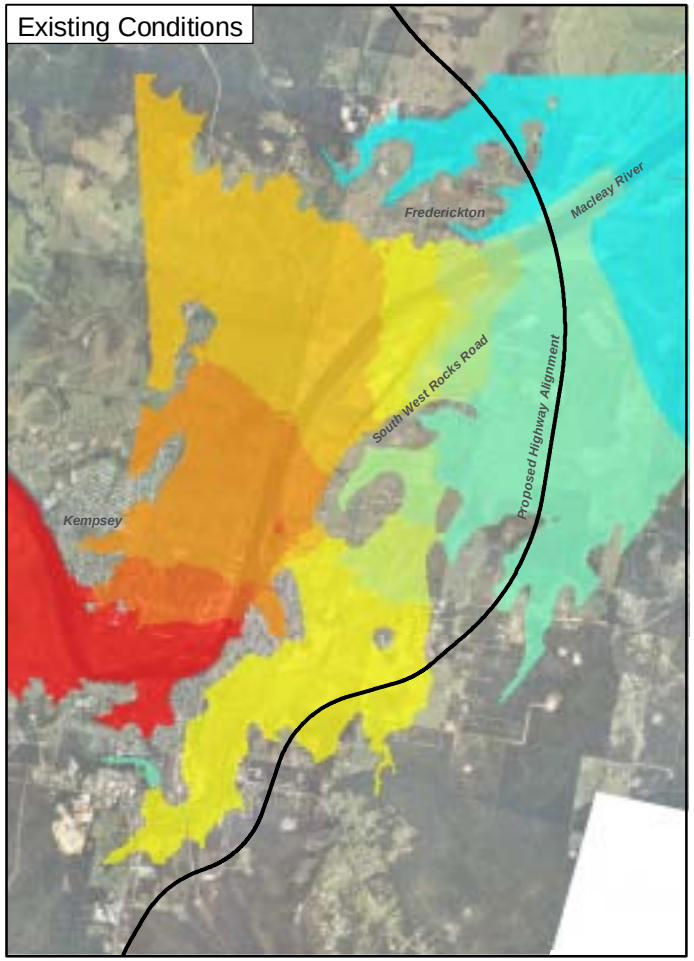
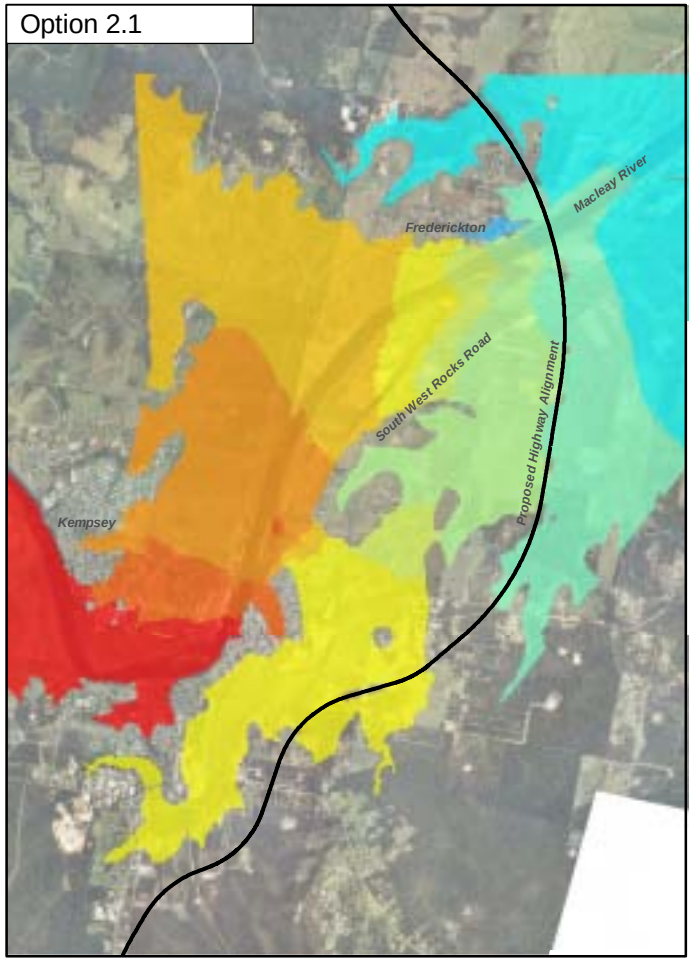
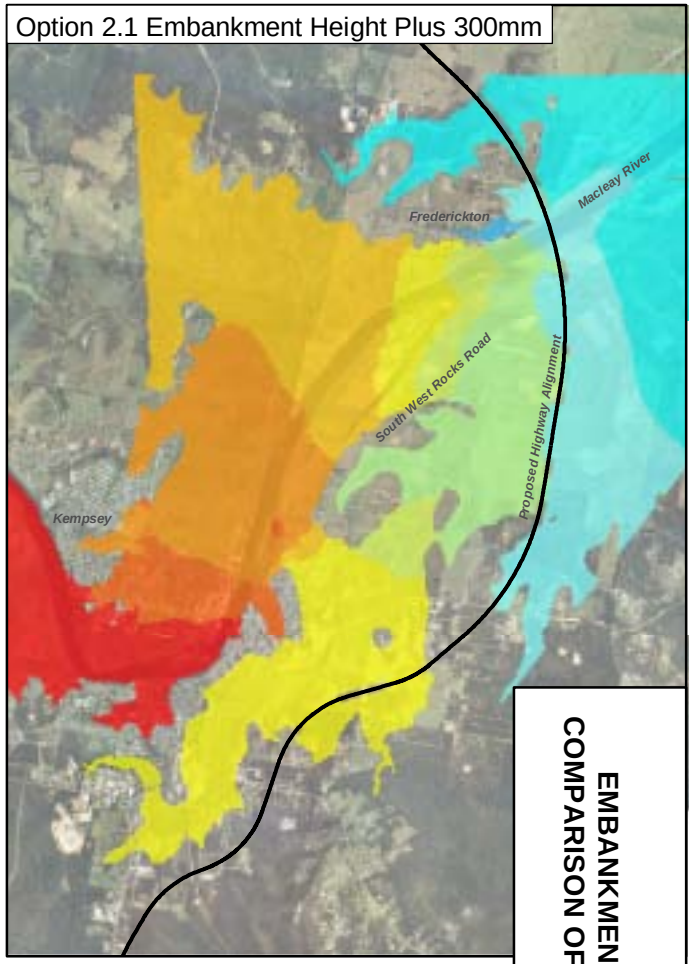


FIGURE 24

EMBANKMENT HEIGHT SENSITIVITY
COMPARISON OF PEAK FLOOD LEVELS
200 YEAR ARI EVENT







Flood Levels (m AHD)

<6	8.01 - 8.5
6.01 - 6.5	8.51 - 9
6.51 - 7	9.01 - 9.5
7.01 - 7.5	9.51 - 10
7.51 - 8	>10

