4.9. Clarence River

4.9.1. Catchment description

The Clarence River is a major coastal river in New South Wales with lower floodplain areas subject to frequent and extensive flood inundation. The catchment of the Clarence River covers around 20,000 square kilometres upstream of Grafton and at times of major flooding some 500 square kilometres downstream of Grafton become inundated.

The major tributaries of the Clarence River located within Sections 3 and 4 of the project to the east of Grafton are Glenugie Creek (catchment area of 136 square kilometres), Coldstream River (catchment area of 277 square kilometres) and Shark Creek (catchment area of 41 square kilometres). Note that an upstream reach of the Coldstream River also crosses the project and has been assessed separately as a creek system (see Section 4.5).

Three sections of the project (Sections 3 to 5) and a total of 62 kilometres of the project are located in the Clarence River catchment.

Due to the large difference in the size of the Clarence River and sub-catchment areas, and the close proximity to the ocean, the Clarence River floodplain experiences different types and combinations of flooding as follows:

- Inundation from a long duration (several days) Clarence River flood
- Short duration (less than one day) flooding in the local catchments
- Ocean storm surge inundation (due to elevated ocean levels at the Clarence River mouth).

Features of the lower Clarence River floodplain

The project would cross the Clarence River floodplain within Sections 3, 4 and 5 between the Glenugie upgrade and the interchange at Iluka Road. This large floodplain area comprises of floodplain areas adjoining the river (eg Chatsworth and Harwood islands) and basins flooded by backup of tributary creeks and rivers (eg Coldstream River basin and Shark Creek basin).

The Coldstream River basin is a large flood storage area filled by tributary catchment inflows as well as Swan Creek and Coldstream River backup flows from the rising Clarence River.

Between Tyndale and Maclean (around Shark Creek), the floodplain east of the Clarence River South Arm is also known as the Shark Creek basin, the extent of which is constrained by the surrounding ranges. Figure 4-21 shows the locations of these two basins.

The Coldstream River basin is substantially larger in both area and volume than the Shark Creek basin. The Coldstream River basin is about 160 square kilometres while the Shark Creek basin is about 30 square kilometres. The volume of flooding in the Coldstream River basin also is significantly larger (in the order of 720,000 ML) compared with the slightly shallower Shark Creek basin (in the order of 130,000 ML).

The Chaselings / Gulmarrad River basin lies between Shark Creek and Maclean and temporarily stores a relatively small volume of water during flood times.

North and east of Maclean, the floodplain extends north across Chatsworth and Harwood islands and south of the river around James Creek and Gulmarrad towards Lake Wooloweyah.

Clarence River flows

The Clarence River catchment upstream of Grafton is very large in comparison with the smaller tributaries downstream of Grafton. Hence, the flooding behaviour of the Lower Clarence River floodplain is dominated by the flow from this part of the catchment in terms of both peak flood levels and duration of inundation. The flow is typically 80 to 90 per cent of the total volume of floodwaters that enters the lower floodplains.

Flood flows can be sustained for several days or weeks due to the large catchment size,. Clarence River floods typically occur from low rainfall intensity events that last several days or even weeks.

On the Clarence River floodplain, the inflows from the smaller tributary catchments downstream play only a minor role in flood behaviour. Even the Coldstream River portion of the floodplain, which has an area of almost 300 square kilometres, is dominated by floodwaters from the Clarence River backing up the Coldstream River and inundating the Coldstream River basin.

The 100 year ARI peak flow in the Clarence River upstream of Grafton (at Mountain View) is in the order of 19,000 cubic metres per second. This flow dominates the cumulative total 100 year ARI peak inflows from all sources of 23,700 cubic metres per second (WBM, 2004).

Clarence River flood model

As summarised in Table 2-4, a detailed two-dimensional TUFLOW flood model of the entire Clarence River floodplain was used for those parts of project that cross the Clarence River floodplain.

This model was originally developed from the then Clarence River County Council between 2000 and 2004. The development and calibration of the model is fully described in the *Lower Clarence River Flood Study Review* (WBM, 2004).

The Clarence River flood model was further refined for the Pacific Highway upgrade studies to improve the accuracy of the flood level and impact predictions. When the model was first developed in 2000, the resolution of the two-dimensional model was 60 metres. That is, each point at which flood parameters are calculated across the model (eg depth, velocity, etc) is a 60-metre by 60-metre area.

