BLACKADDER CREEK SAFETY WORKS

Flood mitigation options assessment

JULY 2014

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Roads and Maritime Services requested Jacobs SKM to assess potential mitigation options to reduce the current impact of the Blackadder Creek Safety Works (BCSW) on the flood behaviour of the Corindi River floodplain. This report documents the findings of these assessments.

The Corindi River has a catchment area of approximately 83km^2 and is located in north-east New South Wales, approximately 35km north of Coffs Harbour. The current Pacific Highway alignment crosses the Corindi River slightly upstream of low density residential areas in Corindi Beach and along Corindi Park Drive. Approximately 800m further north, the current Pacific Highway crosses Blackadder Creek and then Cassons Creek a further 1km north.

In 2011, Roads and Maritime undertook upgrades to the existing Pacific Highway to improve the safety in the vicinity of Blackadder Creek. Amongst other changes, the Pacific Highway was raised to improve flood immunity. Additional cross-drainage culverts were also constructed under the raised highway.

The flood assessment carried out in late 2013 by Jacobs SKM provides the basis for understanding the flood risks on the floodplain. It is apparent from this assessment that there are a number of areas on the floodplain with a high flood hazard exposure. The construction of the BCSW increased flood risks on the floodplain by impeding flow across the highway and increasing flood levels upstream of the highway. This also resulted in a re-distribution of flows on the floodplain and an increase in the peak flow in Cassons Creek.

A range of flood risk reduction measures (or flood mitigation measures) have been considered for the Corindi River floodplain. These include both structural measures and non-structural measures. A summary of the structural measures assessed is presented below:

1) ***Lowering of Pacific Highway at BCSW:*** Two options, A and B, were considered and are discussed below:

    a) Option A would involve lowering about 270m of the Pacific Highway to the levels prior to the BCSW construction. This lowering would allow more flow to pass over / under the BCSW section of highway and alter the distribution of flows across the floodplain. This would reduce flood flows and levels along Cassons Creek (compared to the existing case) and the resulting flood levels would be very similar to the pre-BCSW case (ie the base case).

    To understand the redistribution of floodplain flows, the table below presents the changes to flow distribution immediately downstream of BCSW for the January 2012 flood. Option A would result in a reversal of the situation with the BCSW constructed (ie the existing case) where flows across this section of the floodplain decreased by 14%. Most of this flow decrease was diverted to Cassons Creek. Option A would result in similar total flows (over / under the BCSW section of highway) to the pre-BCSW situation (ie the base case).

Scenario	Southern flowpath	Northern flowpath	Total flow over / under BCSW
Flow without BCSW (base case)	258m^3/s	166m^3/s	424m^3/s
Flow with BCSW (existing case)	203m^3/s (-21%)	161m^3/s (-3%)	364m^3/s (-14%)
Flow with Option A Lowering of BCSW	174m^3/s (-33%)	270m^3/s (+63%)	444m^3/s (+5%)

    b) Option B would involve the same lowering as Option A as well as an additional 150m on the southern end of the BCSW. Assessment of this option indicated that the benefits were not significantly greater than those for Option A.

2) ***Larger culverts under existing Pacific Highway at BCSW:*** There would be considerable costs associated with this option which would require a six-fold increase in the waterway area to accommodate

the flow over the highway. Further, it would not reduce flood levels at Cassons Creek any more than the option of lowering a portion of the BCSW.

3) ***Larger Pacific Highway bridge at Cassons Creek:*** This option is unlikely to change or reduce flood levels downstream of the bridge along Cassons Creek. It may actually lead to increased flood levels downstream of the bridge due to a small reduction in the attenuation volume upstream of the bridge and a minor increase in flows

4) ***Levees:*** In the Cassons Creek area, the potential for reducing flood inundation using levees is hindered by the long lengths of levee that would be required. In the Corindi Park Drive area, there is considerable potential for use of levees to reduce flood risk. Any assessment of levees on the floodplain needs to be considered as part of a formal flood risk management process in conjunction with Coffs Harbour City Council (CHCC). There are a range of issues to be considered in the planning and design of any levees on this floodplain.

In regard to non-structural measures, Roads and Maritime has initiated discussion with CHCC about participating in a floodplain management study of the lower Corindi River catchment. It is envisaged that this will include consideration of flood awareness measures, community readiness measures and evacuation arrangements. A summary of the non-structural measures considered include:

5) ***Flood prediction and warning:*** Roads and Maritime is committed to assisting the Corindi River floodplain residents to reduce their flood risk by working with agencies that have responsibility for the different aspects of floodplain management. As part of this commitment, Roads and Maritime is working with CHCC and the SES and has contributed to funding the installation of rainfall and stream gauges on the floodplain and in the upper catchment.

6) ***Flood awareness:*** Flood awareness relies on regular communication of flood risks particularly for new residents and during the period between major flood events. This is particularly important for the Corindi River given that it is a perched creek where there is a significant change in the flood risks between a moderate and major flood event.

7) ***Community readiness:*** Community flood readiness is an ability to react within the effective warning time. It is based upon on the community as a whole knowing what to do on receipt of a flood warning as well as having the necessary infrastructure to enact their personal evacuation plan.

8) **Evacuation arrangements:** The SES that supports the Corindi River floodplain is particularly aware of the key problem areas for the safe evacuation of the community, having a number of residents with a long association with the area. Evacuation arrangements would assist in formalising this understanding and procedures to support the process into the future. The evacuation arrangements would also involve new procedures to utilise any new flood warning systems.

In summary, the key conclusions of this study are:

- Roads and Maritime has initiated discussion with CHCC about participating in a floodplain management study of the lower Corindi River catchment. As well, Roads and Maritime is working with the SES and has committed to funding the installation of two rainfall and stream gauges. Both of these actions will ultimately reduce the flood risks on the Corindi River floodplain.
- A number of structural measures were considered in order to reduce the increased flood risks resulting from the BCSW. Of these, Option A (lowering of a 270m length of the existing Pacific Highway) would result in a distribution of flow that would be similar to that of the pre-BCSW case. This option would result in a significant decrease in the impacts due to the BCSW. This option (alone or in conjunction with the Pacific Highway upgrade) would not result in increases in flood levels at the Corindi Park Drive area (compared to the base case of no BCSW).

1. Introduction

1.1 Objective

Jacobs SKM was commissioned by Roads and Maritime Services to conduct investigations into possible mitigation options to reduce the impacts of the Blackadder Creek Safety Works.

The objective of this commission was to determine potential mitigation options to reduce the current impact of the Blackadder Creek Safety Works (BCSW) on the flood behaviour of the Corindi River floodplain.

The key objectives of these mitigation options are to:

- Reduce the flood level increases caused by the BCSW in the Cassons Creek area. The sub-objectives for this objective are to result in residual impacts of:
  - less than 20mm to 30mm at inundated dwellings (ie inundated in January 2012 flood or 100 year ARI flood)
  - less than 50mm on the floodplain at property access points
  - in the order of 250mm on grazing land in accordance with the Pacific Highway upgrade criteria
- Reduce the flood risk for floodplain residents through a suite of conventional flood risk management measures.

1.2 Study location

The Corindi River is located in north-east New South Wales, approximately 35km north of Coffs Harbour. The river flows north-east into the Coral Sea of the South Pacific Ocean.

The current Pacific Highway alignment crosses the Corindi River slightly upstream of low density residential areas in Corindi Beach and along Corindi Park Drive. Approximately 800m further north, the current Pacific Highway crosses Blackadder Creek and then Cassons Creek a further 1km north. The dominant flood mechanism in the study area is from the Corindi River catchment, which has a total catchment area upstream of the highway of approximately 83km^2.

In 2011, Roads and Maritime undertook upgrades to the existing Pacific Highway to improve the safety in the vicinity of Blackadder Creek. Amongst other changes, the Pacific Highway was raised to improve flood immunity. Additional cross-drainage culverts were also constructed under the raised highway.

1.3 Reliance statement

The sole purpose of this report and the associated services performed by Jacobs SKM is to provide Roads and Maritime with an assessment of available flood risk reduction options associated with the Blackadder Creek Safety Works impacts in accordance with the scope of services set out in the contract between Jacobs SKM and the Roads and Maritime. That scope of services, as described in this report, was developed with Roads and Maritime.

In preparing this report, Jacobs SKM has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs SKM has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs SKM derived the data in this report from information sourced from the Roads and Maritime (if any) and/or available in the public domain at the time or times outlined in this report.

The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report.
Jacobs SKM has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs SKM for use of any part of this report in any other context.

This report has been prepared on behalf of, and for the exclusive use of Roads and Maritime and is subject to, and issued in accordance with, the provisions of the contract between Jacobs SKM and Roads and Maritime.

Jacobs SKM accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party

2. Overview of flood risk on Corindi River floodplain

2.1 Existing flood risks

A flood assessment of the Corindi River floodplain with specific focus on the Blackadder Creek Safety Works was carried out by SKM in the latter half of 2013 and documented in a draft report in December 2013 (SKM, 2013). This flood assessment provides the basis for understanding the flood risks on the floodplain.

It is apparent from this assessment that there are a number of areas on the floodplain with a high flood hazard exposure. Figure 2.1 shows the peak velocity-depth products for the existing situation on the Corindi River floodplain (ie with the BCSW).