N

0 0.5 1 2 3 4 5 Km

FIGURE 25

EMBANKMENT HEIGHT SENSITIVITY
COMPARISON OF PEAK FLOOD LEVELS
500 YEAR ARI EVENT

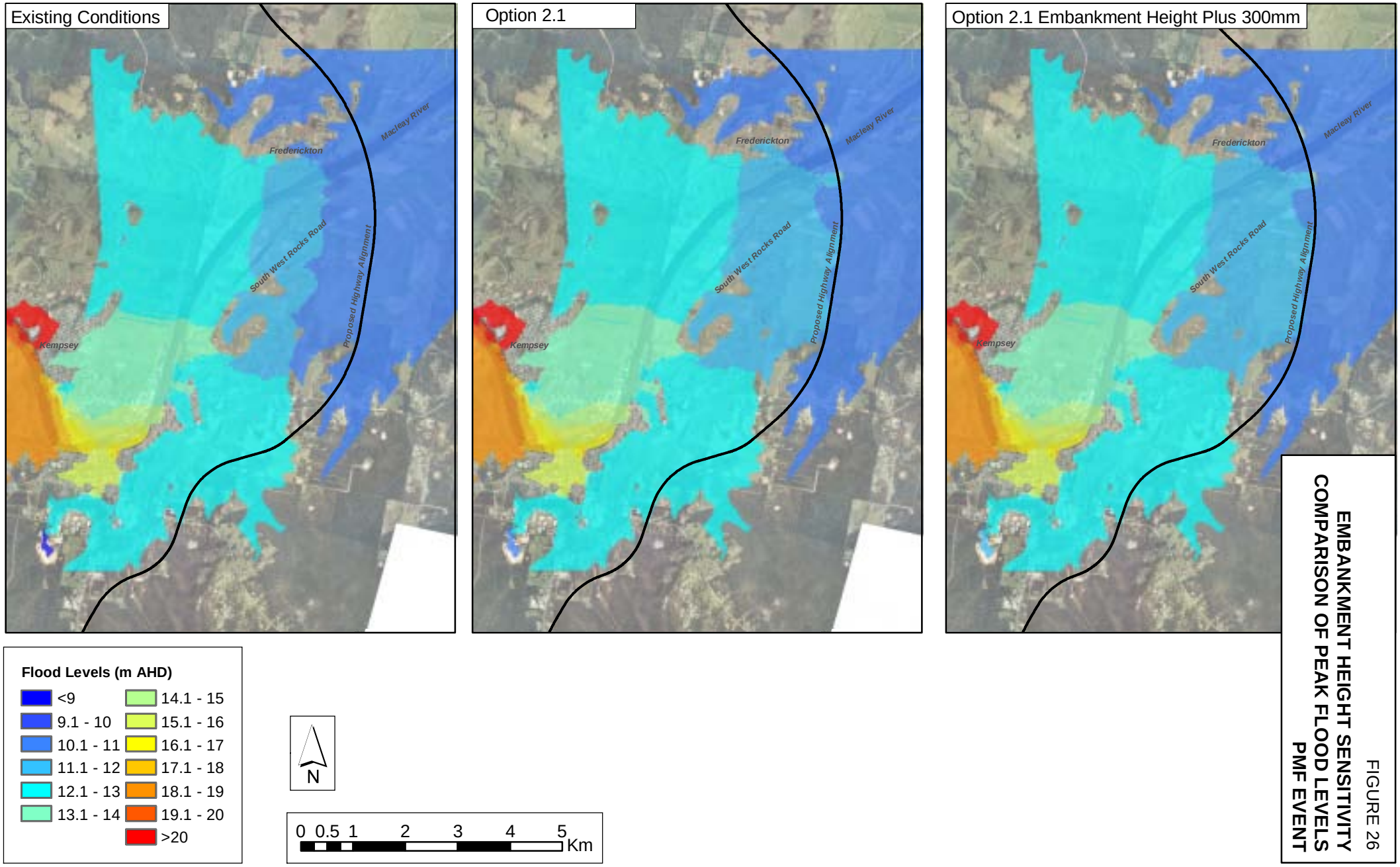
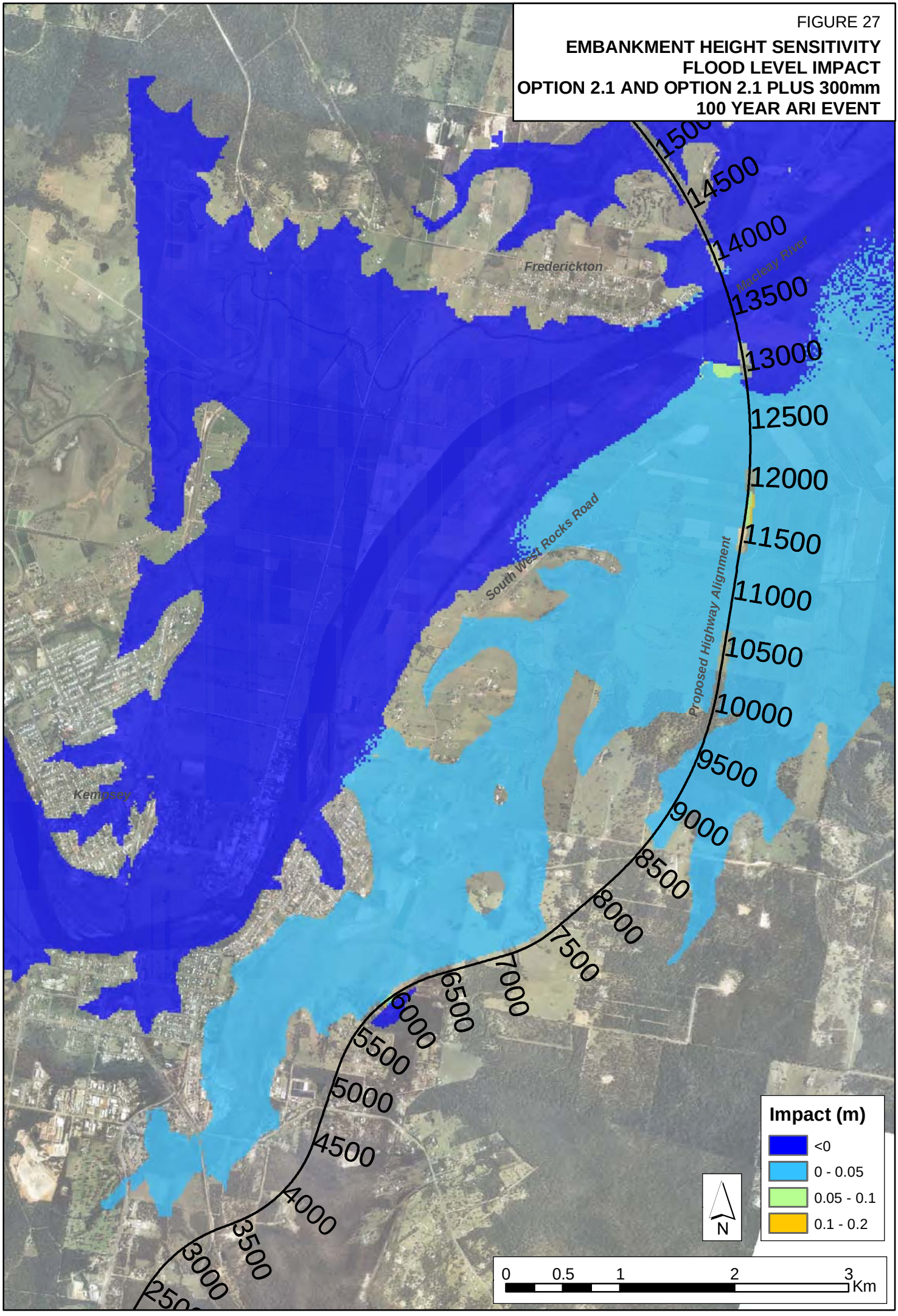


FIGURE 26

EMBANKMENT HEIGHT SENSITIVITY
COMPARISON OF PEAK FLOOD LEVELS
PMF EVENT

FIGURE 27

EMBANKMENT HEIGHT SENSITIVITY
FLOOD LEVEL IMPACT
OPTION 2.1 AND OPTION 2.1 PLUS 300mm
100 YEAR ARI EVENT



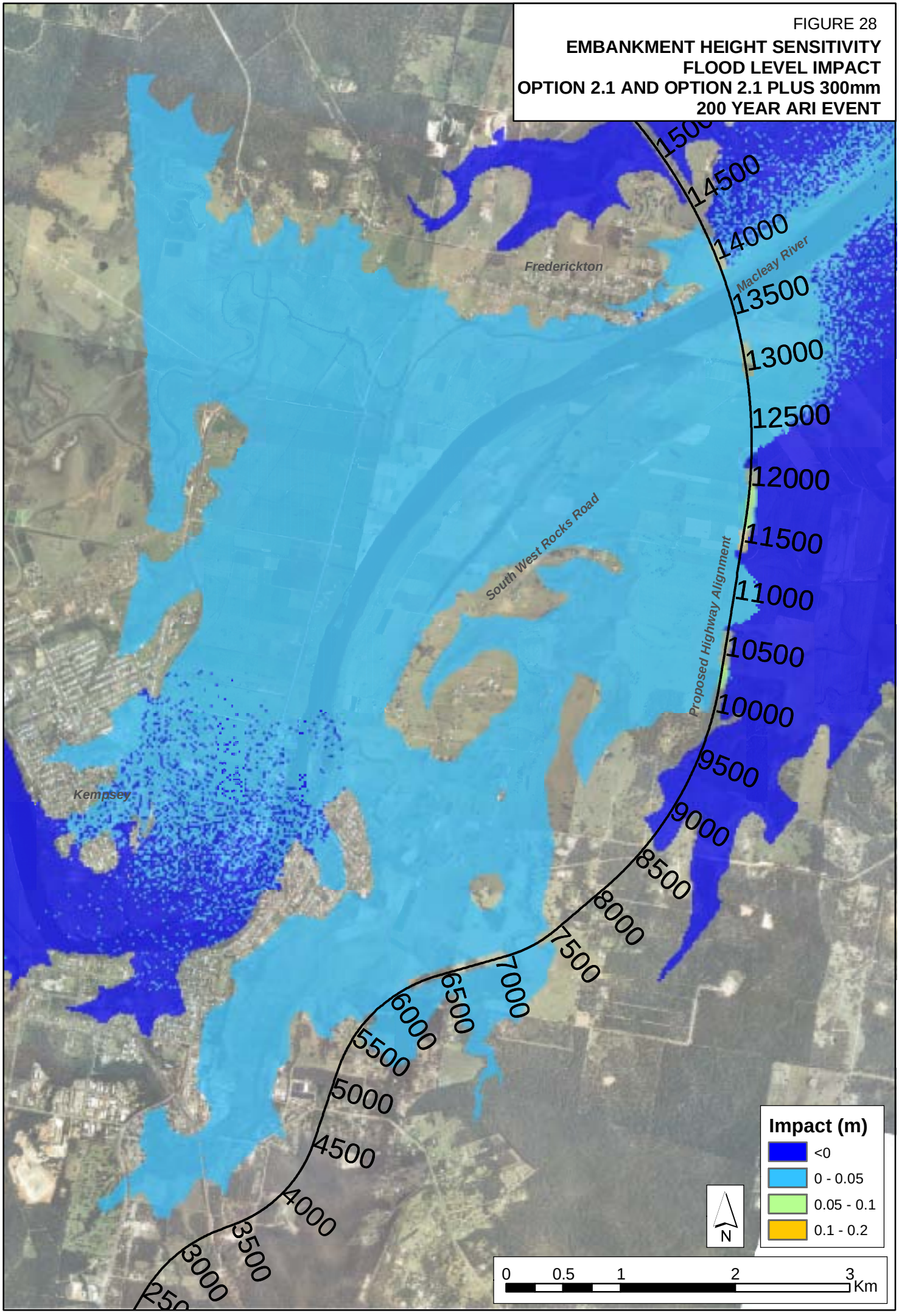


FIGURE 28
EMBANKMENT HEIGHT SENSITIVITY
FLOOD LEVEL IMPACT
OPTION 2.1 AND OPTION 2.1 PLUS 300mm
200 YEAR ARI EVENT
Fredericton
Macleay River
South West Rocks Road
Proposed Highway Alignment
Kempsey
15000
14500
14000
13500
13000
12500
12000
11500
11000
10500
10000
9500
9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
Impact (m)
<0
0 - 0.05
0.05 - 0.1
0.1 - 0.2
N
0
0.5
1
2
3
Km