Two critical areas on the floodplain were refined for the purposes of assessment. The area of Chatsworth and Harwood islands were represented using a 20 metre by 20 metre grid. Also, Serpentine Channel was represented using one-dimensional elements, which provides a better representation of smaller channels. Similarly, the Shark Creek basin was represented using a 20 metre by 20 metre grid and Shark Creek was represented using one-dimensional elements. In addition, the geometry of these areas of refinement (ie Shark Creek basin and Chatsworth and Harwood Islands) was based upon the aerial survey carried out by the RMS for the route selection phase of the Wells Crossing to Iluka Road project.

Both areas of refinement and the creeks represented in one dimension (Shark Creek and Serpentine Channel) were all dynamically linked together along with the remainder of the 60 metre grid areas.

The more detailed modelling of the Clarence River floodplain allowed a re-calibration of the model to recorded flood events. This process was aimed at improving the accuracy of flood level and impact predictions. The refined model was re-calibrated to the 1980, 1996 and 2001 flood events.

The 1980 event was chosen as it is the only event with records over the duration of the flood event at the mouth of Shark Creek (at a gauge called Gregors) and at a location further up Shark Creek (at a gauge called Maloneys). The efforts of the local landholders (ie the Gregors and the Maloneys) in recording these flood levels during the flood event are recognised as a significant contribution to this study.

The 1996 and 2001 flood events were also chosen as they are the two most recent significant floods on record. Hence, the conditions of the river and floodplain (eg levees completed, level of river siltation) reflect those that could be expected today. Further, these flood events are similar to, but slightly smaller than, the 20 year ARI flood event, which is the design flood immunity for the project across this floodplain.

There have been a number of flood events in recent years in the Clarence River. These flood events were small to moderate flood events with magnitudes up to the 10 year ARI flood. As the flood model has been calibrated to six flood events including a range of magnitudes from small (eg May 1980) to very large (eg March 2001), further calibration of the flood model to these more recent events was unlikely to result in changes to flood modelling parameters or the understanding of flood behaviour.

March 2001 flood event

A peak flood level of 3.38 metres AHD was recorded in the Shark Creek basin during the March 2001 flood event. The refined Clarence River flood model was simulated with the inflows and ocean conditions for this flood event. The model predicted a flood level within 0.12 metres AHD of the recorded flood level at this location. This is considered a suitable representation of the recorded flood behaviour.

Another flood level recorded on the bank of the Clarence River where inflows from the Clarence River enter the Shark Creek basin was recorded to be 3.56 metres AHD. The model predicted a flood level within 0.05 metres at this location, which is also close to the recorded level.

The locations of these flood levels and other selected recorded flood levels over the whole Clarence River floodplain are presented in Figure 4-21.

May 1996 flood event

For the May 1996 flood event, a peak flood level of 3.24 metres AHD was recorded on a farm storage shed south of Byrons Lane. The refined Clarence River flood model was simulated with the inflows and ocean conditions for this flood event. The model predicted a flood level within 0.25 metres AHD of the recorded flood level at this location. This is considered a suitable representation of the recorded flood behaviour.

May 1980 flood event

The May 1980 flood event was a relatively small flood event (about a five year ARI event). The refined Clarence River flood model was simulated with the inflows and ocean conditions for this flood event. Anecdotal evidence was that this flood event included particularly high rainfall intensities within the local Shark Creek catchment. Due to the paucity of rainfall records in the catchment during the event, it was assumed that the rainfall on this catchment was about double that for the remainder of the floodplain.

