6.9. Clarence River floodplain (Glenugie to Tyndale)

This section of the Clarence River catchment encompasses the sub-catchments of Pheasant Creek, the Coldstream River, Pillar Valley Creek, Chaffin Creek, and Champions Creek and nearby creeks. In addition to local sub-catchment flooding, Clarence River flooding affects the project along some of these tributaries by backing up into the tributary floodplains that act as storage areas. Clarence River floods are of long duration (several days for the 100 year ARI event), compared to the shorter duration tributary events.

6.9.1. Flood management objectives

Land use within the catchment along the project route is predominantly forest, with some rural and agricultural areas. There are a few houses that are within the 100 year ARI flood extent. The flood management objectives of relevance to this catchment are:

- Less than 50 millimetres increase in flood heights at houses for any assessed flood event less than and equal to 100 year ARI event
- On grazing, forested and other rural areas, generally less than 250 millimetres increase for any assessed flood event less than and equal to 100 year ARI event
- No more than five per cent increase in the flood duration where there are houses
- No more than ten per cent increase in the flood duration in recognition on grazing, forested and other rural lands
- Velocities to remain below one metre per second on grazing, forested and other rural lands where currently below these figures. An increase of not more than 20 per cent where existing velocity is above these figures
- Velocity-depth products for houses, commercial premises and urban areas remain in low hazard category (for children)
- No change to the direction of watercourses or the direction of flood flows except for constriction into and expansion out of discrete openings (culverts and bridges) and constructed diversions.

These objectives are detailed in Section 2.1.

6.9.2. Design

Between Glenugie and Tyndale, Section 3 of the project passes through the sub-catchments listed above that form upper catchments of the Clarence River floodplain.

In some low-lying sub-catchments, such as Champions Creek, Chaffin Creek and an unnamed creek near Bostock Road, backwater flooding of the Clarence River will reach the highway. This backup flooding of the Clarence River is very slow in comparison to local events. As a result, the drainage infrastructure sized to convey the local catchment flows are large enough to convey Clarence River backup flooding. Details on the structures proposed are provided for each local catchment in Sections 6.4 through 6.8.

Further detail on regional flooding of these sub-catchments is provided in Sections 6.7 and 6.8.

6.9.3. Flood impacts

During Clarence River flood events these catchments fill slowly from tributary inflows and Clarence River backup, particularly into the Coldstream River and Swan Creek basins, but also parts of Chaffin and Champion creeks. Floodwaters rise slowly and the project would not create an impediment to this backup flooding.

Flood level impacts

The loss of flood storage due to the construction of the embankments for the project has been assessed in the Clarence River flood model. There would be no discernible change (more than 10 millimetres increase) to flood levels due to this filling.

Flood inundation duration impacts

Based on plots of flood level versus time, there would be no impact to flood inundation durations in these local catchments during Clarence River regional flooding as a result of the project.

Flood velocity and direction impacts

During Clarence River regional flooding, there would be no impacts to flood velocity in these local catchments greater than 0.1 metres per second increase as a result of the project.

Rate of flood rise and warning time impacts

Based on plots of flood level versus time, there would be no impact to the rate of floodwater rise during Clarence River regional flooding as a result of the project.

Flood evacuation and flood access impacts

This section of the project does not follow the existing highway route. As such there is potential for the project to impact on evacuation and access routes (for people and stock during flood events).

Two properties immediately south-east of the confluence of Coldstream River and the Clarence River South Arm are currently used as a refuge for stock during Clarence River regional flooding. These properties are cut by the project with more than two-thirds of land on the far side of the project. Access to the properties would be maintained via a new road and overpass which would connect to Coldstream Road to the west. As this access would not be cut by the project and the properties would not otherwise experience flood impacts as a result of the project, there would be no change to the potential for flood evacuation of the Clarence River floodplain to the Tyndale flood refuge.

Flood evacuation and flood access impacts at the creek catchments along this catchment as a result of regional flooding are discussed in Sections 6.5, 6.7 and 6.8.

Flood hazard impacts

In regard to a broad consideration of flood hazard parameters (depth, velocity, velocity-depth product, duration of flooding, rate of rise, warning times, evacuation and flood access), it is considered that the overall level of flood hazard would not be increased by the project.

Bed and bank stability impacts

Bed and bank stability impacts would be dominated by the much faster moving local floods through these local catchments. These impacts are discussed in the crossings of the Clarence River tributaries in Sections 6.4 (Pheasant Creek) to 6.8 (Champions Creek).

Sensitivity to culvert and bridge blockage on floodplains

Analyses to determine the sensitivity of the flood impacts to assumptions of culvert and bridge blockage for this section of the project have been carried out for local catchment flooding only. This is because local catchment flooding results in greater impacts than regional flooding and therefore is more sensitive to blockages. The results of these analyses are presented in Sections 6.4 through 6.8.

6.9.4. Flood impact summary

The project would meet the stated flood management objectives for this area.

6.10. Clarence River (Tyndale to Maclean)

6.10.1. Flood management objectives

Land use within this portion of the Clarence River catchment consists of residential, forested, cane farm land, and other agricultural and rural uses. The flood management objectives of relevance to this catchment are:

- Less than 50 millimetres increase in flood heights at houses for any assessed flood event less than and equal to 100 year ARI event
- Less than 50 millimetres increase in flood heights on cane farm land for any assessed flood event less than and equal to 100 year ARI event
- On grazing, forested and other rural areas, generally less than 250 millimetres increase for any assessed flood event less than and equal to 100 year ARI event
- No more than five per cent increase in the flood duration where there are houses and cane land
- No more than ten per cent increase in the flood duration in recognition on grazing, forested and other rural lands
- Velocities to remain and below one metre per second on grazing, forested and other rural lands where currently below these figures. An increase of not more than 20 per cent where existing velocity is above these figures
- Velocity-depth products for houses, commercial premises and urban areas remain in low hazard category (for children)
- No change to the direction of watercourses or the direction of flood flows except for constriction into and expansion out of discrete openings (culverts and bridges) and constructed diversions.

These objectives are detailed in Section 2.1.

6.10.2. Design

The route between Tyndale and Maclean in Section 4 would pass to the east of the Clarence River South Arm through the Shark Creek and Chaselings Basin area. A new dual carriageway embankment would be constructed, with the following waterway openings as shown in Table 6-15.

Table 6-15 Proposed structures on Clarence River (Tyndale to Maclean)

Station (km)	Proposed structures[1]
Continuous except for the structures listed below	Embankment
70.46	9 m wide bridges
71.06	2 x 3.3 m x 1.8 m box culverts
71.68	3 x 1.8 m x 1.8 m box culverts
72.59	3 x 1.8 m x 0.9 m box culverts
73.02	1 x 3.6 m x 1.8 m box culvert
73.24	1 x 1.2 m concrete pipe
73.50	6m wide bridge
74.76	A 400 metre long bridge across Shark Creek and the adjacent floodplain (including Gallaghers Lane and Shark Creek Road). The height of this bridge would be dictated by clearances for the local roads and would, therefore, have a soffit above the 100 year ARI flood levels.
75.57	1 x 3.6 m x 2.4 m box culvert
76.45	1 x 2.4 m x 2.4 m box culvert
77.28	2 x 2.4 m x 2.1 m box culverts at an invert of -0.5 m AHD (assumed invert of cane drain) across a drain about two kilometres north of Shark Creek to convey cane runoff to the river (in local flood events) and flood flows from the river to the floodplain.
77.30	3 x 3 m x 2.4 m box culverts
77.84	1 x 3.6 m x 1.8 m box culvert
77.95	1 x 3.6 m x 1.8 m box culvert
78.6 (approx.)	5 x 3 m x 2.1 m box culverts
78.88	2 x 2.4 m x 0.9 m box culverts
78.98	10 x 3 m x 1.2 m box culverts
79.08	1 x 2.4 m x 0.9 m box culvert
79.67	2 x 2.4 m x 0.9 m box culverts
79.94	4 x 3 m x 2.4 m box culverts
80.15	3 bridges
80.34	1 x 0.9 m concrete pipe
80.55	8 x 2.4 m x 1.2 m box culverts

1. Subject to review during future stages of the project.

6.10.3. Flood impacts

Due to the flood storage capacity of the Shark Creek basin, the peak flows into the basin (from the South Arm of the Clarence River) occur when flood levels are well below the peak levels. At the time of peak flood levels, flows into the basin are very small. Hence, the length of the major bridge over Shark Creek was dictated by impacts to the inundation period and the rate of flood water rise, not peak flood levels.

Similar to the Shark Creek basin, the peak inflows to the Clarence River South Arm to the Chaselings Basin occur when flood levels are below the peak levels. Hence, the sizing of the openings in the Chaselings Basin was generally dictated by the rate of rise of flood waters.

Flood level impacts

The waterway openings and the predicted impacts of the project on peak flood levels for the 20, 50 and 100 year ARI flood events are presented in Figure 6-15 to Figure 6-17. Approximate flood impact levels are presented in Table 6-16.

The impact of the project on peak flood levels would be less than 15 millimetres increase for the 100 year flood. The 20 year and 200 year ARI events experience impacts up to 15 and 10 millimetres respectively.

During a five year flood, impacts of 15 millimetres are experienced along the project boundary in Shark Creek. Larger impacts of up to 40 millimetres are experienced between McIntyres Lane and Townsend during a five year ARI event. Houses in the south of Townsend experience increases in flood levels of up to 35 millimetres.

Since original design of the bridge over Edwards Creek, the flood model of this area has been revised and improved. Based on revised flood levels, the bridge design at this location no longer has 20 year ARI immunity. The bridge over Edwards Creek would be raised by around 80 millimetres as part of the detailed design phase to ensure the 20 year ARI flood immunity is maintained. This issue has been further documented in Section 8.1.1.

No house on the floodplain was shown to have an increase in peak flood levels of more than 50 millimetres.

Table 6-16 Flood level impacts in Clarence River (Tyndale to Maclean)

Location	5 year ARI event	20 year ARI event	100 year ARI event	200 year ARI event
Shark Creek	15 mm	15 mm	5 mm	Less than 5 mm
Townsend	35 mm	5 mm	0 mm	Around zero mm
Lawrence Road east of Ilarwill	5 mm	10 mm	15 mm	10 mm

Flood impacts to property

The increase in flood levels results in an increase of about 0.6 per cent in the sum total of average annual flood damages for residences in the impacted area between Tyndale and Maclean. A histogram showing the distribution of increased average annual damages and increased flood levels as a result of the project is presented in Figure 6-13 and Figure 6-14 respectively. There are no properties which experience greater than 50 millimetres increase in flood levels. Increases of less than 50 millimetres would meet the flood management objectives for the area.

The existing mean of average annual flood damages for residences in this area is about $3,500.

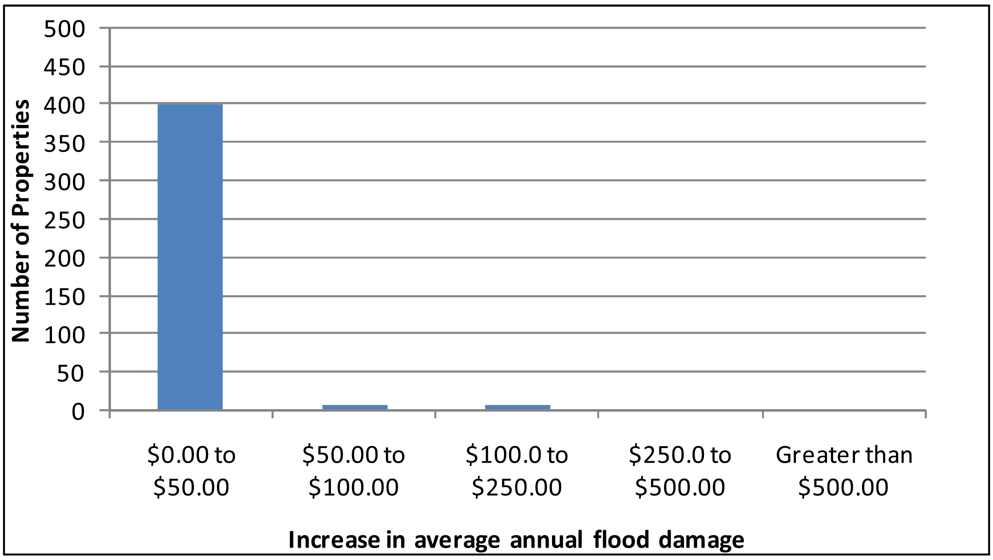


Figure 6-13 Distribution of increase in average annual flood damages between Tyndale and Maclean (including Ashby, Gulmarrad, Woodford Island, South Arm, Shark Creek and Brushgrove)

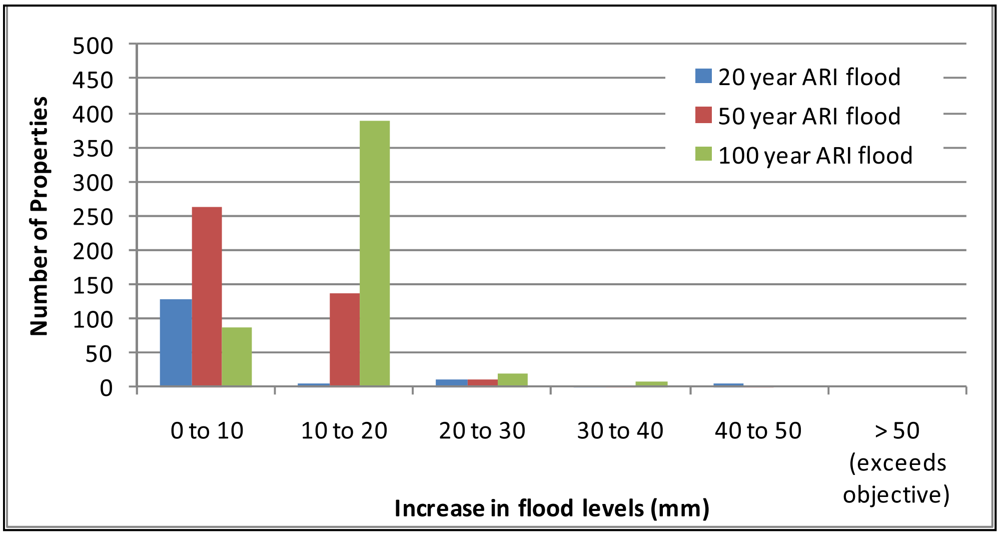


Figure 6-14 Distribution of impact to flood levels between Tyndale and Maclean (including Ashby, Gulmarrad, Woodford Island, South Arm, Shark Creek and Brushgrove)

Flood inundation duration impacts

Based on plots of flood level versus time along the Shark Creek basin, land below 2.2 metres AHD would not experience any change in flood inundation duration. Above 2.2 metres AHD, there are some areas that would experience an increase in the total duration of flood inundation. The maximum impact experienced would be around an 8 per cent increase at 3.0 metres AHD. As the vast majority of land in this area is below 2.0 metres AHD, cane is not expected to be subjected to any increase in the duration of inundation.