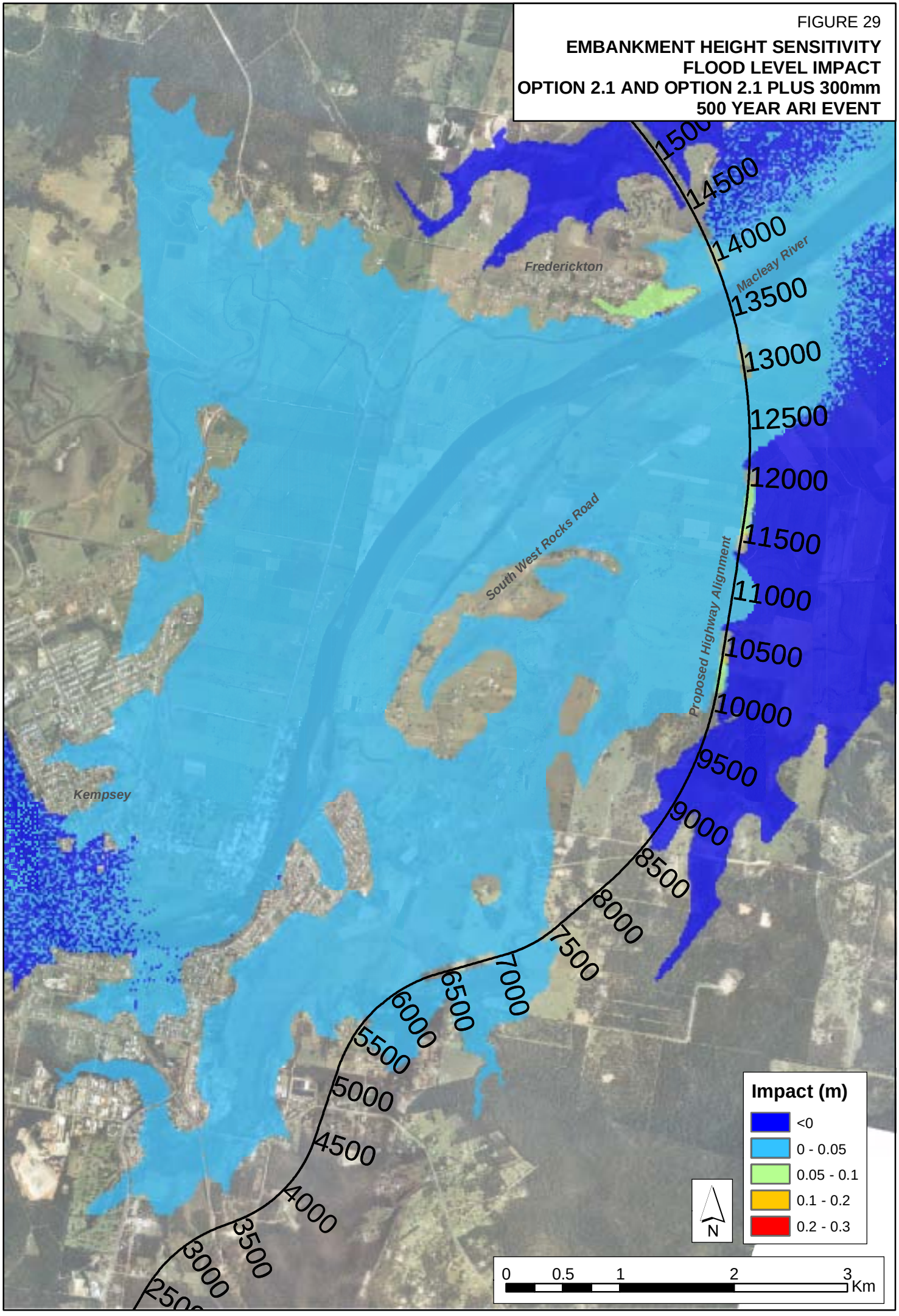


FIGURE 29
EMBANKMENT HEIGHT SENSITIVITY
FLOOD LEVEL IMPACT
OPTION 2.1 AND OPTION 2.1 PLUS 300mm
500 YEAR ARI EVENT
Fredericton
Macleay River
South West Rocks Road
Proposed Highway Alignment
Kempsey
15000
14500
14000
13500
13000
12500
12000
11500
11000
10500
10000
9500
9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
Impact (m)
<0
0 - 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
N
0
0.5
1
2
3
Km