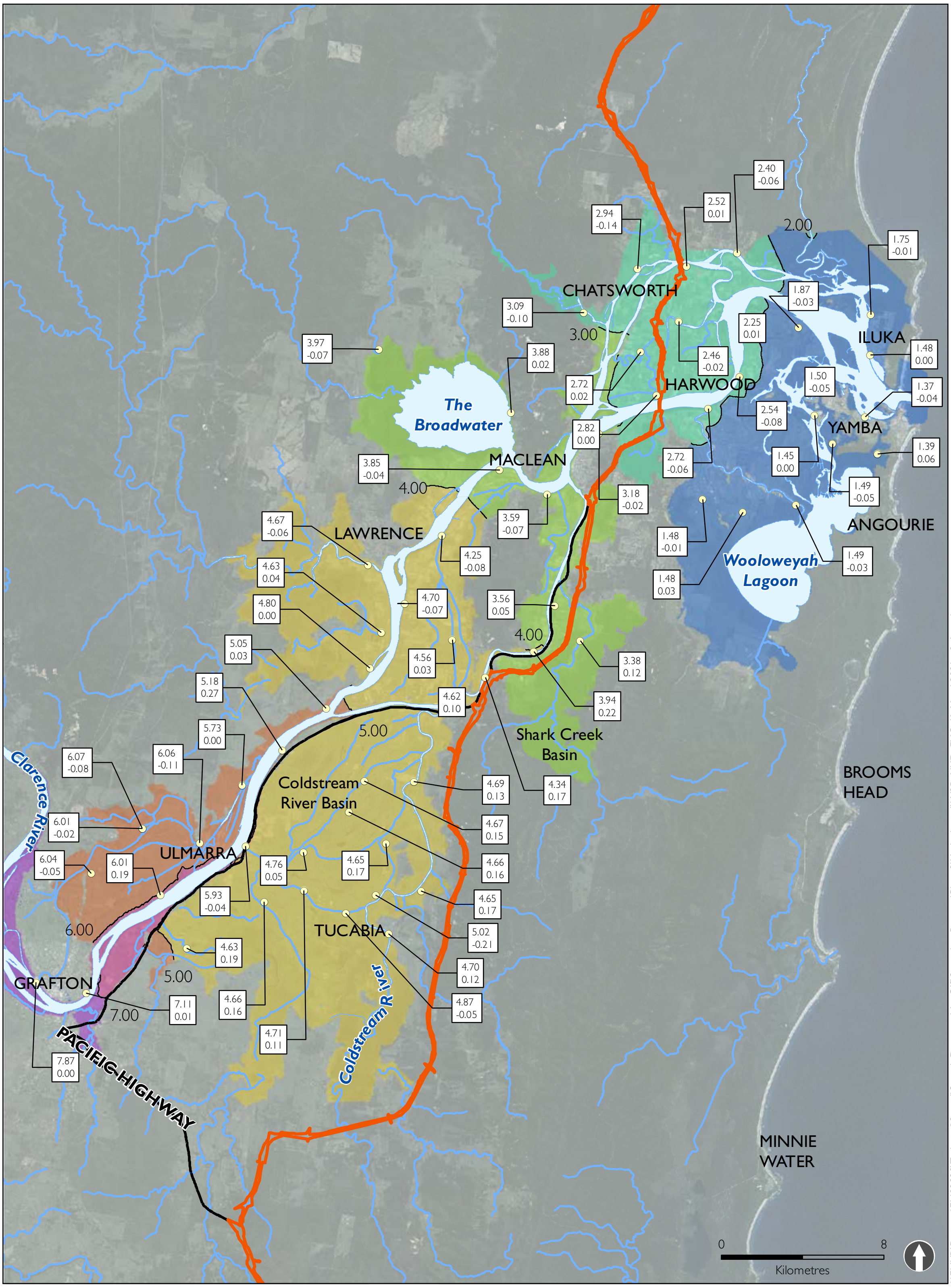
For the May 1980 flood event, a peak flood level of 2.76 metres AHD was recorded on a farm storage shed south of Byrons Lane. The model predicted a peak level of 2.20 metres AHD for the same area. Hence, the model is under-predicting the recorded flood level by about 0.5 metres. This is probably due to a lack of detailed ground survey used in the model to define creek banks and other in-bank features. However, it does indicate that the model may not fully represent the flood behaviour of small floods that are dominated by in-bank Shark Creek back-up flows. For the larger flood events (eg March 2001, 20 year ARI etc), the model provides a good representation of flood behaviour. This is not an issue for this study as the focus is for floods greater than 20 year ARI as that is greatest potential for increased flood risk.

Calibration summary

In summary, it is concluded that the refined Clarence River flood model adequately represents the flood behaviour of the Shark Creek basin for the purposes of the assessment of the project.

There were many other flood levels recorded over the entire Clarence River floodplain for these flood events. The *Lower Clarence River Flood Study Review* (WBM, 2004) provides a full documentation of the calibration of the flood model to these and other flood events.