It is possible there may still be isolated pockets of cane land above 2.2 metres AHD which could experience some increase in inundation duration. However, it could be argued that the increase in inundation period at the start of the flood is less potentially damaging to cane crops than that at the end of the flood event, as it is less likely that there would be sufficient sunshine to heat the water to a level that would damage crops at the start of a flood event. Based on plots of flood level versus time, the nearest elevated land (around 2.6 metres AHD) to where impacts have been modelled would experience less than the objective of no more than five per cent increase. Flood level plots and locations are provided in Appendix G.

There is negligible change to the recession of the flood.

Flood velocity and direction impacts

The most important elements of the proposed cross-drainage are the openings to replace the existing Goodwood Street underpass. The levels of Cameron Street along the riverbank where the Clarence River first breaks its banks would be left unchanged. Hence, the time at which floods first enter the Chaselings Basin would not change, nor would the frequency of flooding of the basin. The replacement openings have been sized to convey a similar rate, velocity and direction of inflow into the basin, resulting in a similar rate of floodwater rise and peak levels.

The very long duration of the event means that flood velocities are low throughout the floodplain (less than one metre per second). Peak velocity impacts and changes in direction as a result of the project are presented in Figure 6-18 and Figure 6-19. Changes in velocities upstream and downstream of structures through this catchment are included in Appendix F.

As for the structures to the south of the Goodwood Street underpass, the proposed location of culverts and bridges would minimise changes in flow direction and flood behaviour. Some constriction and expansion of flow into and out of waterway structures would occur.

Rate of flood rise and warning time impacts

As discussed in the impacts to flood inundation duration, along the western boundary of the project above 2.2 metres AHD, flood levels rise earlier in the project case compared to the existing case. However, as the land in this area is used only for cane farming (and further, the vast majority of land is below 2.0 metres AHD), no residential or commercial premises would experience impacts to the rate of flood rise and warning time. Likewise, no grazing or forested land would be affected.

Flood evacuation and flood access impacts

This section of the project does not follow the existing highway route. As such there is potential for the project to impact on evacuation and access routes (for people and stock during flood events). The majority of the route in this section passes through cane land. The local roads that provide access to the existing highway during times of flood are Byrons Lane and Shark Creek Road will cross the project (Byrons Lane passes over and Shark Creek Road passes under the project). Hence, it is unlikely that access during times of flood will be affected in this area.

However, there is a landholder adjacent to the project on the western side that would have reduced flood access during times of flooding. This owners of this property on Byrons Lane use a small boat to gain access to the existing highway when floodwaters rise sufficiently high to make car access along Byrons Lane not possible. The project will make it very difficult if not impossible to access the existing highway by boat.

Although floodwaters would rise earlier than under existing conditions in the Shark Creek Basin, the size of the catchment means that there is sufficient warning of a flood approach, and the rate of flood level rise is slow enough, to have negligible effect on the ability of stock to evacuate the area safely. There would also be negligible effect on the operations of farming.

Flood hazard impacts

In regard to a broad consideration of flood hazard parameters (depth, velocity, velocity-depth product, duration of flooding, rate of rise, warning times, evacuation and flood access), it is considered that the overall level of flood hazard would not be increased by the project.

Bed and bank stability impacts

Shark Creek is the only watercourse crossed by the project in this section with natural bed and banks. The peak flood velocities for a range of flood events in Shark Creek are shown in Appendix H for the existing case and that predicted with the project. These velocity profiles are taken underneath bridges where generally the greatest changes in velocity are expected as a result of constriction of flow through the structure.

The plots in Appendix H show the changes to velocities at the peak of the flood. However, Shark Creek is unique for crossings of this project in that the peak flood velocities occur on the rising limb of the flood as Clarence River floodwaters flow backwards into the large floodplain storage areas of the Shark Creek floodplain. Hence, the discussion below discusses the changes to the velocities at the peak of the flood as well as the changes to peak backflow velocities.

The project would increase velocities at the peak of the flood from about 0.2 metres per second to 0.5 metres per second. These are low velocities and likely to be lower than the velocities experienced on a daily basis from tidal inflows and outflows. Hence, the changes to the velocities at the peak of the flood are unlikely to result in any change to the bed and bank form of the creek.

The modelling indicates that the maximum back-flow velocity of 1.7 metres per second in Shark Creek on the rising limb of the flood would not change as a result of the project. Further, the temporal distribution of the velocities would also remain unchanged. Hence, it is unlikely that the project would result in any change to the bed and bank form of Shark Creek.

The concept design includes bridge piers located on the banks of Shark Creek. However, the concept design includes 32 metre bridge spans which would be sufficient to avoid piers in the permanent water part of Shark Creek. The piers on the banks would have the potential to result in localised erosion of the bank without appropriate design. The final location of these piers would be determined in the detailed design phase with a more detailed consideration of the bridge spans. The design of these piers in waterways would be in accordance with the NSW Office of Water guidelines for instream works and watercourse crossings to minimise the impacts to the stability and hydrology of the watercourse.

There are three crossings of cane drains in this section which would be crossed by short bridges. These cane drains are maintained by Clarence Valley Council as flood mitigation assets. The potential for the project to impact upon the bed and bank stability of these cane drains is limited as the project would span these drains without obstruction. The common flows in these drains would not be impeded or changed in any way. Flood flows would be similar with very low velocities (less than 0.4 metres per second) when the floodplain is engaged.

Sensitivity to culvert and bridge blockage on floodplains

An analysis was carried out to determine the sensitivity of the flood impacts to assumptions of culvert and bridge blockage during the 100 year ARI flood event on the Clarence River floodplain. The analysis was based on a 10 per cent blockage of bridges and culverts with diagonal span over six metres. Culverts with a diagonal span up to one metre were simulated with a 25 per cent blockage. For culverts with a diagonal span between one and six metres, linear interpolation was used to determine the fraction of blockage.

Little impact occurred in the Shark Creek area, with any impact increase being less than five millimetres.

Sensitivity to Shark Creek vegetation blockage

An analysis was carried out to determine the sensitivity of the flood impacts to the degree of vegetation blockage of Shark Creek during the 100 year ARI flood event on the Clarence River floodplain. The analysis was based on trebling the hydraulic roughness (0.025 to 0.075) which effectively decreases the conveyance capacity of the creek by a factor of three.

The assessment indicated that the change in project flood impacts due to Shark Creek having greater vegetation blockage would be minor. The impacts would decrease by about 10 millimetres in the Shark Creek floodplain and 15 millimetres on the Chatsworth and Harwood islands area. Hence, the assessments documented in this working paper have assumed a conservative level of vegetation blockage in Shark Creek as less blockage results in slightly higher impacts.

The time of inundation of flooding around Shark Creek would generally also be insensitive to vegetation blockage, based on results of the assessment. Changes to vegetation blockage in Shark Creek resulted in less than five percent change in flood inundation time.

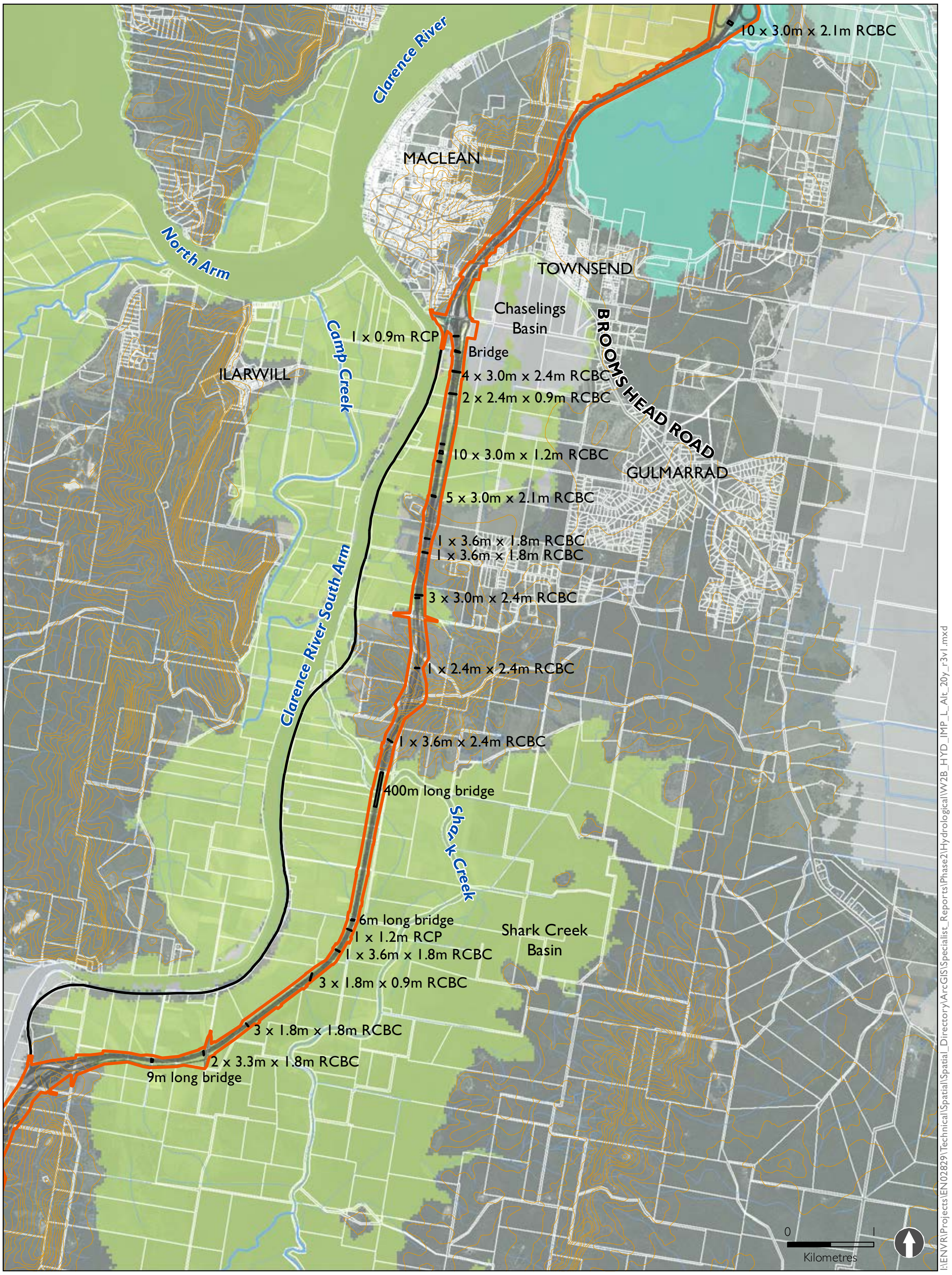
6.10.4. Flood impact summary

Culverts and bridges have been sized and located to minimise the change in flow regime, levels, velocities and inundation times.

In particular, the Goodwood Street underpass is the most important element of the proposed cross-drainage to ensure that flow into the basin is maintained as closely to the existing regime as possible in all flood events modelled.

The project would meet all flood management objectives for this area.

