4.10. Mororo Creek

4.10.1. Catchment description

The Mororo Creek catchment is a local catchment situated to the north of the Clarence River North Arm in the vicinity of the Iluka Road intersection with the Pacific Highway, which drains an area of 12.1 square kilometres into the Clarence River North Arm Channel towards the south. The project runs north to south through this catchment as part of Section 6, traversing several small and steep sub-catchments in the eastern half of the catchment in addition to a relatively wide and flatter main catchment on the Clarence River floodplain.

The land use of the catchment is a mixture of rural/agricultural land and forest. No buildings have been identified within the Mororo Creek floodplain.

4.10.2. Existing flooding behaviour

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. The peak flood levels and depths for the 100 year ARI flood event for Mororo Creek in the vicinity of the proposed upgrade is presented in Figure 4-28 and Figure 4-29. Peak flood levels adjacent to the proposed alignment range from 2.1 metres AHD in the south to 8.8 metres AHD in the north of this catchment.

Section 6 of the project crosses the eastern edge of the Mororo Creek floodplain. Mororo Creek has a total peak flow of about 100 cubic metres per second. A number of local catchments flow from east to west across the project via culverts under the existing highway. These catchments have peak flows ranging from four cubic metres per second to 14 cubic metres per second.

Flow velocities in the minor flow paths crossing the project are in the order of 0.5 metres per second to one metre per second.

4.10.3. 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.

Mororo Creek tributaries

The project runs along the Mororo Creek catchment and, as such, crosses several small tributaries of Mororo Creek without crossing the main channel.

Two of these tributaries are assessed and defined as drainage lines or depressions with stable and well-vegetated banks. The tributaries are shallow, ephemeral and consist of unconnected pools of water.

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

- Bank slumping due to floodplain saturation may occur in all flood events
- For flood events greater than two year ARI, localised channel erosion and slumping may occur
- For events greater than 20 year ARI bank erosion causing channel change is possible.

Plate 4-18 shows a photograph of one of the Mororo Creek tributaries within 100 metres of the project crossing.

Plate 4-18 Mororo Creek tributary looking upstream

Figure 4-28 Peak 100 year ARI flood levels: Clarence River North Arm and Mororo Creek