These flood hazards result from the following flood behaviour:

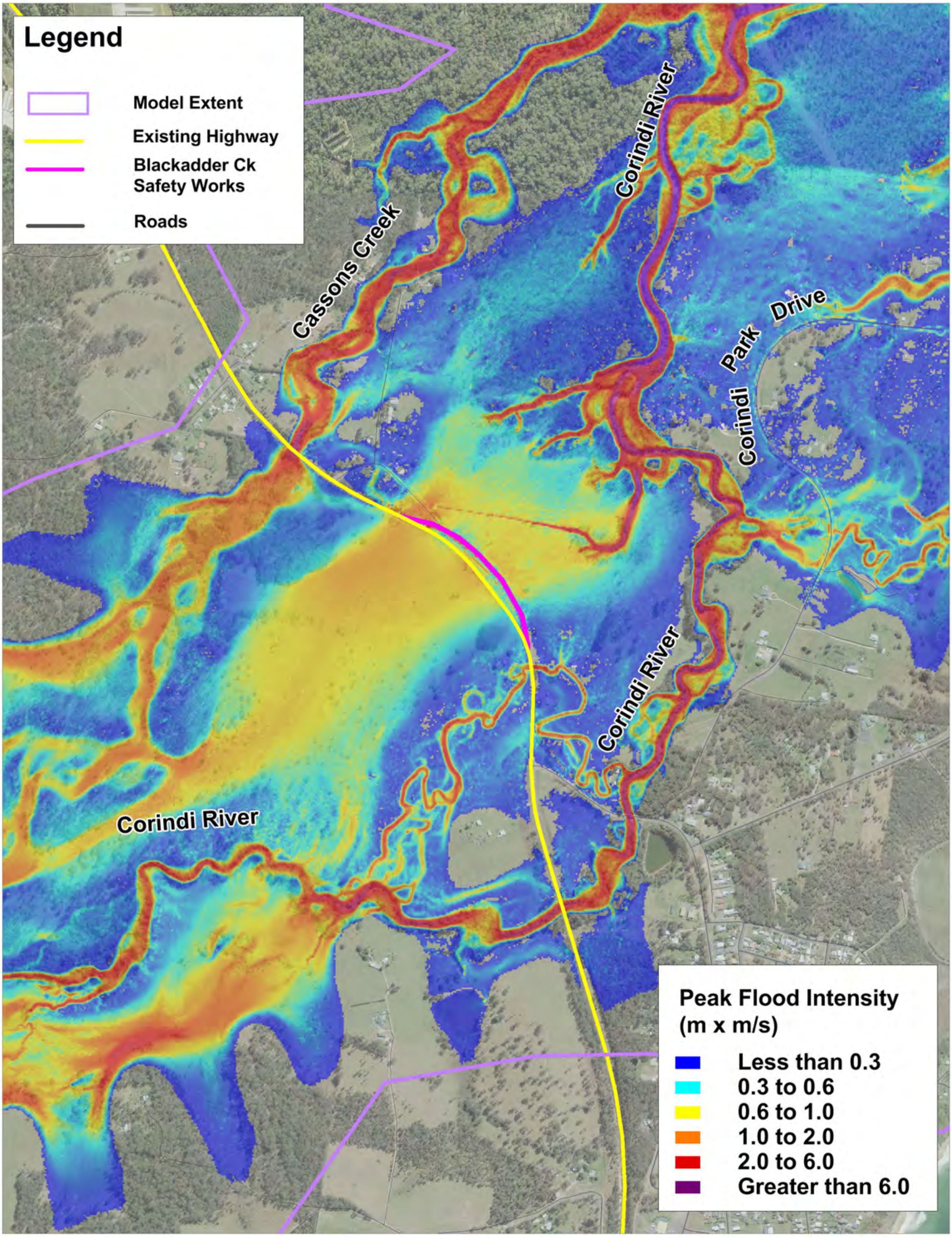
- The capacity of the Corindi River is much less than the 100 year ARI flows. This is not uncommon on floodplains. Hence, flows in excess of the river capacity spill onto the floodplain at a number of locations along the lower reaches (both upstream and downstream of the Pacific Highway).
- The river banks are higher than the surrounding floodplain in most areas. This results in a 'perched' river system in which flows exit the river and take a completely separate route along the floodplain prior to re-entering the river further downstream.
- The perched nature of the river banks results in higher than normal flood hazards for two reasons:
    - Firstly, the warning or expectation of floodplain flows is low due to the floodplain flows exiting the river once the banks levels are exceeded by the river flood levels. Hence, there is a threshold above which floodplain flows commence and there is little warning of this occurrence.
    - Secondly, the perched river banks result in relatively steep floodplains as the levels slope from the river bank towards the low parts of the floodplain. These relatively steep gradients which are in the order of 1 in 200 (0.5%) and are typically double the overall floodplain / river slope of 1 in 400 (0.25%). These steeper slopes result in relatively high velocity floodplain flows.
- The hazards on the floodplain also result from the location of residences on the floodplain. There are a number of residences within high velocity and velocity-depth product areas.
- Additional hazards are associated with flooding in this area due to relatively short warning times. Critical durations are in the order of nine hours and floods rise rapidly within six hours of the onset of intense rainfall.

The 2013 flood assessment only included assessments of the January 2012 flood event and the 100 year ARI flood. Hence, a full assessment of flood hazards across a range of flood probabilities has not been carried out. Only once a full assessment is carried out can a complete understanding of the baseline flood risks be developed for the catchment. It is recommended that this more complete assessment be carried out as part of a formal flood risk management approach.

2.2 Flood risks increased due to BCSW

The BCSW increased flood risks on the floodplain by impeding flow across the highway and increasing flood levels upstream of the highway. As well, the BCSW resulted in a re-distribution of flows on the floodplain and an increase in the peak flow in Cassons Creek.

The changes to flood levels on the floodplain due to the BCSW have been quantified in the 2013 flood assessment and are reproduced here as Figure 2.2.



SINCLAIR KNIGHT MERZ

SKM

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0 250 500
metres

Datum: GDA 94
Projection: MGA Zone 56

Figure 2-1

Existing Case (Post BCSW)
Vx D January 2012 Event

Corindi River Flood Assessments

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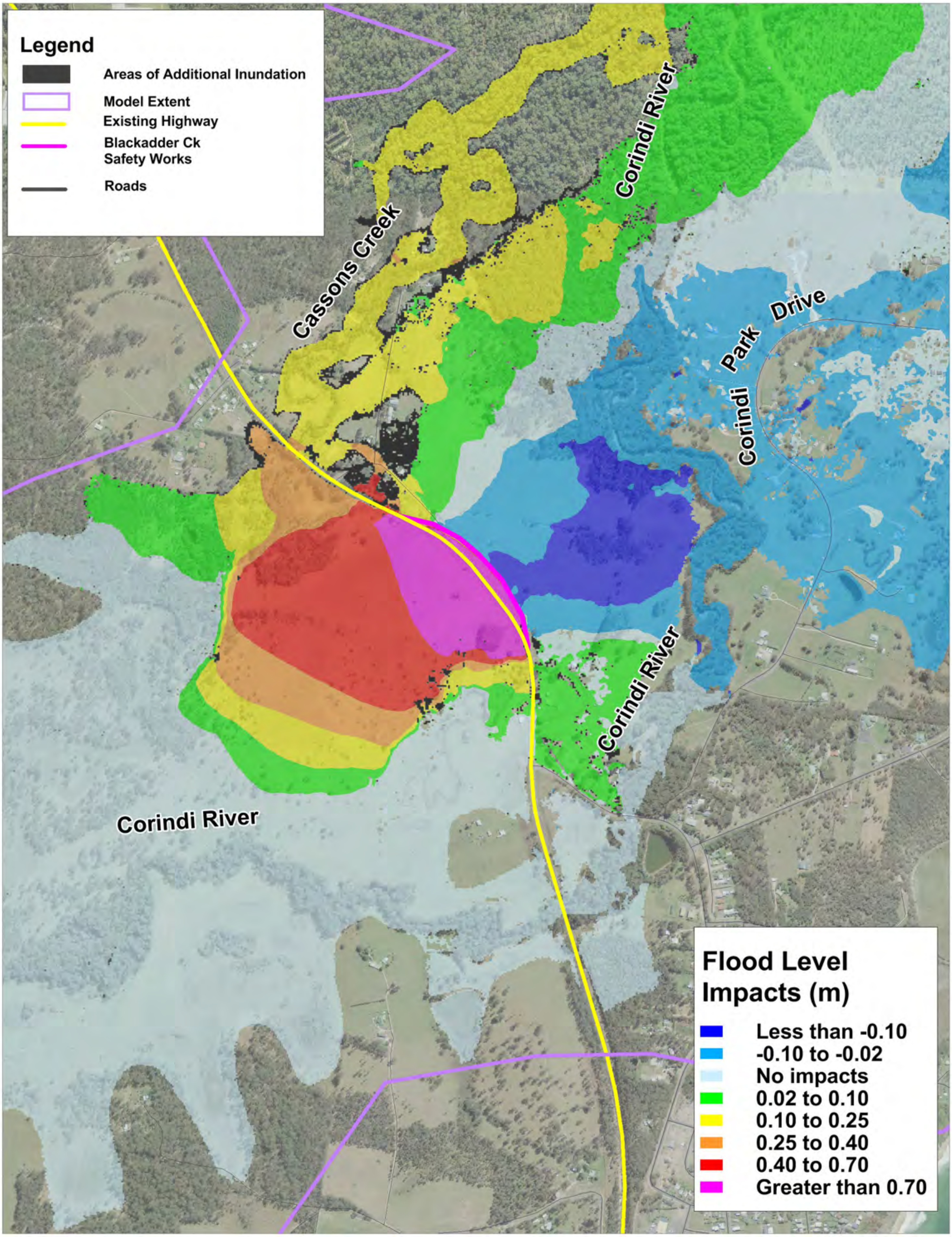

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Figure 2-2

Change in Flood Levels due to BCSW only (base case is without BCSW) for January 2012 Flows

Datum: GDA 94
Projection: MGA Zone 56

Corindi River Flood Assessments

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3. Available flood mitigation options

3.1 Overview of flood mitigation options

Flood mitigation options are measures that are aimed at reducing the flood risk on a floodplain. This can be achieved with a combination of structural and non-structural measures.

Structural measures are those that change the flood behaviour to reduce flood risk. This may be through lowering flood levels (eg creek diversions, capacity improvements) or by changing the direction of flows or areas of inundation (eg levees, flood gates). Alternatively, the magnitude of flows on the floodplain can be reduced through upstream retardation measures (dams, basins, etc).

Non-structural measures are those that do not change the flooding behaviour but alter how the people and property on the floodplain are affected by floodwaters. These measures include removing people from the floodplain (eg land-use zoning, voluntary purchase) or reducing the damage caused by floodwaters (building resilience, etc). As well, non-structural measures include changing the way that people prepare for a flood (flood warnings, readiness, etc) and act during (evacuations, etc) and after a flood event (recovery).

The current NSW Floodplain Development Manual (DIPNR, 2005) describes different flood risk measures in terms of modification to property, modification to response, and modification to floods. These are presented in Table 3-1 also with a categorisation as either structural or non-structural measures.

Table 3-1 Typical floodplain risk management measures (DIPNR, 2005)

Property modification measures (non-structural)	**Response modification measures** (non-structural)	**Flood modification measures** (structural and non-structural)
• Zoning • Voluntary purchase • Voluntary house raising • Building and development controls • Flood proofing buildings • Flood access	• Community awareness • Community readiness • Flood prediction and warning • Local flood plans • Evacuation arrangements • Recovery plans	• Flood control dams • Retarding basins • Levees • Bypass floodway's • Channel improvements • Flood gates

More recently, the federal government has published a more up-to-date and comprehensive guide for managing flood risk on floodplains. "Managing the Floodplain" (Attorney-General's Department, 2013) includes a list of treatment measures for existing and future development. For the Corindi River floodplain, the focus is on treatment of flood risks associated with existing development.

Table 3-2 provides a list of measures for consideration. The table discusses the flood risk in terms of existing flood risk and residual flood risk. Existing flood risk are those associated with floods up to a certain magnitude (or probability) that can be managed and potentially minimised to a very low level.