Figure 6-15 Flood impacts 20 year ARI event: Clarence River at Shark Creek / Maclean



The project
Project concept design
Existing Pacific Highway
10m ground level contours (indicative)

Flood impacts - m

-0.075 -0.050 -0.025 -0.005 0.005 0.025 0.050 0.075 0.150

Figure 6-16 Flood impacts 50 year ARI event: Clarence River at Shark Creek / Maclean

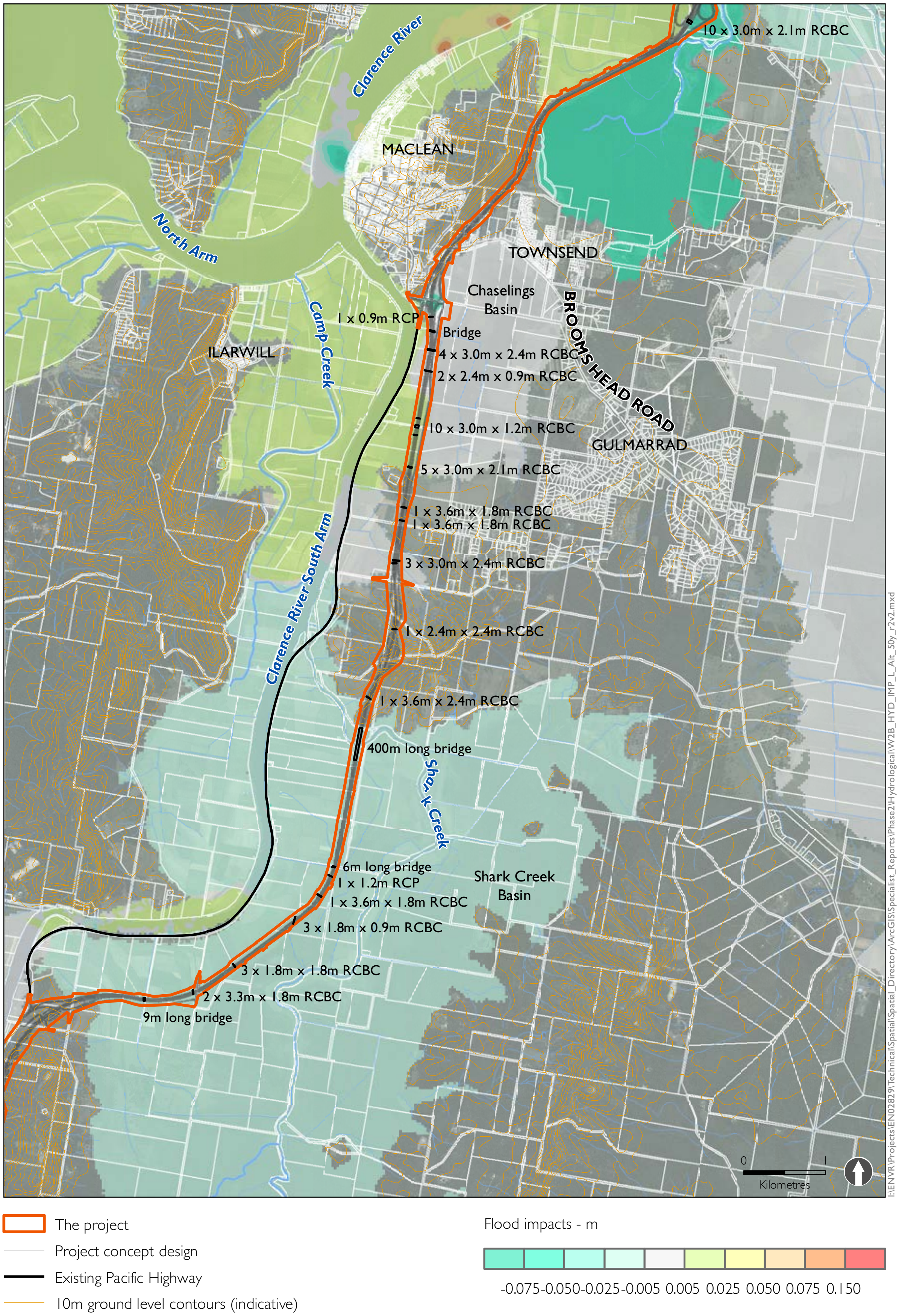


Figure 6-17 Flood impacts 100 year ARI event: Clarence River at Shark Creek / Maclean

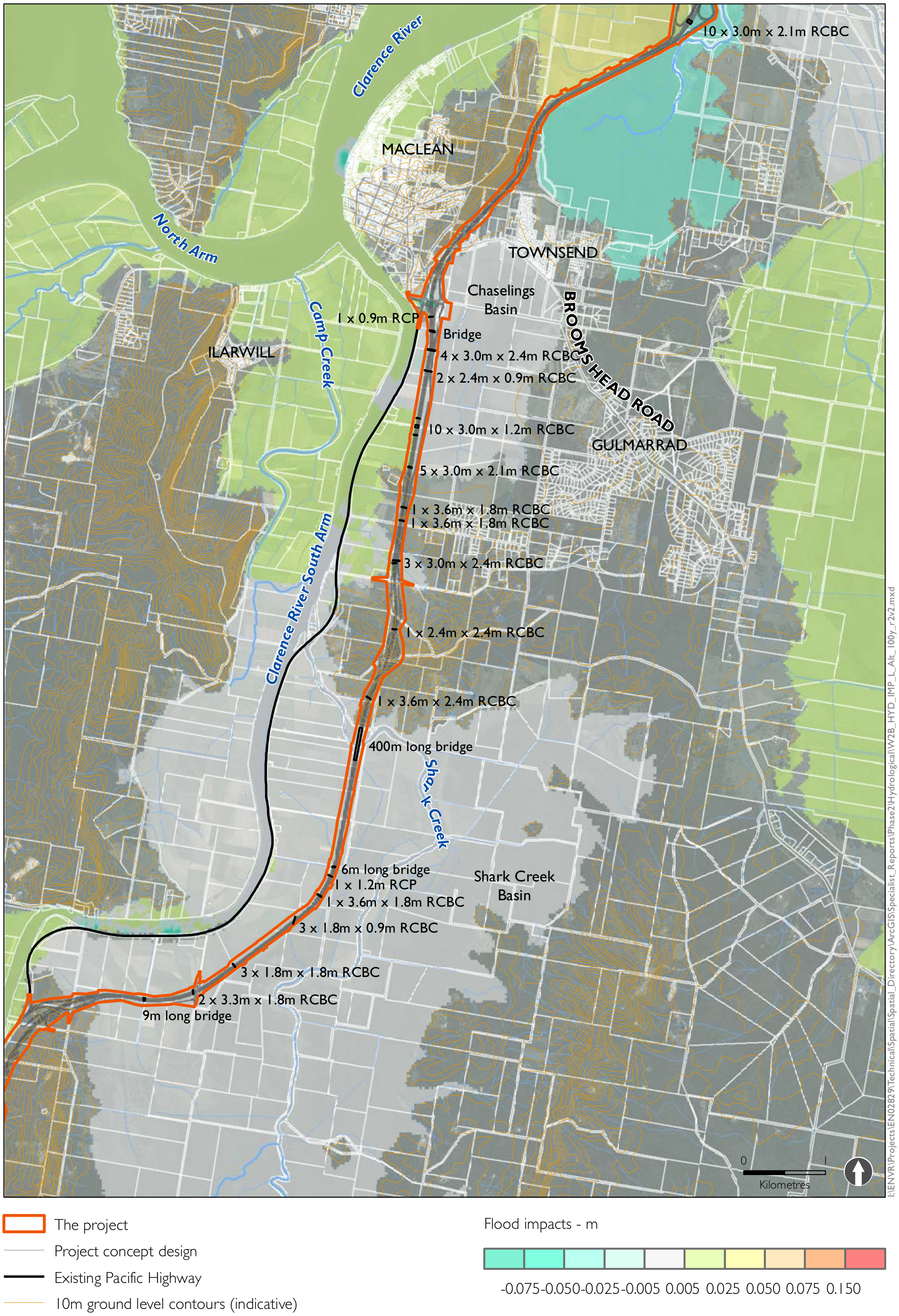
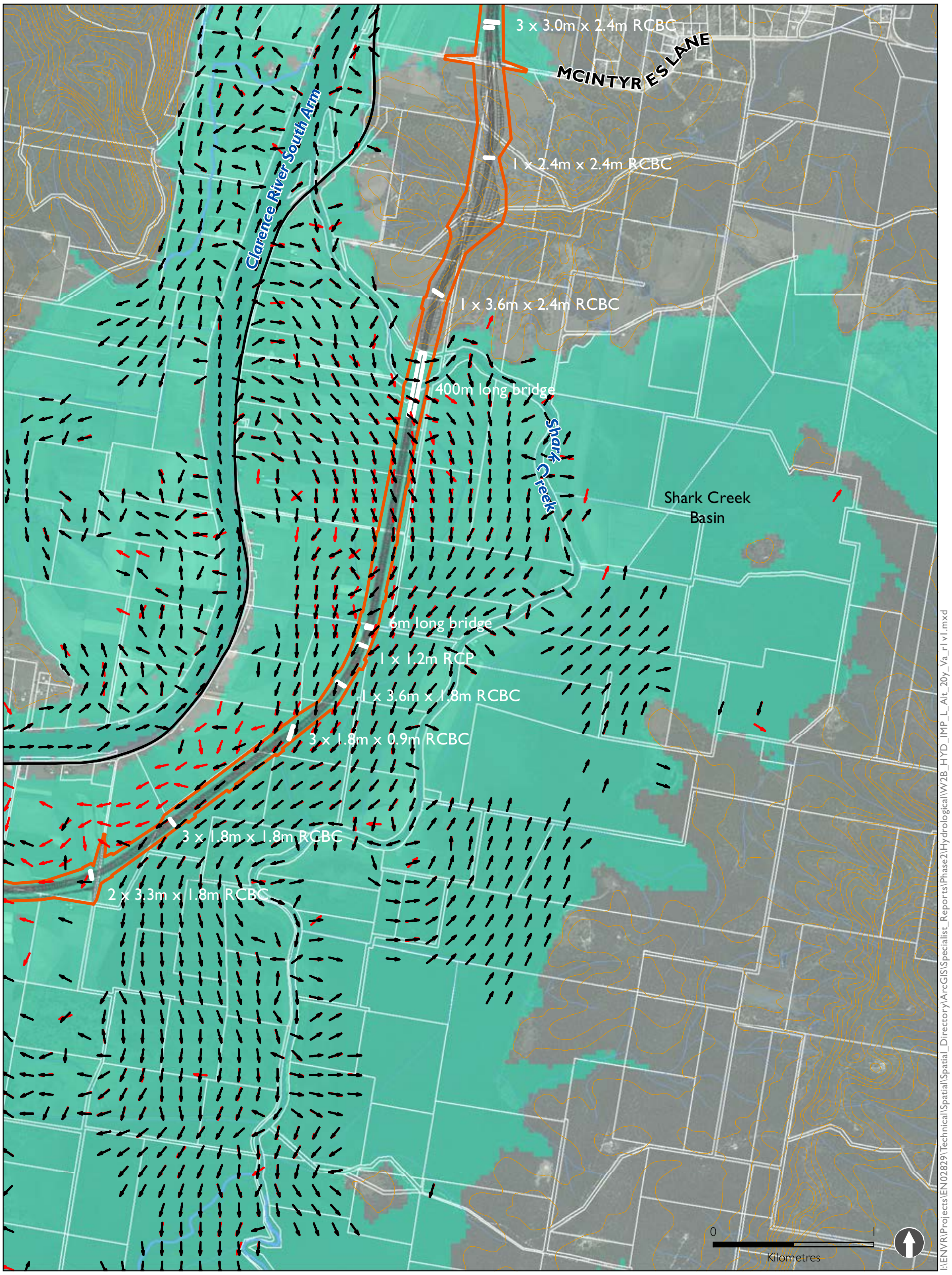