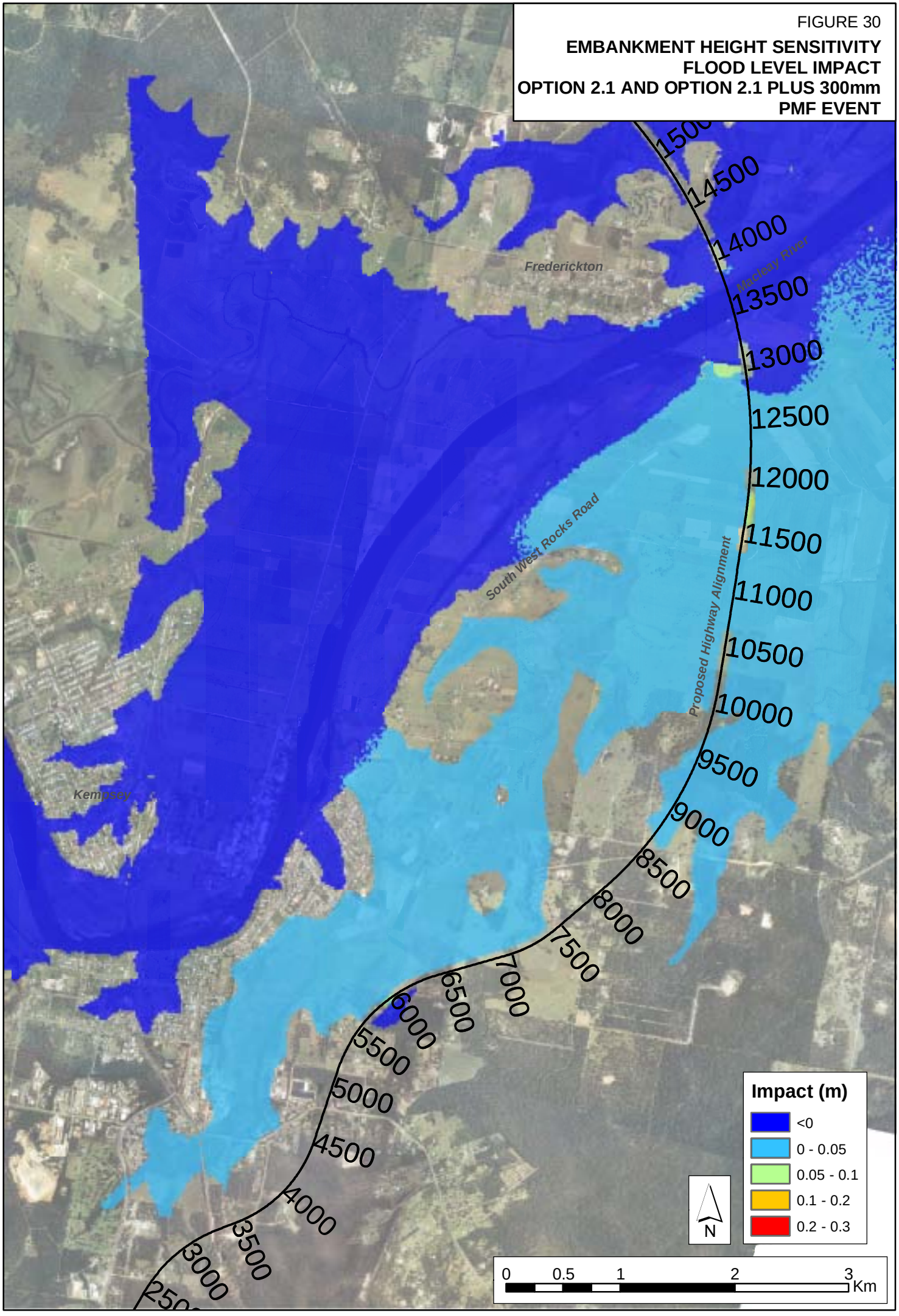
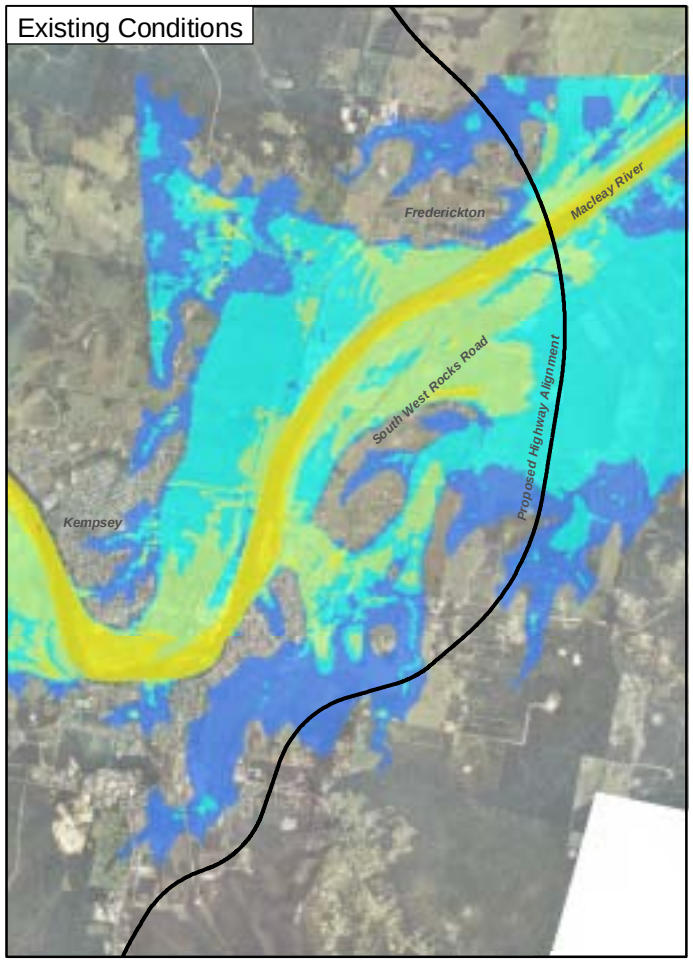
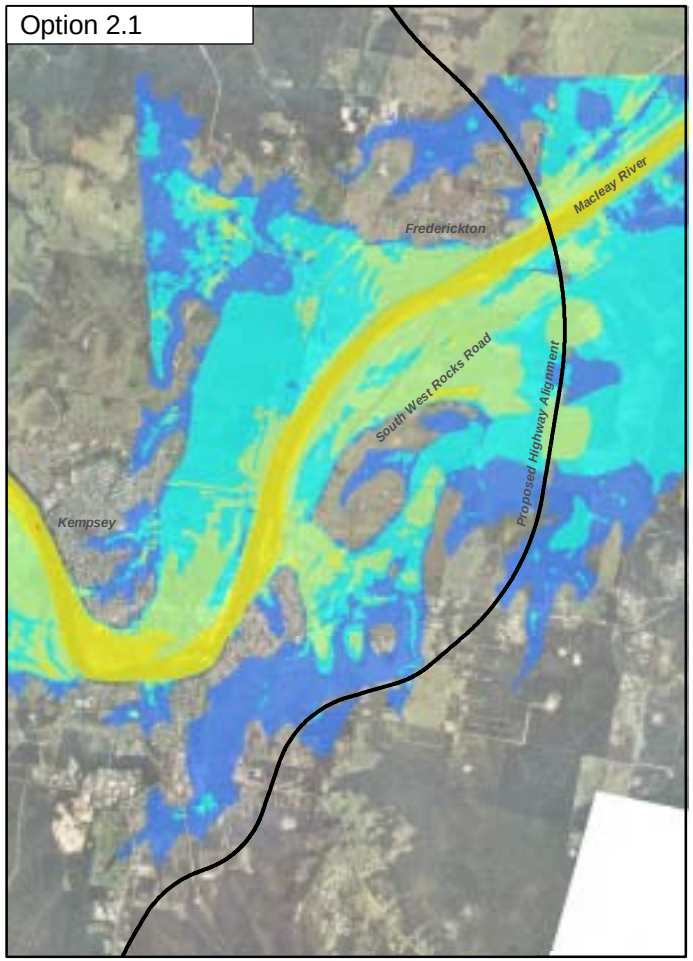
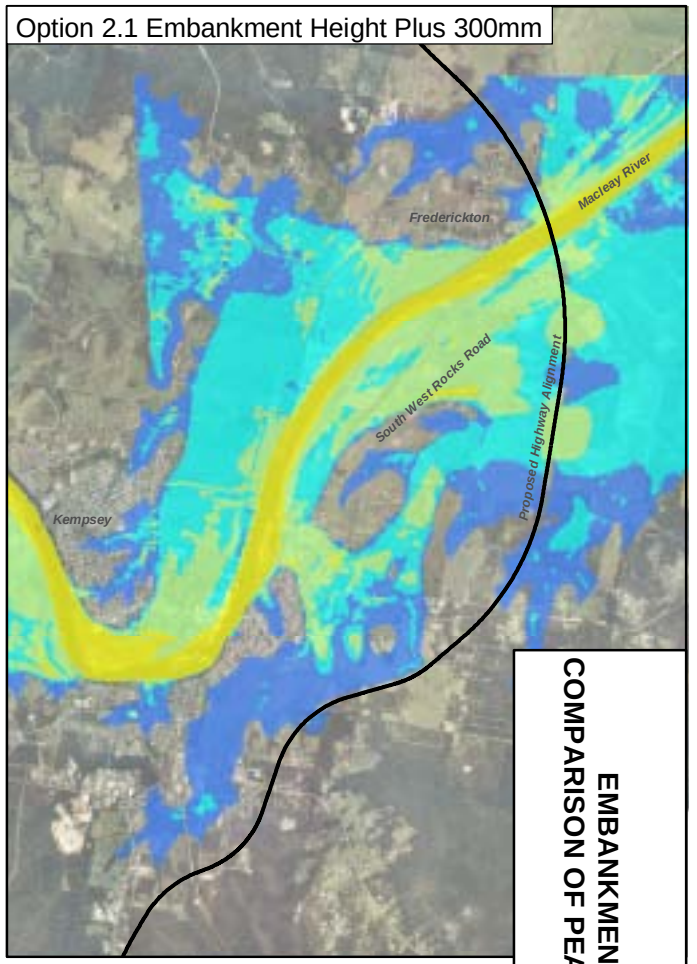


FIGURE 30
EMBANKMENT HEIGHT SENSITIVITY
FLOOD LEVEL IMPACT
OPTION 2.1 AND OPTION 2.1 PLUS 300mm
PMF EVENT
Fredericton
Macleay River
South West Rocks Road
Proposed Highway Alignment
Kempsey
15000
14500
14000
13500
13000
12500
12000
11500
11000
10500
10000
9500
9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
Impact (m)
<0
0 - 0.05
0.05 - 0.1
0.1 - 0.2
0.2 - 0.3
N
0
0.5
1
2
3
Km







Velocity (m/s)

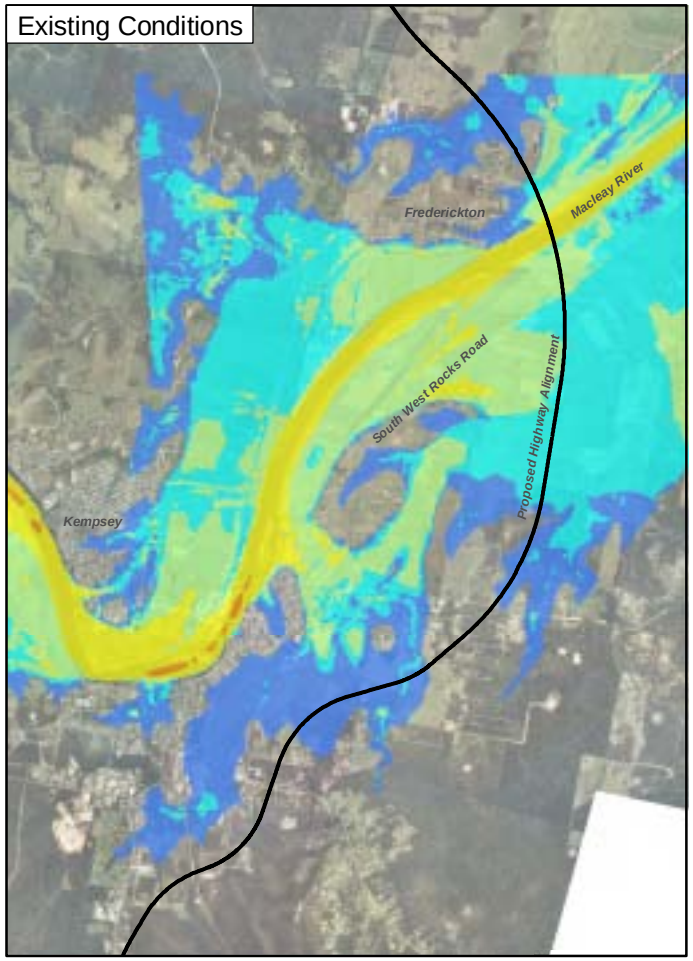
- 0
- 0 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20