Residual flood risks are those associated with rarer floods and represent the residual risk above the managed risk. This approach recognises that it is not feasible or possible to minimise flood hazards for all flood events (including rare floods).

Table 3-2 Treatment measures for existing development (taken from Table 7.1 of Attorney-General's Department, 2013)

Table 7.1: Treatment measures for existing development

Development scale	Type of flood risk	Treatment measures
Community or a specific area	Existing	Flood mitigation dams Retarding and detention basins Permanent levees Flow conveyance improvements Flood gates Temporary barriers Change in property zoning
	Residual	Flood prediction and warning Community-scale emergency response plans Evacuation arrangements Evacuation route upgrade Community flood readiness Community recovery plans
Property	Existing	House raising House purchase Relocation of development Flood proofing of buildings Temporary measures
	Residual	Residual risk management options listed above augmented by appropriate property based emergency management plans

Given the above overview of measures, a range of flood risk reduction measures (or flood mitigation measures) have been considered for the Corindi River floodplain. Ideally, the assessment of these alternatives would be carried out within the framework of a full flood risk management study as guided by the NSW Floodplain Development Manual (DIPNR, 2005).

To that end, Roads and Maritime has initiated discussions with Coffs Harbour City Council (CHCC) about participating in a floodplain management study of the lower Corindi River catchment.

3.2 Structural flood mitigation options

3.2.1 Lowering of existing Pacific Highway

The raised section of the existing Pacific Highway north of Blackadder Creek (called the Blackadder Creek Safety Works or BCSW) has resulted in increased flood levels upstream of the highway. These flood level increases are large (in the order of 1.0m in some places) and cover a large area. Furthermore, the increases in flood level are large enough to divert more flow into the Cassons Creek catchment and increase flows by about 60% (in the January 2012 flood).

In order to reduce the effects of these works, all or a portion of this road raising could be lowered to the old highway levels. This could occur either before or after the completion of the Pacific Highway upgrade to the west of the current alignment. This is discussed further in Section 4.4.

Three lowering options were considered:

- Option A: lowering the northern 250m of the BCSW
- Option B: lowering the northern 250m of the BCSW and the southern 100m of the BCSW
- Option C: lowering of all of the BCSW (i.e. revert to the pre 2011 highway vertical alignment).

Of the above options, A and B were further assessed based on a high-level screening of these three options. Option C would involve considerable costs due to the need to remove the existing culverts in the southern portion. Furthermore, it would not reduce flood levels at Cassons Creek any more than the option of lowering a portion of the BCSW.

Option A and B would be less expensive and potentially deliver similar outcomes to Option C at Cassons Creek.

Both Option A and Option B were assessed using the flood models developed in the 2013 flood assessment (SKM, 2013). However, Option B did not show any significant improvement in flood level reduction and was not pursued further. A full assessment of Option A was carried out and is document in Chapter 4 which also includes discussion on the performance of Option B.

3.2.2 Larger culverts under existing Pacific Highway

Similar to the options discussed above, larger culverts under the BCSW section would reduce the flood level increases upstream and minimise the redistribution of flows on the floodplain (specifically the increased flow to Cassons Creek).

The area of culverts under the BCSW is in the order of 30m^2. Peak flows through or over this section of highway are in the order of 350m^3/s. Hence, assuming a peak culvert velocity of about 2m/s, the culvert waterway area would need to increase to about 175m^2 to accommodate all of the flow and reduce flood levels to an acceptable level. This would require a 6-fold increase in the culvert waterway area.

There would be considerable costs associated with this option and it would not reduce flood levels at Cassons Creek any more than the option of lowering a portion of the BCSW.

3.2.3 Larger Pacific Highway bridge at Cassons Creek

The majority of the area affected by the BCSW is along Cassons Creek. The option of increasing the capacity of the Pacific Highway bridge crossing at Cassons Creek was considered. However, while this option would reduce flood levels upstream of the bridge, it would not change the magnitude of flood flows in the creek.

Hence, this option is unlikely to change or reduce flood levels downstream of the bridge. It may actually lead to increased flood levels downstream of the bridge due to a small reduction in the attenuation volume upstream of the bridge and a minor increase in flows.

3.2.4 Levees

Flood levees on floodplains can be an effective measure for partial protection of residential areas. The partial protection is based on a recognition that some very rare floods could overtop the levee and result in very high hazards.

It is important to note that Roads and Maritime's objective is to address the impacts to flood levels caused by the BCSW. These increases are in the order of 200mm in the Cassons Creek area. However, a levee cannot just reduce flood levels by a prescribed amount. Levees are designed to 'protect' areas behind the levee from any flood inundation (up to a certain flood magnitude / probability).

In the Cassons Creek area, the potential for reducing flood inundation using levees is hindered by the long lengths of levee that would be required. To reduce flood levels in the impacted area of Cassons Creek would require a levee in the order of 1.5km long. This length of levee would result in a significant re-distribution of flood flows over the floodplain and is likely to result in considerable adverse impacts to other parts of the floodplain. Hence, levees were not considered further in this assessment as a possible solution to reducing the impact of the BCSW on the Cassons Creek area and the area upstream of the Pacific Highway.

In the Corindi Park Drive area, there is considerable potential for use of levees to reduce flood risk. Due to the lack of impact of the BCSW on the Corindi Park Drive area, these levees would not be aimed at addressing the changes to flood behaviour as a result of the BCSW in the Corindi Park Drive area. These levees would, however, address the flood risks associated with the location of the residential development and the pre-existing flood risks. A levee of approximately 270m long on the eastern side of Corindi River would block flows exiting the river and passing through the majority of the Corindi Park Drive area.

Any assessment of levees on the floodplain needs to be considered as part of a formal flood risk management process in conjunction with CHCC. This process would include creation of a Flood Risk Management Committee with representation from the local community, CHCC, SES, Department of Environment and Heritage, Roads and Maritime and other relevant organisations that would be adding value to the flood management solutions. Such committees have proven to be very effective when all committee members work together in a constructive way to find the best floodplain management solutions.

This more complete assessment of levee options would include consideration of such issues as:

- Levee alignment
- Level of levee protection (ie what size flood would overtop the levee)
- Controlled levee overtopping in rare flood events.
- Levee form (earth or concrete)
- Aesthetics of levee
- Land ownership and access along levee route
- Maintenance
- Local drainage behind levee
- Geotechnical integrity in relation to potential bank movement
- Environmental issues (vegetation loss etc).

3.3 Non-Structural flood mitigation options

3.3.1 Flood prediction and warning

In January 2012, the Corindi River peaked within six hours of the start of the causative rainfall event. Under the NSW Floodplain Development Manual, floods that peak within six hours are defined as flash floods. Flash flooding is sudden and unexpected and is often caused by sudden local or nearby heavy rainfall. As the rainfall that results in this flooding is localised a local flood warning system can greatly improve the effective warning time[1] for an area.

A flood warning system typically consists of a flood (level and/or flow) gauge and a rainfall gauge which would be installed in the upstream part of the Corindi River catchment. The system relies on development of a relationship between rainfall intensities and flood flows/levels which allows the magnitude of the flood event to be estimated for a given rainfall intensity. The flood modelling completed as part of the Corindi River flood assessment may be used to support the development of this relationship. Once installed the system would assist the SES to predict the order of magnitude of a flood event based on the recorded rainfall.

Roads and Maritime is committed to assisting the Corindi River floodplain residents to reduce their flood risk by working with agencies that have responsibility for the different aspects of floodplain management. As part of this commitment, Roads and Maritime is working with CHCC and the SES and has contributed to funding the installation of rainfall and stream gauges on the floodplain and in the upper catchment. This will assist the SES with warning and evacuation and Roads and Maritime during the construction phase of the Pacific Highway upgrade.

At the time of writing of this report (May 2014), CHCC had issued Roads and Maritime a proposal for their consideration, the locations of two combined rainfall and water level gauges. One location is likely to be at Upper Corindi and the other will be on the current Pacific Highway alignment.

3.3.2 Flood awareness

Flood awareness is defined by the NSW Floodplain Development Manual as "*an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures*". Flood awareness requires the community to be educated regarding the flood risks on the floodplain. Studies have demonstrated that an aware and ready person will reduce losses far more in one or two person-hours of activity than a non-aware person will in six to eight person-hours (NSW Government, 2005).

It is recognised that current residents of the Corindi River floodplain are acutely aware of flooding having recent experience of two large flood events. However, flood awareness relies on regular communication particularly for new residents and during the period between major flood events. This is particularly important for the Corindi River catchment. As the Corindi River is a perched creek, there is a significant change in the flood risks between a moderate and major flood event. Therefore, residents of the floodplain may experience a number of notable floods that result in minor or moderate damages prior to experiencing a major flood with significant consequences.

Roads and Maritime has initiated discussion with CHCC about participating in a floodplain management study of the lower Corindi River catchment. It is envisaged that this will include flood awareness measures.

3.3.3 Community readiness

Community flood readiness is an ability to react within the effective warning time. It relies on the community as a whole knowing what to do on receipt of a flood warning. In a flood ready community residents and property owners would have developed personal evacuation plans and have the ability to implement these effectively when a flood warning is received.

[1] *Effective warning time is defined as the time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions* NSW Floodplain Development Manual 2005.

Flood readiness also relies on the community being aware but also having the necessary infrastructure to enact their personal evacuation plan. For example, access to a vehicle and knowledge of an evacuation route that can be reached within the available warning time.

Roads and Maritime has initiated discussion with CHCC about participating in a floodplain management study of the lower Corindi River catchment. It is envisaged that this will include community readiness measures.

3.3.4 Evacuation arrangements

Evacuation arrangements provide support to the process of evacuating a community as a whole. This process is currently led by the SES. Evacuation arrangements would assist the SES in this process through a number of measures. This would include formalised identification of key problem areas and targeted measures or procedures to address or improve SES capacity and capability. This may include:

- identification of residents requiring special assistance
- bottlenecks in the evacuation system
- support infrastructure.

The SES that supports the Corindi River floodplain is particularly aware of the key problem areas for the safe evacuation of the community, having a number of residents with a long association with the area. Evacuation arrangements would assist in formalising this understanding and procedures to support the process into the future. The evacuation arrangements would also involve new procedures to utilise any new flood warning systems.

Roads and Maritime has initiated discussion with CHCC about participating in a floodplain management study of the lower Corindi River catchment. It is envisaged that this will include evacuation arrangements.

4. Assessments of highway lowering options

4.1 Flood models used

The hydrologic model of the Corindi River catchment was based on the RORB hydrological model developed for the Corindi River Flood Assessment. Further information about the model can be seen in the Corindi River Flood Assessment report (SKM, 2013).

The hydraulic model of the Corindi River floodplain was based on the two dimensional hydraulic TUFLOW model developed for the Corindi River Flood Assessment. Further information about the model can be seen in the Corindi River Flood Assessment report (SKM, 2013).