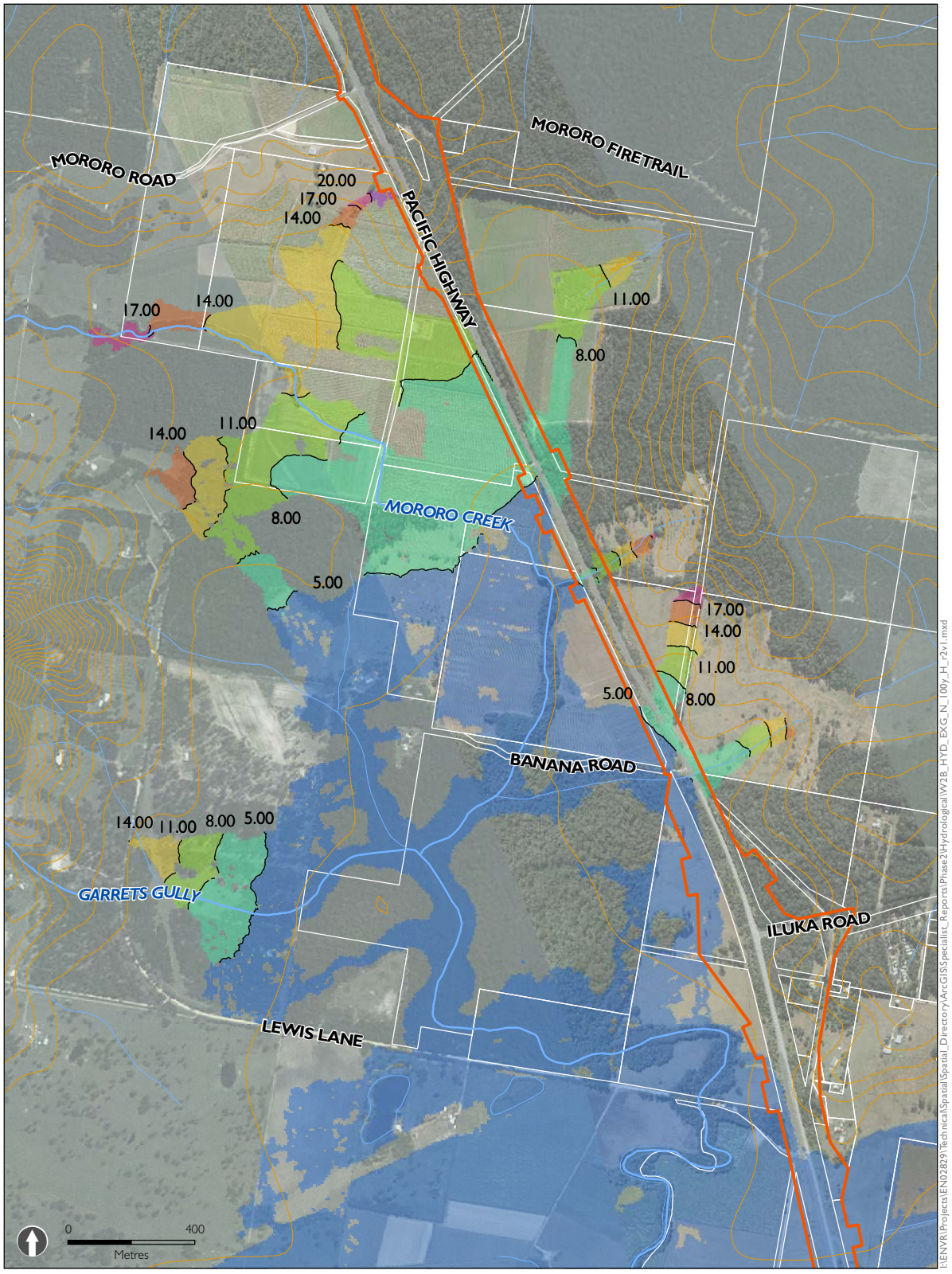
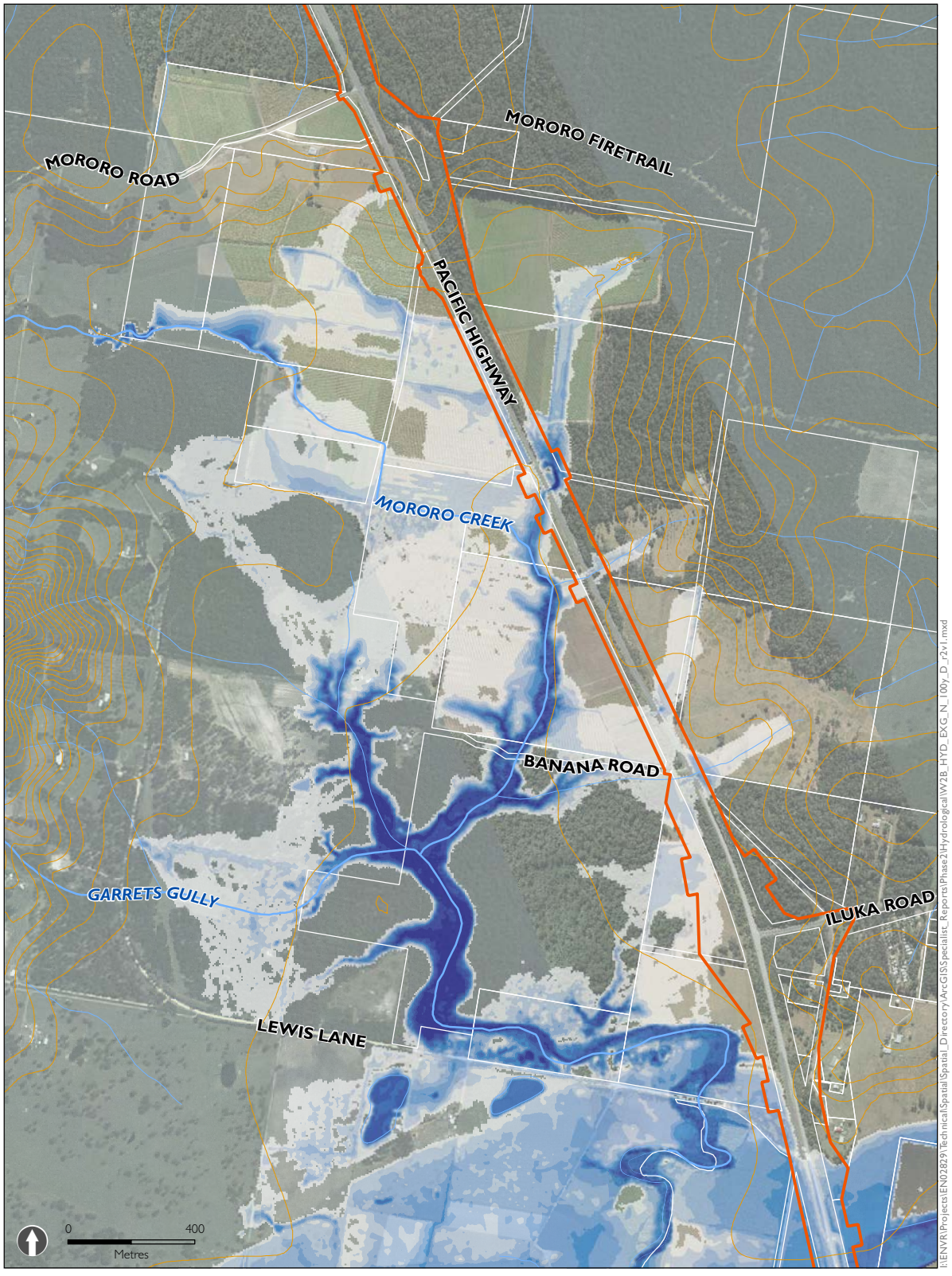


Figure 4-29 Peak 100 year ARI flood depths: Clarence River North Arm and Mororo Creek



4.11. Tabbimoble Creek

4.11.1. Catchment description

Section 6 of the project approaches this catchment from the south-east at Mororo and exits to the north through the middle section of this catchment. Flows in this area are in a west-to-east direction via several main flow paths (including Tabbimoble Creek and Tabbimoble Overflow), in addition to a number of minor sub-catchment flow paths.

The total catchment area upstream of the project is about 27.2 square kilometres. Flow path slopes are gentle, typically in the order of one per cent, while hill-slopes in the upper catchment are steep, with gradients exceeding 20 per cent.

Land use in the catchment is predominantly forest, with some rural and agricultural land use. No buildings have been identified within the Tabbimoble Creek floodplain.

4.11.2. Existing flooding behaviour

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. Flows across the project occur in several main flow paths, in addition to a number of minor flow paths. Peak 100 year ARI flows range from two cubic metres per second to 10 cubic metres per second in the minor flow paths and from 30 cubic metres per second to 100 cubic metres per second in the major flow paths. Flows beneath the existing highway are via two bridges and a series of culverts.

The peak flood levels and depths for the 100 year ARI flood event in this catchment are presented in Figure 4-30 and Figure 4-31. Peak flood levels upstream of the project range from 24 metres AHD to 27.5 metres AHD.

Flow velocities in Tabbimoble Creek, Tabbimoble Overflow and the minor flow paths in the north of this catchment exceed one metre per second in the flow paths in the vicinity of the project. These velocities are due to the relatively steep gradient of the flow paths in this area. The flowpath in the south of this catchment experiences lower velocities, typically in the order of 0.5 metres per second due to the gentler slopes.

4.11.3. Geomorphic characteristics

The geomorphic characteristics of three parts of Tabbimoble Creek have been assessed. These are Tabbimoble Creek, Tabbimoble overflow and a tributary of Tabbimoble Creek. A high level and preliminary geomorphic assessment has been conducted for these waterways based on aerial photography, soil maps and a site inspection.

