NSW Roads and Maritime Services

WOOLGOOLGA TO BALLINA | PACIFIC HIGHWAY UPGRADE

SUBMISSIONS / PREFERRED INFRASTRUCTURE REPORT

Appendix C Supplementary hydrology assessments

November 2013

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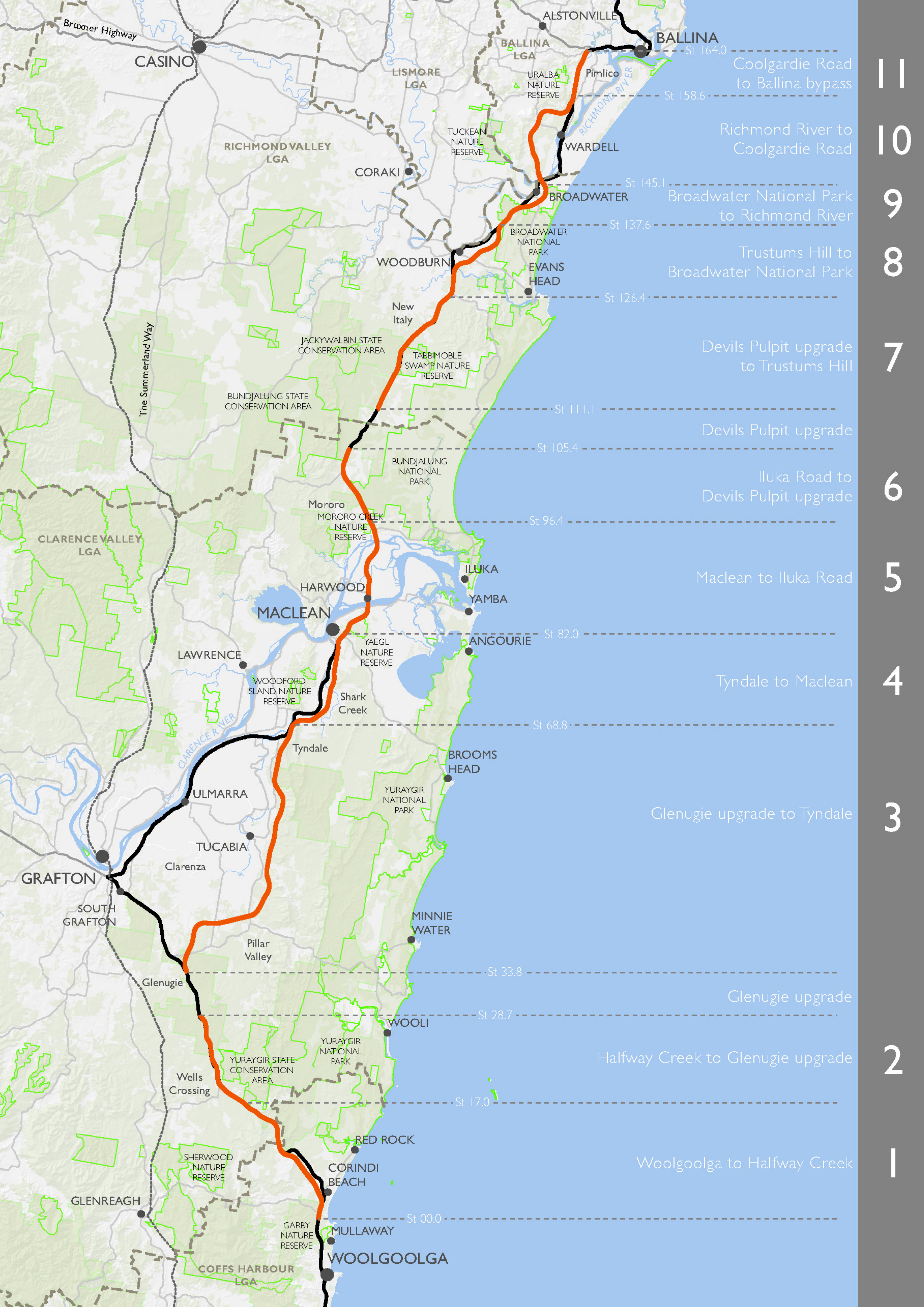

Bruxner Highway
CASINO
ALSTONVILLE
BALLINA
BALLINA LGA
LISMORE LGA
URALBA NATURE RESERVE
Pimlico
RICHMOND RIVER
St 164.0
Coolgardie Road to Ballina bypass
11
St 158.6
TUCKEAN NATURE RESERVE
WARDELL
Richmond River to Coolgardie Road
10
RICHMOND VALLEY LGA
CORAKI
St 145.1
BROADWATER
Broadwater National Park to Richmond River
9
St 137.6
BROADWATER NATIONAL PARK
WOODBURN
EVANS HEAD
Trustums Hill to Broadwater National Park
8
St 126.4
New Italy
JACKYWALBIN STATE CONSERVATION AREA
TABBIMOBLE SWAMP NATURE RESERVE
Devils Pulpit upgrade to Trustums Hill
7
The Summerland Way
BUNDJALUNG STATE CONSERVATION AREA
St 111.1
Devils Pulpit upgrade
St 105.4
BUNDJALUNG NATIONAL PARK
Iluka Road to Devils Pulpit upgrade
6
Mororo
MORORO CREEK NATURE RESERVE
St 96.4
CLARENCE VALLEY LGA
ILUKA
HARWOOD
YAMBA
Maclean to Iluka Road
5
MACLEAN
St 82.0
ANGOURIE
YAEGL NATURE RESERVE
LAWRENCE
WOODFORD ISLAND NATURE RESERVE
Shark Creek
Tyndale to Maclean
4
St 68.8
CLARENCE RIVER
Tyndale
BROOMS HEAD
ULMARRA
YURAYGIR NATIONAL PARK
Glenugie upgrade to Tyndale
3
TUCABIA
Clarenza
GRAFTON
SOUTH GRAFTON
MINNIE WATER
Pillar Valley
St 33.8
Glenugie
Glenugie upgrade
St 28.7
WOOLI
YURAYGIR STATE CONSERVATION AREA
YURAYGIR NATIONAL PARK
Halfway Creek to Glenugie upgrade
2
Wells Crossing
St 17.0
RED ROCK
SHERWOOD NATURE RESERVE
CORINDI BEACH
Woolgoolga to Halfway Creek
1
GLENREAGH
St 00.0
GARBY NATURE RESERVE
MULLAWAY
WOOLGOOLGA
COFFS HARBOUR LGA

Appendix C Supplementary hydrology assessments

C.1 Assessment of debris blockage in January 2013 flood event

In January 2013, the low pressure system associated with Ex-Tropical Cyclone Oswald caused heavy rainfall and widespread flooding that affected many parts of Queensland and northern New South Wales. Following the peak of the event affecting the Tweed and Clarence rivers, Roads and Maritime chartered a helicopter to capture photographs of flooding.

The aim of this assessment was to provide a basic verification of blockage potential for upgraded (eg Tweed and Brunswick river floodplains) and non-upgraded sections of the Pacific Highway from a range of catchments experiencing varying levels of flooding. This included collecting evidence of blockage potential of bridges and viaducts on these rivers and their associated floodplains, as well as some local catchments south of the Tweed River.

Photographs were also captured for bridge crossings in the Richmond River catchment, although these catchments were not experiencing flooding at the time. Analysis of the photos is provided in Table C-1.

Table C-1: Evidence of debris blockage

Reference	Crossing	Flood event	Debris blockage
Plate C-1	Tweed River	Major	No
Plate C-2	Tweed River Floodplain	Major	No
Plate C-3	Clothiers Creek	Minor	No
Plate C-4	Reserve Creek Floodplain	Minor	No
Plate C-5	Cudgera Creek	Minor	No
Plate C-6	Burringbar Creek	Minor	No
Plate C-7	Crabbes Creek	Minor	No
Plate C-8	Brunswick River	Minor	No
Plate C-9	Tuckombil Canal	No flood event	Yes Moderate to major
Plate C-10	Richmond River (Woodburn Bridge)	No flood event	Yes Minor
Plate C-11	Richmond River (Broadwater Bridge)	No flood event	No
Plate C-12	Richmond River (Wardell Bridge)	No flood event	No
Plate C-13	Clarence River Main Arm (Harwood Bridge)	Major flood	Yes Moderate
Plate C-14	Clarence River North Arm (Mororo Bridge)	Major flood	No

Despite experiencing an estimated equivalent 20 year ARI flood event, the photographs from the Tweed River catchment (Plate C-1 to Plate C-4) show no evidence of debris blockage on waterway or floodplain bridge piers. This was also the case for smaller catchments from the Tweed River south to Brunswick River, including the Reserve, Cudgera, Burringbar and Crabbes creek, although the events experienced in these catchments were smaller. Plate C-5 to Plate C-8 shows photographs for highway crossings from Reserve Creek to the Brunswick River.

A large amount of debris blockage was observed on the bridge over Tuckombil Canal in the Richmond River catchment (Plate C-9). This bridge is known to be susceptible to debris blockage in both flood and non-flood conditions, mainly due to the short 10 metre bridge spans and hence the number and closeness of the bridge piers. It is also due to the unusual location of the bridge and the function of Tuckombil Canal, which connects the Richmond River and Rocky Mouth Creek to Evans River. The bridge sits immediately downstream of a bend in Rocky Mouth Creek and immediately upstream of a weir. This weir allows water to flow during flood events while preventing the ingress of saline tidal waters from Evans River entering into Rocky Mouth Creek and Richmond River during low flow. As a result, the canal around the bridge is in backwater when not in flood.

The fact that this bridge frequently experiences debris build-up regardless of flooding conditions demonstrates the importance of good bridge design in minimising debris blockage. Bridge crossings for the project have around 30-metre spans over waterways and floodplains and much higher clearances than existing bridges.

The blockage observed on other bridge piers (such as the Woodburn and Harwood bridges) indicate the extent to which debris blockage may occur. This is particularly relevant for the Clarence River which was experiencing the recession of a major flood event at the time. This extent of debris blockage supports the assumption of a doubling of pier area applied in the blockage sensitivity assessment as part of the hydrology and flooding assessment as a conservative approach.

C.1.1 Conclusion

The main outcomes of this assessment are as follows:

- Noting the respective magnitude of flooding that occurred across these coastal catchments of northern New South Wales, the results of the assessment conclude that the concept design of bridges in the EIS is adequate with respect to minimising blockage.
- Where present, evidence of levels of debris blockage supports the assumptions used in sensitivity modelling for the purpose of understanding the sensitivity of project impacts to debris blockage.
- Consideration should be given to appropriate span lengths of bridges at the detailed design phase with respect to susceptibility of individual watercourse crossings to debris blockage.

Plate C-1 Tweed River (1 February 2013, 2.08pm), showing no evidence of debris blockage.

Plate C -2 Tweed River floodplain (1 February 2013, 2.12pm), showing no evidence of debris blockage.

Plate C -3 Clothiers Creek (1 February 2013, 2.16pm), showing no evidence of debris blockage.

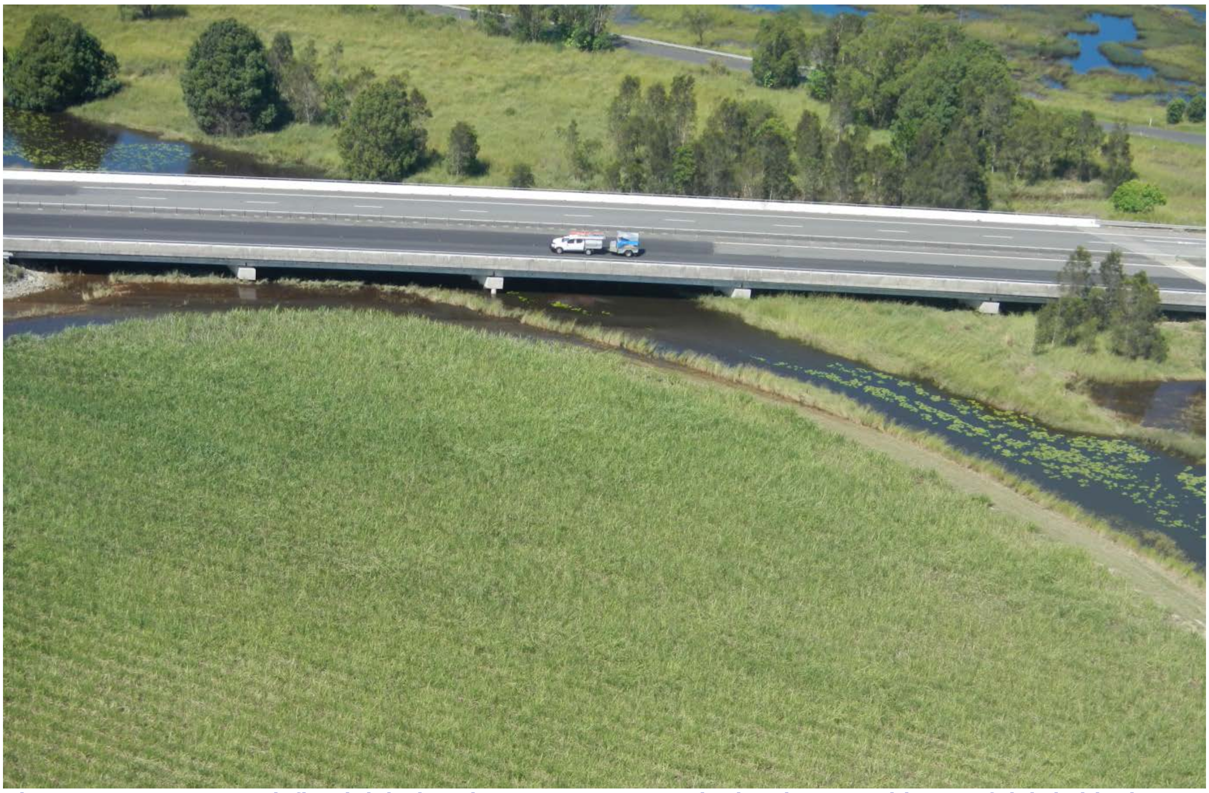

Plate C -4 Reserve Creek floodplain (1 February 2013, 2.19pm), showing no evidence of debris blockage.

Plate C -5 Cudgera Creek (1 February 2013, 2.22pm), showing no evidence of debris blockage.

Plate C -6 Burringbar Creek (1 February 2013, 2.24pm), showing no evidence of debris blockage.

Plate C -7 Crabbes Creek (1 February 2013, 2.25pm), showing no evidence of debris blockage.

Plate C -8 Brunswick River (1 February 2013, 2.29pm), showing no evidence of debris blockage.

Plate C -9 Tuckombil Canal (1 February 2013, 3.20pm), showing moderate to major evidence of debris blockage around bridge piers.

Plate C -10 Richmond River (Woodburn Bridge) (1 February 2013, 3.24pm), showing minor evidence of debris blockage around bridge piers.

Plate C -11 Richmond River (Broadwater Bridge) (1 February 2013, 3.29pm), showing no evidence of debris blockage.

Plate C -12 Richmond River (Wardell Bridge) (1 February 2013, 3.10pm), showing no evidence of debris blockage.

Plate C -13 Clarence River Main Arm (Harwood Bridge) (31 January 2013, 9am-10am), showing moderate evidence of debris blockage around bridge piers.