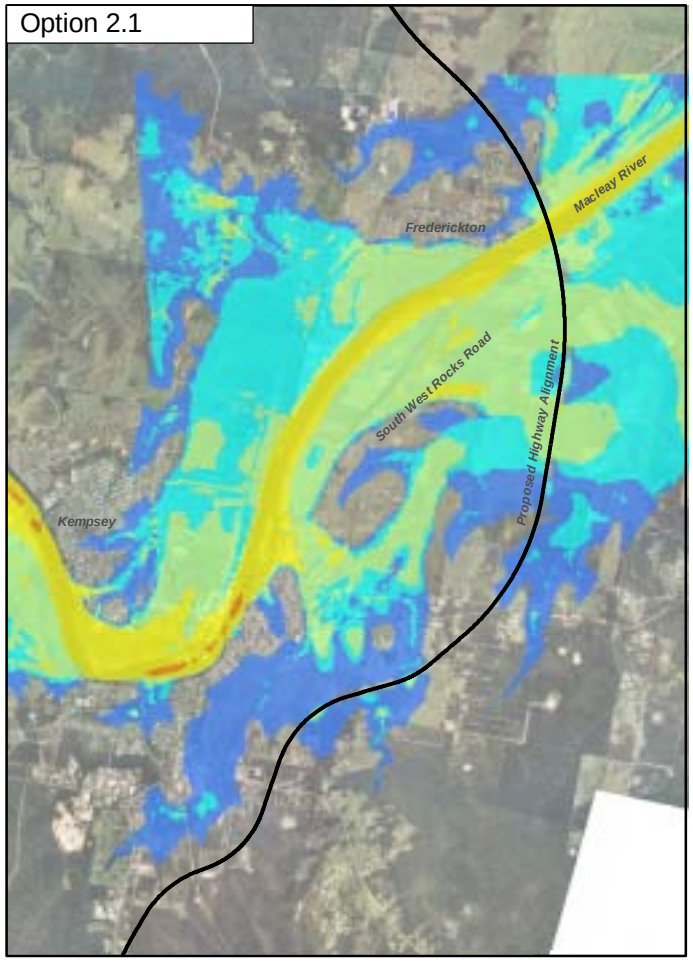
N

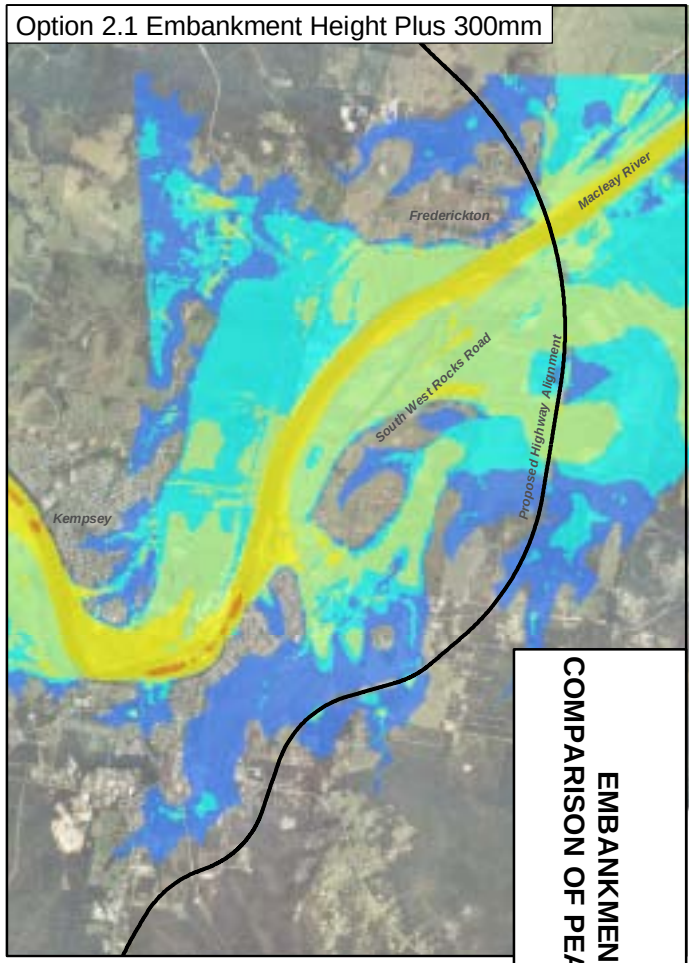
0 0.5 1 2 3 4 5 Km

FIGURE 31

EMBANKMENT HEIGHT SENSITIVITY
COMPARISON OF PEAK FLOOD VELOCITIES
100 YEAR ARI EVENT







Velocity (m/s)

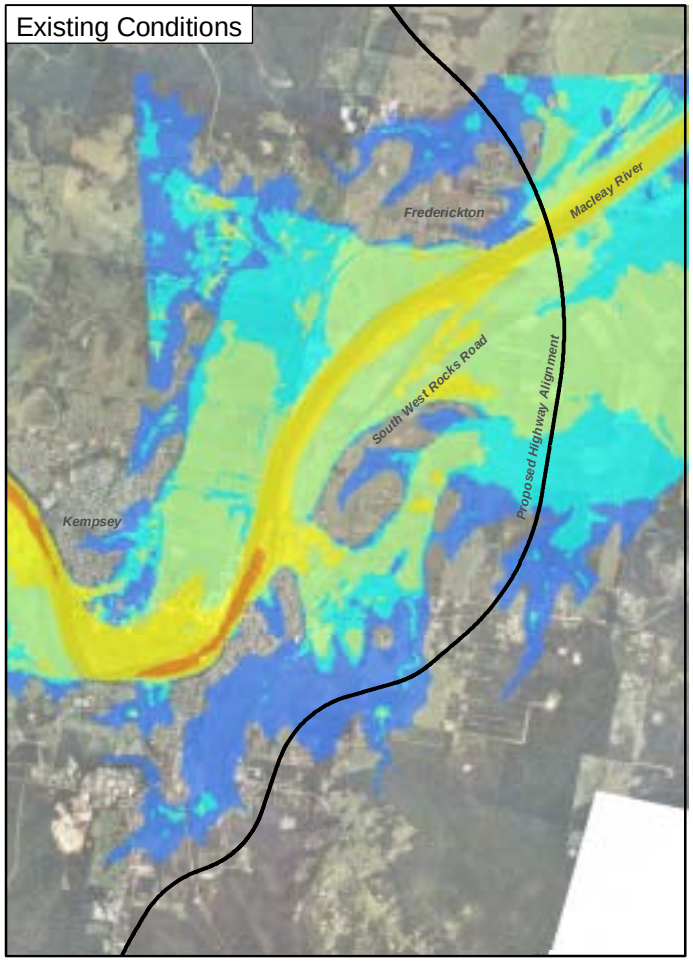
- 0
- 0 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20