Figure 4-21 Clarence River flood model calibration: March 2001 flood



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The project

Existing Pacific Highway

Recorded flood level (mAHD) Modelled level - Recorded level (m)

Flood levels - m (AHD)

2.00 3.00 4.00 5.00 6.00 7.00

4.9.2. Existing flooding behaviour

Clarence River

Existing flooding behaviour has been assessed through hydrological and hydraulic flood modelling. The type of models used in this catchment are summarised in Table 2-4. In general, the Clarence River flooding behaviour can be described as follows (working from upstream to downstream):

- At Grafton, the total flow from the catchment is constrained to the river due to a system of levees that have been constructed on the north and southern sides over the last 100 years
- Downstream of Grafton, river flows and elevated river levels result in floodwaters backing up Swan Creek (in large floods and small floods). This flow then enters the Coldstream River basin. This basin plays an important role in attenuating the flows in the river
- Inundation of the Coldstream Basin is accompanied by flows from local catchments (eg Coldstream River, Glenugie Creek and Pillar Valley Creek). The basin rises slowly (including some minor reverse / backup flow through the mouth of the Coldstream River)
- In large flood events (eg 100 year ARI flood), significant flows short-cut through the Coldstream River basin by overtopping the natural and man-made levees before re-entering the river at the mouth of the Coldstream River
- At Cowper / Brushgrove, the river splits into the main river and the South Arm. The main river and its associated floodplain accommodate about 90 per cent of the total flow. The remaining 10 per cent passes along the South Arm and its associated floodplain
- Between Tyndale and Maclean along the South Arm, the floodplain includes the Shark Creek basin and the Chaselings Basin. The flooding behaviour of these basins are described below
- Between Maclean and the river mouth, the floodplain includes the Chatsworth and Harwood islands areas. The flooding behaviour of these basins is described below.

Shark Creek and Chaselings basins existing flooding behaviour

The Shark Creek basin has a small catchment area relative to the size of the Clarence River floodplain. Flooding primarily occurs as a result of back up from the Clarence River, with Shark Creek providing a conduit for flood waters from the Clarence River to back up into the basin.

Shark Creek has levees on both of its banks. During small floods (ie five year ARI floods and less) and in the early stages of larger floods, water backs up through Shark Creek to the southern part of the basin. Larger floods break (ie larger than five year ARI) the Shark Creek banks further north along the creek. The Shark Creek levee banks vary in level from 2.0 metres AHD to 3.0 metres AHD.

A flood of 10 year ARI or greater conveys flood flows from the Clarence River (South Arm) across the existing highway and into the Shark Creek basin. Events of a 50 to 100 year ARI increase the extent of inundation, with flows breaking over the highway in sections further to the south than for the 10 year ARI events.

The peak flood level in the Shark Creek basin for the 20 year ARI is about 3.75 metres AHD.

The Chaselings Basin (north of Shark Creek) is also a small catchment relative to the size of the Clarence River floodplain. This is primarily a flood storage basin for Clarence River flood flows.

Clarence River flood waters initially enter the northern portion of the basin through the Goodwood Street underpass. The southern portion of Chaselings Basin is inundated by Clarence River flows overtopping the existing highway and then a small levee (Causleys Lane).

The culvert at the Goodwood Street underpass is an important point of conveyance in the Chaselings Basin and conveys the majority of floodwaters that fill the basin during floods. The peak flood level in the Chaselings Basin for a 20 year ARI event is 3.65 metres AHD.

Peak flood levels and depths over this area of the Shark Creek and Chaselings Basins for the 20 year ARI flood event are presented in Figure 4-22 and Figure 4-23. Existing peak velocities are presented in Figure 4-24.

Chatsworth / Harwood islands existing flooding behaviour

At Maclean, the two river arms of the Clarence River converge for a short length. Downstream of Maclean, the river again splits into the main river and the North Arm. Section 5 of the project traverses this part of the Clarence River floodplain.

There is a significant width of floodplain between the two channels which includes Harwood and Chatsworth islands. These islands are divided by a narrow tidal channel called Serpentine Channel.

Peak flood levels and depths over this area for the 20 year ARI flood event are presented in Figure 4-25 and Figure 4-26. Peak flood levels in the 20 year ARI event along the existing Pacific Highway vary from 2.90 metres AHD at Harwood to 2.55 metres AHD at Chatsworth Island (north). Existing peak velocities are presented in Figure 4-27.