Figure 6-18 Velocity impacts 20 year ARI event: Clarence River at Shark Creek

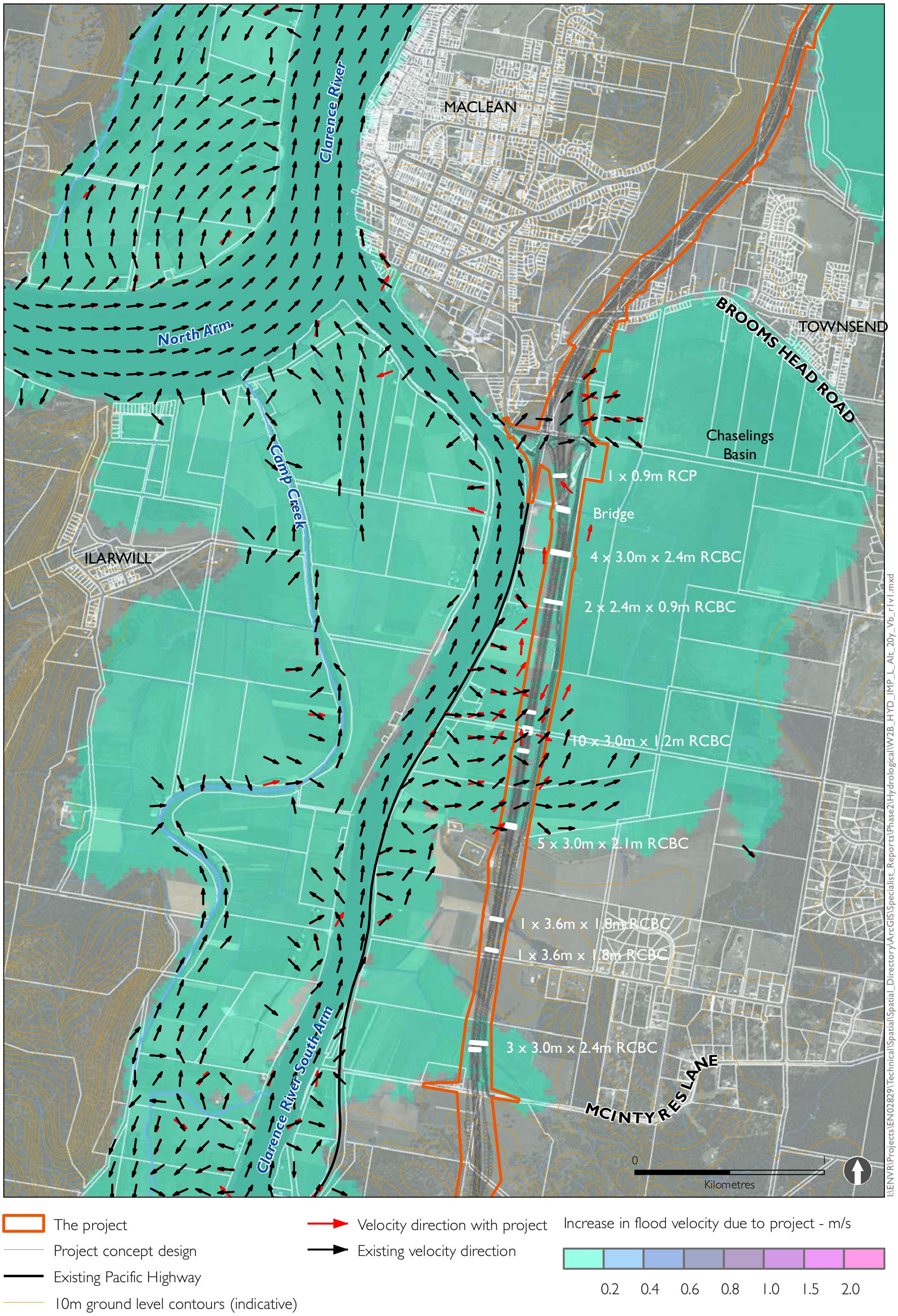


The project
Project concept design
Existing Pacific Highway
10m ground level contours (indicative)
Velocity direction with project
Existing velocity direction

Increase in flood velocity due to project - m/s

0.2 0.4 0.6 0.8 1.0 1.5 2.0

Figure 6-19 Velocity impacts 20 year ARI event: Clarence River south of Maclean



6.11. Clarence River (Maclean to Iluka Road)

6.11.1. Flood management objectives

Land use within this portion of the Clarence River catchment consists of residential, forested, cane farm land, and other agricultural and rural uses. The flood management objectives of relevance to this catchment are:

- Less than 50 millimetres increase in flood heights at houses for any assessed flood event less than and equal to 100 year ARI event
- Less than 50 millimetres increase in flood heights on cane farm land for any assessed flood event less than and equal to 100 year ARI event
- On grazing, forested and other rural areas, generally less than 250 millimetres increase for any assessed flood event less than and equal to 100 year ARI event
- No more than five per cent increase in the flood duration where there are houses and cane land
- No more than ten per cent increase in the flood duration in recognition on grazing, forested and other rural lands
- Velocities to remain below one metre per second on grazing, forested and other rural lands where currently below these figures. An increase of not more than 20 per cent where existing velocity is above these figures
- Velocity-depth products for houses, commercial premises and urban areas remain in low hazard category (for children)
- No change to the direction of watercourses or the direction of flood flows except for constriction into and expansion out of discrete openings (culverts and bridges) and constructed diversions.

These objectives are detailed in Section 2.1.

6.11.2. Design

The embankment of Section 5 of the project has been designed to have 20 year ARI flood immunity. Along most of the length of the embankment, the 50 year ARI event does not overtop the highest road level due to the freeboard and crossfall/camber as described in Section 2.1.5, and the 100 year ARI event does not overtop in some locations.

This section of the project from Maclean to Iluka Road crosses several major waterways, namely the Clarence River Main Arm, Serpentine Channel and Clarence River North Arm, as well as the extensive floodplains between these waterways across Chatsworth and Harwood islands.

The project includes numerous banks of culverts across the Chatsworth and Harwood floodplains to pass flows under the road embankment. The total cumulative length of drainage structures across the Chatsworth and Harwood floodplains (including bridges) would be about 2900 metres. This includes:

- 564 metres of 2.1-metre-high multicell reinforced concrete box culverts
- 9 metres of 1.8-metre-high multicell reinforced concrete box culverts
- 135 metres of 1.5-metre-high multicell reinforced concrete box culverts
- 258 metres of 1.2-metre-high multicell reinforced concrete box culverts
- 315 metres of 0.9-metre-high multicell reinforced concrete box culverts
- 2.5 metres of 0.825-metre-diameter reinforced concrete pipe culverts
- 4.9 metres of 1.22-metre-diameter reinforced concrete pipe culverts.

Structure locations and dimensions are presented in Table 6-17 and Figure 6-24 to Figure 6-26.

Table 6-17 Proposed structures on the Clarence River (Maclean to Illuka Road)

Station (km)	Proposed structures[1]
Continuous except for the structures listed below	Embankment
85.40	10 x 3 m x 2.1 m box culverts
85.60	1323 m Harwood Bridge
87.50	46 x 3.0 m x 2.1 m box culverts
88.20	46 x 3.0 m x 2.1 m box culverts
88.70	60 x 3.0 m x 2.1 m box culverts
89.26	6 x 3.0 m x 2.1 m box culverts
89.34	60 m span bridge over Serpentine Channel replicated
89.91	14 x 3.0 m x 1.2 m box culverts
90.05	8 x 3.0 m x 1.5 m box culverts
90.13	8 x 3.0 m x 1.5 m box culverts
90.23	8 x 3.0 m x 1.5 m box culverts
90.39	8 x 3.0 m x 1.5 m box culverts
90.49	13 x 3.0 m x 1.5 m box culverts
90.85	16 x 3.0 m x 1.2 m box culverts
91.14	13 x 3.0 m x 1.2 m box culverts

Station (km)	Proposed structures[1]
91.40	3 x 3.0 m x 1.8 m box culverts
91.65	8 x 3.0 m x 0.9 m box culverts
91.82	8 x 3.0 m x 0.9 m box culverts
92.15	30 x 3.0m x 1.2 m box culverts
92.30	3 x 0.825 m concrete pipes
92.59	19 x 3.0 m x 0.9 m box culverts
92.70	15 x 3.0 m x 0.9 m box culverts
92.83	2 x 1.22 m concrete pipe
92.84	13 x 3.0 m x 1.2 m box culverts
92.96	20 x 3.0 m x 0.9 m box culverts
93.10	11 x 3.0 m x 0.9 m box culverts
93.40	2 x 1.22 m concrete pipe (extension of existing pipe)
93.44	24 x 3.0 m x 0.9 m box culverts
93.99	Additional 220 m span bridge over the Clarence River North Arm
94.28	20 x 3.0 m x 2.1 m box culverts

1. Subject to review during future stages of the project.

The waterway openings are different to the design of the previous development project in the following ways:

- The rearrangement of the interchange at Harwood has resulted in corresponding alterations to the concept design waterway openings in this vicinity
- An extension of bridge span 220 metres long north of the Clarence River North Arm would ensure the flood management objectives are met in this area
- Refinement of several other banks of culverts associated with the increased detail of the concept design compared to the previous project development phase.

6.11.3. Flood impacts

Flood impacts for the Clarence River that have been assessed in the following section include cumulative impacts from culverts, bridges and road embankments.

An assessment of the sensitivity of the culvert and bridges (including the effects of debris on bridge piers) to blockage is included below. Detailed assessments of flood loadings on the proposed bridges will be undertaken during the detailed design phase of the project.

Flood level impacts

The impact of the concept design on flood behaviour was assessed for the 20, 50 and 100 year ARI events using the two-dimensional Clarence River flood model discussed in Section 2.2.5. Figure 6-24 to Figure 6-26 show the peak flood differences for each of these events respectively. Approximate flood impact levels are presented in Table 6-18.

The concept design generally results in higher flood levels compared to existing conditions to the west of the project and lower flood levels to the east of the project. Increases in peak flood levels are less than 50 millimetres in all areas outside of the project boundary except for an area of 0.6 hectares to the north-west of the interchange at Harwood. This area experiences a maximum impact of 65 millimetres increase at the western edge of the project boundary in the 50 year ARI flood event. This would only affect cane land adjacent to the highway.

An extension of 30 metres of culverts to the south of the interchange would be sufficient to reduce these impacts to 50 millimetres at the project boundary. This measure would be incorporated into the detailed design phase and is included in Chapter 8 (Mitigation and management).

The modelling of the five year ARI event indicates the project has the potential to alter flood behaviour and increase flood levels by about 200 millimetres over a 420 hectare area on Chatsworth Island. This potential change to flood behaviour could occur because the existing highway is only slightly overtopped in this event and acts as an impediment to flow from the east. As the bank of the Clarence River at Chatsworth village is not breached in a five year ARI event, the affected area is inundated from back-up flooding from the eastern parts of Chatsworth Island. The increased culvert capacity in the Class M version of the project would provide a conduit for flow in these smaller flood events, resulting in the increases in flood levels of up to 250 millimetres on cane land. This effect would be mitigated by constructing the project service road to the same level as the existing highway for a length of about 750 metres to serve as a low level levee and maintain the existing flooding behaviour in these smaller events only. This measure is further documented in Chapter 8.

South of the Yamba Road interchange, a multicell culvert about 30 metres long at station 85.4 also has the potential to provide a conduit for flow in these smaller flood events, resulting in the increases in flood levels on the cane land at James Creek west. This effect would be mitigated by constructing the on ramp to the interchange at about 1.0 metres AHD to serve as a low level levee and maintain the existing flooding behaviour in these smaller events only. This measure is further documented in Chapter 8.

Table 6-18 Flood level impacts in Clarence River (Maclean to Iluka) catchment

Location	5 year ARI event	20 year ARI event	50 year ARI event	100 year ARI event	200 year ARI event
James Creek (west)	15 mm	30 mm	20 mm	30 mm	20 mm
Harwood Village	0 mm	35 mm	20 mm	35 mm	35 mm
Harwood Island (1000m west on Watts Lane)	0 mm	20 mm	20 mm	30 mm	25 mm
Chatsworth Village	0 mm	5 mm	20 mm	40 mm	40 mm
Chatsworth Island (500m west on Carrrolls Lane)	0 mm	10 mm	20 mm	35 mm	15 mm

Flood impacts to property

The increase in flood levels to the west of the project results in a three per cent increase in the sum total of average annual flood damages for residences on Chatsworth Island. The sum total of average annual flood damages in the region of Harwood lying west of the project increase by 1.8 per cent. Residences and businesses to the east of the project were not included in this study, but would experience a reduction in the sum total of average annual flood damages. This is a result of 50 and 100 year ARI flood levels mostly reducing in this area and 20 year ARI flood levels either reducing or experiencing a negligible (less than two millimetres) increase.

The existing mean of average annual flood damages for impacted residences in this area is about $3,500 for Harwood Island and about $1,900 for Chatsworth Island. This is likely a reflection of Harwood Island experiencing greater flooding than Chatsworth Island in the more frequent 20 year ARI events. The more frequent a flood event occurs, the greater weighting the damages incurred by that flood have on the average annual flood damage for a property.

Histograms showing the distribution of increased average annual damages and increased flood levels for Chatsworth and Harwood islands and surrounding areas as a result of the project are presented in Figure 6-20 through Figure 6-23. There are no properties which experience greater than 50 millimetres increase in flood levels. Increases of less than 50 millimetres would meet the flood management objectives for the area.