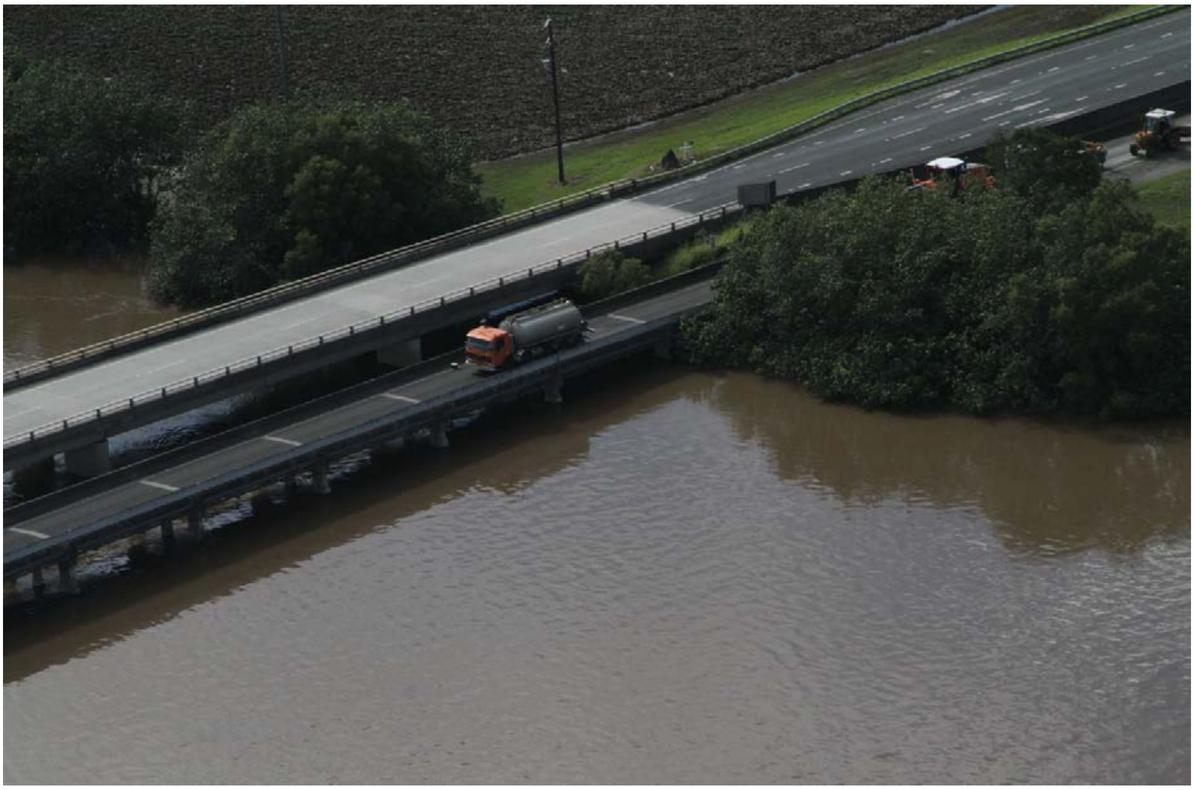

Plate C -14 Clarence River North Arm (Mororo Bridge) (31 January 2013, 9am-10 am), showing no evidence of debris blockage.

C.2 Clarence River flood model verification of January 2013 flood event

C.2.1 Introduction

In late January 2013, a large flood event occurred in the Clarence River. The occurrence of the flood during the exhibition period of the EIS provided an opportunity to determine the performance of the Clarence River flood model for a large flood event.

The existing two-dimensional TUFLOW model of the Clarence River catchment was used to simulate the event using dynamic upstream and downstream boundaries correlating with gauged data from the event.

This modelling was undertaken for the following purposes:

- To further validate the model by comparing peak modelled flood levels to gauged and surveyed peak flood levels in the Clarence River catchment.
- To understand the theoretical impact of the Woolgoolga to Ballina upgrade in this event, had it been completed at the time of flooding, including changes to the period of road closure.

The January 2013 flood event was estimated to be lower than a 20 year ARI flood event.

C.2.2 Characteristics of the Clarence River January 2013 flood event

The January 2013 flood event resulted in the highest flood levels ever recorded at Grafton (since 1839). However, due to the construction of levee works and railway embankments over the last 100 years, flood levels at Grafton do not provide a consistent indication of peak flood flows. Peak flood flows are a more accurate and independent measure of the size of a flood. Based on assessments carried out for the Lower Clarence River Flood Study Review (2004), the January 2013 flood was the equal fourth largest flow since 1839. There were at least three larger floods (in terms of flow) in the latter part of the 19th century.

Furthermore, the rapid rise and fall of the flood meant that the volume was much less than other similar size floods. Hence, as the Clarence River floodplain has a large storage volume, a low volume flood can result in low flood levels further downstream.

Based on flood gauge records and flood levels supplied by landholders, the January 2013 flood event was much lower than the 20 year ARI flood event in the Shark Creek Basin and other parts of the lower Clarence River floodplain. This is mainly due to the fast rate of rise and fall of this flood, which affects how much water can back-flood into the Shark Creek Basin. Furthermore, due to the very dry conditions prior to this flood, there was very little Shark Creek inflow and very low water levels in the basin at the start of the flood.

For the Chatsworth Island and Harwood Island areas, the January 2013 flood event was estimated to be just lower than the 20 year ARI flood event (by about 0.1 metres). Again, this is due to the low volume of the flood and the large flood storage areas available on the Clarence River floodplain prior to this flood event.

C.2.3 Hydraulic modelling of the January 2013 flood event

The 2D flood model of the Clarence River was adapted to use the recorded flood levels at the Prince Street gauge (in Grafton) as the driving boundary for the upstream inflows of the model. This model arrangement had been successfully used previously in the Lower Clarence River Flood Study Review (2004) to simulate the 1950 and 1893 flood events.

The downstream model boundary was the recorded flood levels at the Yamba tide gauge. It is recognised that this gauge is inside the river entrance and would provide an over-estimation of the flood levels in the ocean.

Inflows from the tributary catchments (eg Coldstream River, Shark Creek and Sportsmans Creek) were estimated to be 33 per cent of the five year ARI flood flows. This was an estimate based on the expected low runoff rates from this flood event as there was little rainfall on these catchments and the soil losses would have been very high due to the near drought conditions prior to the flood event.

C.2.4 Model validation to recorded flood data

Recorded flood gauge data from five flood gauges along the Clarence River were obtained from the Bureau of Meteorology website.

Two of these gauges (Prince Street at Grafton and Yamba) were used to derive boundaries for the flood model. Hence, these gauges cannot be used to measure the performance of the flood model to replicate recorded flood levels (as this information was used by the flood model to simulate the flood event).

Figure C-1 shows the performance of the flood model in comparison to the recorded flood levels at the Ulmarra, Brushgrove and Maclean gauges. These plots indicate that the flood model is adequately representing the rise and fall of the flood as well as the peak levels.

A peak flood level of 2.8 metres AHD was obtained from discussions with landholders in the Shark Creek basin. This level was not based on survey but rather comparisons with previously surveyed flood marks for the 2009 flood. The flood model resulted in a peak flood level of 2.75 metres AHD in the Shark Creek basin which represent a very close match between the recorded data and the flood model simulation.

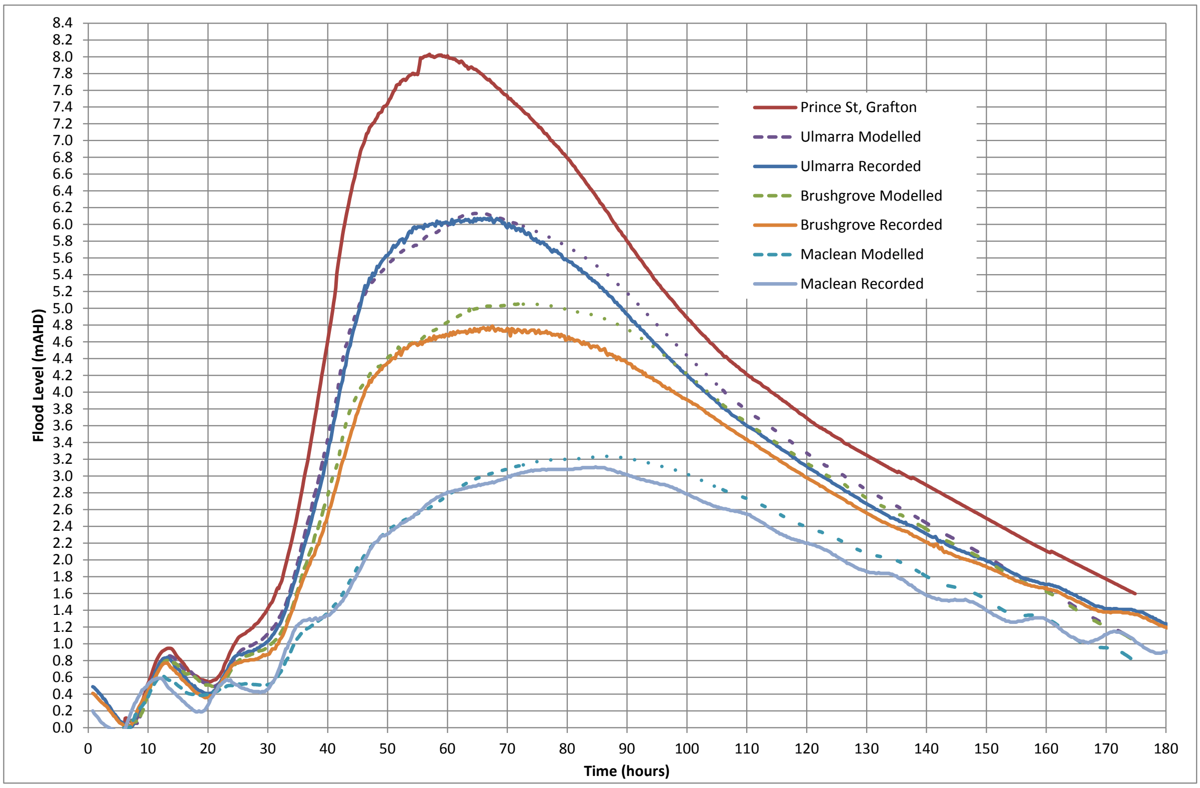

Figure C-1: January 2013 flood gauge comparisons to flood model results (20 year ARI flood event)

C.2.5 Model validation to satellite imagery

Satellite imagery of the January 2013 flood event was obtained from NASA[1] for two specific times during the flood event (2.30 pm on 29 January and 3.15 pm on 30 January).

These satellite images show areas of flood inundation (where there is not cloud cover). It should be noted that some of the areas of inundation may not show up well on the satellite imagery due to the depth of the floodplain vegetation (eg cane crops). These flood inundation areas were compared with the flood model results at these two times. Figure C-2 and Figure C-3 show these comparisons.

It is evident from these figures that the flood model provides a reasonable representation of the flood inundation extent.

[1] Roads and Maritime acknowledges the use of this imagery from the Land Atmosphere Near-real time Capability for EOS (LANCE) system operated by the NASA/GSFC Earth Science Data and Information System (ESDIS) with funding provided by NASA/HQ.

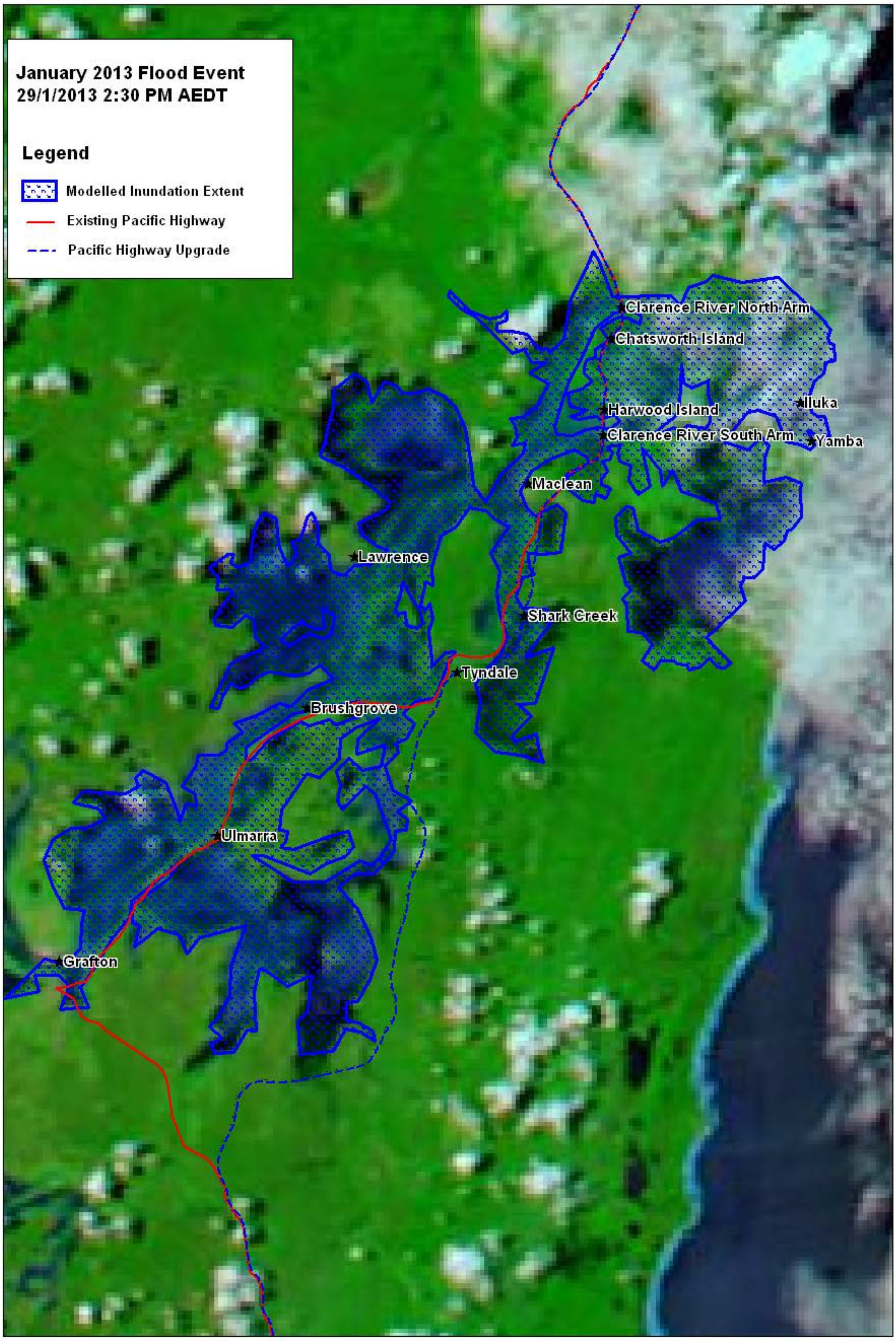

Figure C-2: January 2013 satellite imagery compared to flood model results on 29 January 2013

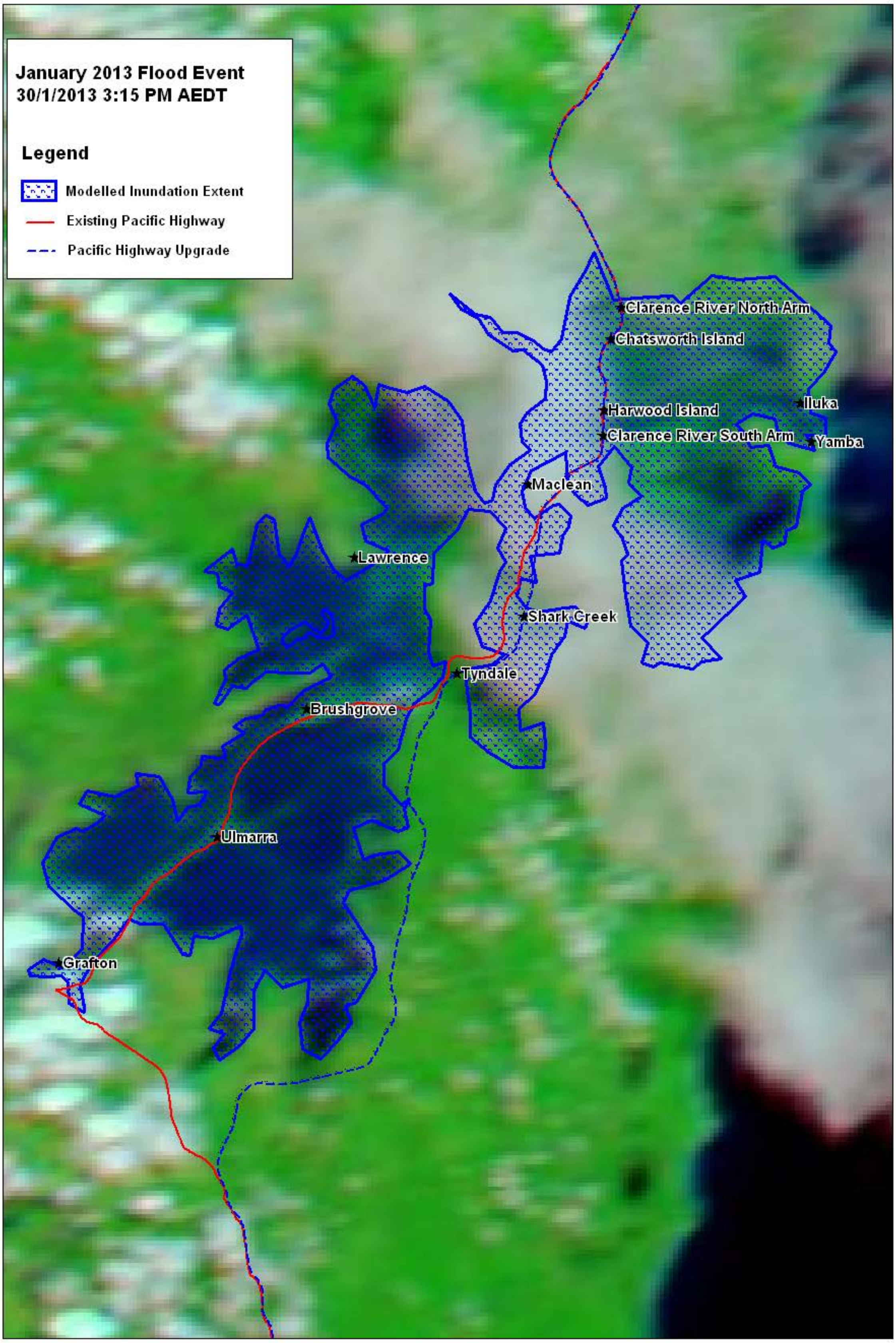

Figure C-3: January 2013 satellite imagery compared to flood model results on 30 January 2013

C.2.6 Existing Pacific Highway time of closure

During the Clarence River flood event of January 2013, the Pacific Highway was cut due to flood water over the road between Grafton and Iluka Road. Figure C-4 shows the times of closure along the section of highway from Shark Creek to Iluka Road.