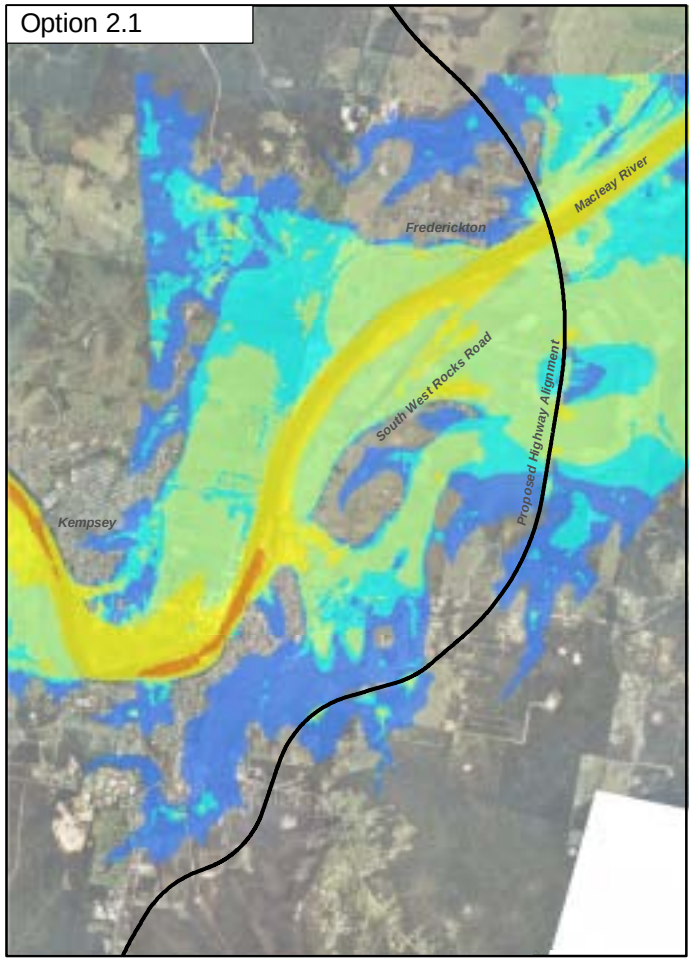
N

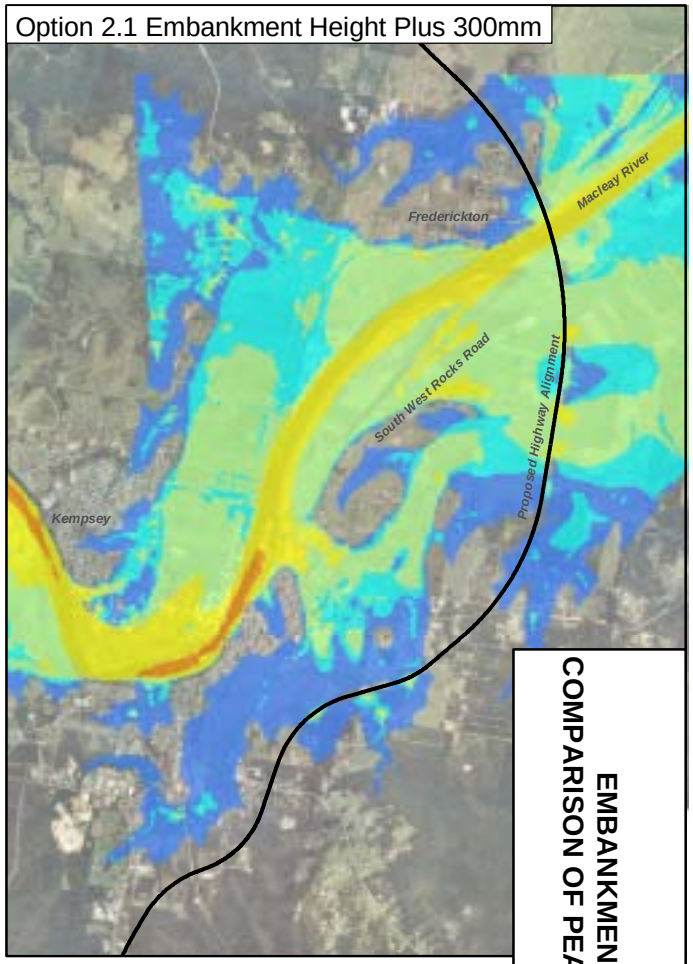
0 0.5 1 2 3 4 5 Km

FIGURE 32

EMBANKMENT HEIGHT SENSITIVITY
COMPARISON OF PEAK FLOOD VELOCITIES
200 YEAR ARI EVENT







Velocity (m/s)

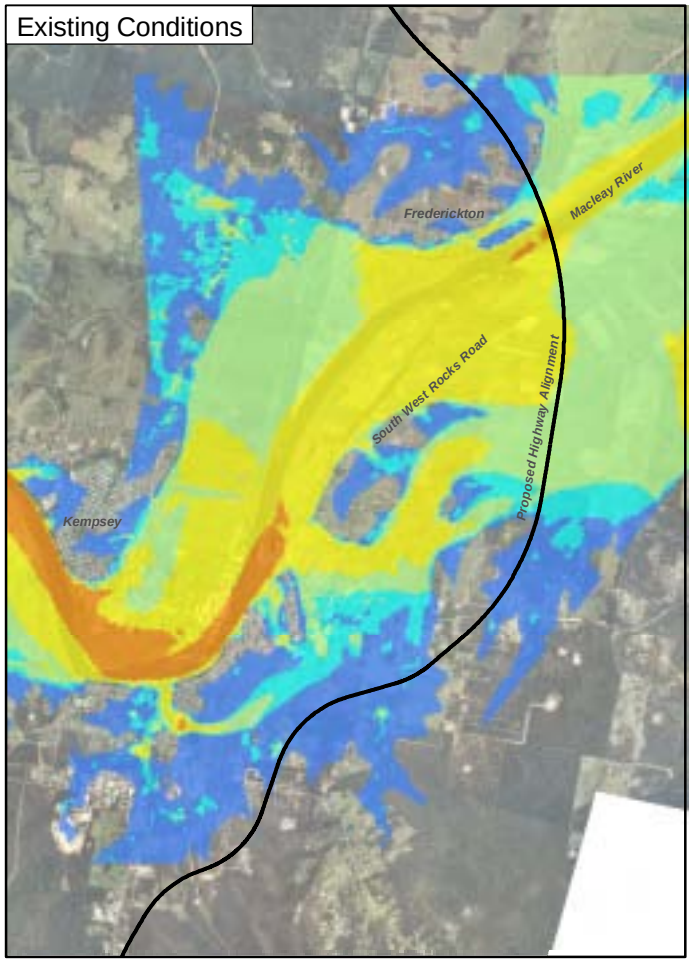
- 0
- 0 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20

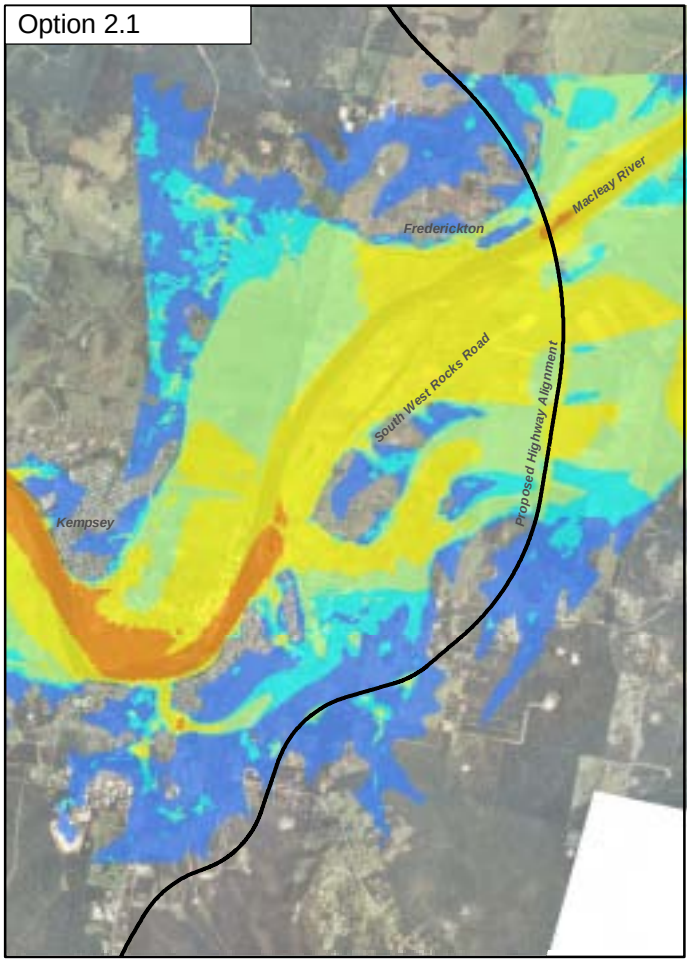
N

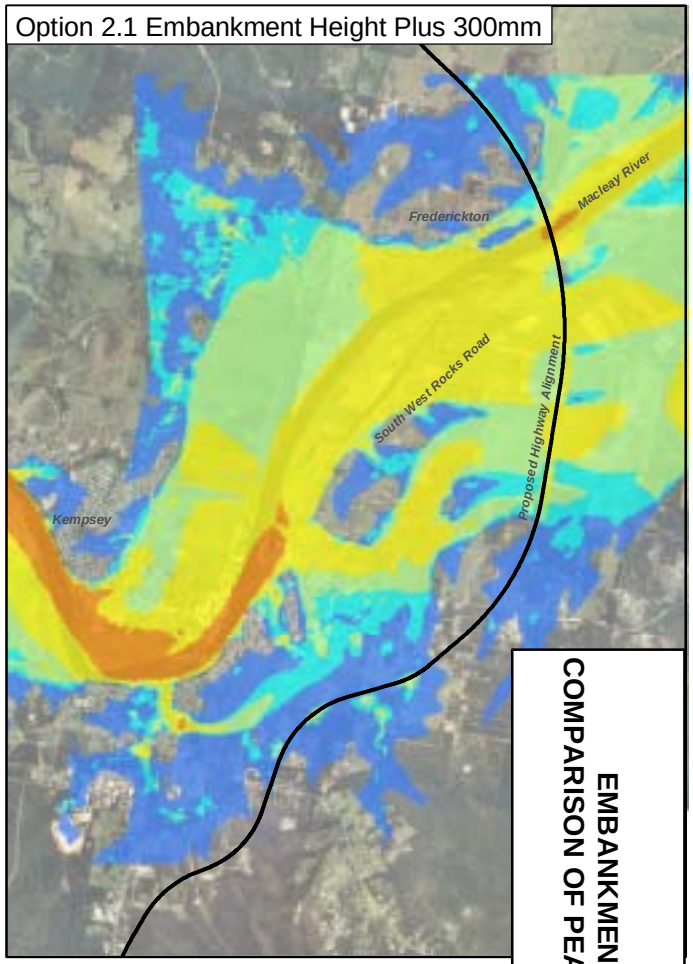
0 0.5 1 2 3 4 5 Km

FIGURE 33

EMBANKMENT HEIGHT SENSITIVITY
COMPARISON OF PEAK FLOOD VELOCITIES
500 YEAR ARI EVENT







Velocity (m/s)