The flood model was amended for some assessments (see Section 4.3) to include the details of the current design of the Pacific Highway upgrade. These details were obtained from the road designers (Arup / PB joint venture) and used directly as input into the flood model.

4.2 Description of Option A

Option A includes lowering of the Pacific Highway over a 270m section of the BCSW. The lowering would be down to the previous highway levels. A transition zone of approximately 55m long would be require to grade the road from the lower levels (nominally 8.9mAHD) up to the higher BCSW level (nominally 9.8mAHD).

The details of this option are presented in Figure 4.1. The road would be lowered by about 0.9m over most of the length. There are two small culverts in this length for the purposes of local land drainage (not floodplain flows) and these could be retained with adequate cover.

The length of transition required to grade the road was considered at a concept level based on a 80km/h design speed. The crest vertical curve minimum is determined by Stopping Sight Distance (SSD) and a desirable minimum length of 60m. The sag vertical curve minimum is determined by comfort and headlight sight considerations. With the assumed 55m, a grade between the two vertical curves of 1.87 % is achievable.

4.3 Assessment of proposed structural mitigation Option A

The flood models discussed above were used to simulate the effect of lowering the 270m section of the BCSW. The January 2012 flood and the 100 year ARI flood (nine hour duration) were simulated. These results were then compared with the base case which is the case without the BCSW (ie pre 2011 case).

Figure 4.2 and Figure 4.3 show the impacts of BCSW with Option A lowering on January 2012 flood levels and 100 year ARI flood levels respectively. These figures show that the lowering would reduce impacts of the BCSW such that the impacts along Cassons Creek would be in the order of 20mm to 40mm for the January 2012 flood and less than 20mm for the 100 year ARI flood. As well, there are some areas of flood impact in the order of 100mm to 200mm south-east of Cassons Creek. Importantly, there would not be any impacts at houses with inundated floor levels.

Of more relevance is the assessment of flood impacts in a cumulative manner with the Pacific Highway upgrade in place. This is important because the lowering of the BCSW would not occur prior to the construction and opening of the Pacific Highway upgrade. Hence, the scenario of lowering the BCSW alone is not a valid option for assessment.

Figure 4.4 and Figure 4.5 show the impacts of BCSW with Option A lowering and the Pacific Highway upgrade on January 2012 flood levels and 100 year ARI flood levels respectively. These figures show that the combination of the BCSW partial lowering and the Pacific Highway upgrade would result in minor decreases in flood levels along most of the Cassons Creek area.

There would be an area south-east of Cassons Creek that would experience impacts in the order of 150mm. This impact is largely due to the redistribution of floodplain flows resulting from the lowered BCSW. This area of impact does not include any houses.

To understand the redistribution of floodplain flows, Figures 4.6 to 4.8 are provided. As well, Table 4-1 presents a tabulation of the changes to flow distribution downstream of BCSW for the January 2012 flood.

Table 4-1 Changes to Distribution Downstream of BCSW for Option A

Scenario	Southern flowpath	Northern flowpath	Total flow over / under BCSW
Flow without BCSW (base case)	$258m^3/s$	$166m^3/s$	$424m^3/s$
Flow with BCSW (existing case)	$203m^3/s$ (-21%)	$161m^3/s$ (-3%)	$364m^3/s$ (-14%)
Flow with Option A lowering of BCSW	$174m^3/s$ (-33%)	$270m^3/s$ (+63%)	$444m^3/s$ (+5%)

The following commentary is also provided on these changes to flow distribution:

- Figure 4.6 shows the flow distribution for the January 2012 flood event for the base case (no BCSW). In this case, the split of flows downstream of the BCSW section has $166m^3/s$ in the northern portion and $258m^3/s$ in the southern section.
- Figure 4.7 shows the flow distribution for the January 2012 flood event for the case with BCSW (ie the existing case). In this case, the split of flows downstream of the BCSW section has changed to $161m^3/s$ in the northern portion and $203m^3/s$ in the southern section. The reduction in flow through this section is due to the diversion of about $30m^3/s$ north to Cassons Creek.
- Figure 4.8 shows the flow distribution for January 2012 flood event for the case with BCSW with Option A lowering and the Pacific Highway upgrade. In this case, the split of flows downstream of the BCSW section has changed to $270m^3/s$ in the northern portion and $174m^3/s$ in the southern section. Compared with the existing case (Figure 4.7), there would be a large change in the flow distribution downstream of BCSW. Approximately, an additional $110m^3/s$ would flow on the northern part of the flowpath. This is due to the more efficient flowpath over the lowered highway section compared to the raised section with culverts. It also should be noted that this option would result in a net decrease of 33% in the peak flow (i.e. $258m^3/s$ reduced to $174m^3/s$) heading towards the Corindi Park Drive area.

As shown in Table 4-1, Option A would result in a reversal of the situation with the BCSW constructed (ie the existing case) where flows across this section of the floodplain decreased by 14%. Option A would result in similar total flows (over / under the BCSW section of highway) to the pre-BCSW situation (ie the base case).

Option A (and the Pacific Highway upgrade) would also result in less flow heading towards the Corindi Park Drive section of the floodplain. In general, this would result in a reduction in flood levels in the Corindi Park Drive section of the floodplain of approximately 0.03m to 0.06m.

4.4 Description of Option B

Option B includes the same lowering as Option A and additional lowering of the Pacific Highway over a 150m section at the southern part of the BCSW. Similar to Option A, the lowering would be down to the previous highway levels. The details of this option are presented in Figure 4.9. The road would be lowered by about 0.9m over most of the length.

4.5 Assessment of proposed structural mitigation Option B

The flood models were used to simulate the effect of lowering the 270m section and the 100m section of the BCSW. The January 2012 flood and the 100 year ARI flood (nine hour duration) were simulated. These results were then compared with the base case which is the case without the BCSW (ie pre 2011 case).

Figure 4.10 and Figure 4.11 show the impacts of BCSW with Option B lowering on January 2012 flood levels and 100 year ARI flood levels respectively. These figures show that the additional lowering of the BCSW to the south would not add greatly to the benefits of Option A.

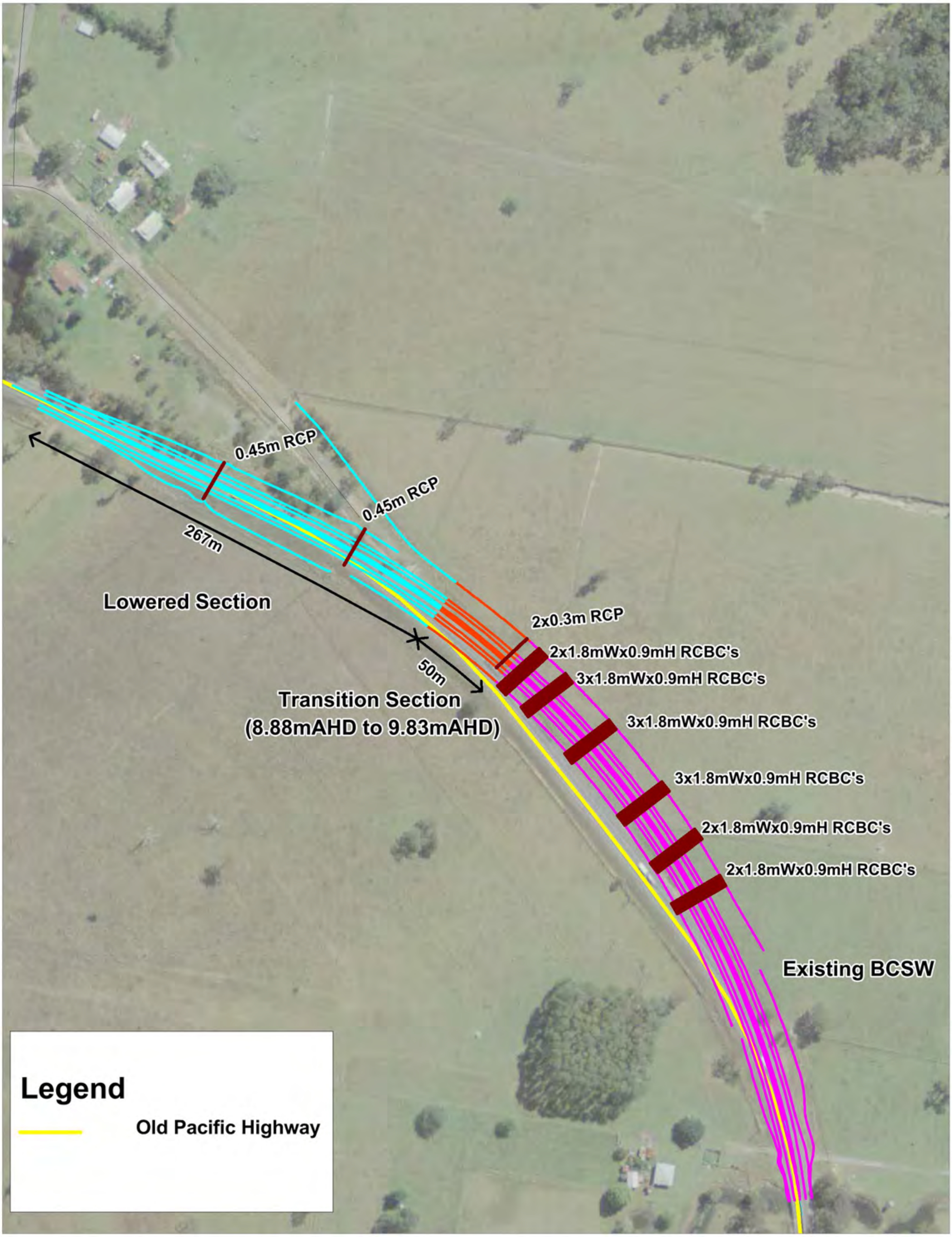
Option B would have more cost and disruption than Option A and would not yield much additional benefit. Hence, Option A was identified as the preferred option.

4.6 Timing of BCSW lowering

The timing of the lowering of a portion of the BCSW requires some consideration. These considerations should cover issues such as flood risk, construction costs and construction traffic risks.

If the lowering of the existing Pacific Highway was constructed prior to the opening of the upgrade, then there would be considerable disruption to all Pacific Highway traffic. This would result in increased costs and construction traffic safety issues. However, the benefits of the lowering would be achieved earlier which could lower the risk of flooding to the affected residents in Cassons Creek and upstream of the BCSW. As well, the lowering of the BCSW prior to the opening of the upgrade would result in a low flood immunity highway during this period (possibly lower than the flood immunity that existed prior to the BCSW construction).