The majority of the flow in this lower part of the river system is conveyed by the two main river channels. Table 4-1 shows the distribution of peak flows across the lower portion of the Clarence River floodplain. It is apparent that over 90 per cent of the flow is conveyed in the main arm and the North Arm. Only six per cent of the total flow is conveyed across the Chatsworth and Harwood Island floodplains.

Table 4-1 Distribution of peak 20 year ARI flow across Clarence River floodplain

Section	Peak Flow (m^3/s)	Per cent (%)
South of Clarence River main arm	117	1
Clarence River main arm	6569	76
Harwood Island	229	3
Serpentine Channel	85	1
Chatsworth Island	256	3
Clarence River North Arm	1356	16
North of Clarence River North Arm	46	1
TOTAL	**8,657**	**100**

At the mouth of the Clarence River system, training walls confine the outflow to a well-defined channel. Storm surges can also result in significant inflows (ie reverse flow) into the river system resulting in inundation usually prior to fluvial runoff inundation (ie due to heavy rainfall) described above.

Flood immunity of the existing highway

An assessment was undertaken to determine the flood immunity of the existing Pacific Highway within the Clarence River floodplain. The following flood immunities have been estimated for the length of existing highway from Grafton to Tyndale:

- The highway would be overtopped at Tyndale upstream of the Coldstream Road intersection in a seven year ARI event
- The section of highway north of Ulmarra would overtop in an eight year ARI event
- The remainder of the highway along this section would overtop in a 15 year ARI event.

The following flood immunities have been estimated for the length of the existing highway from Tyndale to Maclean:

- This section would be cut off south of the Shark Creek bridge during a three to four year ARI event
- The Ferry Park area would be overtopped during a 10 year ARI event
- The highway would overtop near Causleys Lane in Gulmarrad during a six year ARI event.

The flood immunity for the length of existing highway from Maclean to Iluka Road was also estimated. Nominally, this section of highway would overtop north of Serpentine Channel during a five year ARI event. However, a section on Chatsworth Island may also overtop during a three to four year ARI event. The section of highway north of Maclean at Farlows Flat has been recently raised to provide 14 year ARI flood immunity. Previously, it was the most flood-prone part of the highway along the entire project route, with flood immunity in the order of 2 years ARI.

Property inundation on the lower Clarence River floodplain

Many properties experience flooding in these basins and floodplain areas. Properties identified as being inundated in the impacted parts of Chatsworth, Harwood and surrounding areas, and from Tyndale to Maclean for the 20, 50 and 100 year ARI floods are summarised in Table 4-2, Table 4-3 and Table 4-4 respectively.

Table 4-2 Flooded properties in the impacted parts of Chatsworth Island and surrounds

Flood event	Level of flooding (depth above floor level)	Commercial properties	Fully detached			Multi-unit	
			Single story	High-set	Double storey	Single storey	Double storey
20 year	0.5 m +	0	0	5	0	0	0
	0-0.5 m	0	0	1	3	0	0
50 year	0.5 m +	0	0	6	1	0	0
	0-0.5 m	4	9	0	3	0	0
100 year	0.5 m +	0	0	6	2	0	0
	0-0.5 m	7	12	0	4	0	0

Table 4-3 Flooded properties in the impacted parts of Harwood Island and surrounds

Flood event	Level of flooding (depth above floor level)	Commercial properties	Fully detached			Multi-unit	
			Single story	High-set	Double storey	Single storey	Double storey
20 year	0.5 m +	2	2	32	8	0	0
	0-0.5 m	6	3	2	2	1	0
50 year	0.5 m +	4	3	33	10	0	0
	0-0.5 m	6	11	2	0	1	0
100 year	0.5 m +	8	4	34	10	1	0
	0-0.5 m	8	23	1	0	0	0

Table 4-4 Flooded properties in the impacted areas from Tyndale to Maclean (including Ashby, Gulmarrad, Woodford Island, South Arm, Shark Creek and Brushgrove)

Flood event	Level of flooding (depth above floor level)	Commercial properties	Fully detached			Multi-unit	
			Single story	High-set	Double storey	Single storey	Double storey
20 year	0.5 m +	2	3	23	13	0	0
	0-0.5 m	4	6	1	2	0	0
50 year	0.5 m +	54	134	24	17	1	1
	0-0.5 m	22	110	0	3	0	0
100 year	0.5 m +	66	162	24	17	1	1
	0-0.5 m	12	102	0	4	0	0

As discussed above, there are a number of towns on the Clarence River floodplain that are afforded some degree of flood protection by levees. These towns include Grafton, South Grafton, Ulmarra and Maclean. All of these levee systems are limited in the protection provided (ie there is a flood event of a particular probability that would overtop the levees and result in inundation of the 'protected' areas).