Tabbimoble Creek

Tabbimoble Creek may be defined as a partially confined creek. These waterways are relatively stable and likely to be stabilised by rock bars and valley margins. These are assisting in providing a stable stream environment. The adjacent land generally comprises forested valley floors and flats, and alluvial flood plain. These waterways tend to have deeper channels and higher banks, and tend to be confined due to geological features such as bedrock and less erodible banks.

Plate 4-19 shows Tabbimoble Creek within 100 metres of the project crossing.

Plate 4-19 Tabbimoble Creek at the existing Pacific Highway looking downstream (left to right)

Tabbimoble overflow

The overflow channel of Tabbimoble Creek may be defined as a minor waterway. Erosion tends to be prevalent in minor waterways due to their deeper and narrower channels, which have resulted from bed and bank erosion or slumping at this location. This debris may reinforce the stability of the channel.

Plate 4-20 shows Tabbimoble overflow within 100 metres of the project crossing.

Plate 4-20 Tabbimoble overflow looking downstream (right to left)

Tabbimoble Creek tributary

The tributary of Tabbimoble Creek appears to be a culvert outlet. It appears that there has been past erosion issues at this site due to the presence of dumped rock near the culvert apron. During the site visit there was evidence of the build up of silt at the culvert apron.

Plate 4-21 shows Tabbimoble Creek tributary within 100 metres of the project crossing.

Plate 4-21 Photograph of Tabbimoble Creek tributary looking downstream

These streams are well-vegetated and it is unlikely bed deepening will occur. Localised bank erosion may occur in events of the order two year ARI or greater. During events greater than 20 year ARI bank erosion causing channel change is possible.

Figure 4-30 Peak 100 year ARI flood levels: Tabbimoble Creek

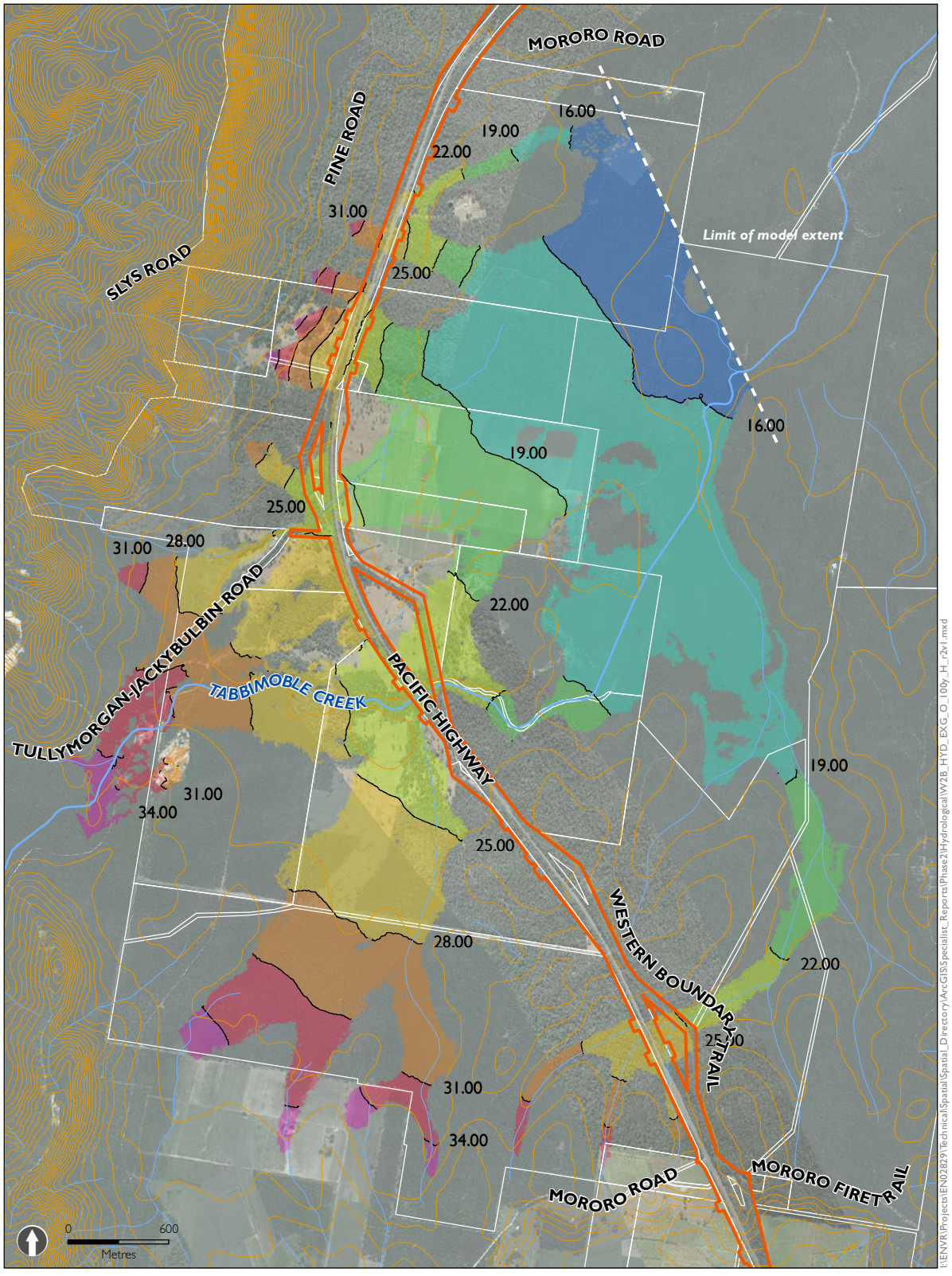
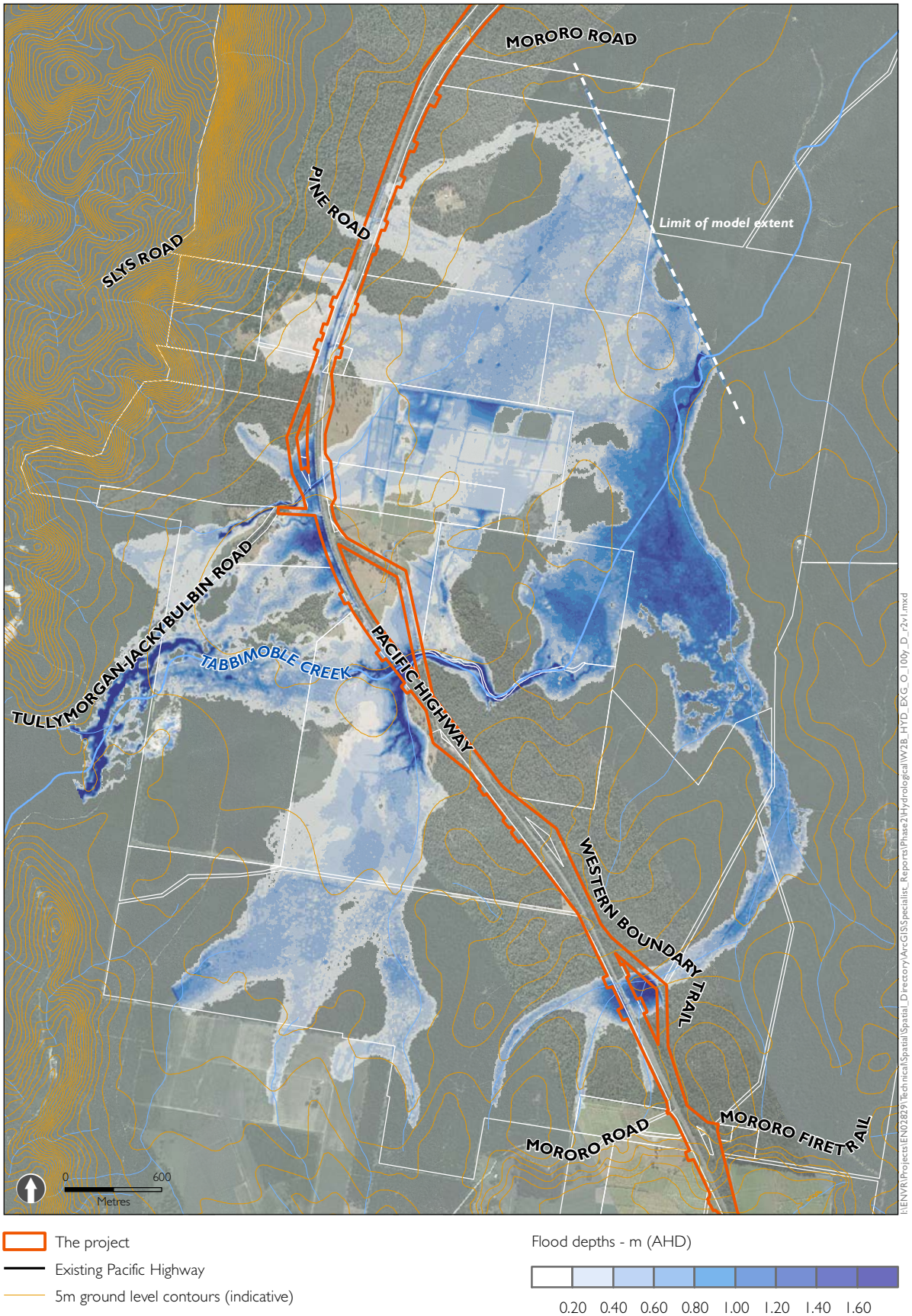