If the lowering of the existing Pacific Highway was constructed after the opening of the upgrade, then the construction would result in some disruption to local traffic. However, the benefits of the lowering would be delayed. The benefits of the works would only be delayed if a flood event of sufficient magnitude occurred in the delay period. Given that the delay period is likely to be in the order of three years and the frequency of flood events that result in major impacts is in the order of decades, then the probability of the benefits being actually delayed is low.



SINCLAIR KNIGHT MERZ SKM

N

0 125 250 metres

Datum: GDA 94
Projection: MGA Zone 56

Figure 4-1

Option A: Proposed BCSW Remediation

Corindi River Flood Assessments

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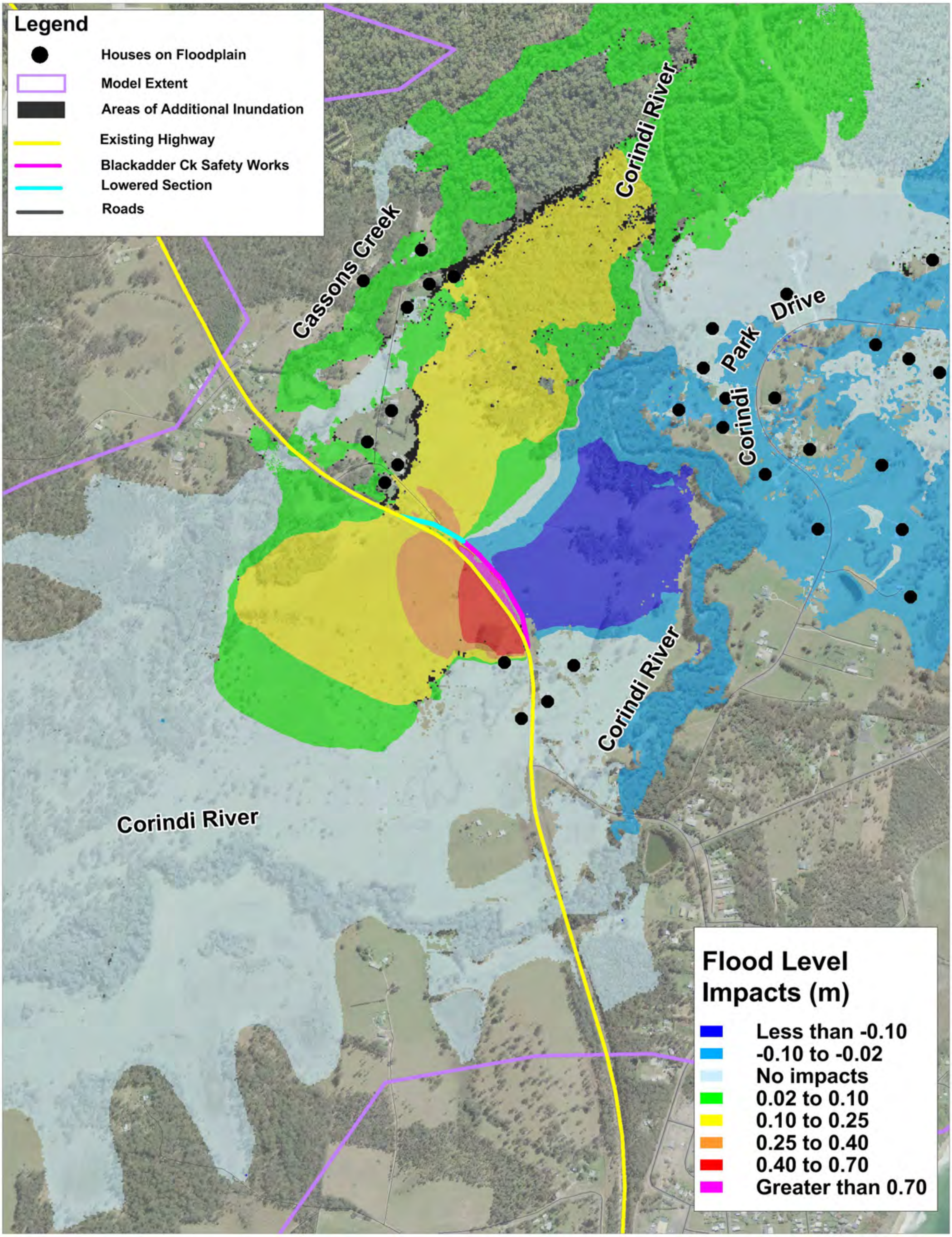

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metres

Datum: GDA 94
Projection: MGA Zone 56

Figure 4-2

Change in Flood Levels due to BCSW Lowering Option A (base case is without BCSW) for January 2012 Flows

Corindi River Flood Assessments

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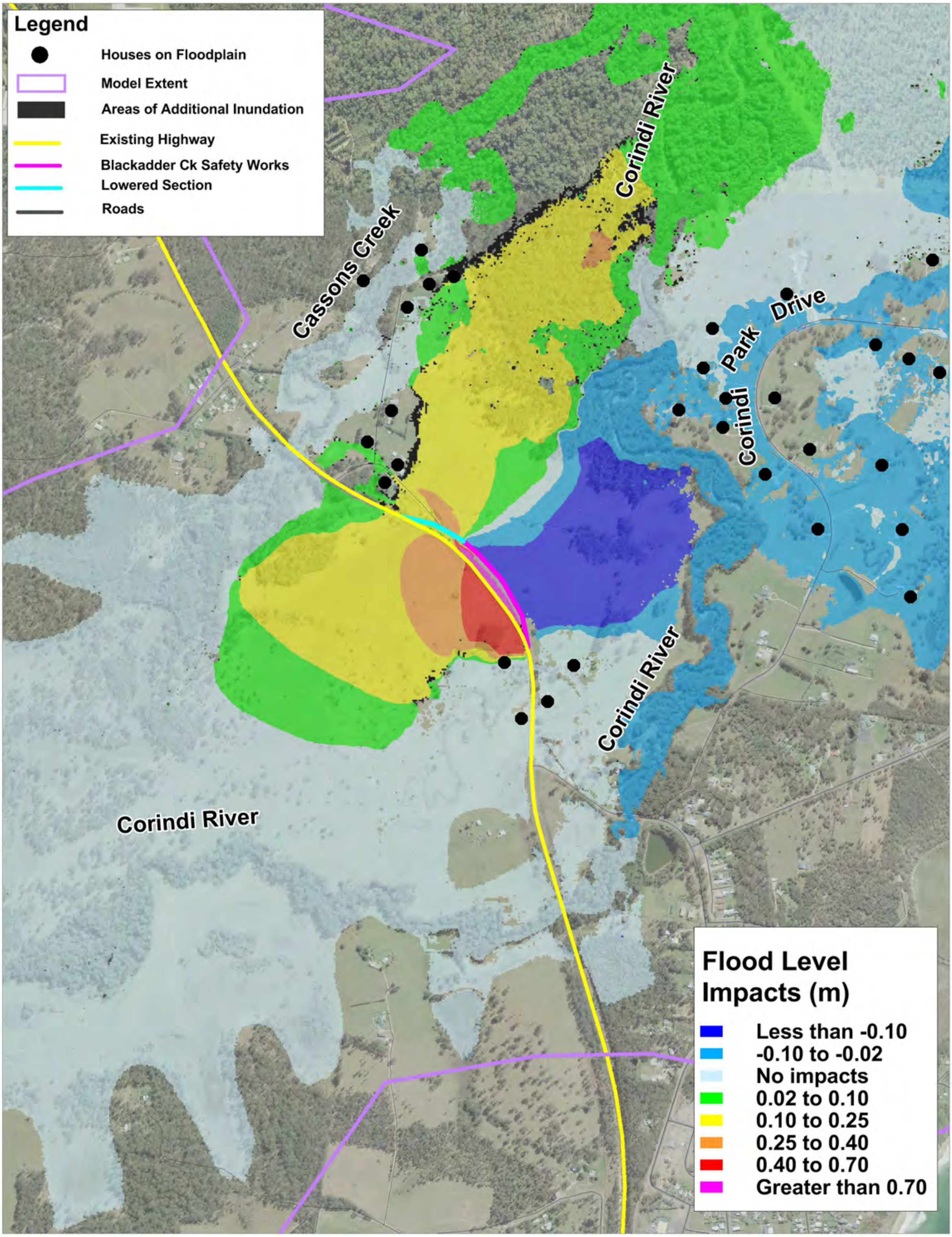

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metres

Datum: GDA 94
Projection: MGA Zone 56

Figure 4-3

Change in Flood Levels due to BCSW Lowering Option A (base case is without BCSW) for 100 year ARI Flows

Corindi River Flood Assessments

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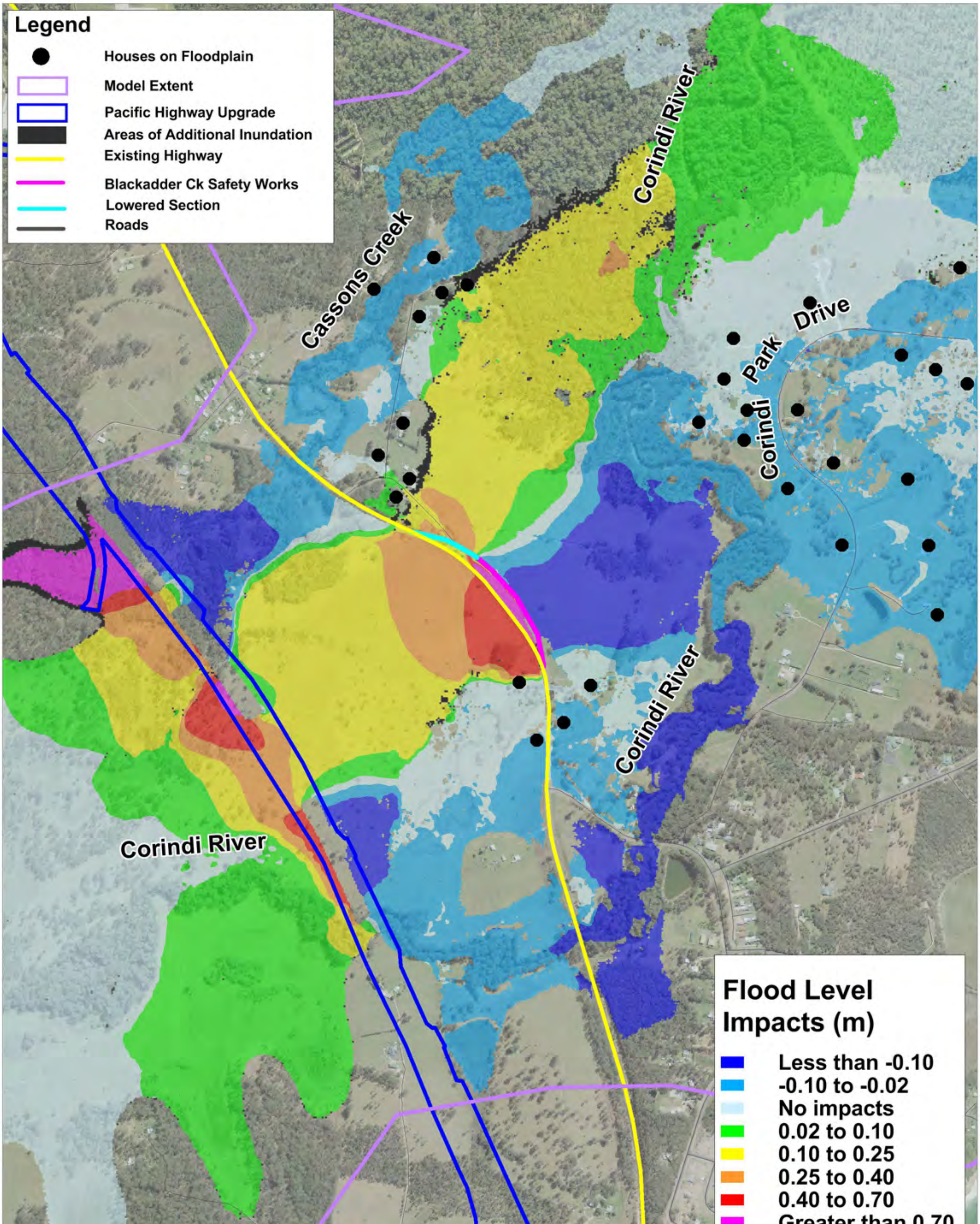