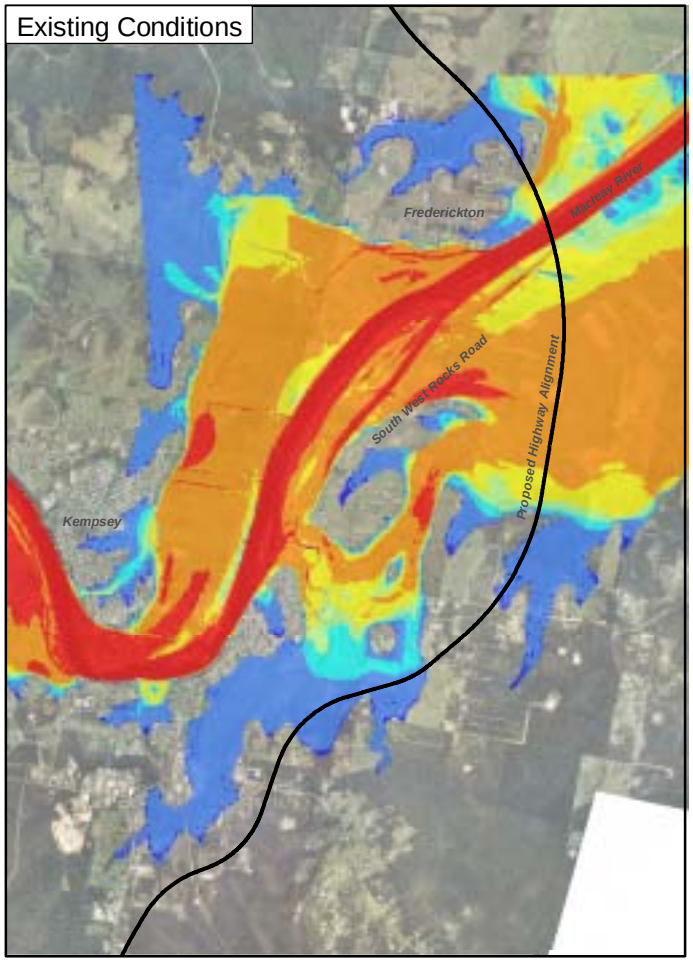
- 0
- 0 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 25

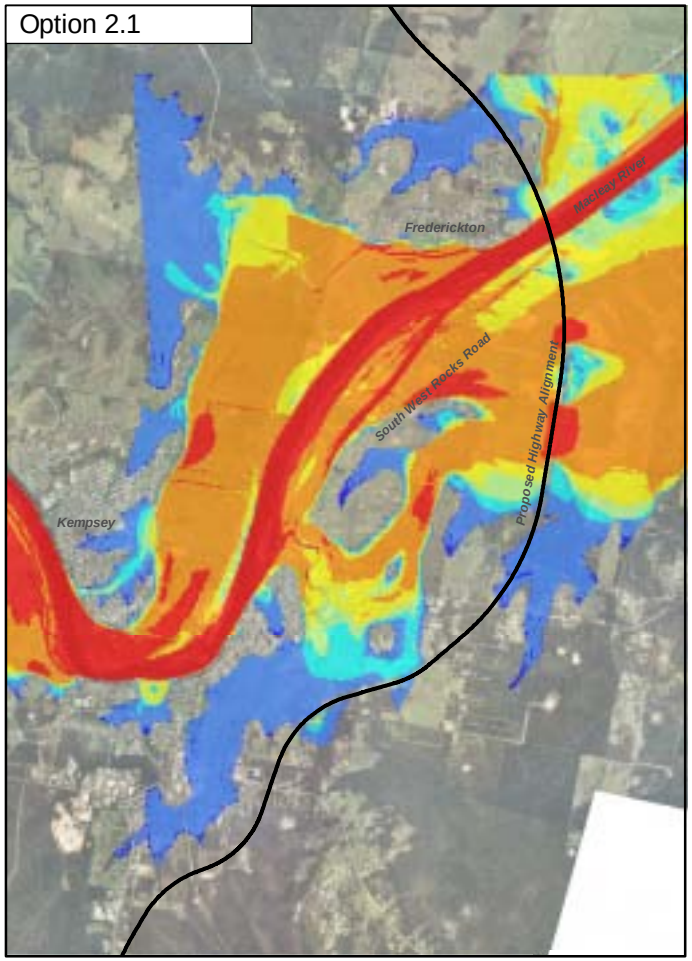
N

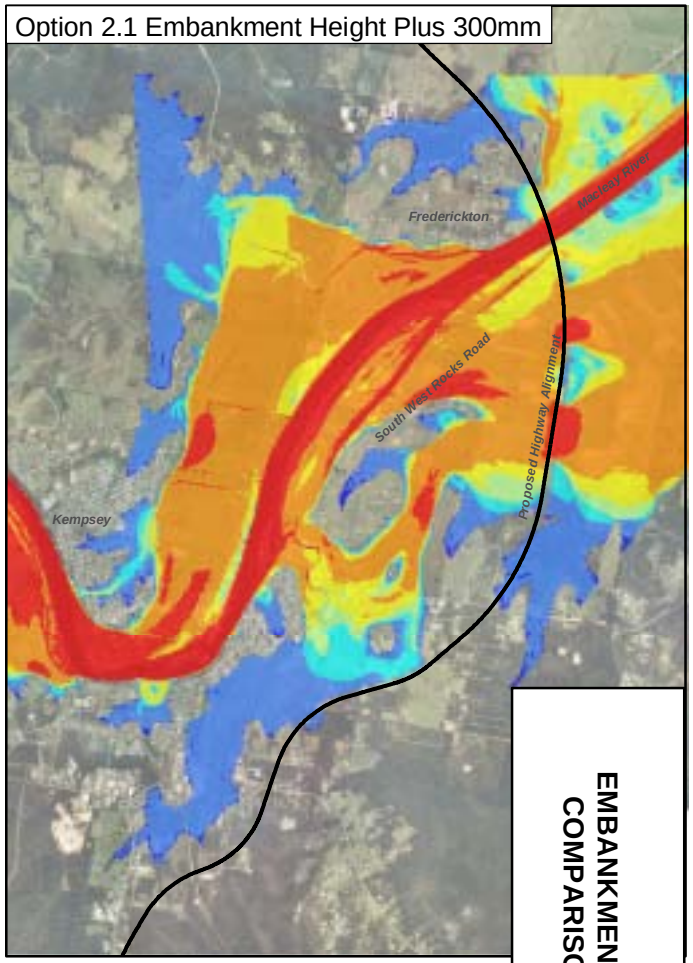
0 0.5 1 2 3 4 5 Km

FIGURE 34

EMBANKMENT HEIGHT SENSITIVITY
COMPARISON OF PEAK FLOOD VELOCITIES
PMF EVENT







Flood Hazard (m2/s)