The first section of road closed to traffic was around Shark Creek, when water inundated the highway at around 11.00 pm on Monday, January 28, 2013. This part of the road remained closed until late evening on Thursday, January 31, 2013.

The Pacific Highway was inundated at several other locations with Serpentine Channel area being the last section of road to reopen at 6.00 pm, February 1, 2013. In total, the stretch of highway from Iluka Road to Grafton experienced closures for a total of 91 hours.

If Farlows Flat had not been upgraded before this event, time of closure would have been around 31 hours longer. It is estimated from hydraulic modelling of this event that the highway at Farlows Flat would have been cut two hours earlier than Shark Creek at 9.00 pm, January 28 and would not have reopened until 7.00 pm, February 2, 2013. This would have given a total time of closure of 118 hours in this event. This estimate reflects only the time of inundation and does not include additional time to inspect the road before reopening.

C.2.7 Pacific Highway upgrade flood closures in January 2013 flood

The Woolgoolga to Ballina Pacific Highway Upgrade would be constructed such that the minimum flood immunity of the entire route would be to the 20 year ARI flood event. For the sections of the project not on the Clarence River and Richmond River floodplains, the flood immunity would be to the 100 year ARI flood event.

For the section between Tyndale and Iluka Road, the project would cross a number of parts of the Clarence River floodplain. Fill embankments have been designed along these sections to provide the upgrade with the desired flood immunity. As well, waterway openings have been sized to accommodate a range of flood magnitudes to result in acceptable impacts to adjoining landholders.

Based on the assessments of the January 2013 flood compared to the upgrade design levels, the upgraded Pacific Highway would not have been cut in any location for any period of time for this flood. There would not have been any floodwaters on the lanes or the road shoulders and traffic would not have been impeded in any location.

If the Pacific Highway Upgrade was completed to the Class A level at the time of the January 2013 Clarence River flood event, contra flow measures would need to be used to allow the highway to remain open. A contra flow would be needed along a five kilometre section from Chatsworth Island to Harwood Island. This contra flow would need to be in place at 7.00 am, January 29 through to 9.00 am, February 1, 2013.

C.2.8 Conclusion

The main outcomes of this assessment are as follows:

- Verification of the Clarence River flood model against the January 2013 event further demonstrates that the model provides adequate representation of a large flood event in this catchment and further confirms the results of the flood modelling used in the EIS.
- The Clarence River flood model provides a useful tool for estimating highway closure times, the area of inundation and hence potential impact of the project.

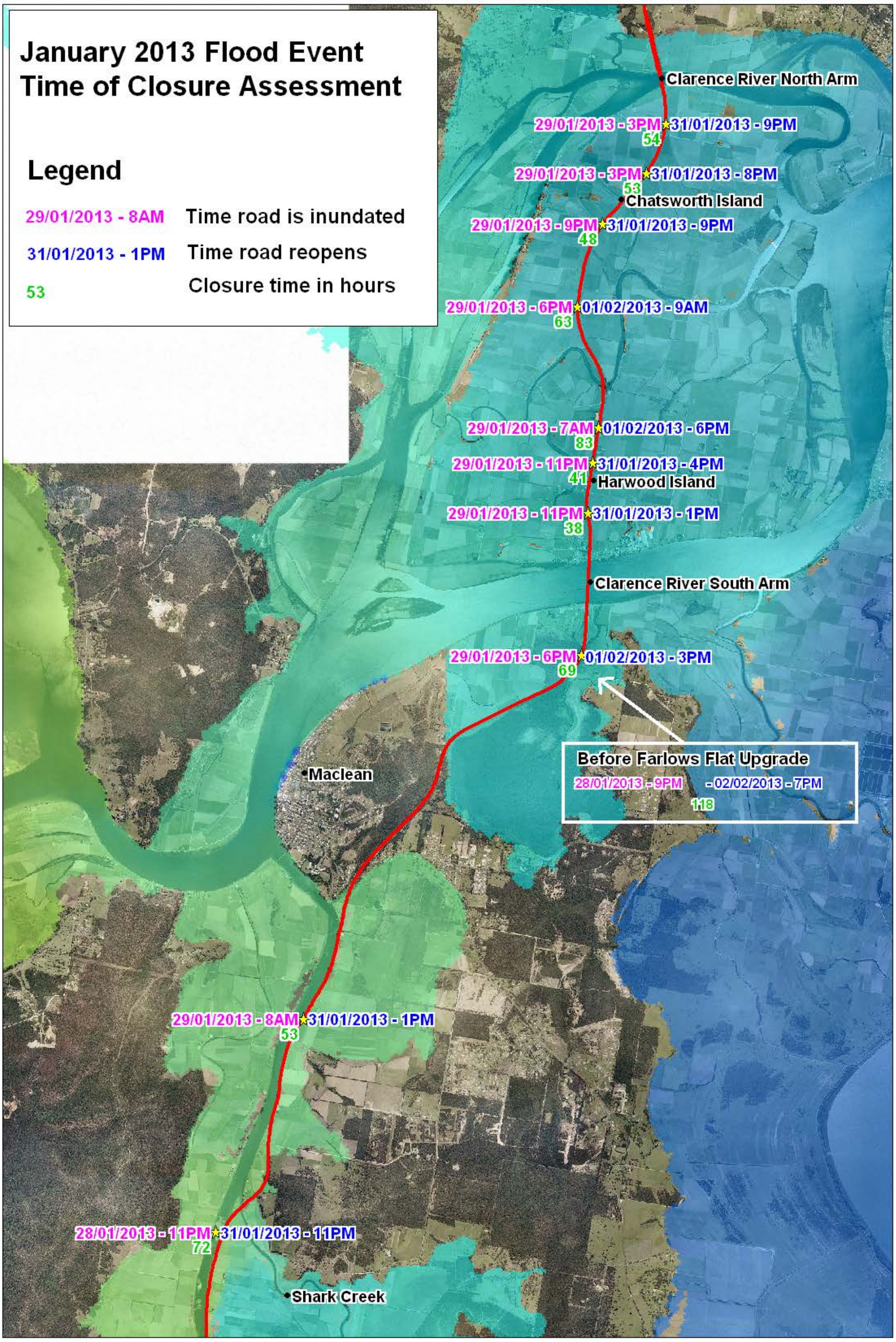

Figure C-4: January 2013 highway flood closure times

C.3 Shark Creek drainage network

C.3.1 Introduction

The project crosses several cane farms in the Shark Creek basin. This basin has a very complicated flooding and drainage behaviour due to the low level of the land and the network of cane drains and floodgates used to drain the area.

The design of an appropriate drainage system is required to ensure that the time of inundation is not increased by the upgrade, as this could lead to destruction of crops. Floodwater velocities must also be managed to prevent erosion on any bare cane land (or with juvenile cane).

This section details modelling work undertaken to design a potential alternative drainage system in Shark Creek that will meet the flood management objectives for this project. The culverts, bridges and drain re-alignments listed in the EIS were a possible solution. However, a number of submissions to the exhibition of the EIS were received from Shark Creek cane farmers as well as separate discussions at cane industry workshops and EIS displays.

Based on this information and a better understanding of the proposed operations of the cane farms following land resumptions for the project, a potential alternative flooding and drainage system associated with the project was developed, based on a revision to the current concept design (refer to Figures C-5 and C-6). This potential alternative would be further discussed with relevant landowners during detailed design.

C.3.2 Existing flooding and drainage behaviour

The flooding behaviour in Shark Creek is very different to the drainage behaviour. This is largely due to the system of cane drains and floodgates. The rate of recession tends to be around three times slower than the rate rise of a flood event.

Floodwaters enter the cane lands through two main flowpaths. One flowpath is from the banks of Shark Creek to the south as the flows backing up Shark Creek (or local Shark Creek catchment flows) break the levee banks along the western side of Shark Creek. A second breakout occurs from the Clarence River South Arm just south of its junction with Shark Creek. This water flows south through the area of Lees Drain and tributaries. The two flowpaths converge within 50 hours of the commencement of flooding and the floodplain fills between the banks of Shark Creek and the Clarence River South Arm.

The two main cane drains in the area are Lees Drain (Tyndale cane drain 2) and Crackers Drain (Tyndale cane drain 1). Both of these drains have floodgates at the outlet to the south arm of the Clarence River. Lees Drain is located between Shark Creek and Clarence River and conveys flow into the river. Cracker’s Drain begins at the southern end of the model area and drains north to the Clarence River.

The flood then recedes over a period of around 10 days. The floodgates and drainage system conveys flow into Clarence River South Arm and Shark Creek through a series of floodgates. The rate of recession is largely dependent on the Clarence River’s rate of recession.

C.3.3 Assessment of flooding

The hydraulic modelling software TUFLOW was used to analyse the Shark Creek cane drainage system. The assessment included particular attention to detail around Lees Drain and tributaries, Cracker’s Drain and drainage between the floodplain and Shark Creek.

A sub-model of the Shark Creek area was developed from the larger Clarence River flood model. The 20 year ARI flood event without any Shark Creek inflows (from Shark Creek catchment runoff) was used to test various bridge, culvert and drainage scenarios with the Pacific Highway upgrade. This model was updated with the latest terrain data obtained from Roads and Maritime (under licence from the Department of Land and Property Information). The new terrain data used in the flood model provided a better understanding of the flooding and drainage mechanisms in the Shark Creek basin.

C.3.4 Proposed flooding and drainage system at Lees Drain

The Shark Creek basin model was altered to include the proposed highway embankment and associated bridges and culverts to reflect conditions when the project is built.

Based on an improved understanding of the flooding behaviour and landholder farming operations, a potential alternative bridge, culvert and drainage system associated with the project was developed, based on a revision of the current concept design.

Figure C-5 and Figure C-6 show a possible arrangement of bridges, culverts and a revised drainage system recommended around Lees Drain.

Lees Drain and a drain entering Lees Drain from the north would be crossed by the upgrade. Two 15-metre bridges would be constructed over Lees Drain and culverts to the north to allow the passage of water through the upgrade embankment.

A reinforced concrete box multicell culvert on Lot 113 / DP 751389 draining into Lees Drain from the south was included to prevent backup behind the highway. This multicell culvert consisted of two cells measuring 2.4 metres wide by 2.1 metres high.

A drain running through Lot 113 / DP 751389 would be constructed to convey flow into Lees Drain from the south along the western side of the upgrade.

Another drain would run from the north (beginning south of Shark Creek) to Lees Drain. This drain would pass from the western side of the upgrade to the eastern side through of a concrete box multicell culvert of three cells measuring 2.4 metres wide by 2.4 metres high before travelling south to join Lees Drain.

A small levee system was included within the project boundary to maintain the integrity of the existing levee system on the cane farms to the south of Lees Drain.

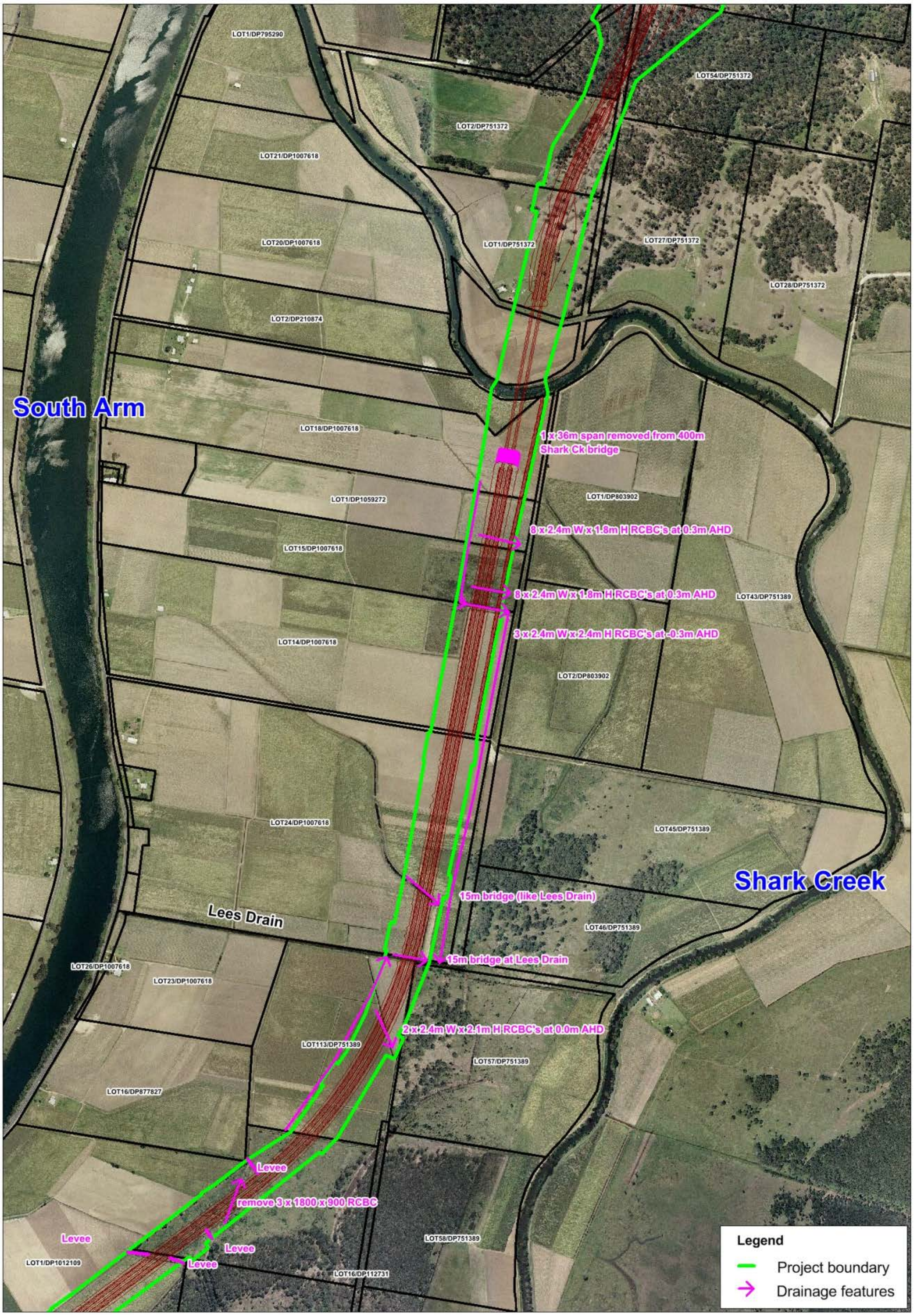

Figure C-5: Potential alternative Shark Creek flood and drainage design at Lees Drain