Figure 4-4

Datum: GDA 94
Projection: MGA Zone 56

Change in Flood Levels due to Pacific Highway Upgrade and BCSW Lowering Option A (base case is without BCSW) for January 2012 Flows

Corindi River Flood Assessments

SINCLAIR KNIGHT MERZ
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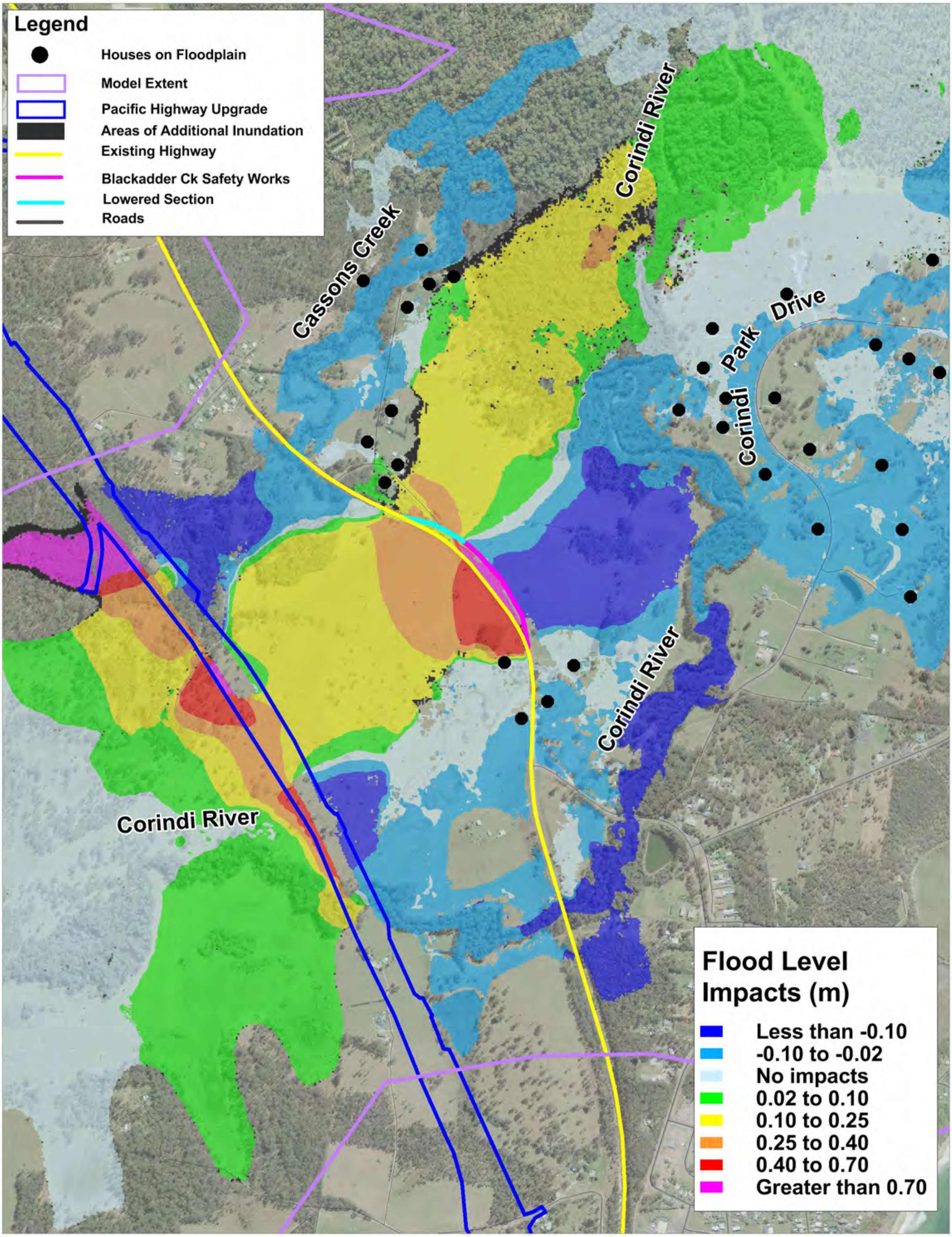

Figure 4-5

SINCLAIR KNIGHT MERZ
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metres

Datum: GDA 94
Projection: MGA Zone 56

Change in Flood Levels due to Pacific Highway Upgrade and BCSW Lowering Option A (base case is without BCSW) for 100 year ARI Flows

Corindi River Flood Assessments

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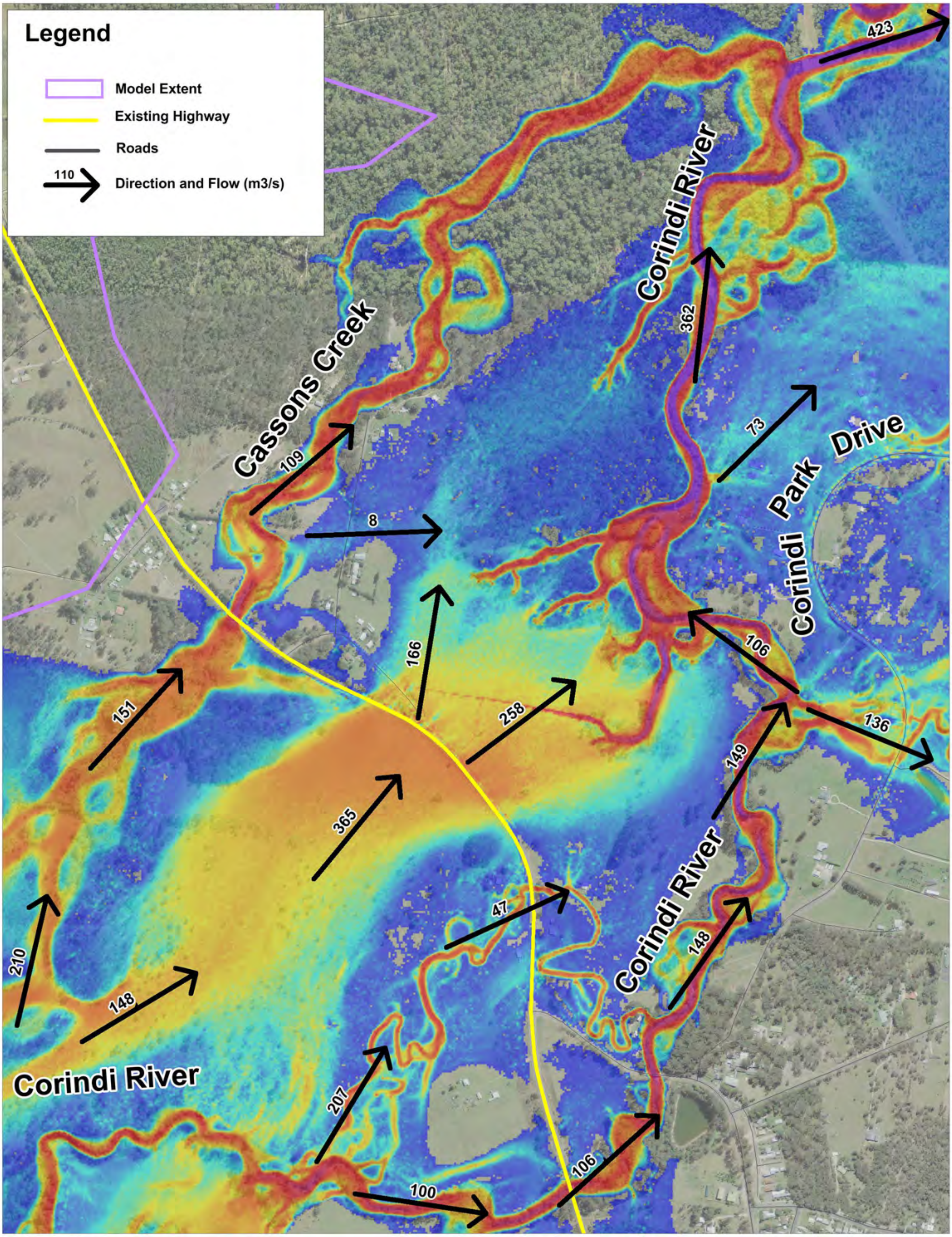