The volume of water overtopping the levee and the resulting depth of inundation of the 'protected' areas is a function of 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.

As well, there are a number of other villages on the Clarence River floodplain that are not protected by levees. These towns include Cowper, Brushgrove, Tucabia and Harwood and are also subject to varying degrees of flood inundation.

4.9.3. Geomorphic characteristics

A high level and preliminary geomorphic assessment has been conducted for this waterway based on aerial photography, soil maps and a site inspection.

Shark Creek

Shark Creek is a meandering medium alluvial stream which forms a major tributary of the Clarence River South Arm.

The creek is well-vegetated with good cover of native trees and shrubs. The land comprises alluvial floodplain which is utilised for productive farming and cropping enterprises. The creek has stable banks, but has the potential to actively meander, and is unconfined within the floodplain.

To instigate a change in channel form or for considerable erosion to occur in Shark Creek, the following events would need to occur:

- Major flooding of the order of five year ARI or greater
- Bank slumping due to floodplain saturation.

Plate 4-13 shows Shark Creek within 500 metres of the project crossing.

Plate 4-13 Shark Creek looking downstream

Edwards Creek

Edwards Creek is an open drain which flows into the Clarence River South Arm, a short distance upstream of its junction with the main channel of the Clarence River. The creek was once natural but is now heavily modified to improve floodplain drainage of land to the east of the project. As such, the drain is low gradient, with limited potential for erosion and has banks stabilised by grasses.

The creek has mounted flood gates to prevent tidal inundation of the very low-lying land in the Chaselings Basin. The adjacent land generally comprises alluvial flood plain, for agricultural production.

The waterway is sparsely vegetated, comprising mainly grasses and weeds, with very little overstorey growth. The buffer between surrounding agricultural cropping enterprises and the edges of this drain appears to be less than 50 metres.

Erosion could occur on these drains when saturation of the floodplain causes slumping.

Plate 4-14 shows Edwards Creek within 250 metres of the project crossing.

Plate 4-14 Edwards Creek looking upstream

Clarence River

The Clarence River is a major alluvial river with stable bed and banks. Land near the crossing points of the Clarence River comprises mainly alluvial floodplain, which the majority has been cleared for productive farming.

Waterways appear stable; however, streams have the potential for later erosion or potentially slumping. There are strips of native vegetation along the edges of the river which contributed to river health and the stability of banks.

To instigate a change in channel form or for considerable erosion to occur at the Clarence River, the following events would need to occur:

- Bank slumping due to floodplain saturation
- Flood events greater than five year ARI (localised channel erosion and slumping)
- Flood events greater than 20 year ARI (bank erosion causing channel change).

Plate 4-15 shows the Clarence River main channel, looking downstream within 100 metres of the project crossing.

Plate 4-15 Clarence River main channel (looking downstream)

Serpentine Channel

The Serpentine Channel is a meandering medium alluvial stream which runs between the Clarence River North Arm and Clarence River main channel, splitting the Chatsworth and Harwood islands. The channel has stable, unconfined banks within the floodplain with the potential to actively meander.

This alluvial stream is situated within land comprising of alluvial floodplain utilised for productive farming and cropping enterprises. The waterway is well-vegetated with good cover of native trees and shrubs.

To instigate a change in channel form or for considerable erosion to occur within the Serpentine Channel, the following events would need to occur:

- Major flooding of the order of five year ARI or greater
- Bank slumping due to floodplain saturation.

Plate 4-16 shows Serpentine Channel within 100 metres of the project crossing.

Plate 4-16 Serpentine Channel looking upstream

Clarence River North Arm

The Clarence River North Arm is a major alluvial stream and anabranch of the Clarence River located north of Chatsworth Island.

The waterway has stable bed and banks, however may have the potential for later erosion or potentially slumping. The land in the vicinity of the project crossing comprises mainly alluvial floodplain, of which the majority has been cleared for productive farming.