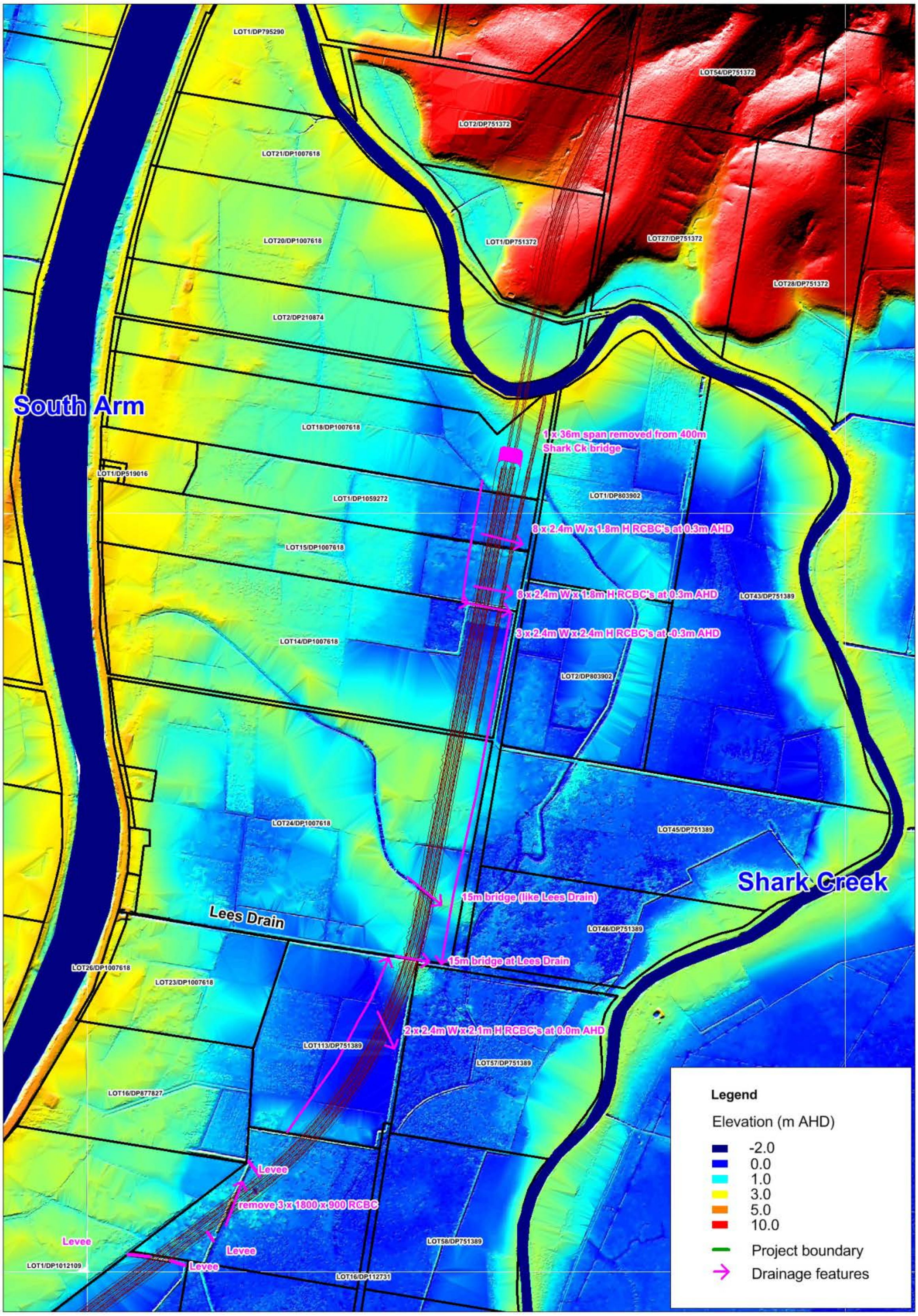

Figure C-6: Potential alternative Shark Creek flood and drainage design and upgrade at Lees Drain with terrain

C.3.5 Culverts south of Shark Creek Bridge

Peak flow rates, in the order of 250 cubic metres per second, flow from the overtopped banks of the Clarence River South Arm eastward across the Shark Creek floodplain (in a 20 year ARI flood event).

To convey these flows through the project embankment, five 36 metre spans (totalling 180 metres of bridge length) are included on the southern side of Shark Creek (part of the 400 metre bridge crossing the Shark Creek floodplain and Shark Creek).

However, recently obtained terrain data indicates that the lowest terrain is not immediately south of Shark Creek, but further to the south. In order to pass more flow though the lower terrain and to better maintain the existing flooding patterns, a potential arrangement of culverts through the embankments was developed and assessed.

It was found that the bridge could be decreased in length by 36 metres (one span) and replaced with around 45 metres of floodplain culverts further south. Two reinforced concrete box multicell culverts of eight cells measuring 2.4 metres wide by 1.8 metres high (ie a total of 16 culvert cells, each 2.4 metres wide) would supplement the crossing of the drain along the upgrade (from west to east). This drain crossing would be achieved with a concrete box multicell culvert of three cells measuring 2.4 metres wide by 2.4 metres high. Hence, the total width of floodplain culverts in this area would be 45 metres.

By spreading the waterway openings out across the floodplain, flood flows are dispersed across the upgrade embankment to better manage flow velocities and reduce afflux behind the upgrade.

A further alternate design could include a longer bridge over Shark Creek and part of the adjacent flood plain. A lengthened bridge would need to extend over the low lying section of the floodplain (around Station 74.5). The overall length of the bridge would need to be 650 metres, lengthened from 400 metres to accommodate flows on the floodplain.

The detail design would determine the preferred arrangement taking into consideration appropriate bridge spans, plank depths, flow coefficients and hydraulic performance of culverts verses bridges also importantly the consideration of the depth of soft soils at this location the treatments and the preferred structures for the ground conditions.

The potential refinement to the drainage system in this area would be further investigated during detailed design in consultation with adjacent landowners.

C.3.6 Potential alternative flooding and drainage system at Crackers Drain

Figure C-7 and Figure C-8 show a potential arrangement of bridges, culverts and a revised drainage system around Cracker's Drain.

Crackers Drain would be crossed by the project. As part of this revised drainage, a 15-metre bridge (ie 12-metre opening) over the drain would be constructed to allow water passage under the project. Three culverts (two to the east of Cracker's Drain and one to the west) would be constructed to allow the passage of water underneath the upgrade at low points in the terrain. Directions of flow are shown in Figure C-7 and Figure C-8.

Further, as part of this potential alternative drainage system, a drain would be constructed to convey water from the north-eastern side of the project into Cracker's Drain. This new drain would replace the drain under the project embankment. Runoff from the areas to the south of the upgrade (and west of Crackers Drain) would pass through a bridge or culvert to drain into this new drain and then into Crackers Drain.

As per the cane farm strategy principles, new drains for cane land drainage, including this new drain, would need to be located on private land outside the road boundary. However, in this location there is future potential to reduce the project boundary so that there is no net loss of farmable land to land owners compared to the current concept design. The potential future reduction in the project boundary is shown in Figure C-7 and Figure C-8.

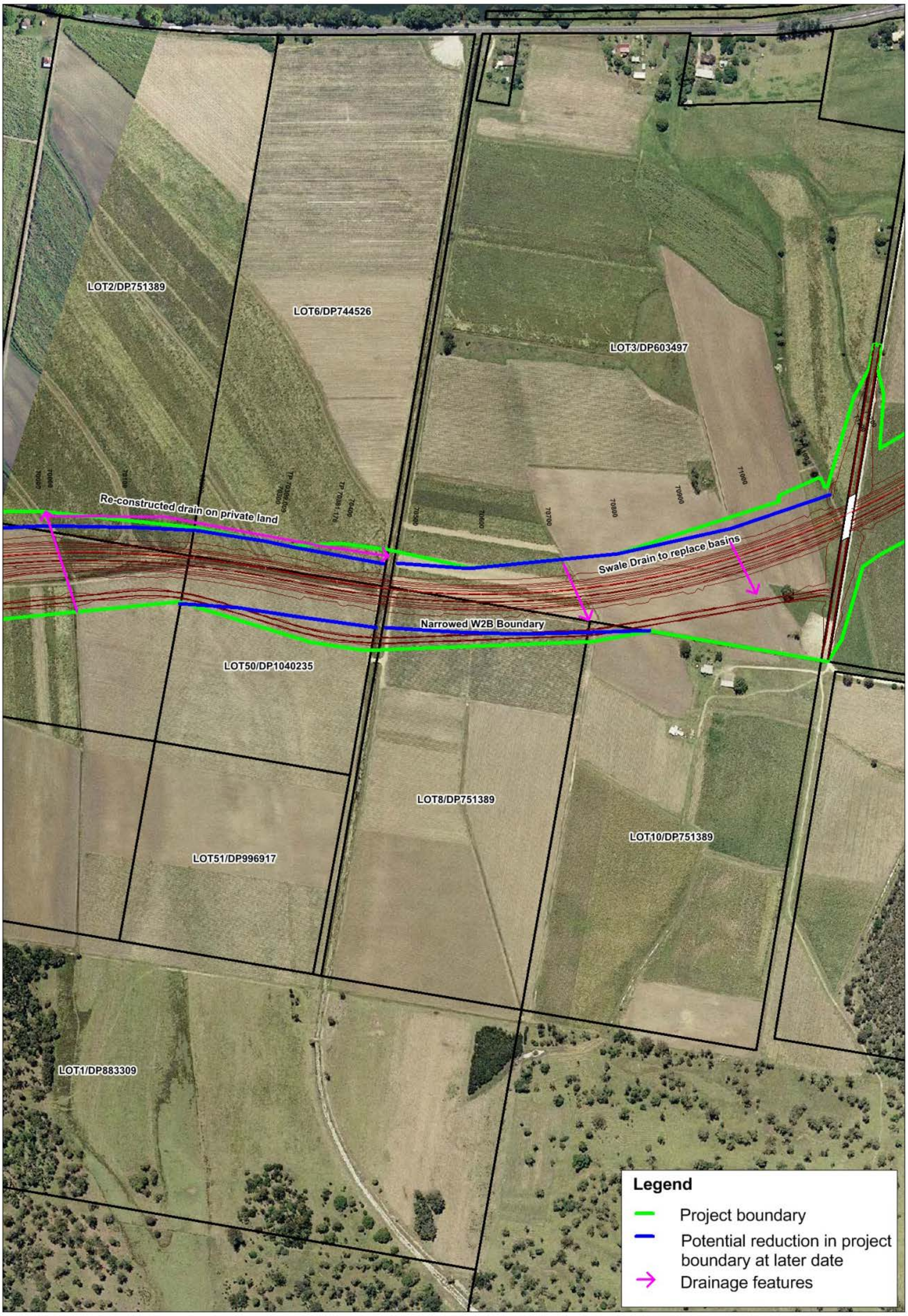

Figure C-7: Possible Shark Creek flood and drainage design with project at Crackers Drain

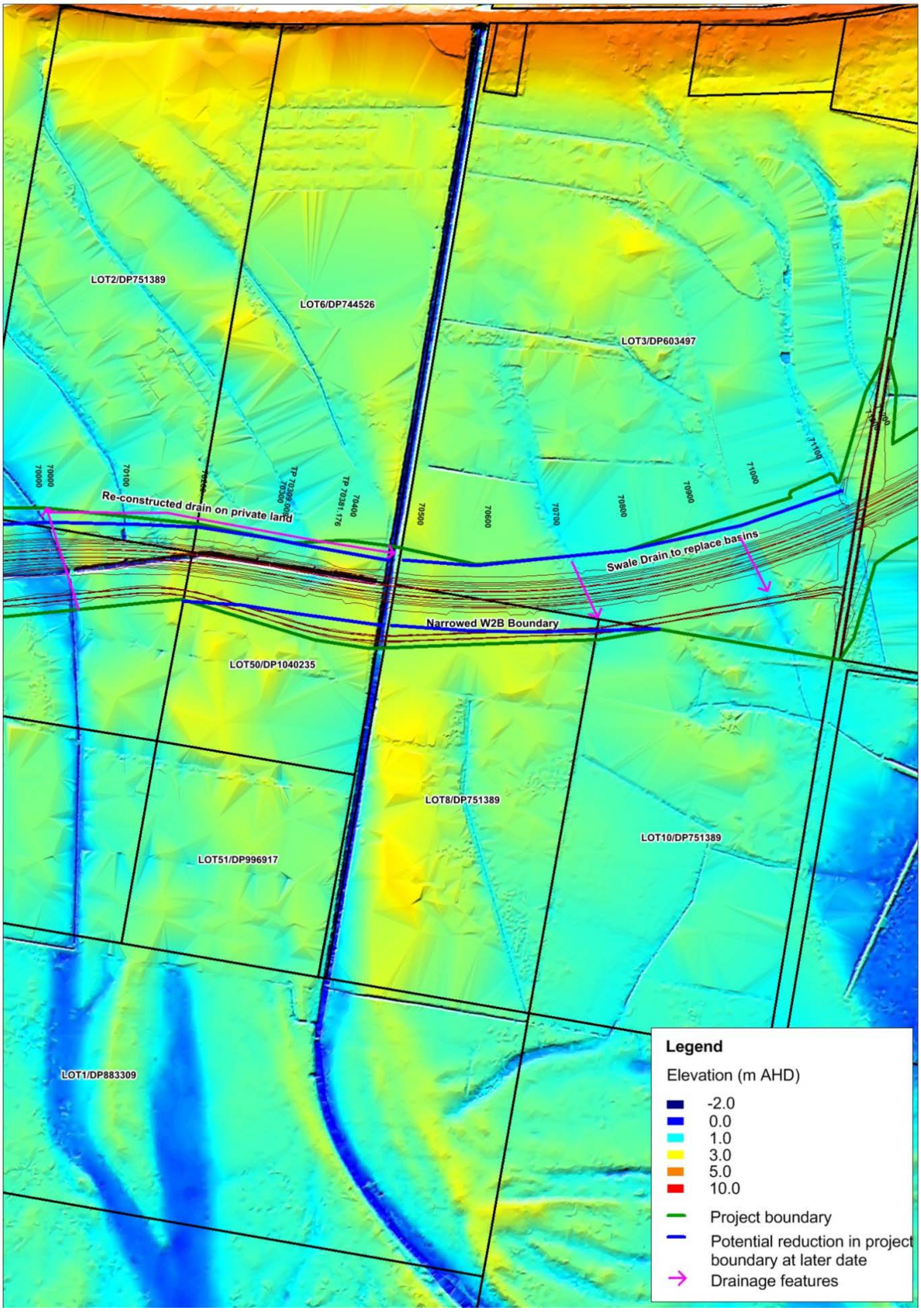

Figure C-8: Possible Shark Creek flood and drainage design and upgrade at Crackers Drain with terrain

C.3.7 Assessment of potential alternative flooding and drainage system

The modelling simulations of the Shark Creek flood and drainage design indicated that the potential alternative cane drainage system proposed in this re-assessment would meet the flood management objectives of the project.

The flood levels (H) and flows (Q) at a number of sample points around the highway were compared for the existing and developed cases. Figure C-9 shows the locations of where flood behaviour (levels or flows) were reported to compare the performance of the proposed update to the concept drainage design with the existing condition.

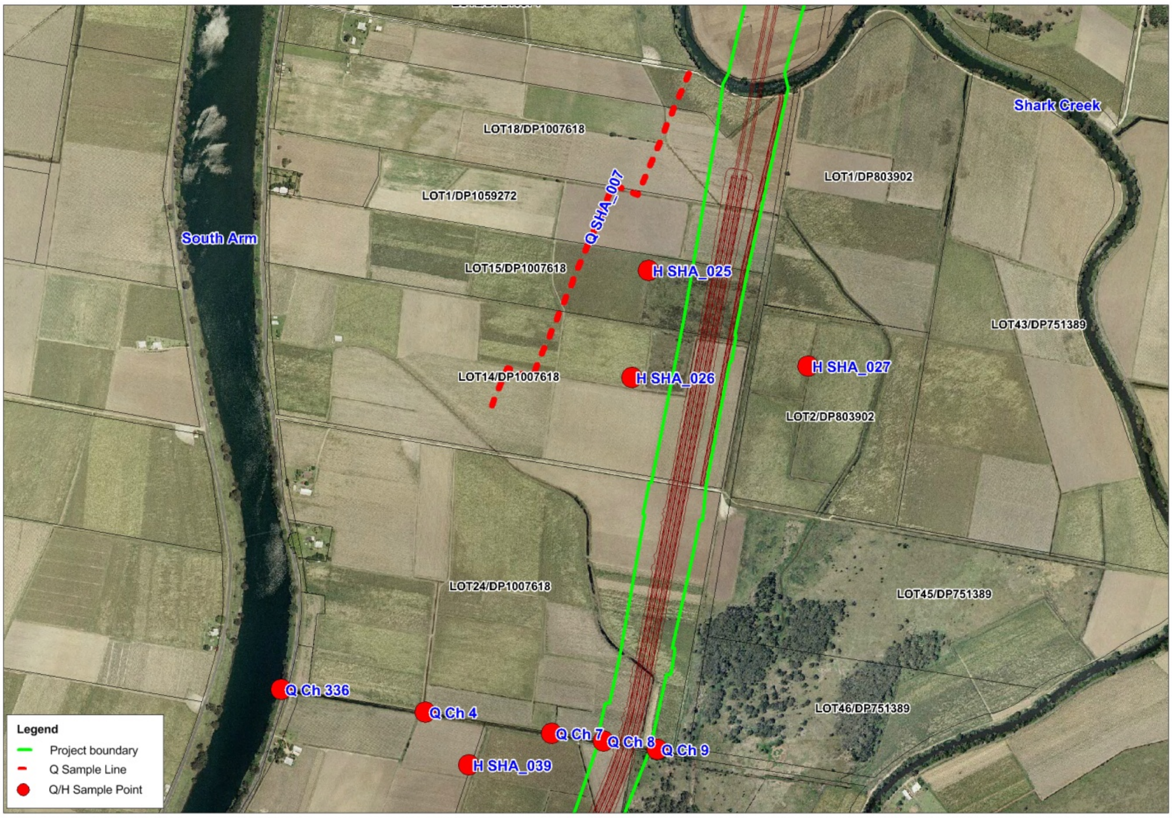

Figure C-9: Locations of flood results for possible Shark Creek flood and drainage design

Figure C-10 to C-13 show the water level comparisons for the existing case and that with the upgrade and the revised waterway opening concept design. The locations of these figures are shown in Figure C-9 above.