Figure 4-6

Flow Distribution for Base Case (without BCSW) for January 2012 Flows

Corindi River Flood Assessments

SINCLAIR KNIGHT MERZ

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metres

Datum: GDA 94
Projection: MGA Zone 56

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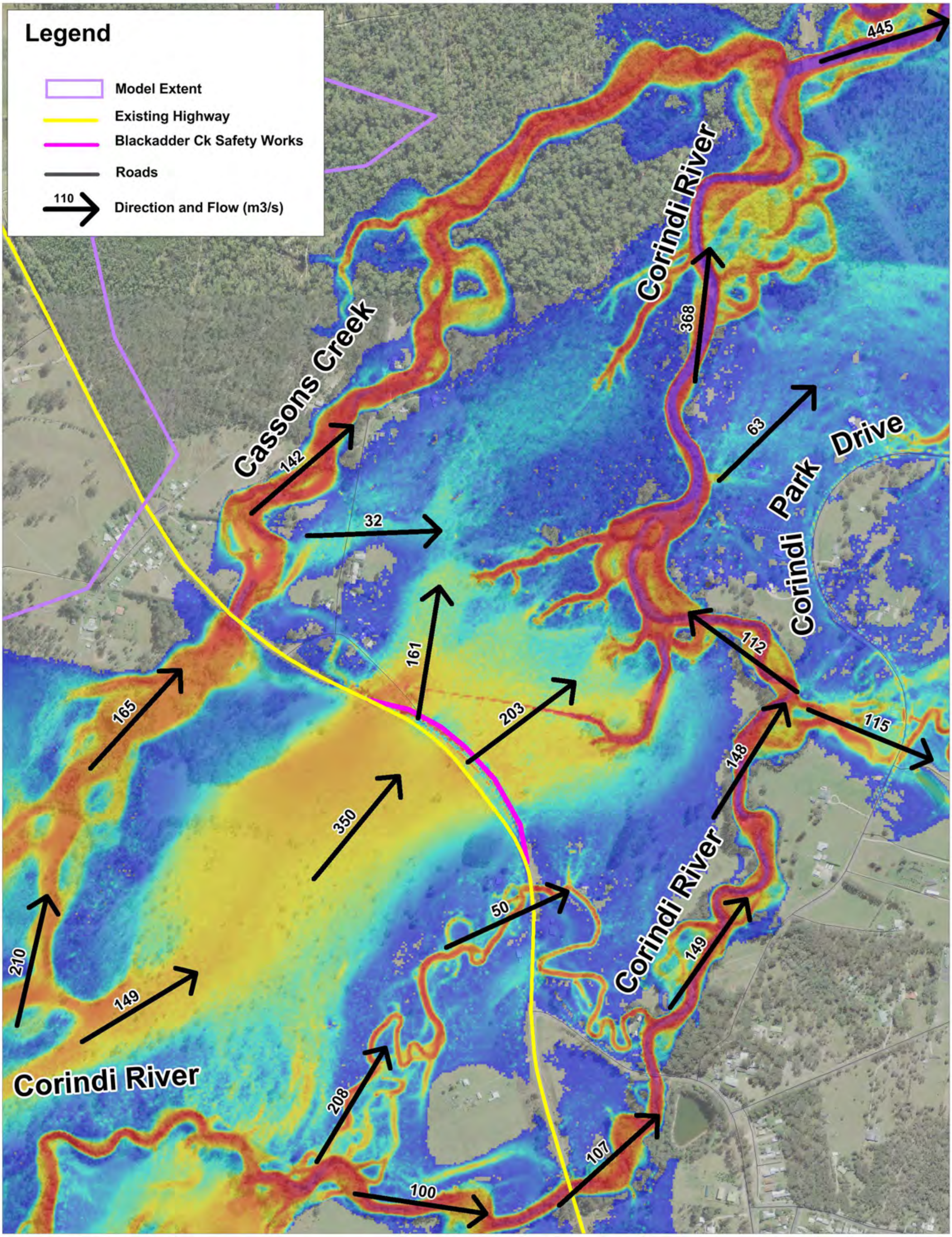

Figure 4-7

Flow Distribution for Existing Case (with BCSW) for January 2012 Flows

Corindi River Flood Assessments

SINCLAIR KNIGHT MERZ

SKM

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metres

Datum: GDA 94
Projection: MGA Zone 56

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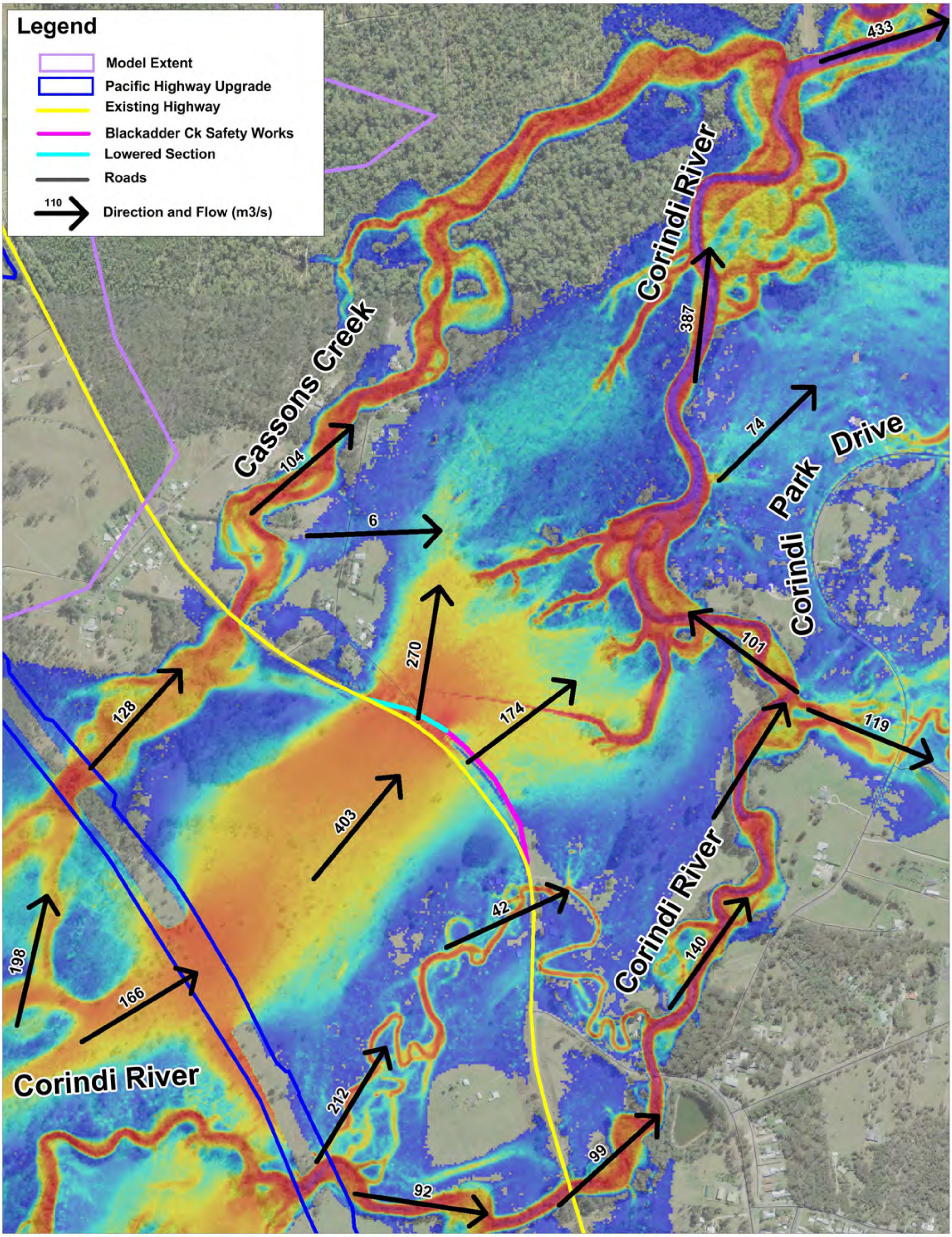

Figure 4-8

Flow Distribution for Pacific Highway Upgrade (with Option A BCSW) for January 2012 Flows

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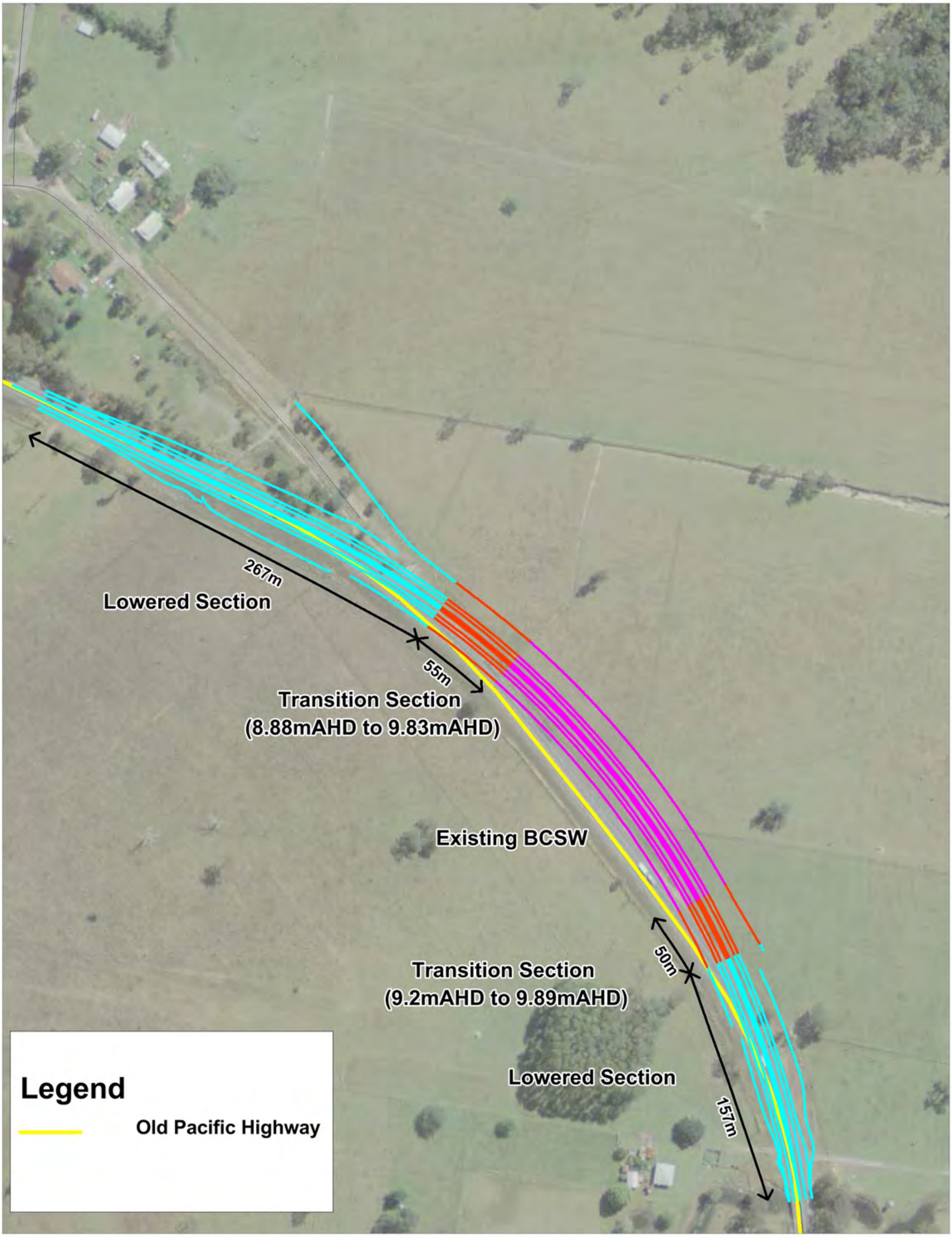
Datum: GDA 94
Projection: MGA Zone 56