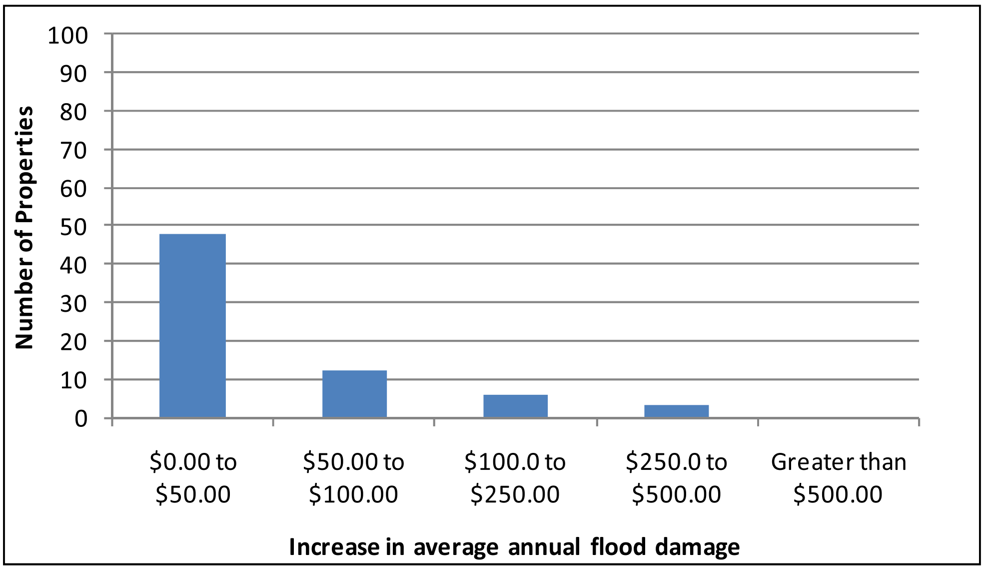


Figure 6-20 Distribution of increase in average annual flood damages on Chatsworth Island and surrounding areas

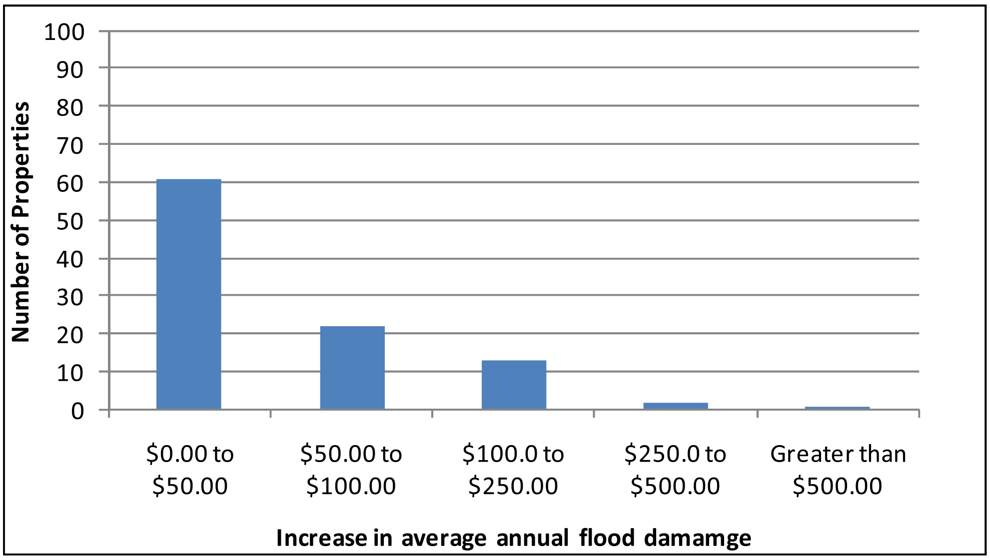


Figure 6-21 Distribution of increase in average annual flood damages on Harwood Island and surrounding areas

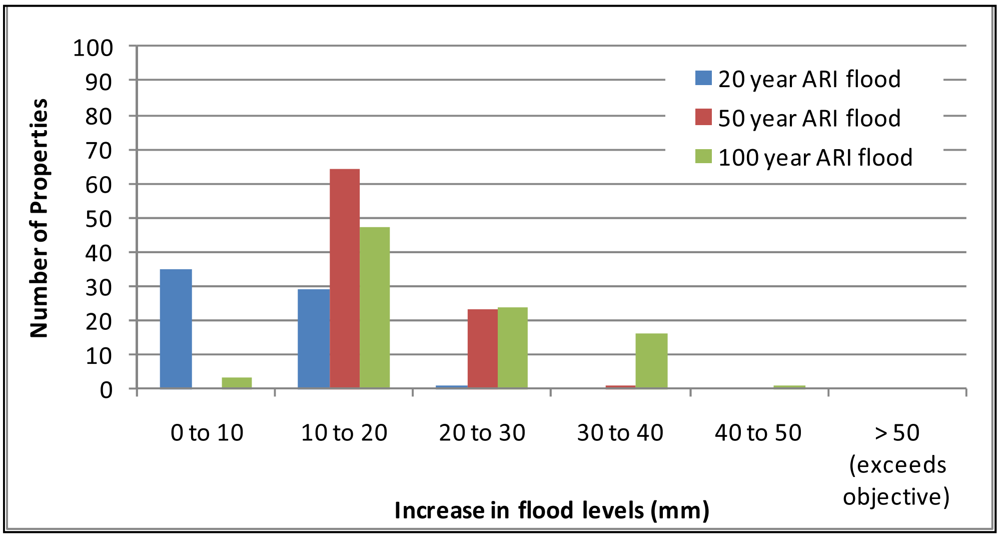


Figure 6-22 Distribution of impact to flood levels on Chatsworth Island and surrounding areas

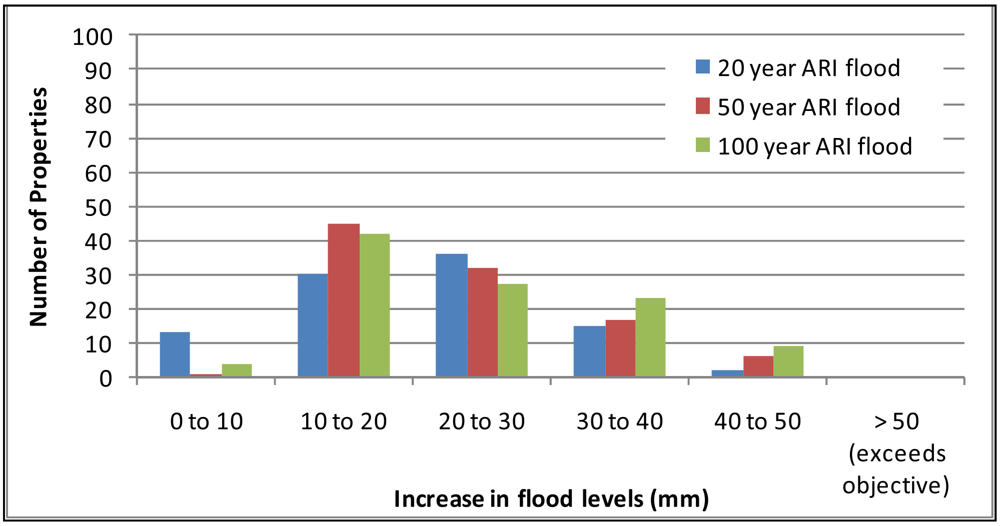


Figure 6-23 Distribution of impact to flood levels on Harwood Island and surrounding areas

Impacts on flood immunity of Maclean levee

The levee at Maclean provides limited flood protection to the town. That is, there is a flood (with a certain probability of occurrence) that will overtop the levee and result in inundation of the 'protected' areas. The volume of water overtopping the levee and the resulting depth of inundation inside is a function the depth of water above the levee crest. As these depths are usually very shallow, any minor increase in the depth of overtopping can result in a much larger increase in flood depths inside the levee system.

The existing levee system at Maclean is predicted to provide protection up about the 36 year ARI flood event. Flood modelling predicts that the project would result in increases of about 10 millimetres to the peak river flood levels in the 35 year ARI flood event. This increase would be sufficient to result in minor overtopping of the levee in some locations.

Impact assessments of defined flood events between the 35 year ARI and 50 year ARI flood events indicate that the project would result in increases in flood levels greater than 50 millimetres inside the levee. This is because in these flood events the project would result in a minor increase in the river flood level (in the order of 10 millimetres) and therefore a slightly longer period and higher depth of overtopping. As the levee is only just overtopped in these events and there is insufficient time to fill the area inside the levee to the height of the river flood levels, the minor increase in the river makes a much larger difference inside the levee.

A better representation of the impact of the project on Maclean is to understand the change in the flood immunity of the levee. Based on the flood modelling carried out for the Clarence River floodplain, the project would result in the flood immunity of the levee reducing from 36 year ARI to 35 year ARI. Another way of expressing this impact is to consider the annual risk of levee overtopping. The annual risk is currently 2.7 per cent (ie there are 27 chances in 1000 of the levee overtopping in any one year). The annual risk of levee overtopping with the project would increase to 2.8 per cent (or 28 in 1000). This represents an increase of 0.1 per cent or 1 in 1000 chance in any one year.

For flood events larger than the 50 year ARI flood event, the degree of overtopping is sufficient to result in little difference between the flood levels inside and outside the levee system. In these larger flood events, the impacts in the river and reflected inside the levee system.

Flood inundation duration impacts

Based on plots of flood level versus time, the project would have a little impact on the times of flood inundation and rates of floodwater rise and recession for most of Chatsworth and Harwood islands. The only areas that would experience any increase in inundation time are low-lying areas south-west of the Yamba Road interchange and along the western boundary of the project between Serpentine Channel and Chatsworth Road. These impacts amount to around three per cent and five per cent increase in inundation duration respectively.

Flood level plots and locations are provided in Appendix G.

Flood velocity and direction impacts

Velocity impacts upstream and downstream of structures are considered representative of greatest velocity impacts that would be experienced outside the property boundary. Changes in velocities upstream and downstream of structures through this catchment are included in Appendix F.

Peak velocity impacts and changes in direction as a result of the project are presented in Figure 6-27 to Figure 6-32.

The upstream velocities will be related to flood debris impact on bridge piers. The changes to the upstream velocities (including changes as a result of flood debris) are minimal.

Velocities are less than one metre per second upstream and downstream of all structures in the 100 year ARI event, and across the entire Chatsworth and Harwood Island.

Flow distribution throughout this part of the river system would not be greatly impacted by the project. The majority of flow is conveyed by the Clarence River Main Arm and North Arm. Table 6-19 shows the distribution of peak flows across the lower Clarence River floodplain for the 20 year ARI flood event and Figure 6-33 illustrates this distribution.

Table 6-19 Distribution of peak flows for existing and project case: 20 year ARI flood event

Sections	Existing case		Project case	
	Peak flow	Fraction (%)	Peak flow	Fraction (%)
South of main arm	117	1	185	2
Clarence River main arm	6569	76	6593	76
Harwood Island	229	3	185	2
Serpentine Channel	85	1	87	1
Chatsworth Island	256	3	243	3
Clarence River North Arm	1356	16	1296	15
North of North Arm	46	1	91	1

It should be noted that the velocity of flow through the culverts during the 20 year ARI event would be around 0.5 metres per second to one metre per second, whereas the velocity of flow through the sugar cane on the floodplain is in the order of 0.05 metres per second. Hence, the culverts would carry 10 to 20 times more flow per linear width than the floodplain.

The contraction and expansion of this flow into and out of the culverts would occur over a relatively short length of floodplain. This could result in scouring at the inlet and outlet of the culverts that may require erosion protection measures. Detailed design would consider the need for erosion protection measures.

Rate of flood rise and warning time impacts

Based on the plots of flood level over time on the northern bank of the Clarence River Main Arm, the project would have a similar rate of rise as the existing case. Flood level plots and locations are provided in Appendix G.

Based on the plots of flood level over time at the upstream edge of the project boundary south of the Yamba Road interchange, the rate of rise is slightly faster than the existing case. There is a reduction in warning time for land below 1.5 metres AHD of up to five hours. As the land use around and immediately upstream of this location is agricultural, this is not expected to have any impact on flood warning time for residents.

Immediately downstream of the project at Harwood, there would be around 80 millimetres difference in the initial storm surge peak between the existing case and the project case. As a result, land within this elevation range (between around 2.15 to 2.25 metres AHD at the project boundary) would experience flooding approximately 10 hours earlier (with around 20 hours warning time). As most houses have habitable floor levels well above the height of this initial storm surge peak, it is unlikely that any houses would flood earlier than they would under the project case. It may, however, reduce the time for residents in a small number of high-set houses with ground levels within this 80-millimetre-range to protect items stored underneath their houses.

On Chatsworth Island, between the Serpentine Channel and Chatsworth Road, there would also be a decrease in flood warning time of up to 10 hours for land below 1.5 metres AHD. As the land use around this location (and below 1.5 metres AHD) is agricultural, this is not expected to have any impact on flood warning time for residents. Above 1.8 metres AHD, there is little change in flood warning time.

Flood evacuation and flood access impacts

There would also be a decrease in evacuation time available in low-lying areas south-west of the Yamba Road interchange and between Serpentine Channel and Chatsworth Road. However, these low-lying areas are agricultural and as such no impacts are expected to be experienced by residents.

The increased immunity of the highway would in most cases provide greater ability to evacuate during large flood events. Meetings with the State Emergency Services in the Clarence River area indicated that there would need to be changes to the emergency plans to accommodate the changes in highway access locations and the improved flood immunity of the highway.

The clearance under the Harwood Bridge during the peak of a 100 year ARI flood event would be in the order of 12 metres. Hence, this bridge is unlikely to cause any impediment to boat movements during flood events associated with disaster management or evacuations.

Flood hazard impacts

In regard to a broad consideration of flood hazard parameters (depth, velocity, velocity-depth product, duration of flooding, rate of rise, warning times, evacuation and flood access), it is considered that the overall level of flood hazard would not be increased by the project.

Bed and bank stability impacts

The peak flood velocities for a range of flood events in the Clarence River crossings (main arm and north arm) are shown in Appendix H for the existing case and that predicted with the project. These velocity profiles are taken underneath bridges where generally the greatest changes in velocity are expected as a result of constriction of flow through the structure.

For the main arm crossing of the Clarence River, these plots show that the project would increase velocities on the bed and banks by less than 10 per cent for all floods. These changes are unlikely to result in changes to bed form of the channel erosion due to the generally stable nature of the bed and banks and the relatively low velocities predicted.

For the north arm crossing of the Clarence River, these plots show that the project would increase velocities on the bed and banks by about 10 to 20 per cent for all floods. These changes are unlikely to result in changes to bed form of the channel erosion due to the generally stable nature of the bed and banks and the relatively low velocities predicted.