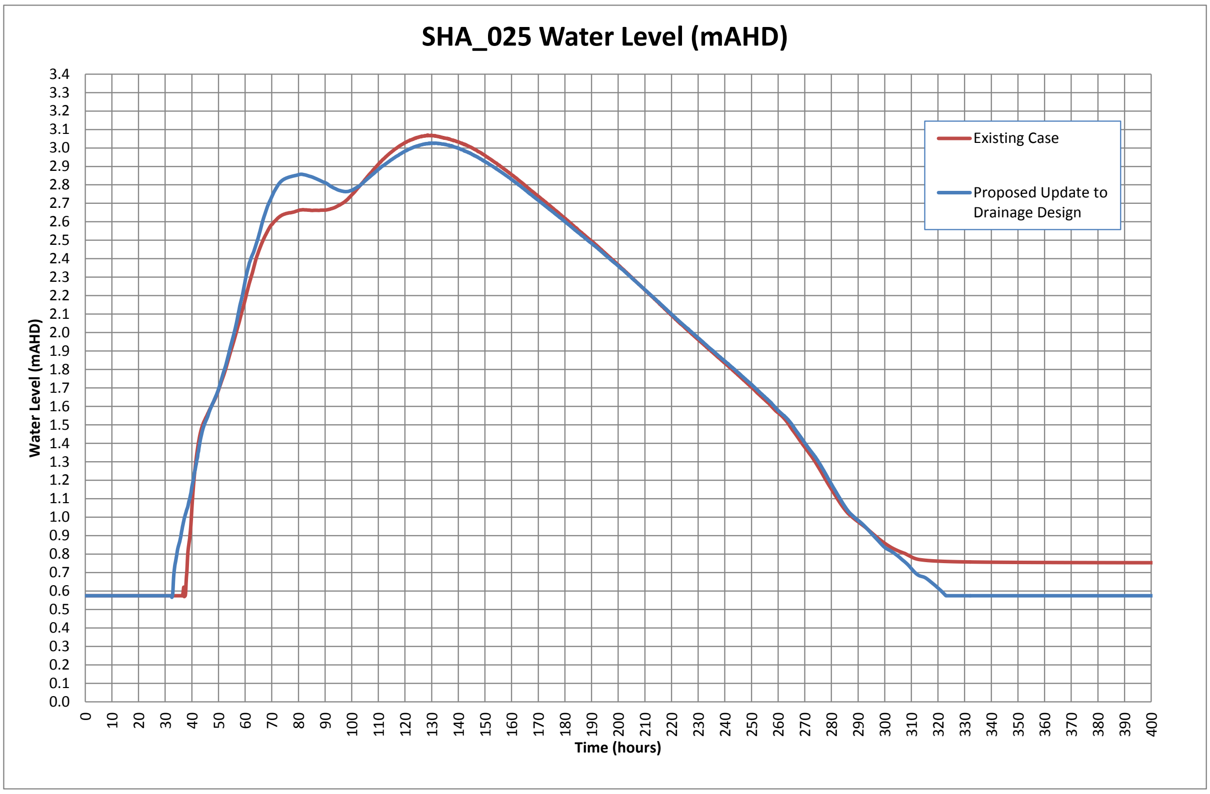

Figure C-10 Flood levels at SHA_025 for existing and proposed update to drainage design

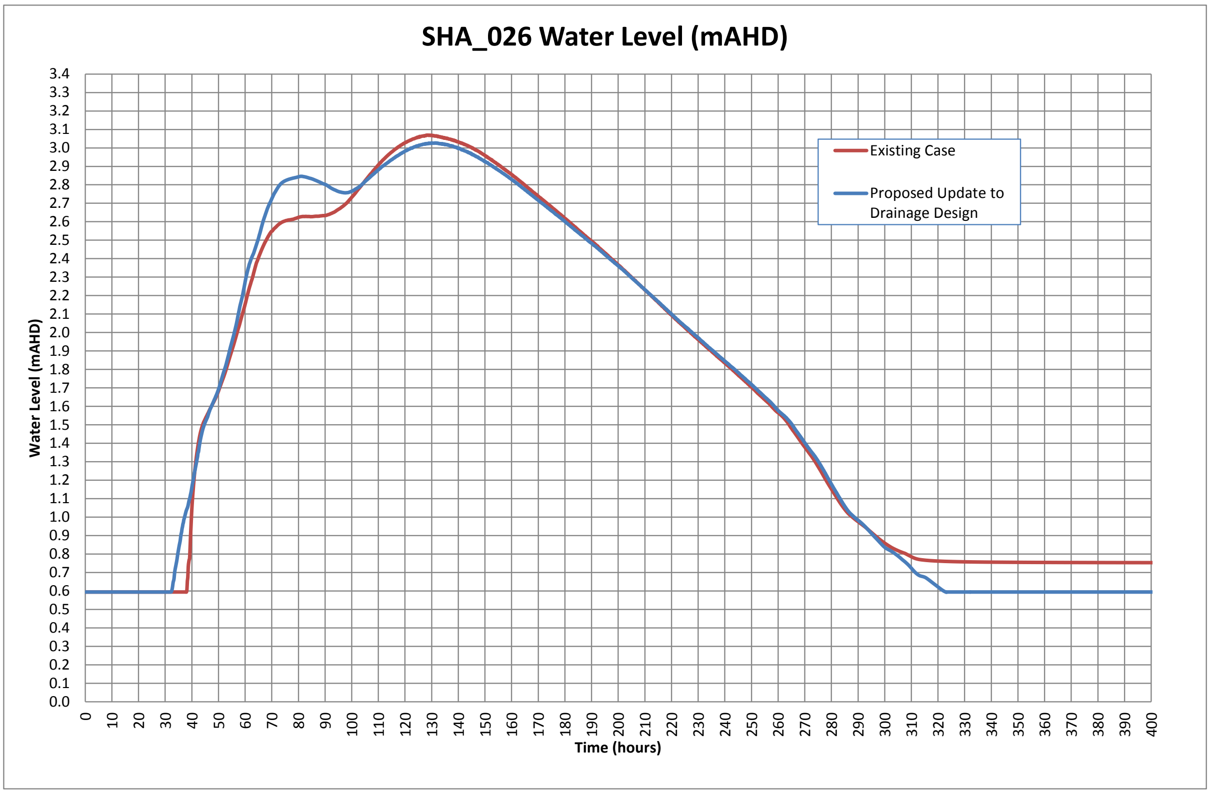

Figure C-11 Flood levels at SHA_026 for existing and proposed update to drainage design

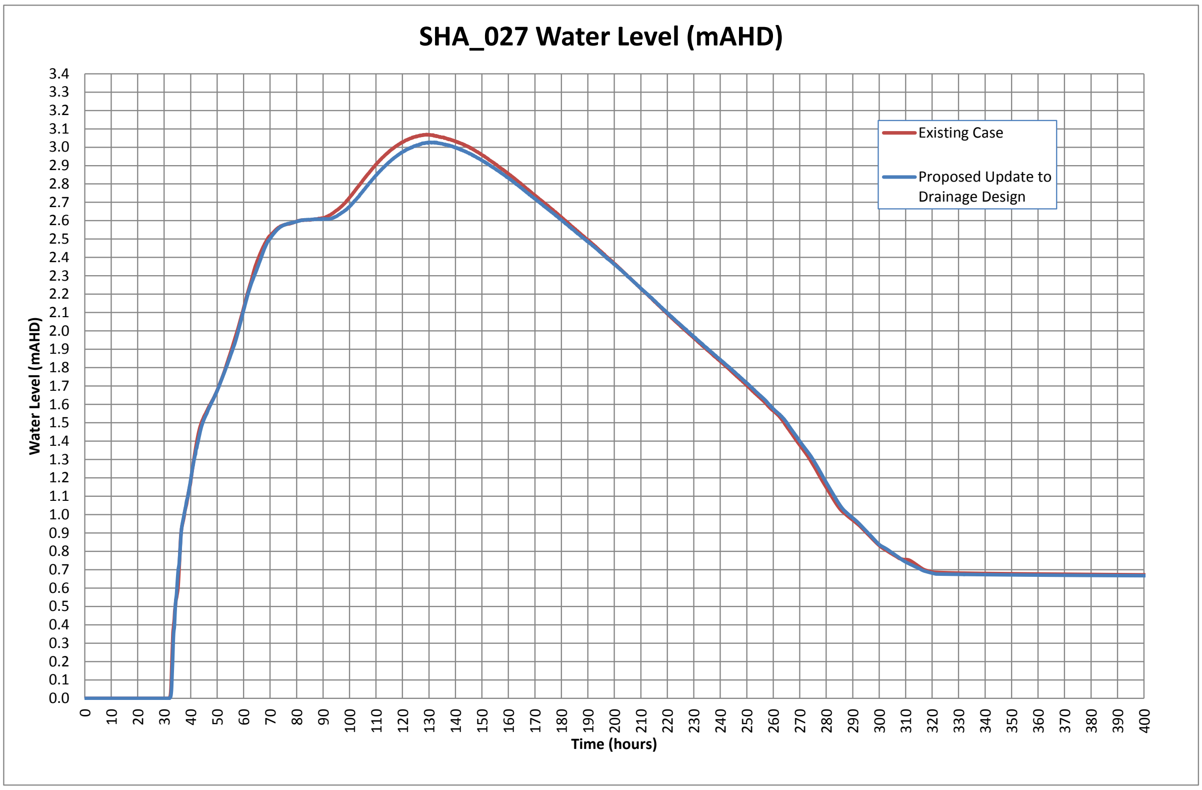

Figure C-12 Flood levels at SHA_027 for existing and proposed update to drainage design

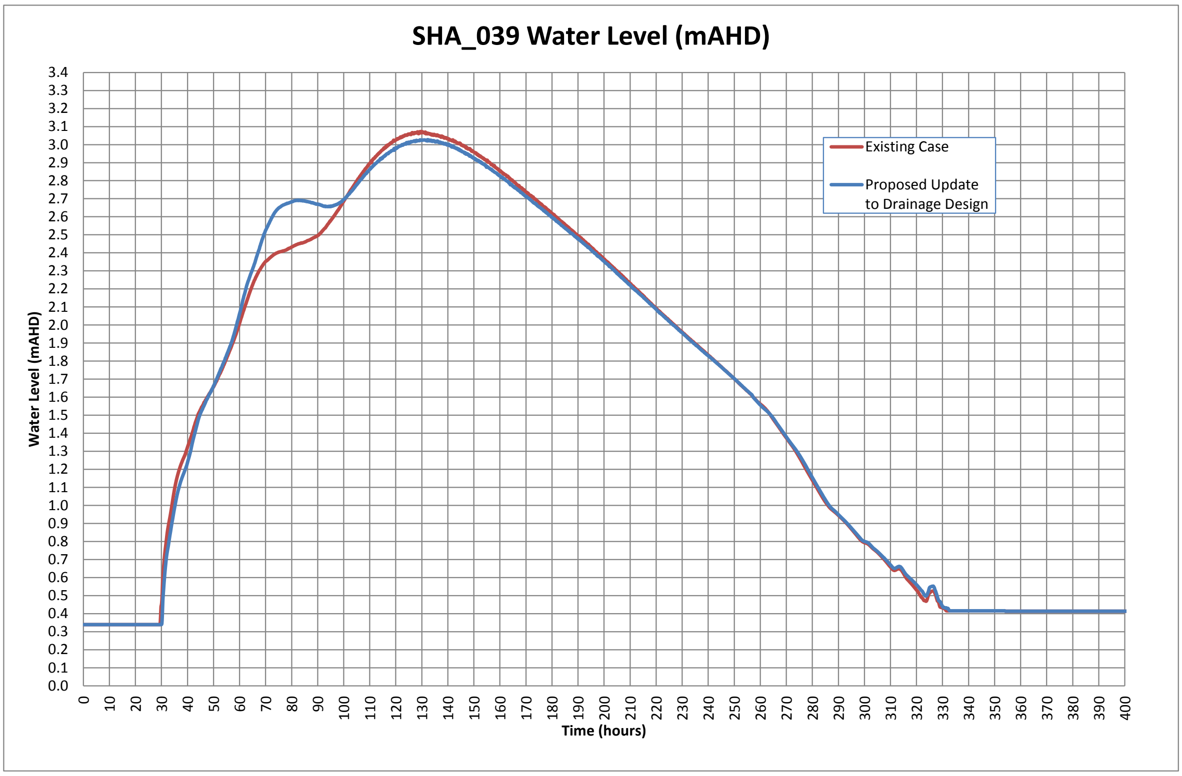

Figure C-13 Flood levels at SHA_039 for existing and proposed update to drainage design

The locations to the west of the upgrade (SHA_025, SHA_026, SHA_039) show a change in the shape of the hydrograph, with a smaller peak being reached about 70 hours before the main peak. This is due to a change in the flow behaviour as a portion of the floodwaters would not pass under the project but would flow south along the project before being conveyed through the Lees Drain area. This change in flood behaviour would not affect existing peak flood levels or times of inundation at lower levels.

The time of inundation at the reporting locations increase slightly. However, the increases would be less than the five per cent increase listed in the flood management objectives for the project.

Figure C-14 shows the flow upstream of the culverts proposed south of Shark Creek Bridge. This plot indicates that the flows heading east towards the upgrade route in both the existing case and the upgrade case are very similar. The flows for the upgrade case are slightly smaller and the residual 20 m^3/s that does not flow eastward flows southward towards Lees Drain.

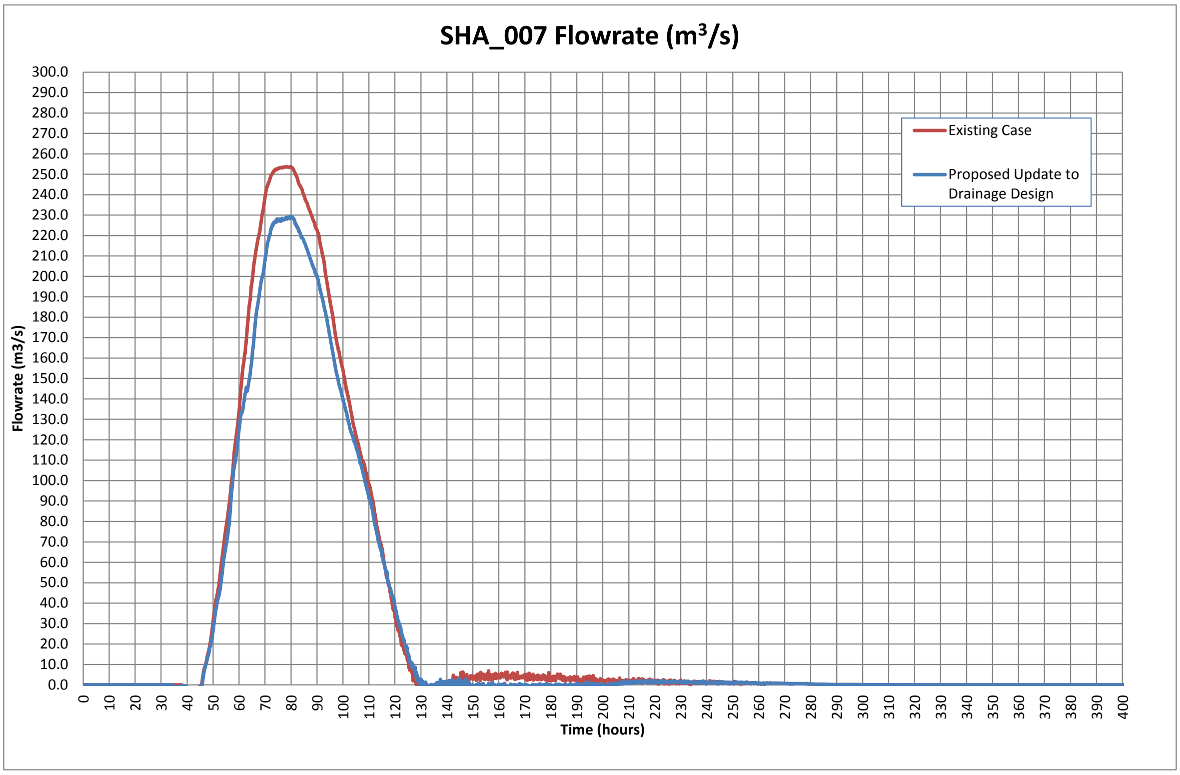

Figure C-14 Flood flows at line SHA_007 for the proposed update to drainage design against existing conditions

Figure C-15 to C-19 show the flow through Lees Drain for the existing and upgrade case. The locations of these figures are shown in Figure C-9 above. These plots show that the project would result in changes to the flow direction in this flood scenario during the phase of the flood when the basin is filling with flood inflows from the Clarence River.