Figure 4-31 Peak 100 year ARI flood depths: Tabbimoble Creek



4.12. Tabbimoble Floodway No. 1

4.12.1. Catchment description

The Tabbimoble Floodway 1 catchment is crossed by Section 7 of the project almost directly from north to south over a distance of about three kilometres. The main floodway has an upstream catchment area of 15.8 square kilometres, while a minor flow path to the south has an upstream catchment area of 3.9 square kilometres.

Catchment slopes are typically flat and in the order of one to two per cent.

The catchment upstream of the project is entirely within the Double Duke State Forest. The waterway flows alongside the southern boundary of Tabbimoble Swamp Nature Reserve and subsequently into Bundjalung National Park. No buildings have been identified within the Tabbimoble Floodway floodplain.

4.12.2. Existing flooding behaviour

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. The peak flood levels and depths for the 100 year ARI flood event in the Tabbimoble Floodway 1 catchment are presented in Figure 4-32 and Figure 4-33. Peak flood levels upstream of the project range from 13.3 metres AHD to 13.7 metres AHD.

Peak 100 year ARI flows across the proposed alignment are about 80 cubic metres per second in the main flow path and seven cubic metres per second in the minor flow path. Flow velocities are moderate, typically in the range of 0.5 metres per second to one metre per second in the vicinity of the project.

4.12.3. 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.

Tabbimoble Floodway No. 1

Tabbimoble Floodway No. 1 is defined as an unconfined minor gully. Based on Plate 4-22, the banks of the floodway appear stable.

This waterway has well-vegetated banks. To instigate a change in channel form or for considerable erosion to occur on these waterways, the following events would need to occur:

- Bank slumping due to floodplain saturation may occur in all flood events
- For flood events greater than two year ARI, localised channel erosion and slumping may occur
- For events greater than 20 year ARI bank erosion causing channel change is possible.

Plate 4-22 shows Tabbimoble Floodway No. 1 within 100 metres of the project crossing.