For the crossing of Serpentine Channel, the modelling predicts that the project would not increase velocities for the common five year ARI flood events. For the rarer 20 year and 100 year ARI flood events, it is predicted that the project would increase velocities by about 20 per cent from 0.9 metres per second to 1.1 metres per second. These changes are unlikely to result in changes to bed form of the channel erosion due to the generally stable nature of the bed and banks and the relatively low velocities predicted. Velocities would reduce to less than one metre per second at the project boundary upstream and downstream of this crossing.

The concept design includes bridge piers located on or near the bed and banks of both the Clarence River (main arm and north arm) and Serpentine Channel. These piers would have the potential to result in localised erosion of the bed and bank without appropriate design. The final location of these piers would be determined in the detailed design phase with a more detailed consideration of the bridge spans. The design of these piers in waterways would be in accordance with the NSW Office of Water guidelines for instream works and watercourse crossings to minimise the impacts to the stability and hydrology of the watercourse.

Clarence River and North Arm bridge pier impacts

The project bridges over the Clarence River main and North Arm channels are duplications of the existing bridges. The additional bridge piers associated with the project bridges at these crossings would be in line with the existing bridge piers. That is, there would not be any increase in obstructed flow area perpendicular to the direction of flow.

As discussed, flood impacts for the Clarence River that have been assessed in this section include cumulative impacts from bridges and bridge piers. The models include representation of the turbulence created by the bridge piers. For the case with the project, the turbulence represented was increased to account for the increased number of piers in the direction of flow. The resulting predicted impacts to velocities and flood levels at these locations are minor. Increases to flood levels in the river would be less than 10 millimetres and increases to velocities in the river would not be discernible.

Detailed assessments of flood loadings on the proposed bridges will be undertaken during the detailed design phase of the project.

In addition, as part of the response to the independent review of flood modelling, a check on bridge losses was undertaken using a one-dimensional hydraulic model (HEC-RAS). This assessment is detailed in Appendix B. The results of the assessment indicate that the current flood model has calculated realistic and conservative afflux from the project bridges. As such, the form losses applied in the current flood model is considered appropriate.

Sensitivity to Clarence River and North Arm bridge blockage

The susceptibility to debris blockage of the piers would not be increased due to the project as the piers for the project would line up with the existing piers.

An assessment to determine sensitivity of the flood impacts to blockage of floodplain bridges and culverts (ie not main channel bridges) was undertaken and is discussed below.

Sensitivity to culvert and bridge blockage on floodplains

An analysis was carried out to determine the sensitivity of the flood impacts to assumptions of culvert and bridge blockage during the 100 year ARI flood event. The analysis was based on a 10 per cent blockage of floodplain bridges (ie not main channel bridges) and culverts with diagonal span over six metres. Culverts with a diagonal span up to one metre were simulated with a 25 per cent blockage. For culverts with a diagonal span between one and six metres, linear interpolation was used to determine the fraction of blockage.

Small increases in impact would occur across most of the floodplain, with effects concentrated around the Chatsworth-Harwood Island. Here, an increase in impact of five to 15 millimetres was identified between the upstream project boundary and Clarence River North Arm. Increases in impact were approximately 10 to 15 millimetres within Chatsworth and approximately five millimetres within Harwood.

6.11.4. Flood impact summary

Although the embankment is designed for immunity in the 20 year ARI event, the freeboard and crossfall/camber of the road mean that most of the embankment is not overtopped in the 50 year ARI event and some locations are not overtopped in the 100 year ARI event.

The project generally increases flood levels to the west of the project and decreases levels to the east. The design of drainage structures across Chatsworth Island would be further reviewed during detailed design to enable the most appropriate and cost-effective structures to be installed.

Figure 6-24 Flood impacts 20 year ARI event: Clarence River at Chatsworth and Harwood islands

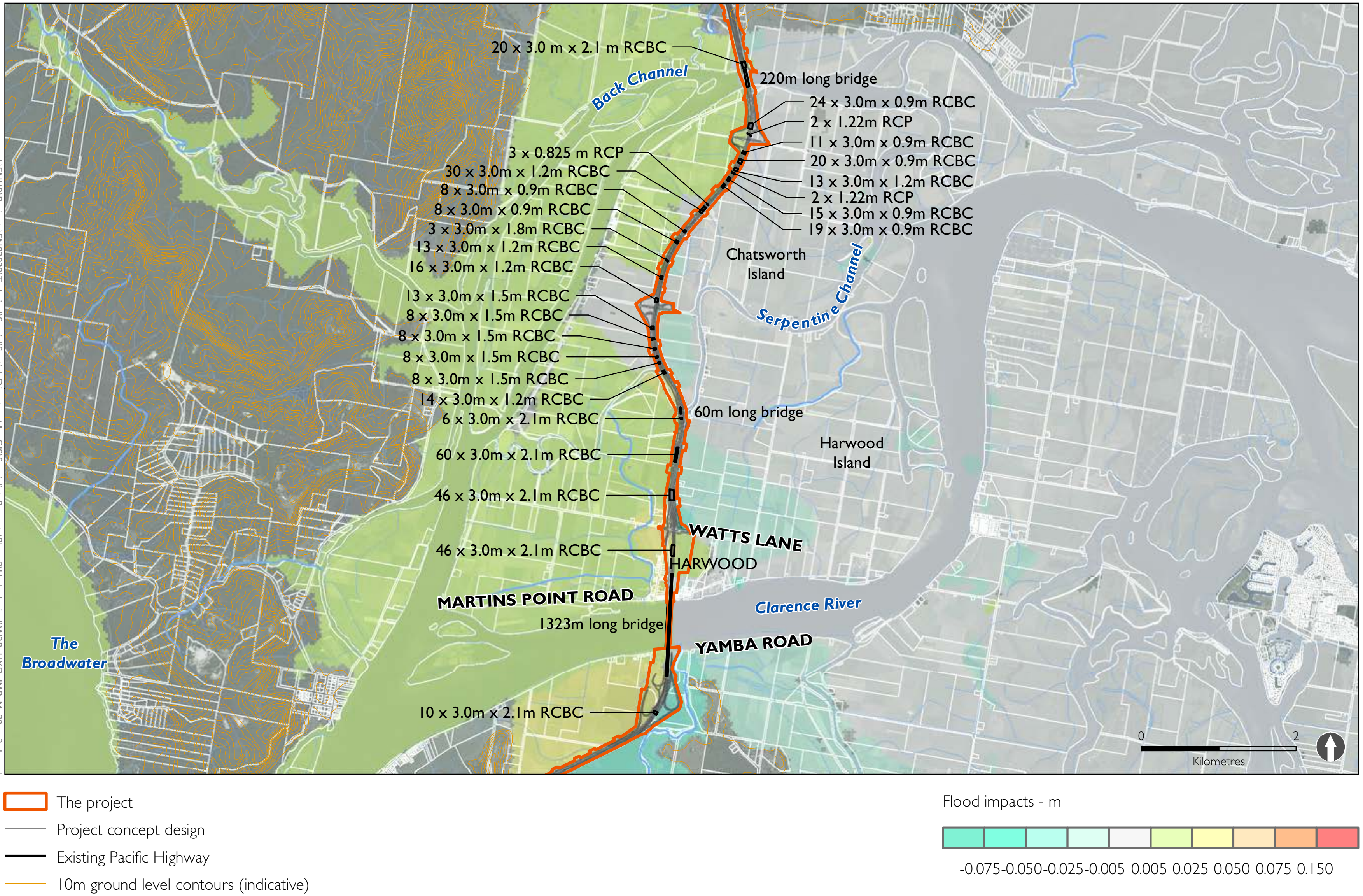


Figure 6-25 Flood impacts 50 year ARI event: Clarence River at Chatsworth and Harwood islands

The project

Project concept design

Existing Pacific Highway

10m ground level contours (indicative)

Flood impacts - m

-0.075 -0.050 -0.025 -0.005 0.005 0.025 0.050 0.075 0.150

Figure 6-26 Flood impacts 100 year ARI event: Clarence River at Chatsworth and Harwood islands

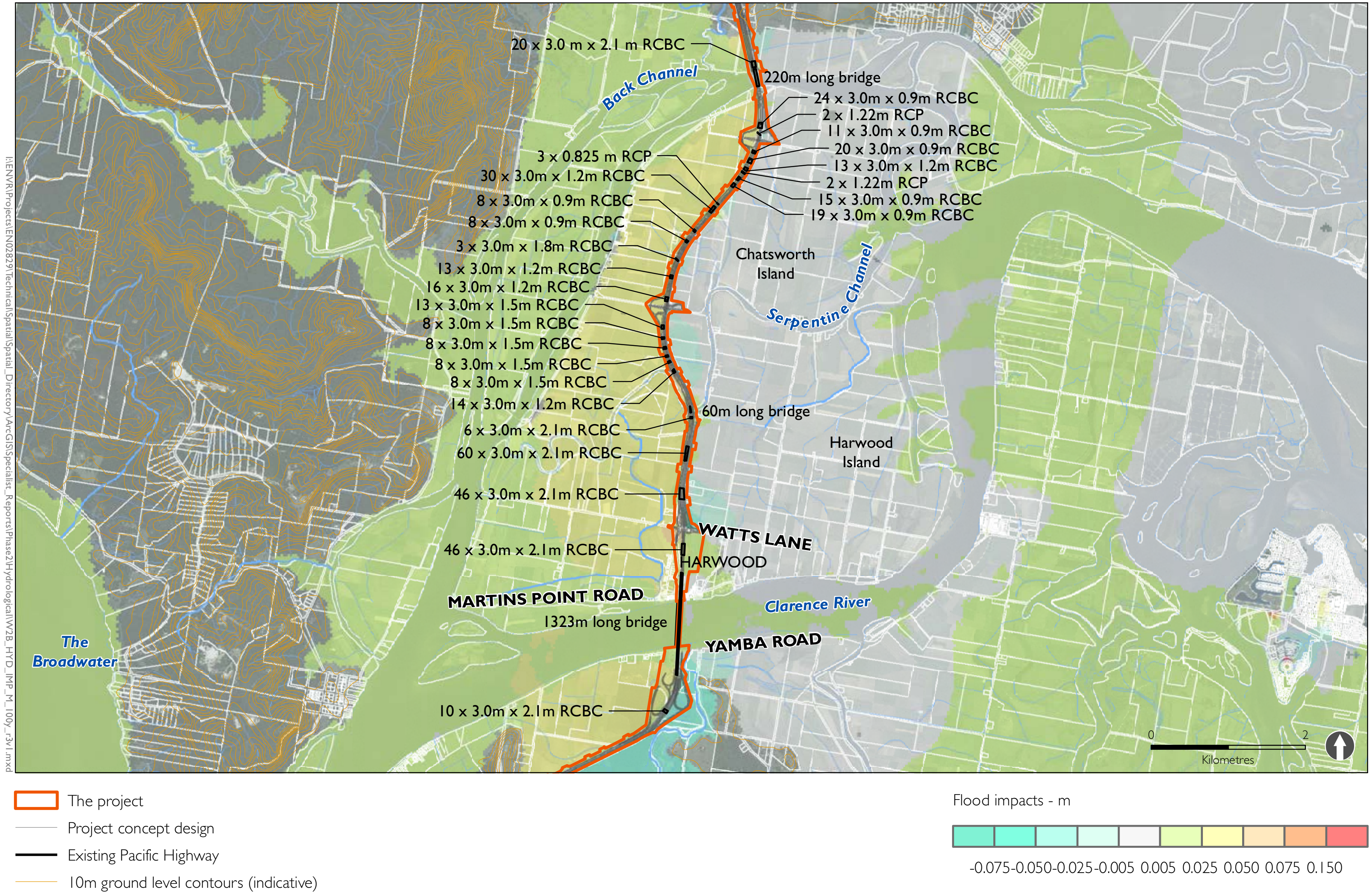
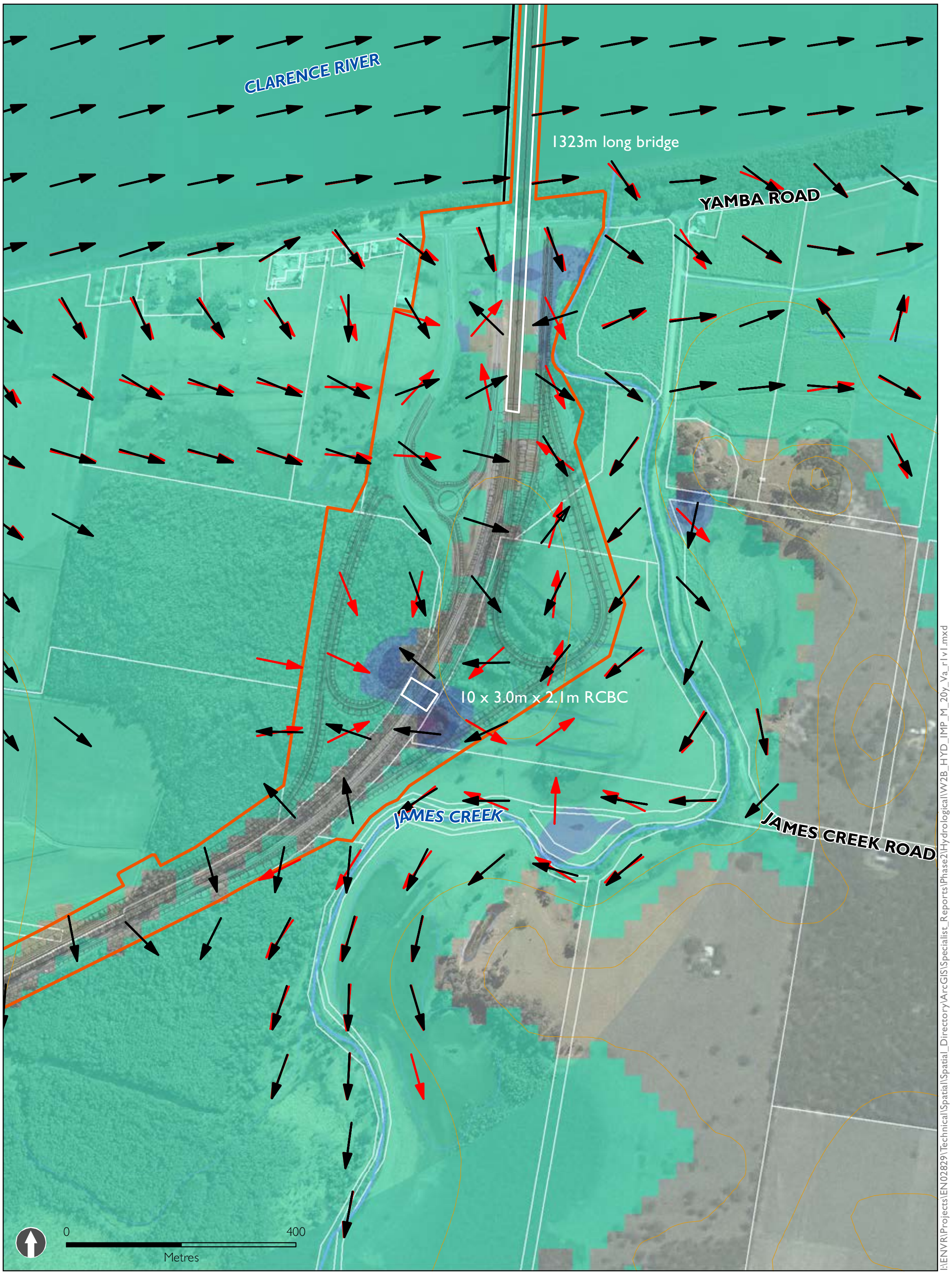