The flow regimes at the downstream end of Lees Drain (channels 4 and 336) remained relatively unchanged between the existing and project cases. However, further upstream in channels 7, 8 and 9, a change in the direction of flow is evident in Lees Drain. Floodwater would run down the western side of the project and enter Lees Drain and flows east to reach the other side of the upgrade. In the existing case, this water flows around to the east north of Lees Drain and enters Lees Drain flowing west. This change in flood behaviour is not expected to increase flood peaks or time of inundation.

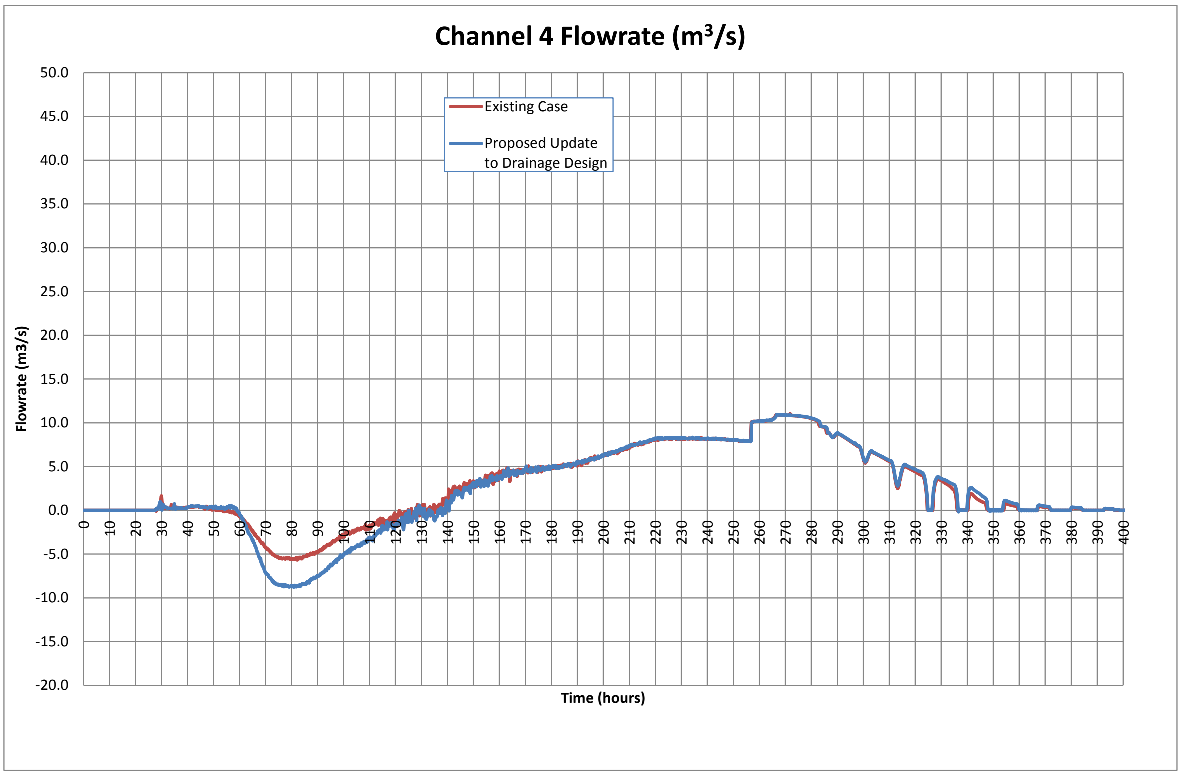

Figure C-15 Flood flows at Chanel 4 (in Lees Drain) for the proposed update to drainage design against existing conditions

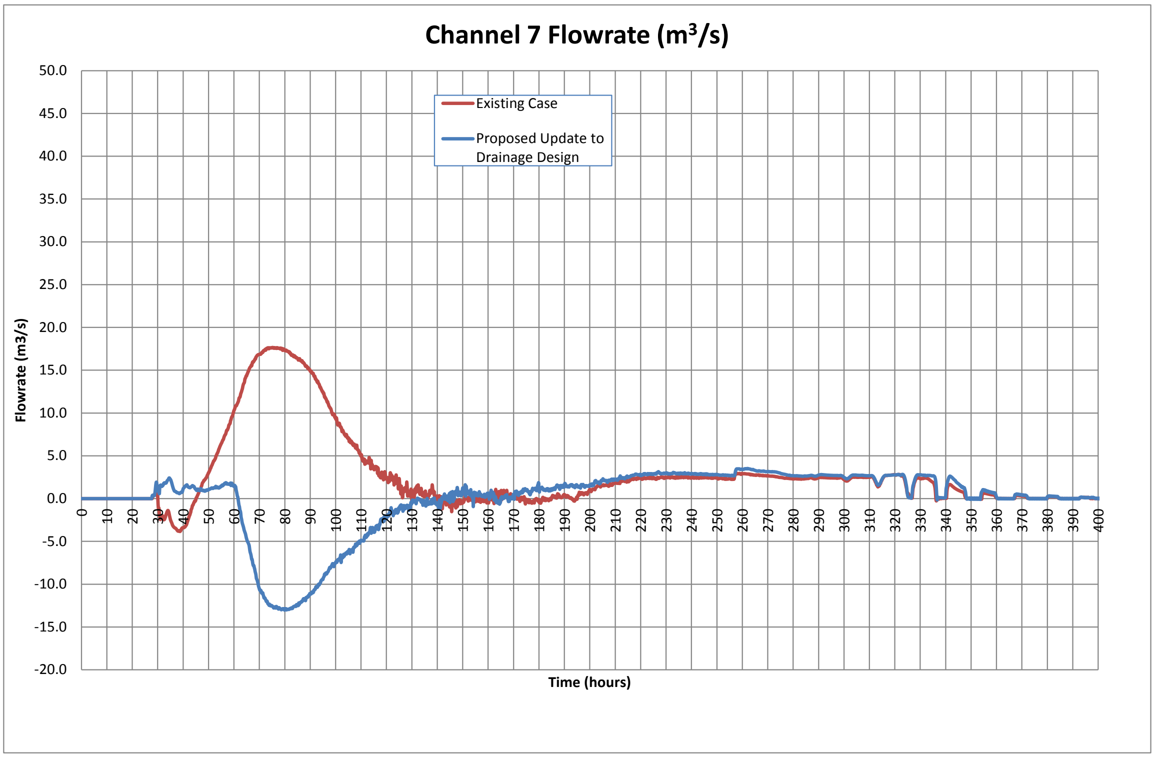

Figure C-16 Flood flows at Chanel 7 (in Lees Drain) for the proposed update to drainage design against existing conditions

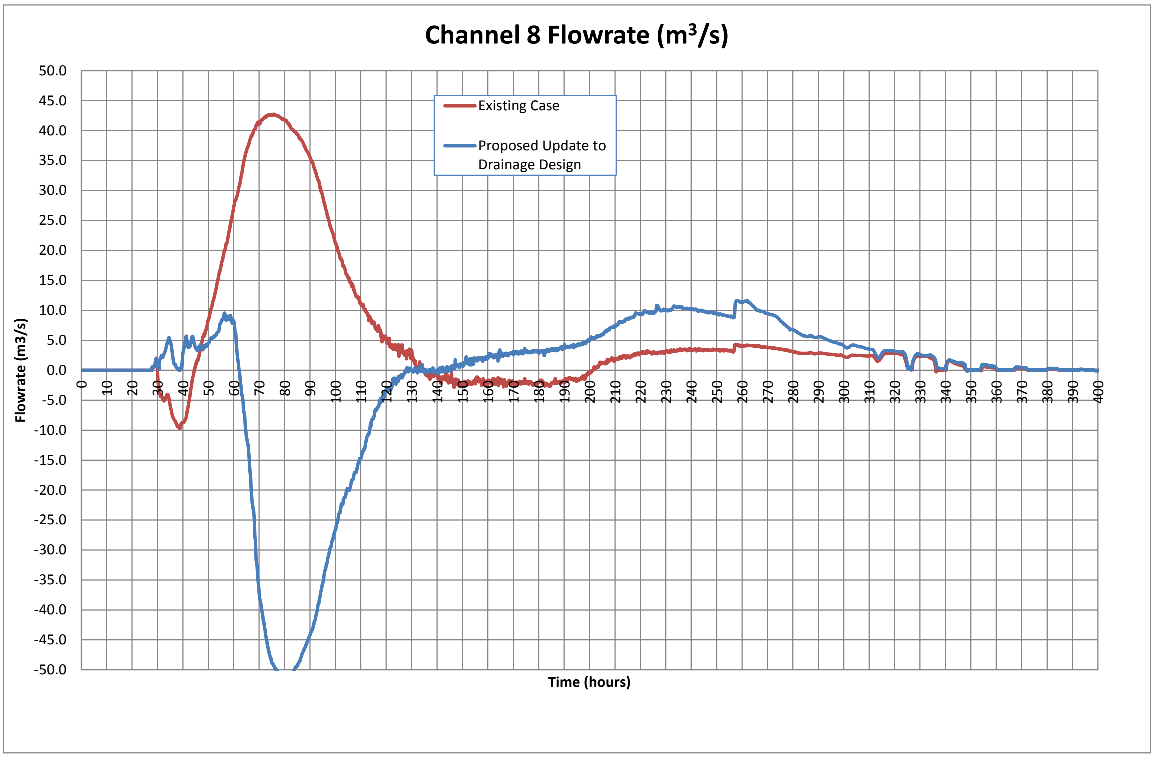

Figure C-17 Flood flows at Chanel 8 (in Lees Drain) for the proposed update to drainage design against existing conditions

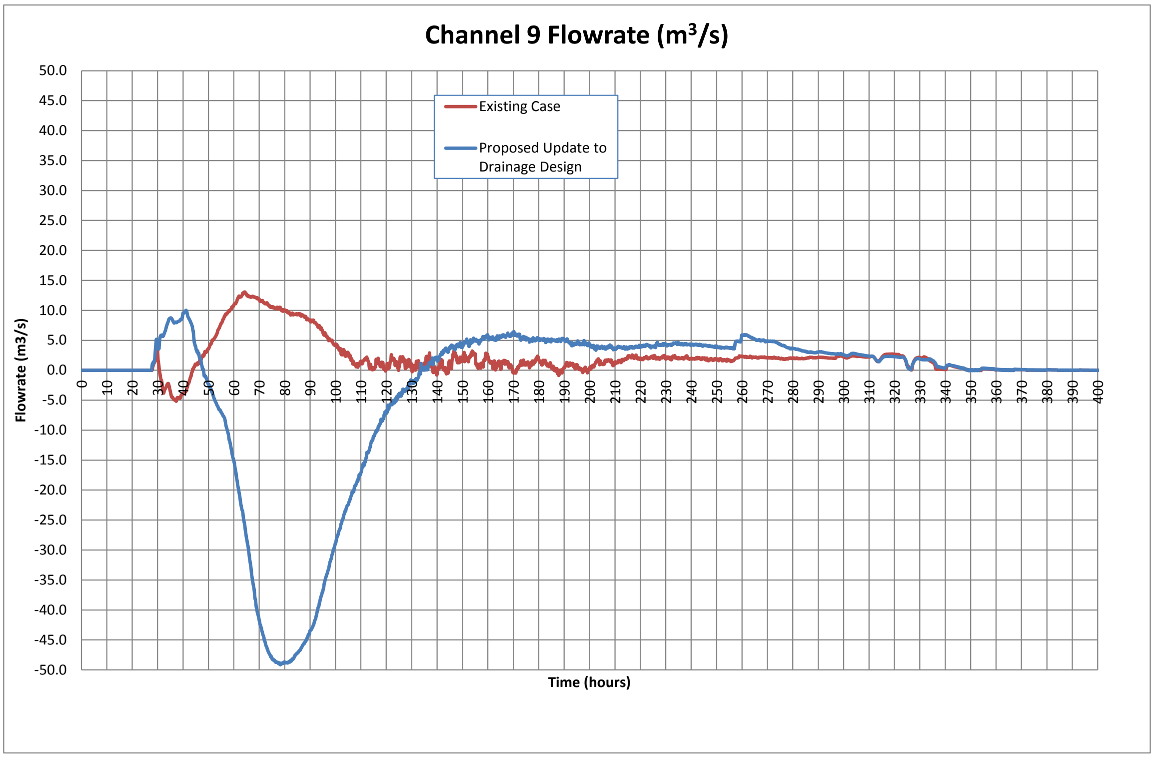

Figure C-18 Flood flows at Chanel 9 (in Lees Drain) for the proposed update to drainage design against existing conditions

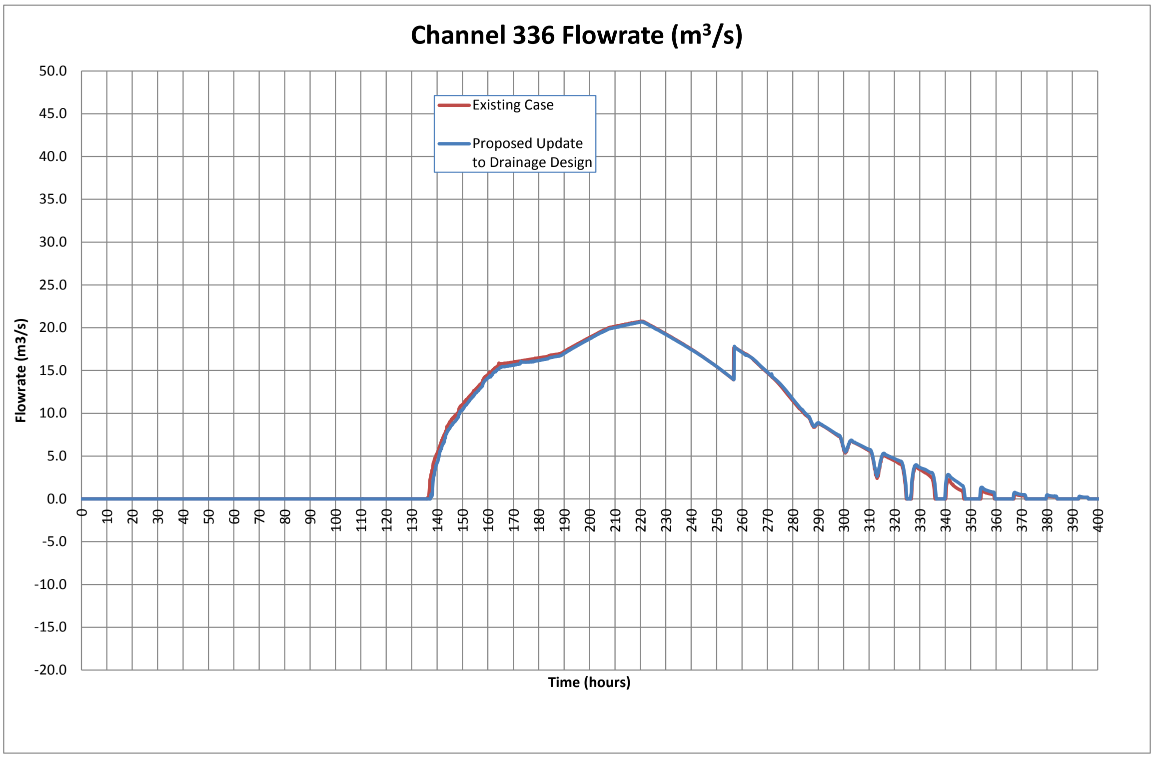

Figure C-19 Flood flows at Chanel 336 (in Lees Drain) for the proposed update to drainage design against existing conditions

As another check to confirm the performance of the modified Lees Drain, a calculation of flow rates based on approximate area to be drained and rate of flood recession was carried out. The rate of fall of the flood level in the existing case was calculated to be around 16 millimetres per hour, based on Figure C-11. The area of cane land to drain out through Less Drain is around 150 hectares or 1.5 square kilometres.