Plate 4-22 Tabbimoble Floodway No. 1

Figure 4-32 Peak 100 year ARI flood levels: Tabbimoble Floodway No. 1

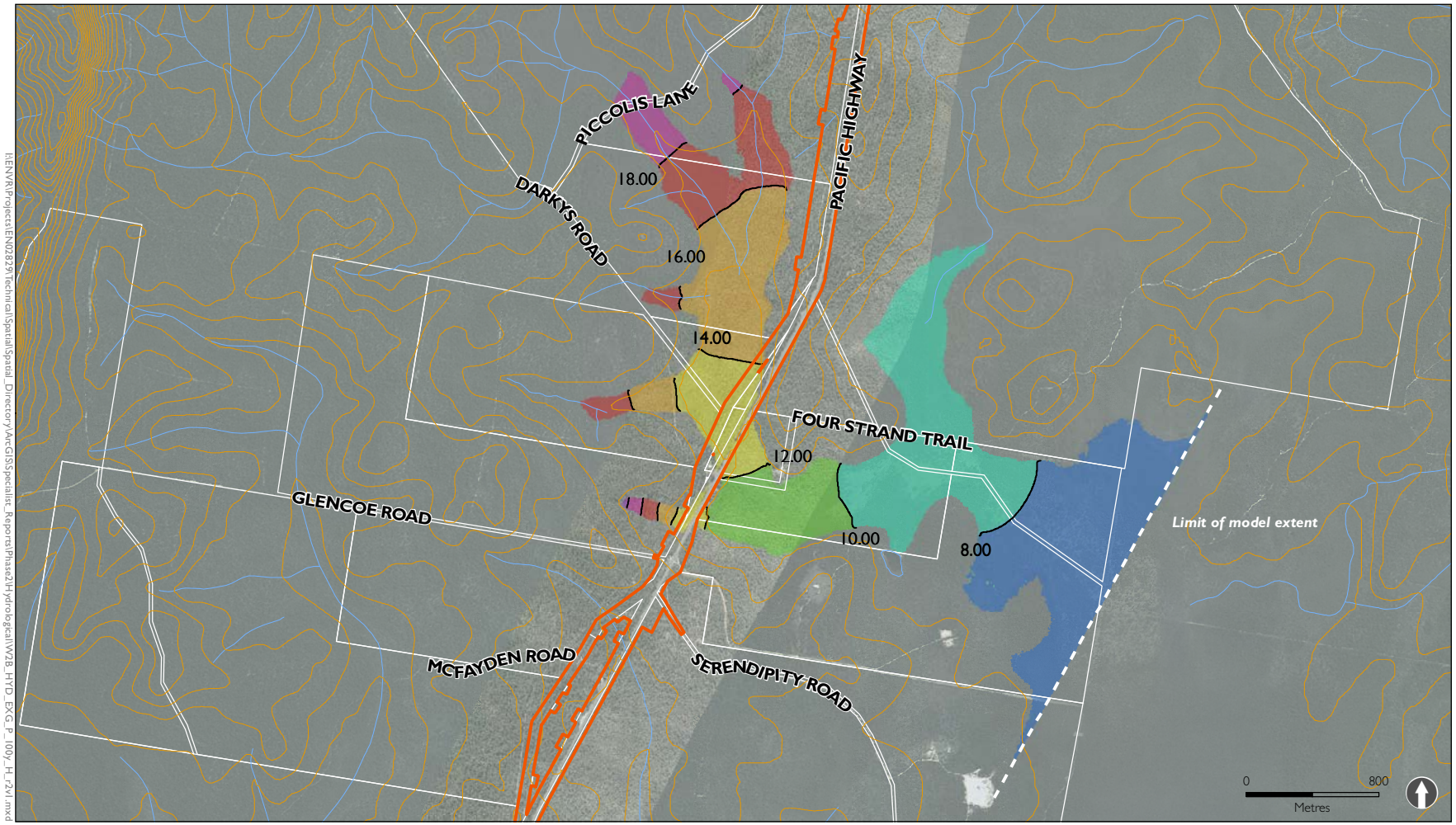
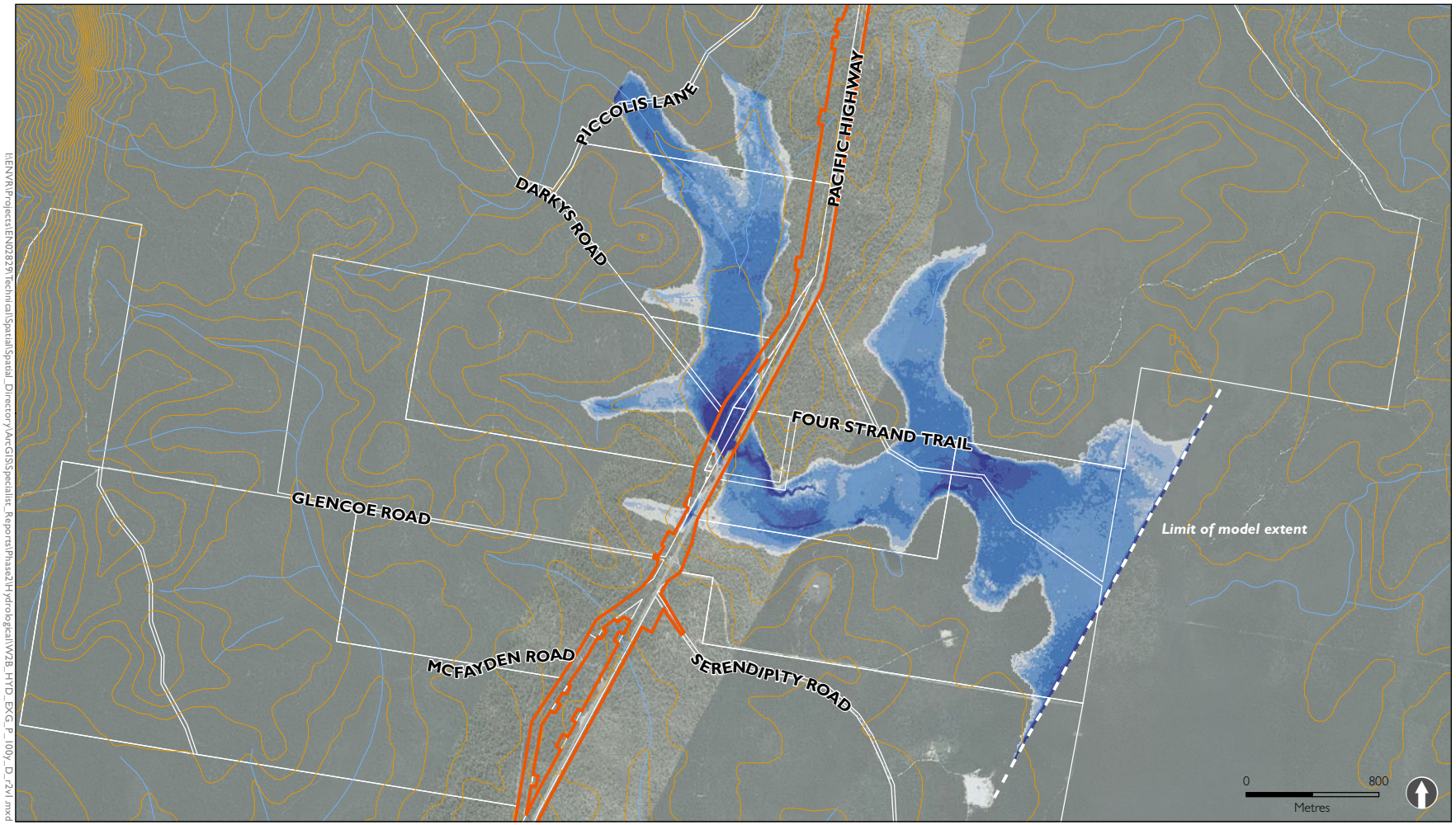