Figure 6-27 Velocity impacts 20 year ARI event: Clarence River at Yamba Road Interchange



The project
Project concept design
Existing Pacific Highway
5m ground level contours (indicative)
Velocity direction with project
Existing velocity direction

Increase in flood velocity due to project - m/s

0.2 0.4 0.6 0.8 1.0 1.5 2.0

Figure 6-28 Velocity impacts 20 year ARI event: Clarence River at Harwood

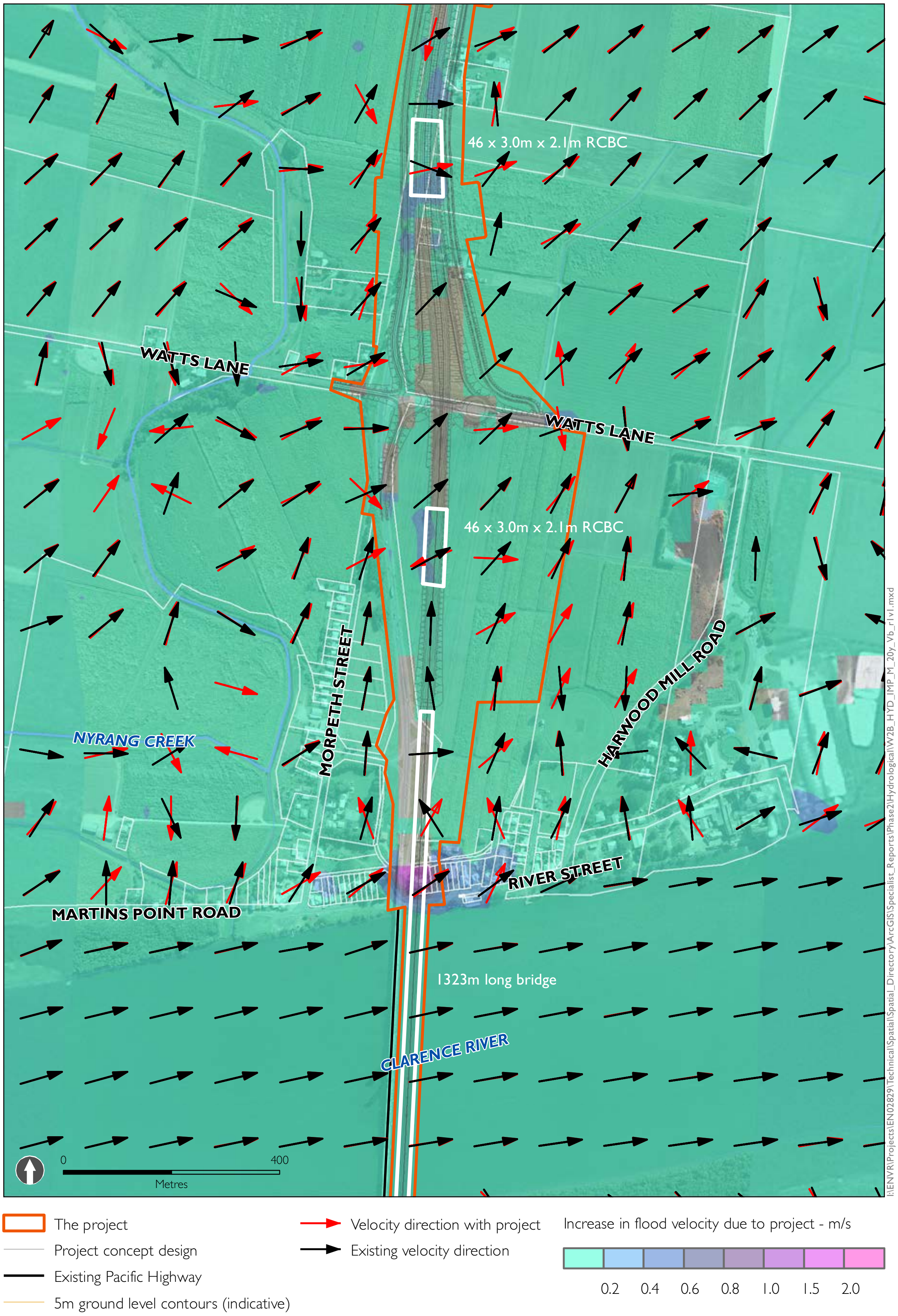
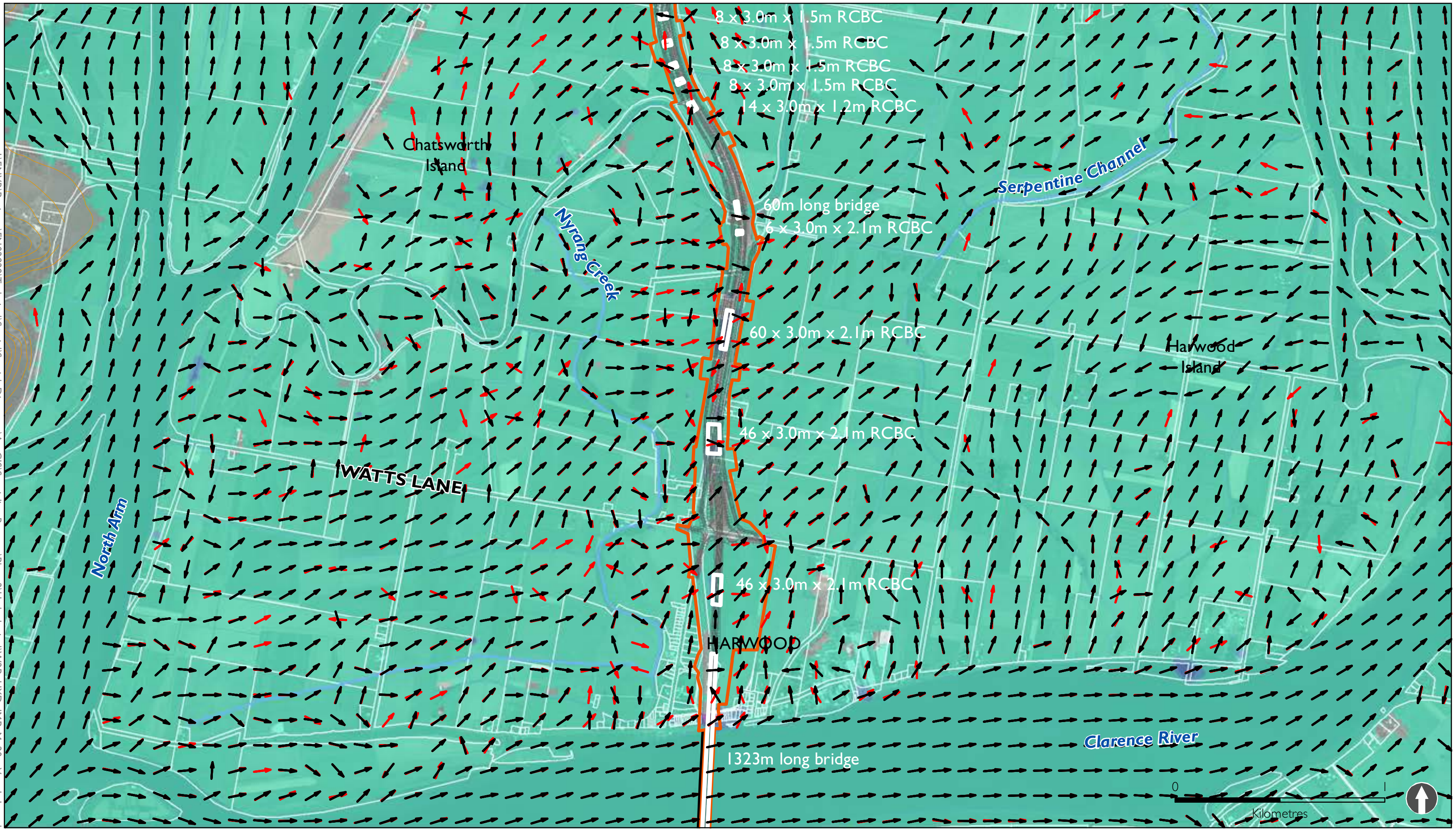


Figure 6-29 Velocity impacts 20 year ARI event: Clarence River at Harwood Island

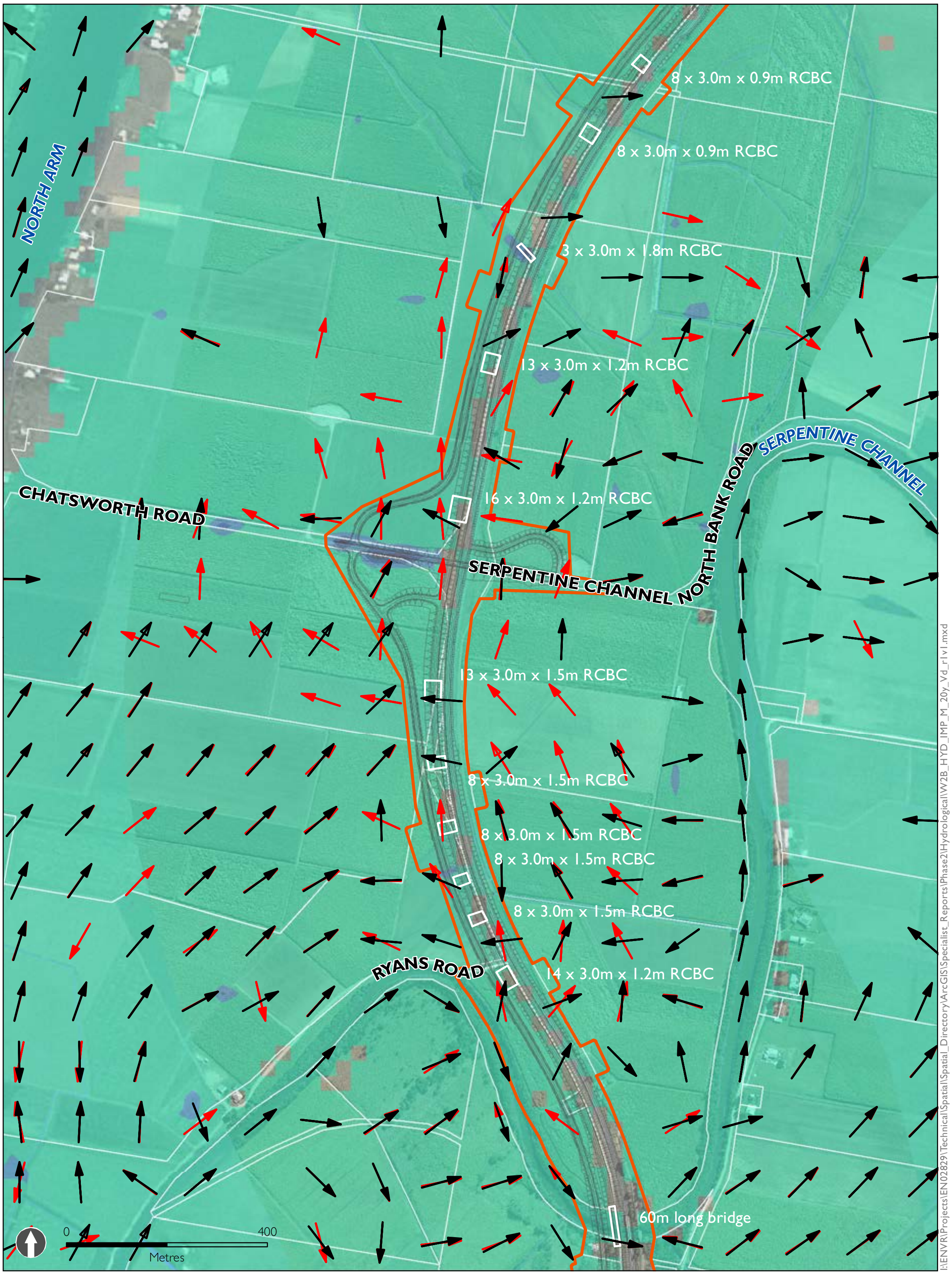


The project
Project concept design
Existing Pacific Highway
10m ground level contours (indicative)
Velocity direction with project
Existing velocity direction