The existing case flow rate of water draining from the area was calculated at 6.8 cubic metres per second. To simulate these conditions, the proposed bridge over Lees Drain would need to convey flow at the same rate during the flood recession. By considering the cross-sectional area of the channel under the bridge over Lees Drain, a flow velocity of 0.6 metres per second would be required. This matches the modelled velocity closely, indicating that the model is appropriately representing a system that drains the cane fields at a rate similar to the existing case.

C.3.8 Upgrade of floodgate draining at Lees Drain

A potential scenario was investigated with the project in place and the floodgates draining Lees Drain into the Clarence River increased from three 1.8 metre reinforced concrete pipe culverts to six 1.8 reinforced concrete pipe culverts. The purpose of this scenario was to test whether the time of inundation of the cane fields could be significantly reduced by the addition of culverts at this location.

Figure C-20 indicates that the time of inundation was around 20 hours shorter when the additional culverts were installed at the Lees Drain floodgate. This option could represent a significant improvement to the Shark Creek cane drainage system.

A scenario of installing an additional six 0.6 metre reinforced concrete pipe culverts (above the current three 1.8 metre reinforced concrete pipe culverts) was also assessed. This indicated that the additional six 0.6 metre culverts would only reduce the flood inundation time by around two hours.

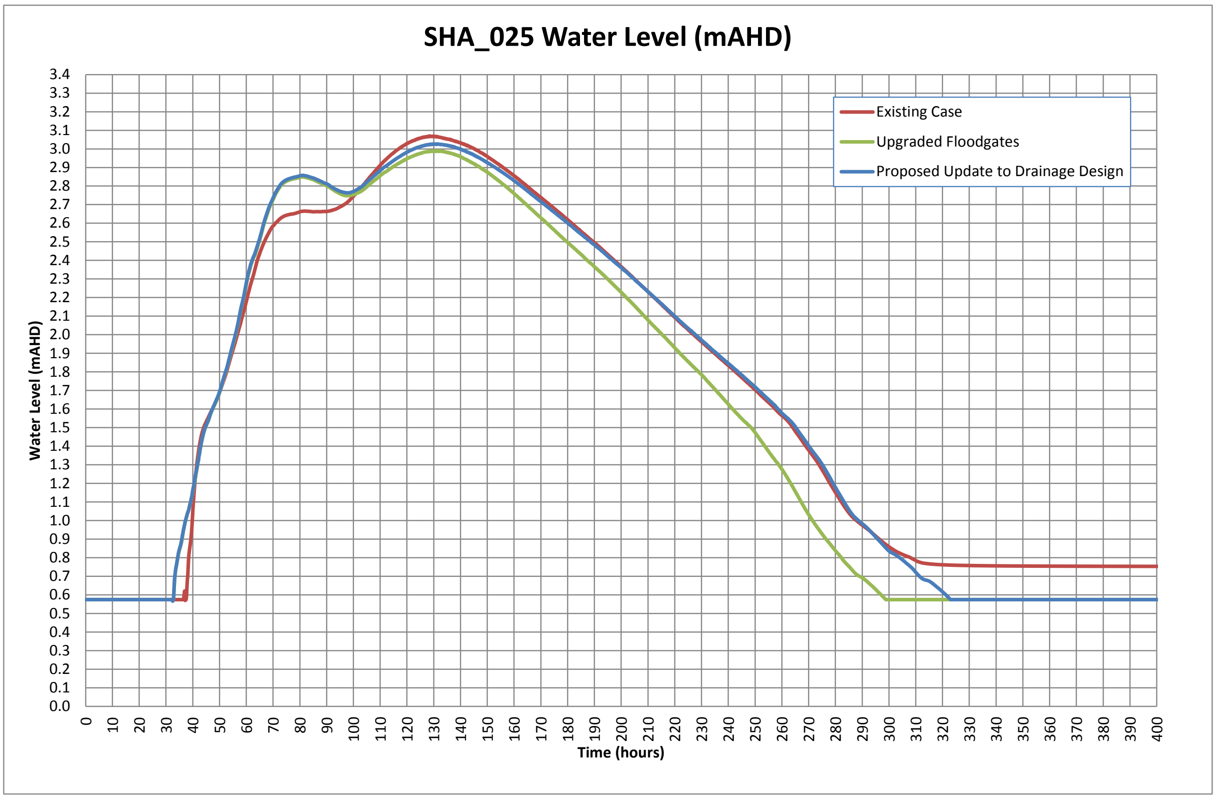

Figure C-20 Flood levels at SHA_025 for the proposed update to drainage design against existing conditions

C.3.9 Conclusion

This assessment identified possible changes to the drainage network around Shark Creek. This does not form part of the project but would be considered further during detailed design in consultation with landowners and stakeholders.

The main outcomes of this assessment are as follows:

- This assessment above has outlined the need for a fit-for-purpose drainage system for the cane farms on the Shark Creek floodplain. The proposed update to the project drainage design discussed above meets the flood management objectives of the project. However, further detail of the system can be discussed with landholders as the project progresses.
- A further opportunity to improve drainage at a minimal cost in the Shark Creek area was also investigated. This option involved increasing the size of the floodgate from Lees Drain to the Clarence River. It was found that doubling the flow area of the floodgate reduced the time of inundation by around 20 hours, which would represent a significant improvement in drainage. The mechanism for the implementation of this system could be achieved through partnership with the Clarence Valley Council (refer to management measure HF27).
- Any changes to the design of the bridge over Shark Creek would be considered as part of the Connectivity Strategy to preserve any combined functionality of the structure as a fauna crossing (refer to management measure HF28).

C.4 James Creek drainage network

Based on landowner discussions and submissions to the EIS, the flow capacity of James Creek has reduced over time due to the increases in riparian vegetation and debris. This has resulted in slower rates of flood recession for the floodplain areas of James Creek following Clarence River flood events.

The aim of this assessment was to identify opportunities to improve the efficiency of project drainage at a minimal cost in the James Creek area.

The hydrology of the James Creek area is relatively complicated due to the interaction of a brackish creek system on the south-eastern side of the highway and a freshwater cane drainage system on the north-western side of the highway.

There are currently few cross-drainage structures under the Pacific Highway along the Farlows Flat floodplain section (in between Maclean and Yamba Road interchange).

In 2012, Roads and Maritime raised the Pacific Highway at Farlows Flat. This changed the flood behaviour in the vicinity such that there would be less floodwater draining from the James Creek floodplain north-west across the highway to the cane lands and then to the Clarence River. As a result of the raised highway at Farlows Flat, it is now likely that more floodwaters are now required to drain out the James Creek floodplain system.

The project would further raise the highway at Farlows Flat to above the 20 year ARI flood levels. This would further separate floodwaters on either side of the highway during and after flood events.

It would seem possible to include additional flood conveyance capacity for the James Creek floodplain as part of the project. This additional flood conveyance capacity would assist in improving the rate of flood recession of this floodplain. Essentially, the system proposed for further consideration is to create a flood channel along the eastern side of the project and link that channel into James Creek around 300 metres upstream of its mouth. This most downstream section of James Creek has a relatively high flood flow capacity. However, the proposed drainage scheme would provide a parallel flood flowpath for the more constrained reaches further upstream.

Figure C-21 and Figure C-22 show a possible arrangement of a parallel drain and culverts under the ramps which would assist in improving flood recession from the James Creek area. It is recommended that this scheme be further considered at detailed design.

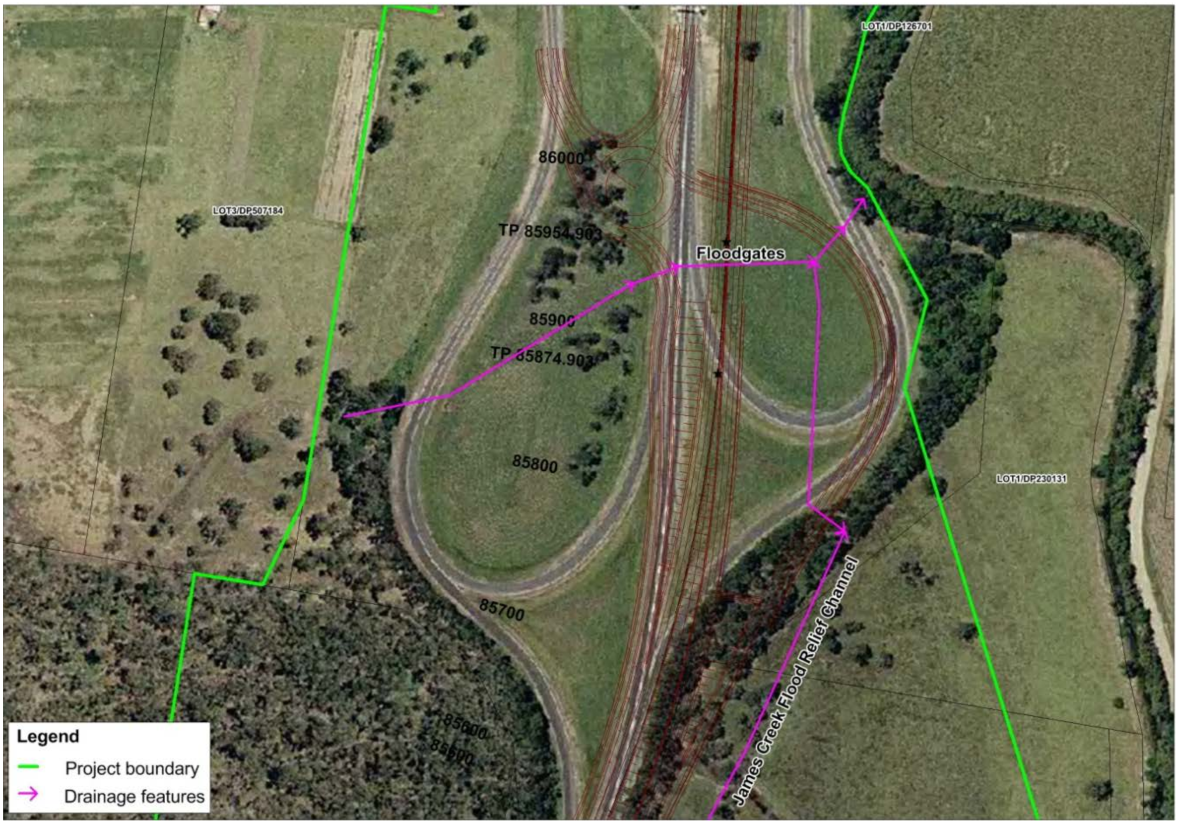

Figure C-21: Potential alternative drainage design for James Creek area with aerial

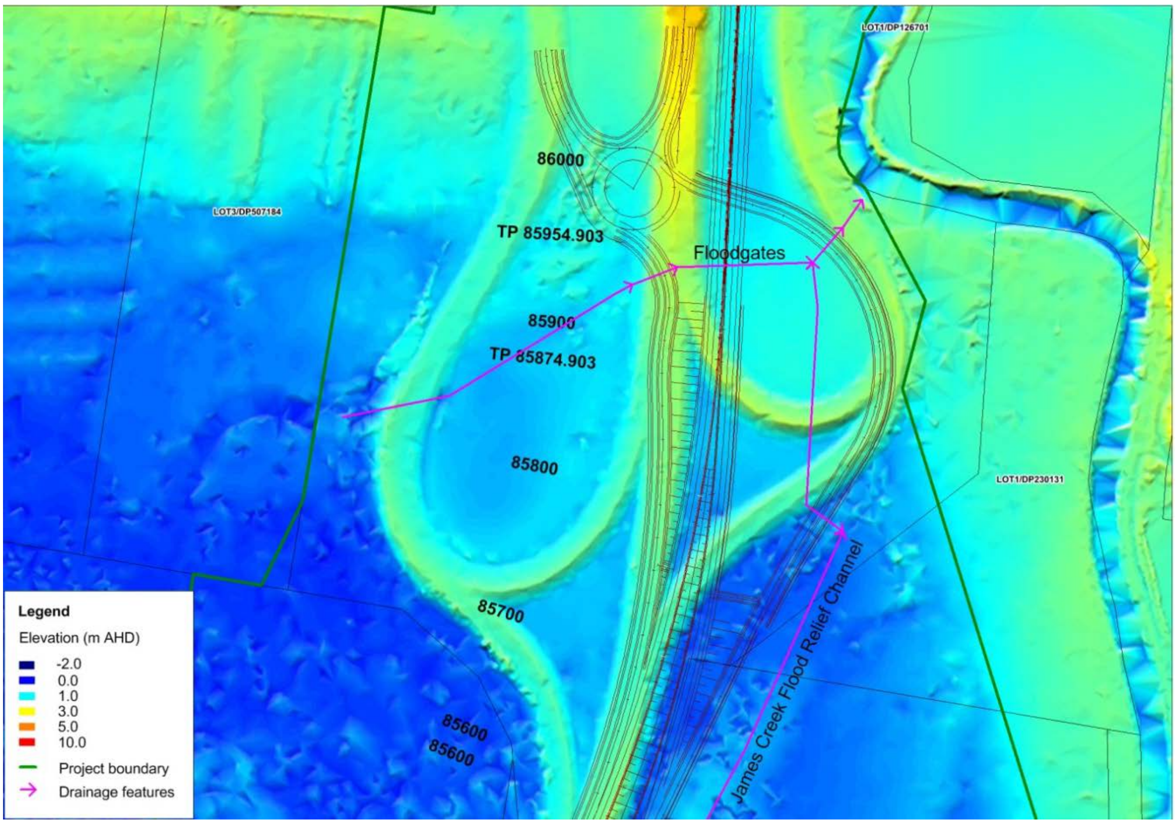

Figure C-22: Potential alternative drainage design for James Creek area with terrain

C.4.1 Conclusion

The main outcomes of this assessment are as follows:

- It is recognised there is potential to create a parallel flood flow path for James Creek as a viable option for improving flood drainage in the James Creek area.
- This option should be considered at the detailed design phase as a means for improving drainage, including further modelling to assess its compatibility with future M Class and future six lane upgrades. This should be considered in consultation with surrounding landowners (refer to management measure HF29).

C.5 Corindi River flood impact assessment

C.5.1 Background

A number of submissions were received during the exhibition of the EIS regarding the impacts of the existing Pacific Highway Blackadder Creek Safety Works (safety works being undertaken including the widening of travel lanes and increasing the height of the pavement to minimise flood related closures of the highway). These works were undertaken as a separate project and do not form part of the project. These submissions claimed that areas of Corindi, particularly Corindi Park Drive were flooded during the January 2012 floods as a result of these works. However, submissions also expressed concerns that the safety works were not taken into consideration for this project's EIS flood modelling.

These concerns were previously raised by residents with Roads and Maritime following the January 2012 flood event. Roads and Maritime then commissioned SMEC to develop a TUFLOW model (the 'SMEC model') of the Corindi River catchment to undertake a flood impact review of the Blackadder Creek Safety Works. This review found that the expected impact of the works in a 100 year ARI flood event immediately upstream of the existing highway would be an increase in flood level of one metre (1000 millimetres). However, the review also found that the Blackadder Creek Safety Works "did not result in an increase in water levels experienced along Corindi Park Drive. The water levels there were estimated to be slightly reduced as a result of the road safety improvement works due to the increased storage of flood water upstream of the highway" (Roads and Maritime & SMEC, 2012).

Due to submissions made to the EIS, Roads and Maritime undertook further consultation with the community to address this issue.

C.5.2 Further consultation

In June 2013, Roads and Maritime formed a focus group for the Corindi, Blackadder and Arrawarra communities. The purpose of the group was to provide input and discussion on various project issues including flooding, noise, property access arrangements, lighting and fauna and flora connectivity.

The first meeting was held on Wednesday 5 June 2013 to listen to concerns (including about the separate Blackadder Creek Safety Works) and to identify the results of the preliminary Corindi River cumulative assessment (as discussed above). A second meeting (27 June 2013) outlined an approach to further work to be undertaken regarding the calibration of flood models and assessing impacts. This included further consultation with the community and property owners to expand on the input of local knowledge and lived experience.

The additional flood assessment includes:

- Addressing the flood issues at Corindi (associated with the detailed design and the Blackadder Creek safety works) in accordance with Roads and Maritime and community expectations.