There are narrow strips and pockets of native vegetation along the edges of the waterway which contributes to river health and the stability of banks.

To instigate a change in channel form or for considerable erosion to occur on the Clarence River North Arm channel, the following events would need to occur:

- Major flooding of the order of five year ARI or greater
- Bank slumping due to floodplain saturation.

Plate 4-17 shows the Clarence River North Arm at the project crossing.

Plate 4-17 Clarence River North Arm looking upstream

Figure 4-22 Peak 20 year ARI flood levels: Clarence River at Shark Creek / Maclean

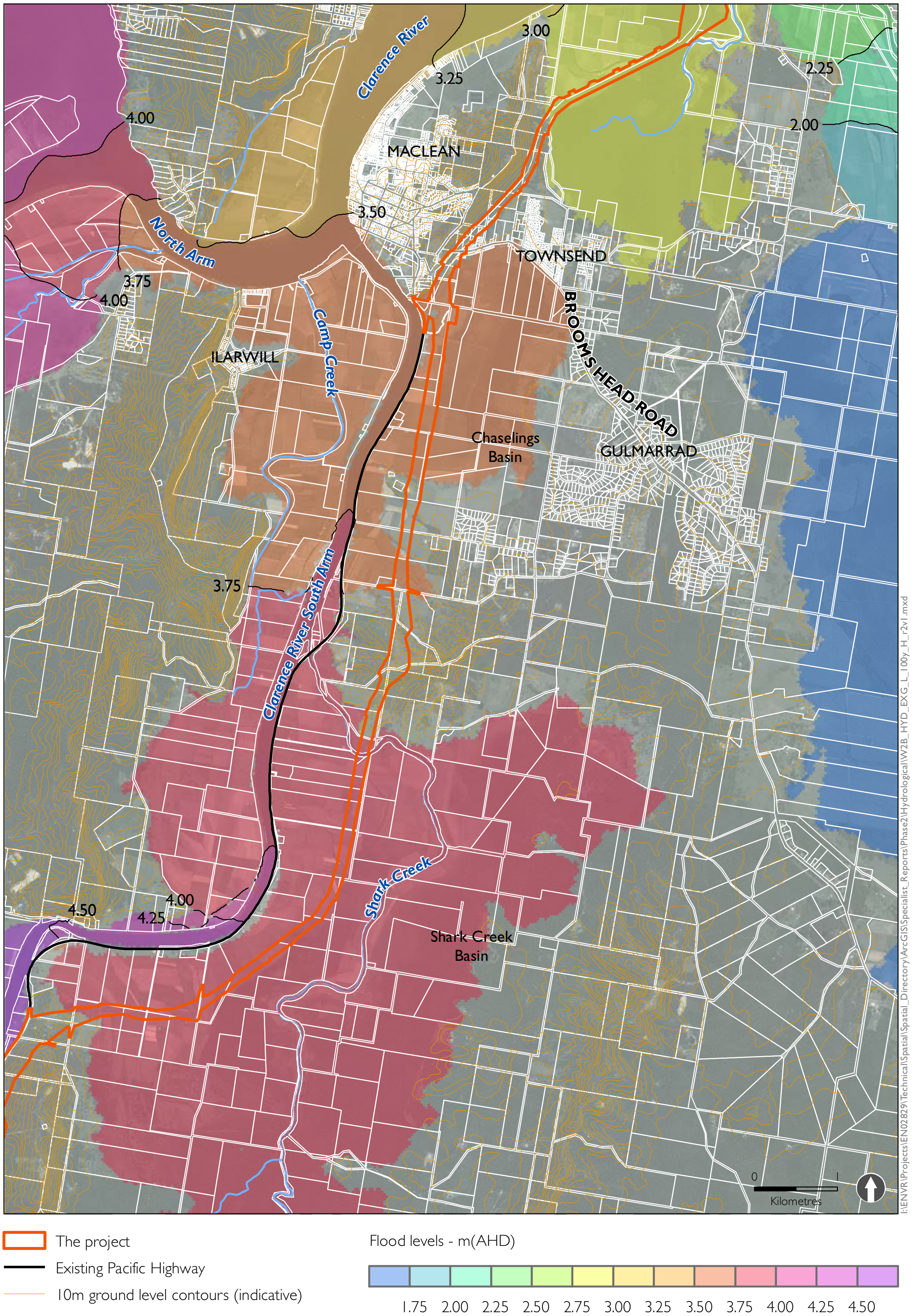

Figure 4-23 Peak 20 year ARI flood depths: Clarence River at Shark Creek / Maclean