Figure 4-33 Peak 100 year ARI flood depths: Tabbimoble Floodway No. 1



4.13. Oakey Creek

4.13.1. Catchment description

Oakey Creek is a tributary of the Evans River. It is crossed by Section 7 of the project and the existing Pacific Highway at a location about nine kilometres south of Woodburn and three kilometres east of New Italy.

The catchment upstream of the project is 19.7 square kilometres flowing south-east to north-west and forms the upper reaches of the Evans River. The project crosses two arms of the creek, with the main arm (Oakey Creek) located to the south and two minor sub-catchments forming the north arm (Norton's Gully).

The floodplain generally has gentle slopes (less than one per cent), while the hill-slopes along the catchment's eastern and south-eastern boundaries are steep (grades exceeding 20 per cent).

The predominant land use in the catchment is forest, with small clearings comprising rural residential areas. One shed on the Pacific Highway is near the river crossing, located 600 metres north-east of New Italy. No other buildings have been identified within the Oakey Creek floodplain.

4.13.2. Existing flooding behaviour

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. The peak flood levels and depths for the 100 year ARI flood event for Oakey Creek in the vicinity of the proposed upgrade is presented in Figure 4-34 and Figure 4-35. Peak flood levels upstream of the project are in the range of the 3.7 metres AHD to 4.0 metres AHD on the main southern arm of the creek (Oakey Creek) and 3.4 metres AHD to 3.6 metres AHD on the northern arm (Norton's Gully).

Peak 100 year ARI flows across the proposed alignment are about 46 cubic metres per second in the main arm and 13 cubic metres per second in the north arm.

Existing flow velocities are typically low (less than 0.5 metres per second) in the vicinity of the project, due to the flat terrain in this area.

4.13.3. 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.

Oakey Creek and tributaries

Oakey Creek and two of its tributaries – all crossed by the project – have been assessed to define their geomorphic characteristics.

The main crossing of Oakey Creek is a densely forested alluvial stream. The forested waterway is well vegetated with good cover of native trees and shrubs. Oakey Creek is shown in Plate 4-23, within 100 metres of the project crossing.

The two tributaries of Oakey Creek (Plate 4-24 and Plate 4-25) show minor drainage paths. Minor drainage paths are typically situated within both public and private lands. The adjacent land is often roadside or drainage lines through agricultural lands. These waterways tend to have vegetated banks, often with a high weed component. However, one of the tributaries has steep, incised banks with little underlying vegetation.

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

- Bank slumping due to floodplain saturation may occur in all flood events
- For flood events greater than two year ARI (minor drainage paths) or five year ARI (Oakey Creek), localised channel erosion and slumping may occur
- For events greater than 20 year ARI bank erosion causing channel change is possible.