- Improving the project flood modelling by getting community input into flood levels and calibrating the Corindi River flood model to the January 2012 and February 2013 flood events (using radar rainfall data).
- Assessing the design rainfall estimate used in the design against actual rainfall events to provide evidence of the accuracy of the rainfall estimates used in the project flood modelling.
- Re-modelling a range of three different scenarios including:
  - Scenario 1: Pre Blackadder Creek Safety Works (for 2012 flood event, 2013 flood event, 100 yr ARI flood event)
  - Scenario 2: Current (for 2012 flood event, 2013 flood event, 100 yr ARI flood event).
  - Scenario 3: Blackadder Creek Safety Works and W2B detailed design (for 2012 flood event, 2013 flood event, 100 yr ARI flood event).
- Re-assess the impacts of the cumulative assessment (as detailed in section C.5.3 below) (including a culvert blockage sensitivity analyses) and identify any changes (if required) to the detail design for structures across the Corindi River floodplain.
- Re-assessing identified evacuation issues of residents upstream of the project.
- Get an independent review of the process via WMAWater.

Roads and Maritime has engaged the services of the independent reviewer for the project (WMAWater), who would review the assessment outputs.

This process is being undertaken as part of the project, but separate to the Submissions/ Preferred Infrastructure Report. Once the details of the Blackadder Creek Safety Works flood modelling is known, any further work required in relation to the safety works would be undertaken separate to the project.

Two additional meetings are planned with the community to identify and discuss the results of the calibration of the flood model to the recent flood events and the other to identify the results of the additional modelling and impact assessment. Roads and Maritime will continue to consult with the community to address this issue.

C.5.3 Preliminary Corindi River cumulative flood impact assessment

Prior to the establishment of the community focus groups and agreement to undertake further work, a preliminary cumulative flood impact assessment was undertaken of the project and the Blackadder Creek Safety Works. The SMEC model was used for this cumulative flood impact assessment.

The cumulative assessment was undertaken consistent with the approach taken in the EIS for other catchment areas where other road infrastructure has been recently constructed in the floodplain, such as the Ballina Bypass and the works at Farlows Flat. Both of these areas have been assessed with the so-called ‘base-case’ representative of flooding prior to construction of these projects.

To undertake the cumulative assessment, the SMEC model was updated to include the project by migrating the EIS Corindi River TUFLOW model (the ‘EIS model’) elements that represent the project into the SMEC model. Changes to peak flood levels in the 100 year ARI event due to both the Blackadder Creek Safety Works and the Woolgoolga to Ballina project are presented in Figure C-23.

The results of the flood model were assessed against the flood management objectives for this catchment, as set out in the EIS. The relevant flood management objectives for the Corindi River 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 with localised increases of up to 400 millimetres for short duration/ local catchment flooding acceptable over small areas (nominally less than five hectares) up to the 100 year ARI event.

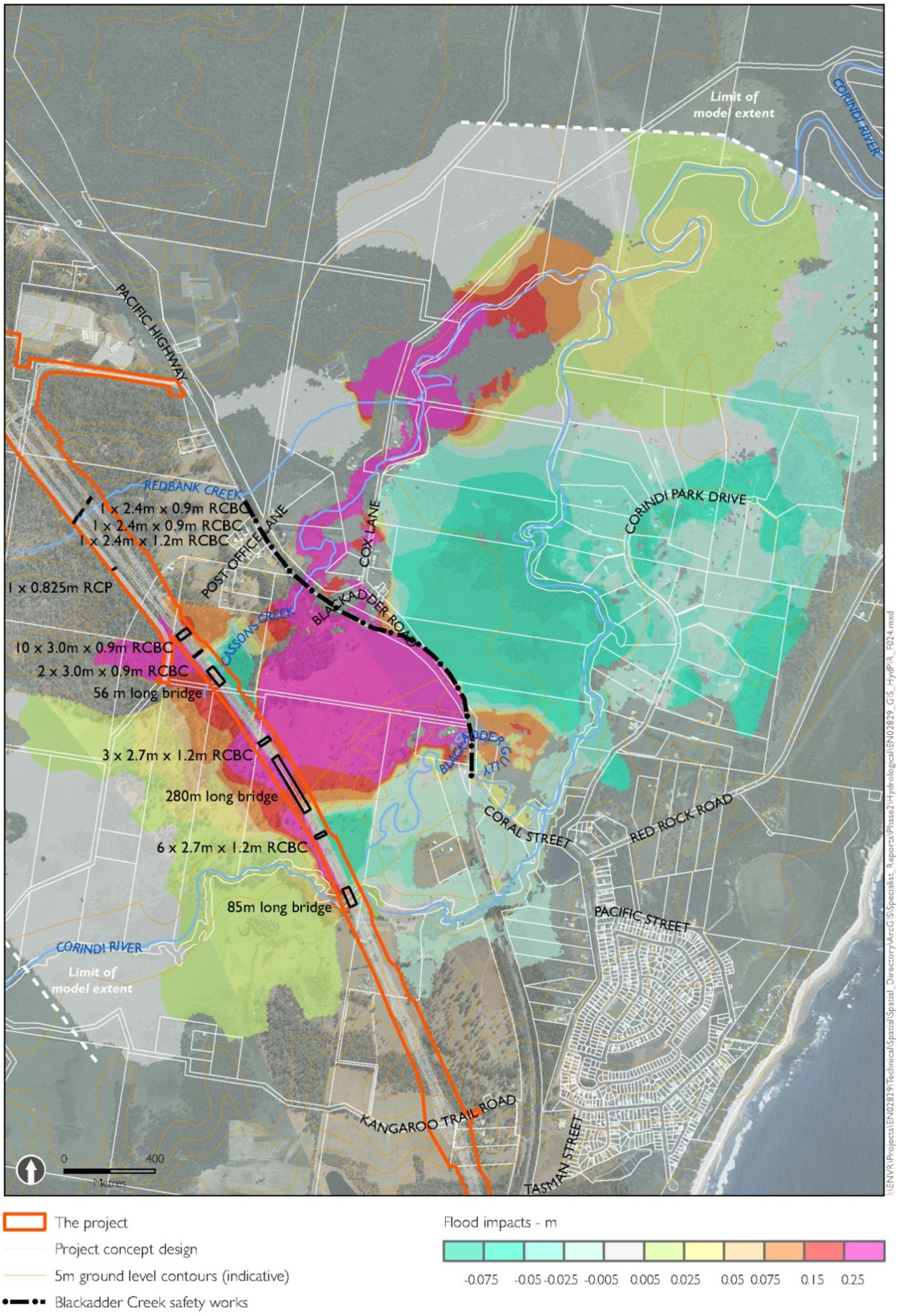

Figure C-23 Corindi River flood impacts 100 year ARI event

The cumulative assessment found that downstream of the project, around Corindi Park Drive, there would be a reduction of peak flood levels from the base-case (ie pre-2011) flood levels. For the majority of properties this decrease would be between five and 50 millimetres, with some small areas still experiencing a decrease in flood impacts of greater than 50 millimetres. This is with the exception of two northern properties on Corindi Park Drive, which would cumulatively experience an increase in flood levels of up to 25 millimetres. However, all increases in peak flood levels for residences on Corindi Park Drive are within the flood management objective of 50 millimetres increase.

The assessment has identified that upstream of the project, there would be exceedances of the flood management objectives. The area of land upstream of the project boundary with impacts exceeding 250 millimetres is about nine hectares in total. In a small area (around 1.2 hectares) upstream of the project along the floodplain between the Corindi River and Cassons Creek, flood levels increase by more than 400 millimetres. Impacts are up to around 600 millimetres in the 100 year ARI event and reduce to less than 250 millimetres within 170 metres of the project. These impacts do not meet the flood management objectives for this catchment as impacts exceed 400 millimetres and the area of land with impacts greater than 250 millimetres exceeds five hectares. These cumulative impacts would need to be further considered for project design at the detailed design phase.

As the impacts of the Blackadder Creek Safety Works propagate upstream to the location of the project, the consideration of cumulative impacts upstream of the project in the project design is warranted, and should be addressed at the detailed design phase.

Results of preliminary modelling

The main outcomes of the preliminary cumulative assessment are as follows:

- Model results show that the cumulative impacts of the project and the Blackadder Creek Safety Works would result in a decrease of peak flood levels for the majority of properties along Corindi Park Drive. For the majority of properties this decrease would be between five and 50 millimetres, with some small areas still experiencing a decrease in flood impacts of greater than 50 millimetres. This is still with the exception of two northern properties on Corindi Park Drive, which would cumulatively experience an increase in flood levels of up to 25 millimetres, however this increase in peak flood levels is within the flood management objective of 50 millimetres increase for residential areas.
- Impacts from the Blackadder Creek Safety Works propagate upstream to the location of the project (ie they affect the impacts of the project). As a result, consideration of cumulative impacts is warranted and should be adopted as part of the design process at the detailed design phase.
- Upstream of the project, cumulative impacts in terms of increases in peak flood level would exceed 400 millimetres in the 100 year ARI event. The area upstream of the project boundary with impacts exceeding 250 millimetres is about nine hectares in total. These cumulative impacts do not meet the flood management objectives and would need to be further considered for project design at the detailed design phase.

C.6 Modelling of rare flood events

Large / rare flood events (ie rarer than the 200 year ARI flood event up to a peak maximum flood) were not simulated for the project in the EIS. The focus of the flood impact assessments for the EIS has been for the two year ARI event to the 200 year ARI flood event. The EIS has demonstrated that there are minor changes to rates of rise in flood events up to the 100 year ARI flood event. However, the changes to rates of floodwater rise in rarer flood events is expected to be proportionally less in larger floods due to the flow rate over the upgrade (at the 20 year ARI flood level). Hence, it is expected there would be minimal changes to flood behaviour for floodprone habitable areas upstream of the project for rarer events. As a result, it was considered unnecessary to model extreme events (2000 year ARI and PMF) for this project at this stage.

Rarer flood events can result in higher flood hazards due to the ‘creation’ of flood islands as floods rise. In these locations, residents can be trapped in non-inundated areas but surrounded by floodwaters. As the flood magnitude increases, these flood islands can become inundated and result in high flood hazards.

As an example, one location on the Clarence River floodplain is Chatsworth Village which is located on a low ridge on the river bank. As floods rise and exceed the 100 year ARI flood levels, the entire village area is inundated well after the closing of evacuation routes.

However, the key issue for the EIS is whether the project increases the flood risks in Chatsworth Village through changed flood behaviour. The assessment of the rise and fall of flood levels is contained in Appendix G of the Working Paper - Hydrology and flooding. The plots at stations 91.2 (W) and 92.6 (W) (on pages 513 and 514 respectively) show that the rate of floodwater rise for the 100 year ARI event is almost unchanged from the existing situation with the project constructed. The time to the peak of the flood is reduced by around 2 hours (over a 70 hour rising limb) in the 100 year ARI flood event. Hence, it is reasonable to conclude that the increase to the flood hazard of this area is minor due to this increased rate of rise. It also needs to be noted that the reductions in flood rise only occur once flood levels reach 2.8mAHD. At this level, flood evacuation routes from the village would already be cut. Hence, the reduced time to flood peak does not result in a reduced flood evacuation time.

In rarer flood events, there would be less of a change to flood behaviour. This is due to the level of the project being lower than the 100 year ARI flood events across the major floodplains. When flood levels exceed the 100 year ARI flood levels in rare flood events, there would be very long lengths of highway overtopped and the majority of floodwaters would pass over the highway. The expected effect on flood behaviour as flood levels rise typically diminishes as the fraction of floodwater ‘weiring’ over the highway increases.

In regard to the likely location of flood islands with habitation occurring in rare flood events along the project, the following is provided.

The Richmond River and Clarence River floodplains are the only floodplains where floodprone settlements / urban areas exist upstream of the project (for those upstream areas affected by the project). The exception to this is a house on Firth Heinz Road near Chaffin Creek. This house is not inundated in the 100 year ARI event but likely to be inundated in rarer flood events. Due to the clearance under the bridge further downstream across Chaffin Creek being well above the 100 year ARI flood levels, the impacts of the project are expected to be somewhat linear (in regard to increasing flood afflux for rarer flood events). The occupants of this house have access to Firth Heinz Road as an evacuation route (as the road is higher than the house) and there are no ‘flood islands’ created in rarer flood events.

C.7 Identification of the flood level impact objective

Bridges and culverts within the length of the floodplain crossings would minimise the changes in existing flood patterns (flood height, flood durations, flood flows, directions and velocities). However, it is not possible to achieve zero impact in all areas of the floodplains. Localised changes to flood patterns would occur where the project crosses the floodplains, such as constriction and expansion of flood flows through proposed culverts resulting in afflux.

Therefore, realistically achievable changes to flood patterns are determined with consideration of the risks and impacts of those changes. Flood management objectives include:

- Flood level impact objectives.
- Flood inundation duration impact objectives.
- Flood velocity and direction impact objectives.

For houses, commercial premises and urban areas, the flood level impact objective is less than a 50 millimetre increase in flood height. This is the most stringent objective, with grazing, forested and other rural areas having a flood level impact objective of up to 400 millimetres. While cane farm land would normally have a higher flood level impact objective (as per grazing land), within the project area, there are many houses located in cane fields. As such, the area would still need to meet the objective of less than 50 millimetres. Therefore, cane land was allocated a flood level impact objective of 50 millimetres

This flood level impact objective is consistent with flood level impact objectives adopted by other Pacific Highway projects in adopting a flood level impact objective of 50 millimetres. This is particularly important where there is an adjoining project on the same floodplain. For example, it would be inconsistent to adopt a different afflux for houses on the Ballina floodplain when the adjoining Ballina Bypass used the objective of 50 millimetres.

The flood level impact objective was developed during the route selection phase of the project and has been carried through to the EIS and concept design phases. Consultation regarding project flood management objectives and flooding impacts have been ongoing with property owners and the cane industry since the route selection phase. The main concern with flooding impacts in relation to cane land was the increased time of inundation rather than flood levels. It was also generally accepted that no increase in flood level was not possible. Similarly, meetings with the community (through Flood Focus Groups) have been made aware of the flood management objectives, including the flood level impact objective of 50 millimetres for houses. At the last Flood Focus Group meetings, Roads and Maritime prepared individual flood property reports for all attendees of the groups. These reports were a two page document that identified the specific flood impacts (based on the flood management objectives) of the project for each house.

The flood management objective for the project was shown to have only minor increases to total average annual damages of affected communities. The hydrological assessment for the project showed that increases to house flood damages was limited to between 0.6 and three per cent on the Clarence River floodplain and between 0.6 and 1.1 per cent on the Richmond River floodplain.

It is acknowledged the project would, in some areas; result in a flood level increase of 50 millimetres, which is higher than limits placed on other floodplain development. However, the project, as a road infrastructure project is being undertaken to improve the condition of the highway, resulting in wide community benefits that justifies the level of the objective. These benefits are detailed in chapters 3 and 21 of the EIS and would include improved access, travel times and conditions along the highway. For local communities, this would include improved amenity and improved evacuation and access.

C.8 Cumulative assessment of Pacific Highway improvements

The existing Pacific Highway and decades of maintenance works could have altered drainage of land from the ‘predeveloped’ state (ie prior to the paving of the Pacific Highway). These works typically involved highway ‘overlays’ which add about 200mm to the road level for pavement rehabilitation. Based on consultation carried out with landholders throughout the EIS process, the following locations were raised as areas of concern in this regard:

1) Blackadder Creek (safety works constructed in early 2011).
2) Shark Creek overlays (constructed over recent decades).
3) Farlows Flat highway raising (constructed in 2012).
4) Bruxner Highway overlays near Duck Creek, Ballina (constructed over recent decades).

These works typically have had impacts on frequent flood events (eg up to 10 year ARI flood event) due to the low level of the current highway. Larger flood events completely overtop the highway and the influence of these works on flood levels is diminished.

These works mentioned above have most impact of the rates of floodwater recession on cane land. The minor raising of the highway can result in longer times of floodwater recession as it creates a shorter period in which floodwaters can recede to the river over the highway.

A cumulative impact of these works and the project on the pre-developed state of the highway has not been considered in detail in the EIS and Submissions/ Preferred Infrastructure Report. However, it needs to be noted that the project would mainly affect larger floods (eg 20 year ARI and larger). The overlays and changes to the existing Pacific Highway mainly affect the more common smaller floods. Hence, the potential for cumulative impacts is low.

However, improving floodwater recession would result in benefits to cane farmers that could offset some of the impacts of the project. To that end, discussions with the cane industry in 2013 resulted in the development of a Cane Farm Strategy for the project.

One of the actions listed in the Cane Farm Strategy is listed below:

“Where opportunities exist to improve the cane drainage network, these should be explored with cane farmers and CVC / RRCC to assess costs and performance improvements. This could include Roads and Maritime funding of improvements to flood gates well outside the project boundary at Lees drain”

The Cracker Drain/ Lees Drain (south of Shark Creek) area is one of the key areas identified by Roads and Maritime where drainage performance could be improved (as discussed earlier in this Appendix).