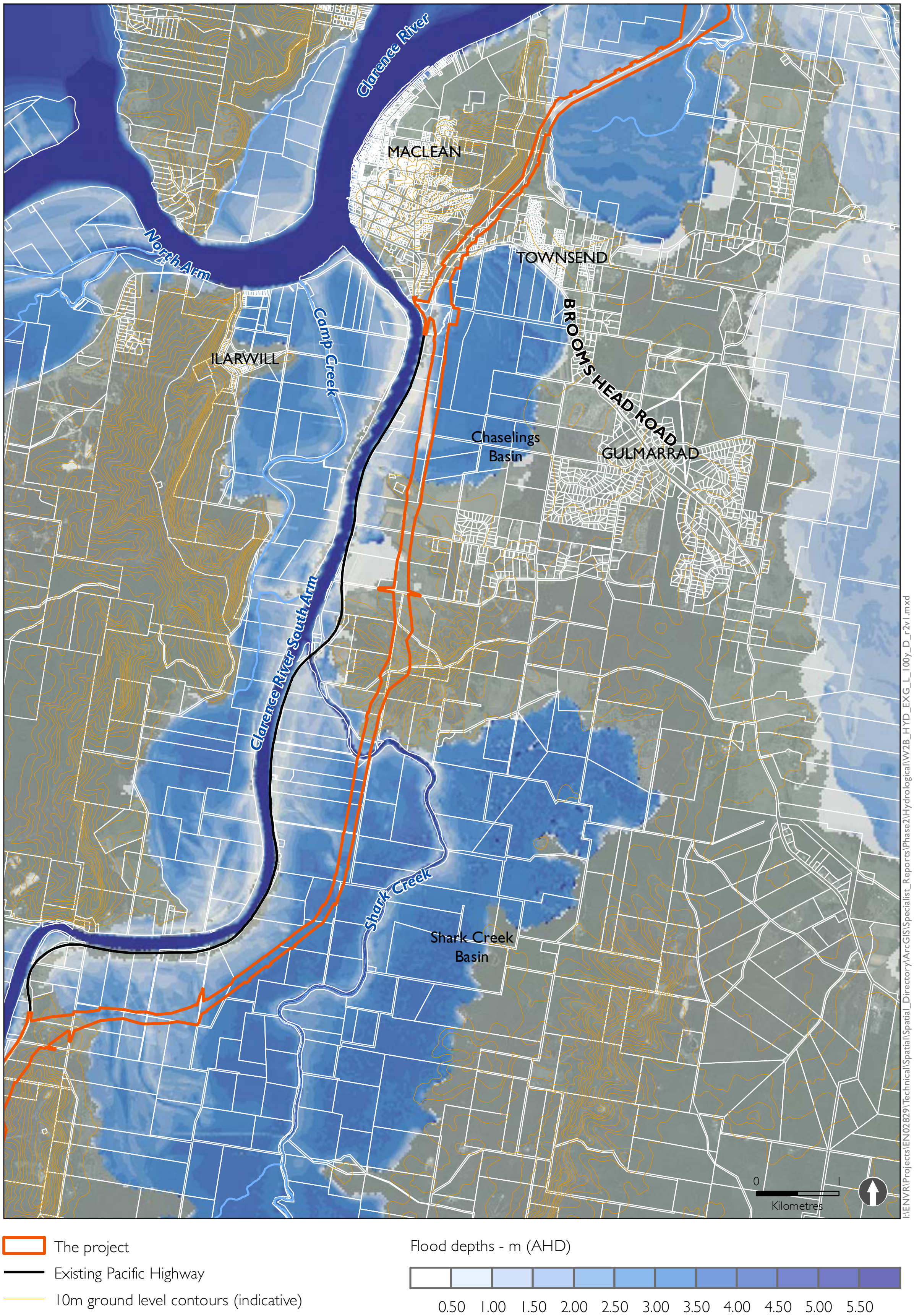

Figure 4-24 Peak 20y ARI flood velocities: Clarence River at Shark Creek / Maclean