Plate 4-23 Oakey Creek looking downstream

Plate 4-24 Oakey Creek Tributary 1 looking downstream

Plate 4-25 Oakey Creek Tributary 2 looking downstream

Figure 4-34 Peak 100 year ARI flood levels: Oakey Creek

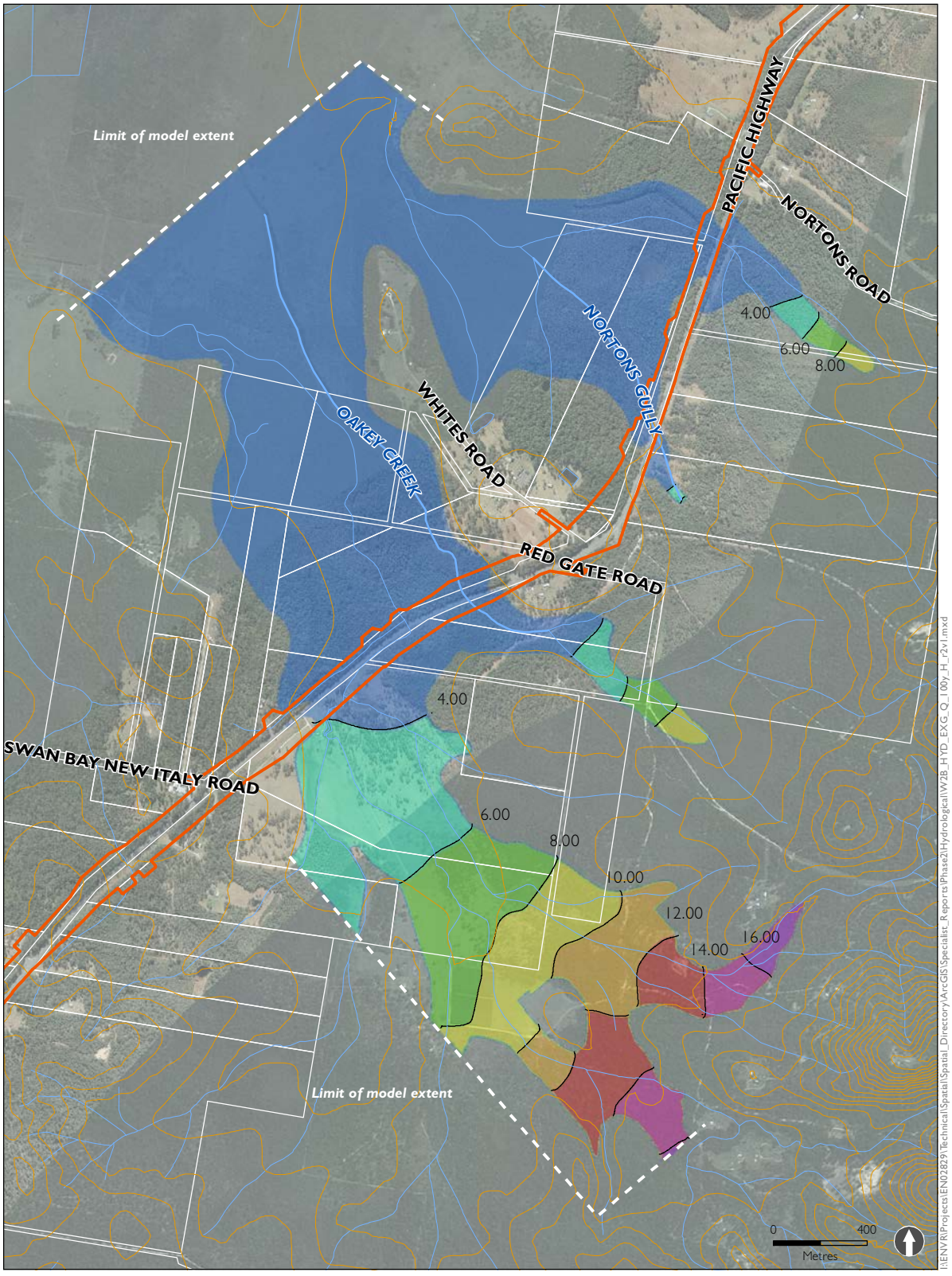
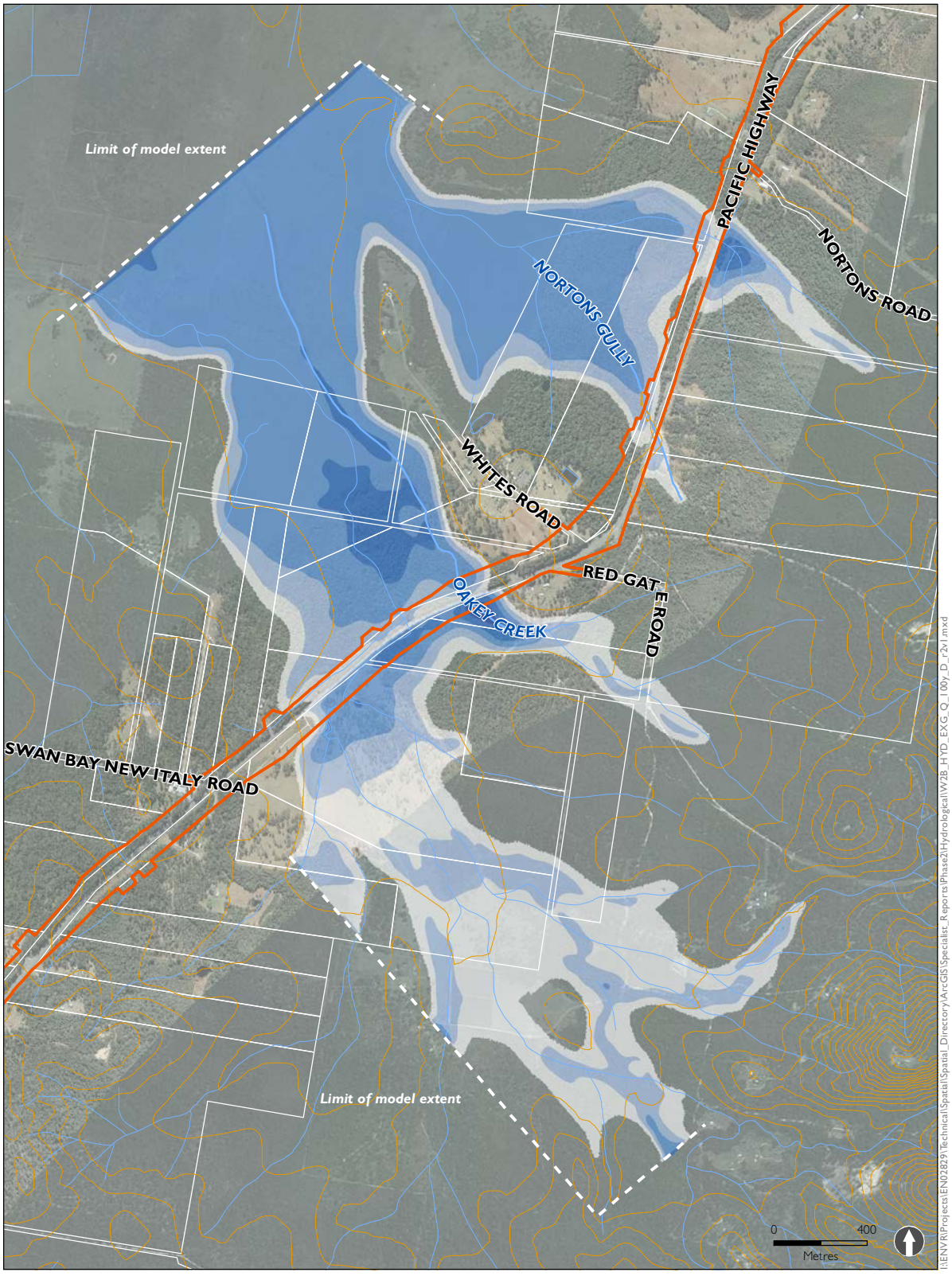


Figure 4-35 Peak 100 year ARI flood depths: Oakey Creek



4.14. Mid Richmond River

4.14.1. Richmond River catchment description

The Richmond River is a major coastal river in New South Wales. The catchment covers an area of about 6850 square kilometres, extending from the Nightcap, McPherson and Richmond Ranges to the ocean at Ballina. The Richmond River itself (often referred to as the main arm) is 170 kilometres in length, with the tidal limit being 90 kilometres from the ocean, extending upstream of Lismore on the Wilsons River and beyond to Tatham.