Increase in flood velocity due to project - m/s

0.2 0.4 0.6 0.8 1.0 1.5 2.0

Figure 6-30 Velocity impacts 20 year ARI event: Clarence River at Chatsworth Island (South)



The project
Project concept design
Existing Pacific Highway
5m ground level contours (indicative)
Velocity direction with project
Existing velocity direction
Increase in flood velocity due to project - m/s
0.2 0.4 0.6 0.8 1.0 1.5 2.0

Figure 6-31 Velocity impacts 20 year ARI event: Clarence River at Chatsworth Island (North)

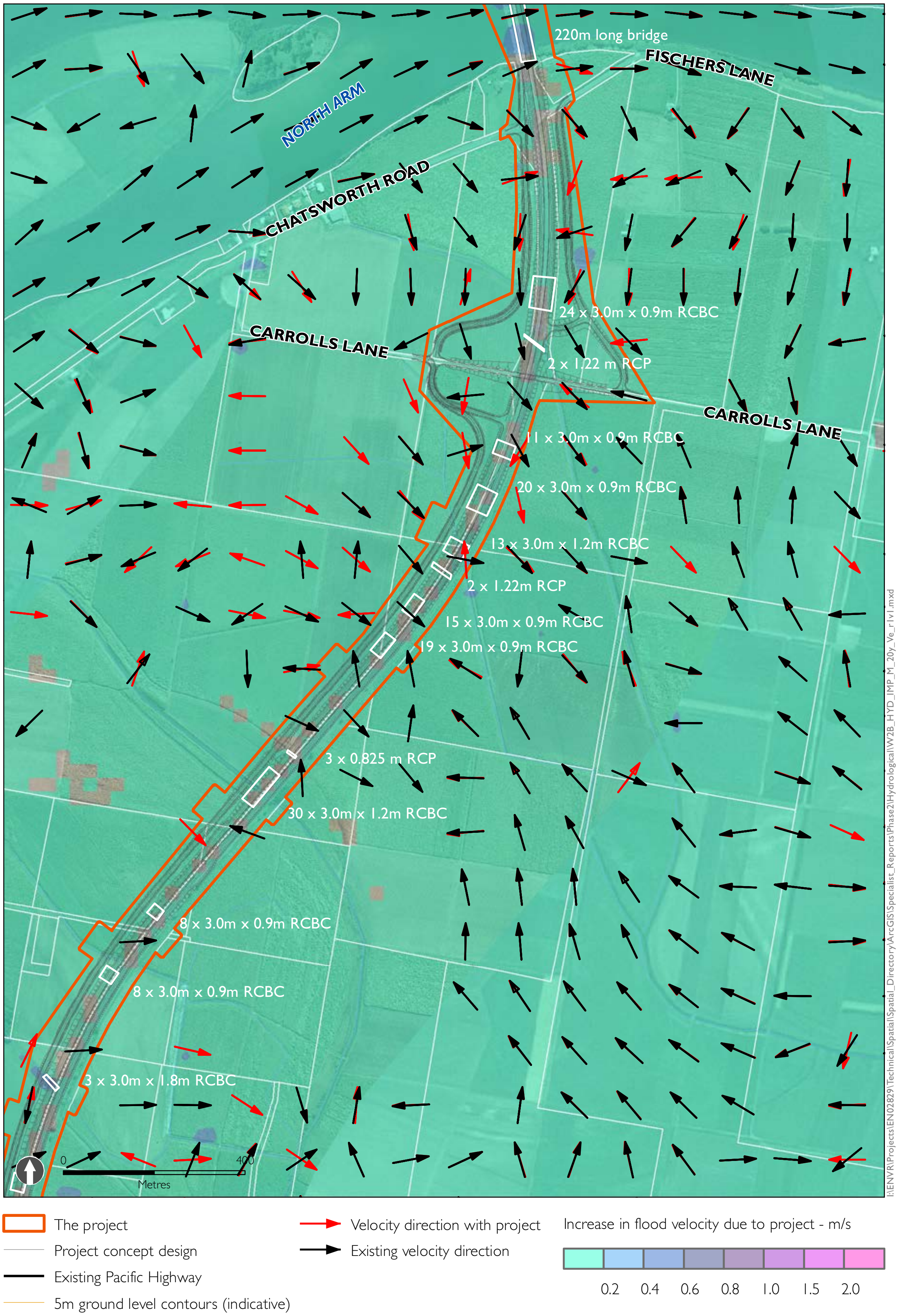
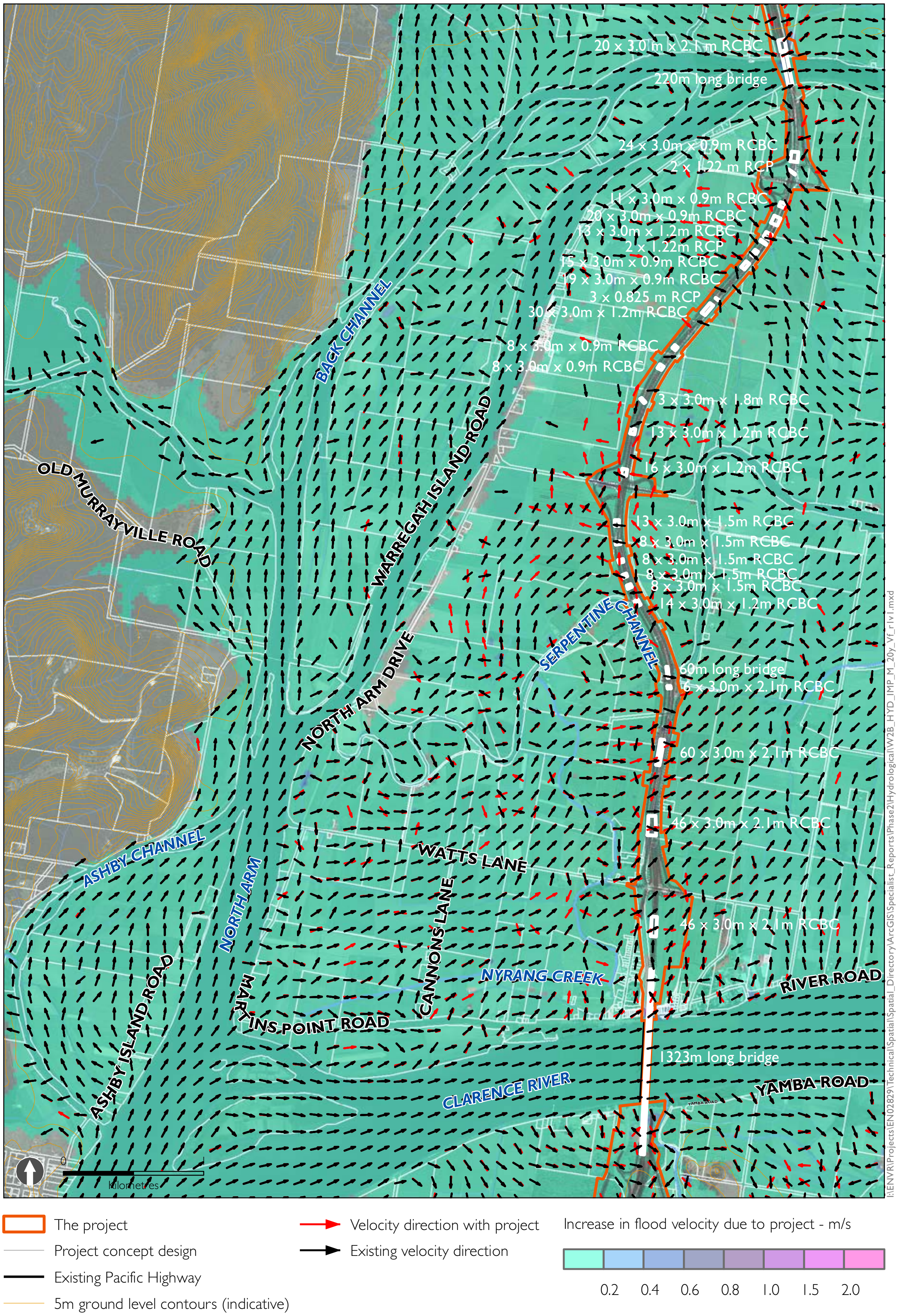


Figure 6-32 Velocity impacts 20 year ARI event: Clarence River at North Arm



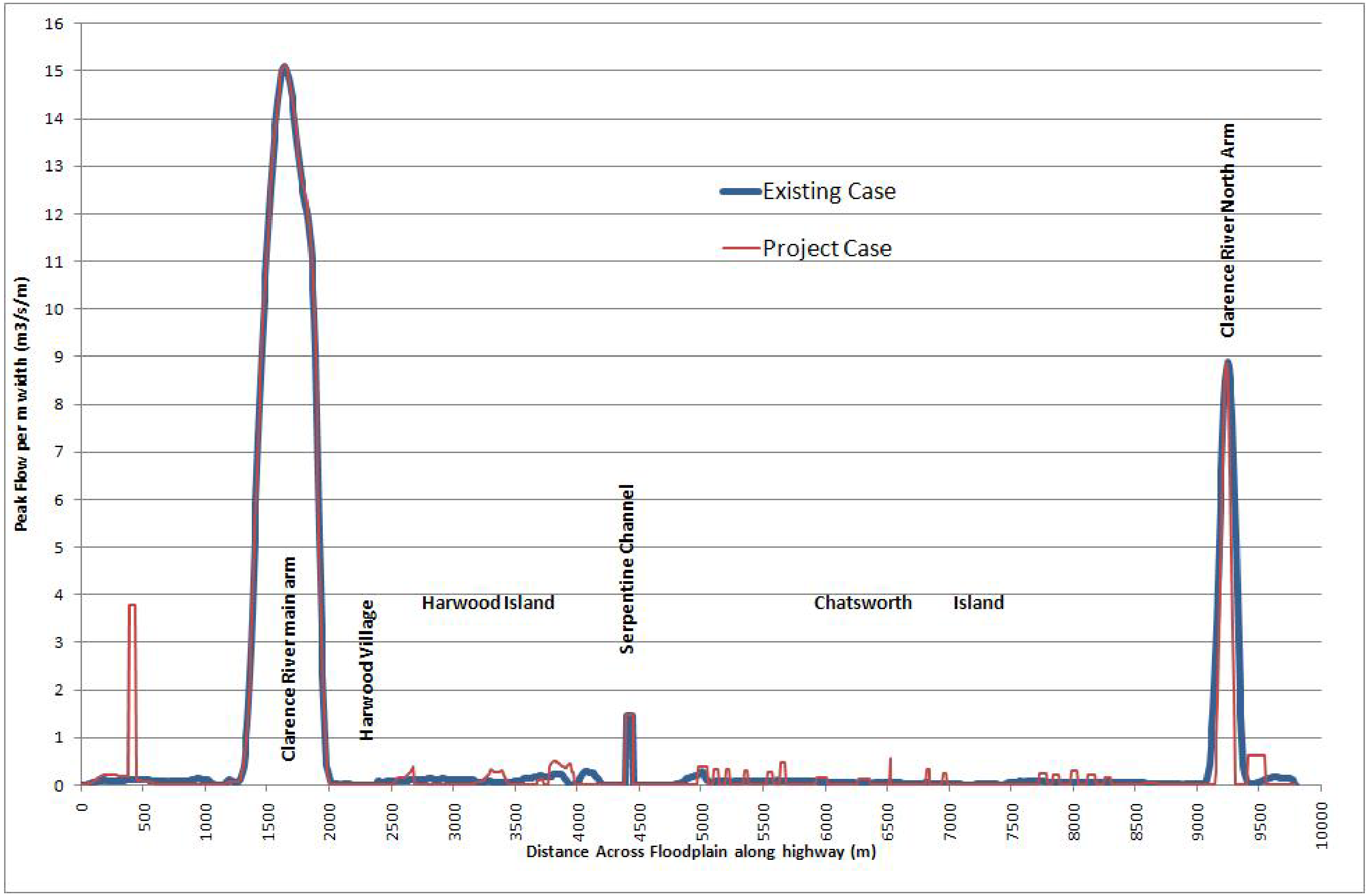


Figure 6-33 Clarence River 20 year ARI flows across lower floodplain