- 0
- 0 - 0.2
- 0.2 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 5
- >5

N

0 0.5 1 2 3 4 5 Km

FIGURE 35

EMBANKMENT HEIGHT SENSITIVITY
COMPARISON OF FLOOD HAZARD
100 YEAR ARI EVENT

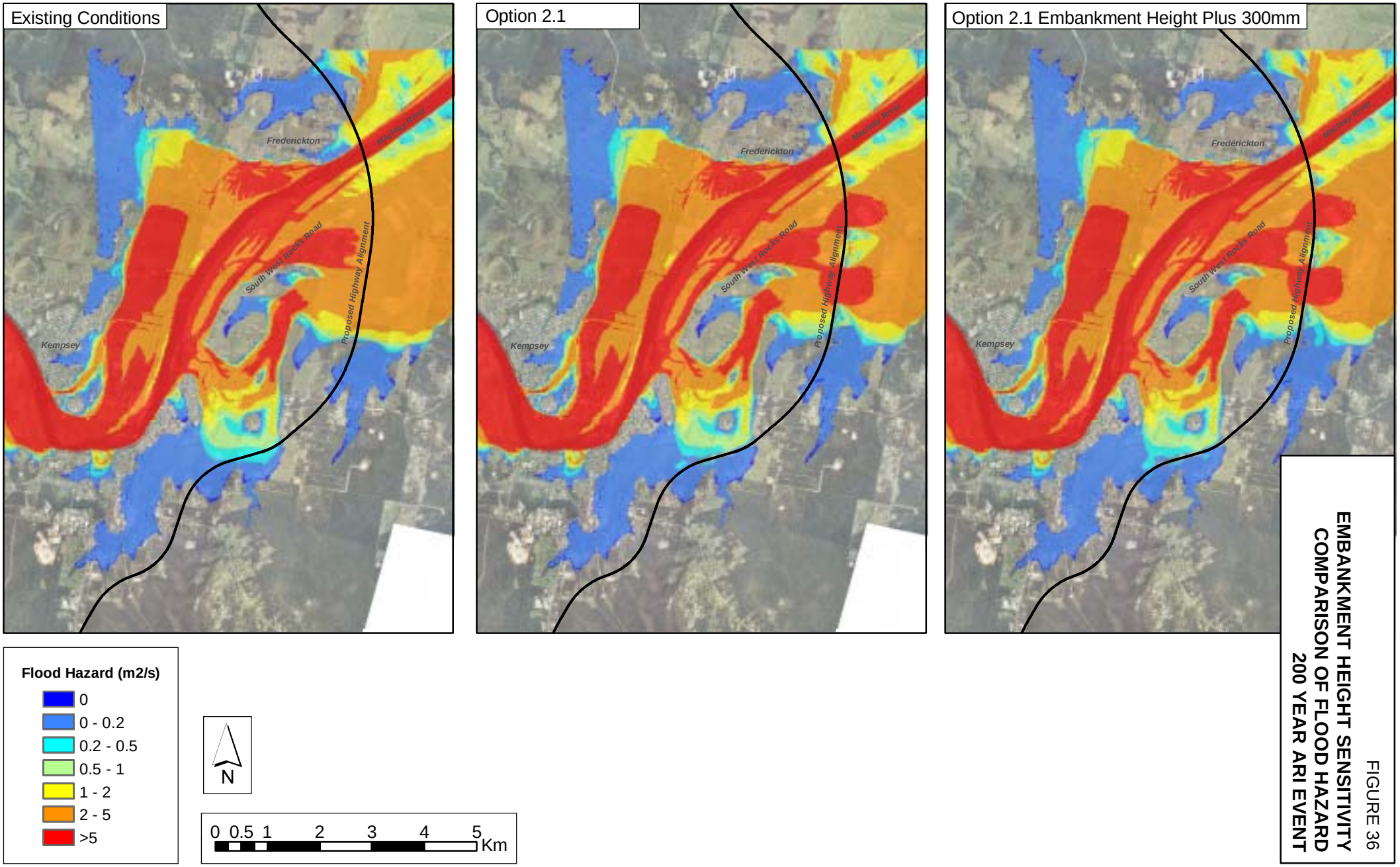
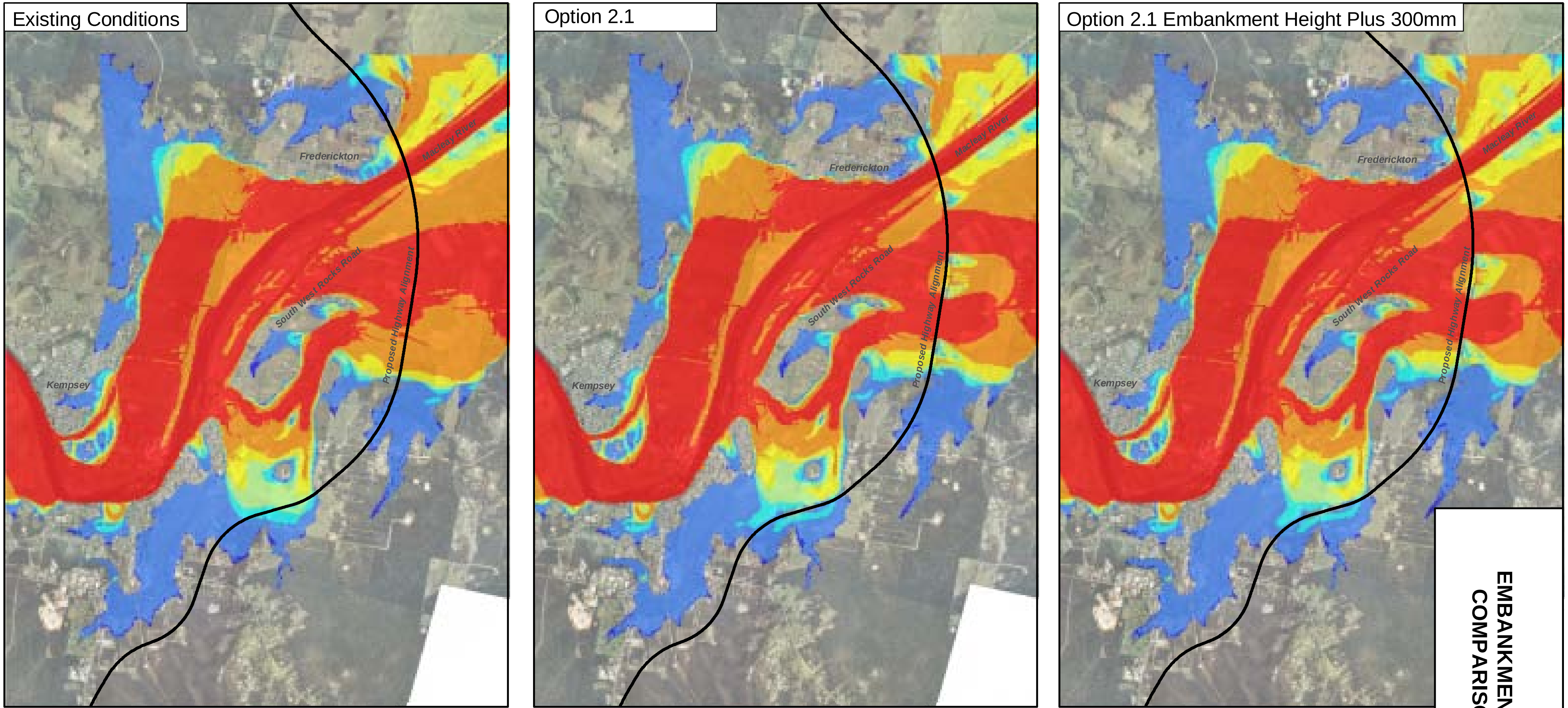


FIGURE 36

EMBANKMENT HEIGHT SENSITIVITY
COMPARISON OF FLOOD HAZARD
200 YEAR ARI EVENT



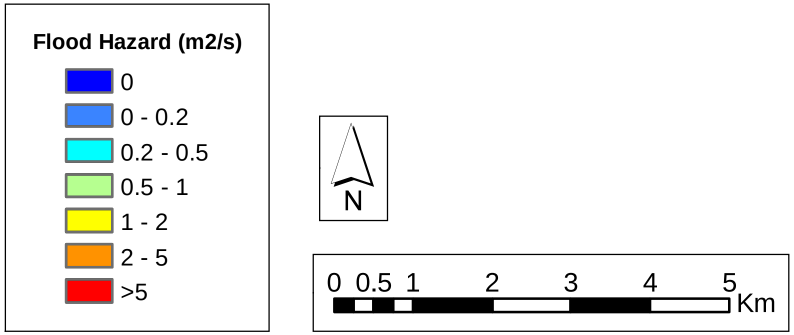


FIGURE 37

EMBANKMENT HEIGHT SENSITIVITY
COMPARISON OF FLOOD HAZARD
500 YEAR ARI EVENT

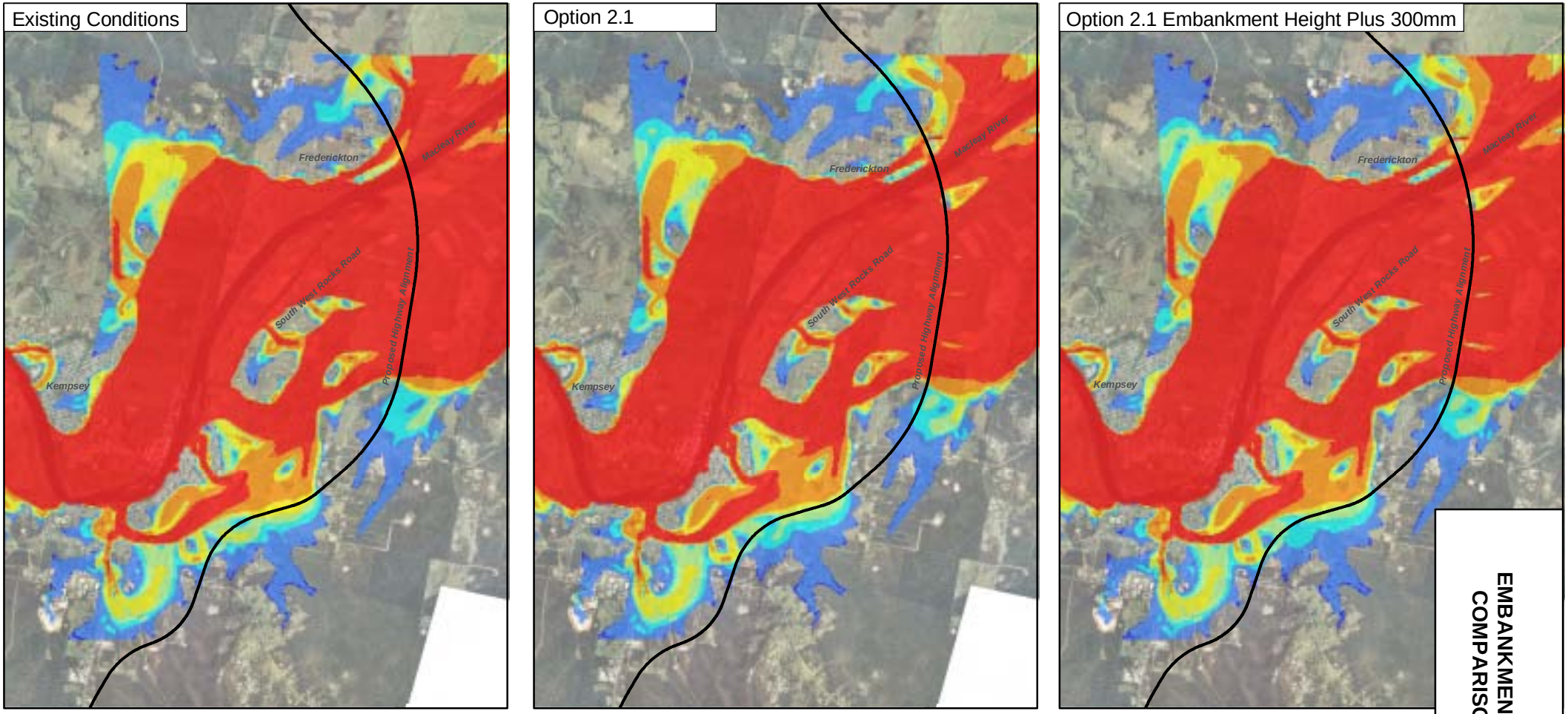


FIGURE 38

EMBANKMENT HEIGHT SENSITIVITY
COMPARISON OF FLOOD HAZARD
PMF EVENT