Corindi River Flood Assessments



SINCLAIR KNIGHT MERZ SKM

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metres

Datum: GDA 94
Projection: MGA Zone 56

Figure 4-9

Option B: Proposed BCSW Remediation

Corindi River Flood Assessments

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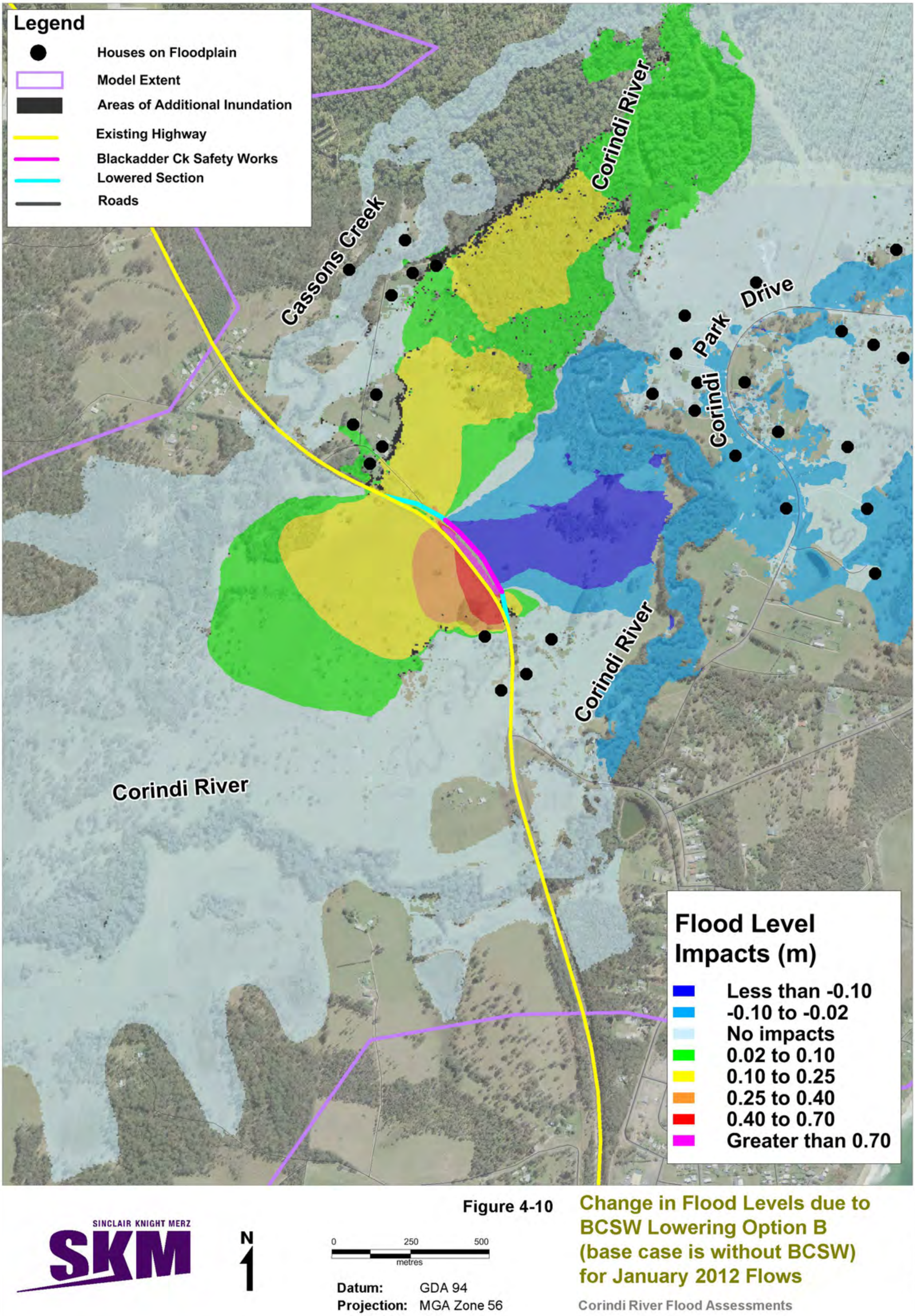

Figure 4-10 Change in Flood Levels due to BCSW Lowering Option B (base case is without BCSW) for January 2012 Flows

Corindi River Flood Assessments

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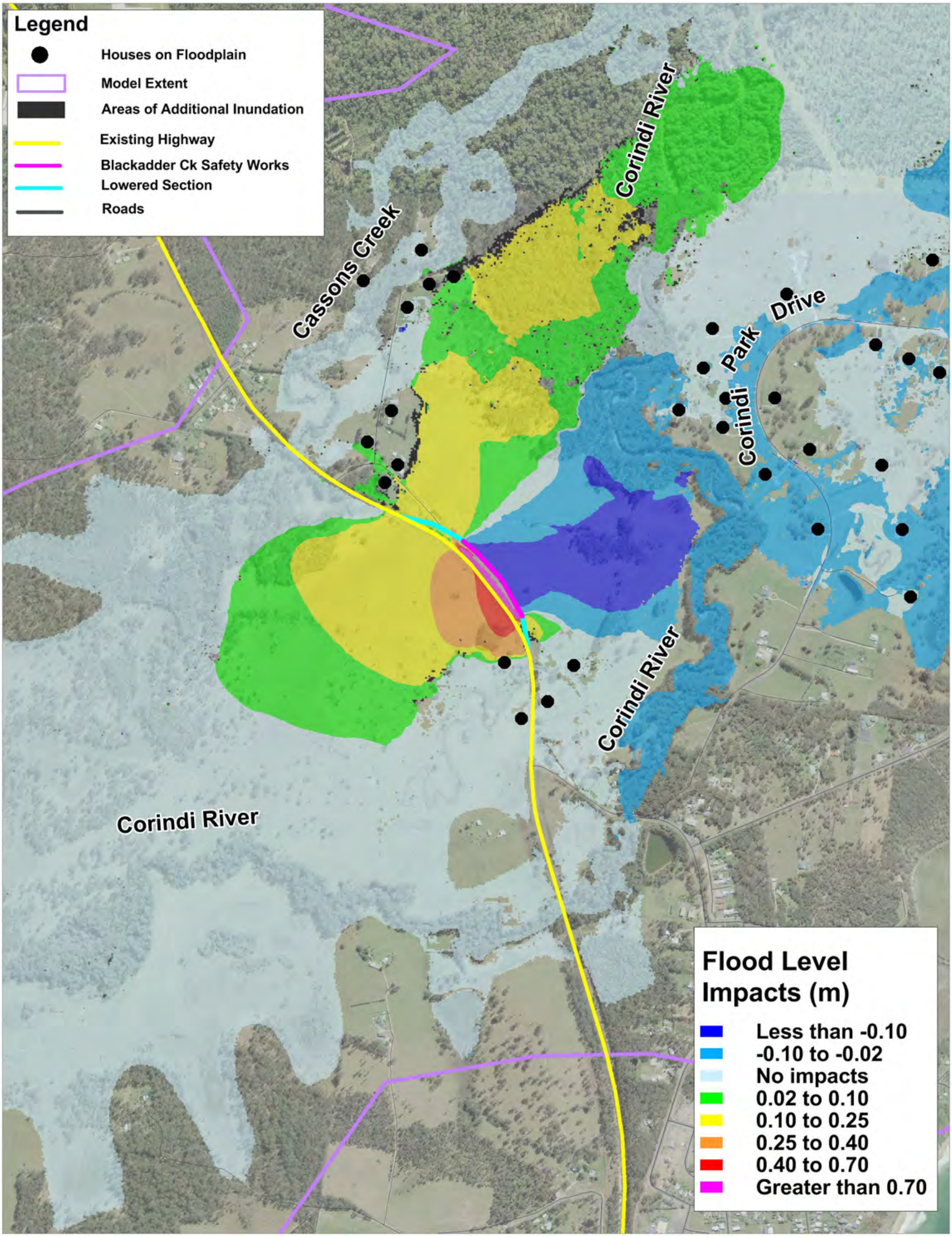

SINCLAIR KNIGHT MERZ

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0 250 500
metres

Datum: GDA 94
Projection: MGA Zone 56

Figure 4-11 **Change in Flood Levels due to BCSW Lowering Option B (base case is without BCSW) for 100 year ARI Flows**

Corindi River Flood Assessments

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5. Conclusions

The following conclusions are drawn from this assessment of flood risk management measures for the Corindi River floodplain:

1) There are some areas of high hazard on the Corindi River floodplain.
2) Some of these high hazard areas have experienced an increase in hazard due to the BCWS (mainly around Cassons Creek and the floodplain immediately upstream of BCSW).
3) There are a range of flood risk management measures (or flood mitigation measures) that can be considered to reduce the existing flood risk and the increased flood risks resulting from the BCSW. These include both structural and non-structural measures.
4) There are a range of structural and non-structural measures that could be used to reduce the existing flood risks on the Corindi River floodplain. Most of these measures would be best considered in a holistic manner as part of a formal flood risk management process in conjunction with Coffs Harbour City Council.
5) Roads and Maritime has initiated discussion with Coffs Harbour City Council about participating in a floodplain management study of the lower Corindi River catchment.
6) Roads and Maritime is committed to assisting the Corindi River floodplain residents to reduce their flood risk by working with agencies that have responsibility for the different aspects of floodplain management. As part of this commitment, Roads and Maritime is working with the SES and has committed to funding the installation of two rainfall and stream gauges.
7) A number of structural measures were considered in order to reduce the increased flood risks resulting from the BCSW. Of these, Option A was assessed in some detail. It includes lowering of a 270m length of the existing Pacific Highway after the construction and opening of the Pacific Highway upgrade.
8) Option A would reduce the impacts of the BCSW to an acceptable level and more so in conjunction with the Pacific Highway upgrade. No inundated houses would experience increases in flood levels (compared to the base case of no BCSW). Furthermore, increases in flood levels around houses would be generally in the order of 50mm and impacts on grazing land would be in the order of 150mm (except for an area of about 10ha immediately upstream of the BCSW section that would not be lowered).
9) This option (alone or in conjunction with the Pacific Highway upgrade) would result in more flow on the northern part of the floodplain and no increases in flood levels at the Corindi Park Drive area (compared to the base case of no BCSW). In general, this would result in a reduction in flood levels in the Corindi Park Drive area of approximately 0.03m to 0.06m.

6. References

New South Wales Government. (2005) *Floodplain Development Manual: the management of flood liable land.* Sydney: Department of Infrastructure, Planning and Natural Resources.

Australian Government Attorney General's Department . (2013). Managing the floodplain: a guide to best practice in flood risk management in Australia . Canberra: Australian Emergency Management Institute.

Sinclair Knight Merz. (2013). Corindi River Flood Assessments