Four sections of the project (Sections 8 to 11) and a total of 66 kilometres of the project are located in the Richmond River catchment.

The upper reaches of the Richmond River flow from the Qld/NSW border through steep mountain creeks. At Kyogle, the river exhibits meandering and a pronounced floodplain forms before it reaches Casino. The Richmond River continues from Casino to its confluence with the Wilson River at Coraki, a major tributary of the Richmond River. The Wilsons River catchment consists of two major tributaries, the Wilsons River and its tributary Leycester Creek, which meet at Lismore.

The Richmond River continues south from Coraki where it meets with Bungawalbyn Creek, another major tributary of the river. The Bungawalbyn Creek catchment consists of steep mountain creeks in its upper reaches and joins with another major tributary named Sandy Creek before flowing into the Richmond River.

Further downstream, before the Richmond River reaches Woodburn, is Tuckombil Canal. The Evans River is connected to the Richmond River at Woodburn via the Tuckombil Canal and Rocky Mouth Creek. The Canal was constructed to relieve flooding in the Richmond Valley. The Evans River is about 20 kilometres in length and its catchment area is about 62 square kilometres. The town of Evans Head is located at the mouth of the Evans River.

The Tuckean Swamp is located immediately to the west of the middle of the study area and is a major source of floodwater that flows into the floodplain between Broadwater and Cabbage Tree Island. Tuckean Swamp has been progressively drained since the 1800s for a variety of agricultural purposes and the tidal influence in the swamp was limited with the installation of the Bagotville Barrage around 1970. The barrage was designed to minimise the periodic inundation of agricultural land by facilitating the discharging of water from the swamp at low tide and barring its return on the high tide (ie acting as a tide gate).

4.14.2. Existing flooding behaviour

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. Peak flood levels and depths for the 20 year ARI flood event (72 hour duration) are presented in Figure 4-36 and Figure 4-37. This figure shows that the extent of flooding in this event is considerable. Flood gradients on the floodplain are very flat (about 1 in 125,000 or 0.0008 per cent). Existing peak velocities are presented in Figure 4-38.

The flooding behaviour of the Wardell area is relatively complex. Flooding is dominated by the Richmond River flows. For the 20 year ARI flood event, peak flows in the river are predicted to be in the order of 2,300 cubic metres per second. A fraction of this flow (about 300 cubic metres per second in a 20 year ARI flood event) passes southward (ie backward) up Rocky Mouth Creek. This southward backflow combines with northward runoff from the Rocky Mouth Creek catchment (about 200 cubic metres per second in a 20 year ARI flood event). The resulting 500 cubic metres per second flows south-eastward within the banks of the constructed channel of Tuckombil Canal. This flow then heads towards the Evans River and the second opening of the Richmond River catchment to the ocean at Evans Head.

Complimenting this flow in the Tuckombil Canal is a broad area of floodplain flow exiting the Richmond River and heading south-eastward. This flow is a fraction of the total Richmond River flow and about 400 cubic metres per second in a 20 year ARI flood event. This floodplain flow also enters the Evans River and exits to the ocean at Evans Head.

North of Broadwater, there is a natural constriction in the Richmond River floodplain. The project would cross the Richmond River and floodplain at the narrowest part of the floodplain. At this location, the majority of the flood flow in the 20 year ARI event is contained within the Richmond River. The peak flow in the river is 2800 cubic metres per second compared to only 40 cubic metres per second on the southern bank. The north bank at the bridge site is high ground with no flow.

Peak flood levels based on the Richmond River County Council model results are presented in Table 4-5 for selected locations on the mid Richmond River floodplain.

Table 4-5 Peak flood levels at selected locations on mid Richmond River floodplain

Location	20 year ARI flood level (metres AHD)	100 year ARI flood level (metres AHD)
Bungawalbin Junction	4.76	5.49
Boggy Creek Road	4.83	5.70
Swan Bay	4.34	5.06
Woodburn Gauge	3.74	4.68
Tuckombil Barrage	4.04	4.84
Rileys Hill Dock	3.21	4.42
Broadwater Gauge	2.77	4.00
Bagotville Barrage	2.82	4.24

Flood immunity of the existing highway

An assessment was undertaken to determine the flood immunity of the existing Pacific Highway within the Richmond River floodplain. From Woodburn to Broadwater, the immunity of this section is between a five and a 10 year ARI event. From the model results, it is estimated that the road will be overtopped during an eight year ARI event.

Property inundation on the Mid Richmond River floodplain

Many properties experience flooding along the Mid Richmond River, and impacts would be experienced in the townships of Woodburn and Broadwater. Properties identified as being inundated in impacted areas for the 20 and 100 year ARI floods are summarised in Table 4-6 and Table 4-7 respectively.

Table 4-6 Flooded properties in the impacted parts of Woodburn 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 +	1	1	0	14	0	0
	0-0.5 m	13	2	0	2	0	0
50 year	0.5 m +	14	2	0	17	0	0
	0-0.5 m	13	10	0	1	0	0
100 year	0.5 m +	28	11	0	18	0	0
	0-0.5 m	2	30	0	2	0	0

Table 4-7 Flooded properties in the impacted parts of Broadwater 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	1	0	0	0	0
	0-0.5 m	5	1	0	9	0	0
50 year	0.5 m +	9	4	0	23	0	0
	0-0.5 m	6	21	0	8	0	0
100 year	0.5 m +	16	29	0	31	0	0
	0-0.5 m	0	27	0	1	0	0

4.14.3. 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.

Tuckombil Canal

Tuckombil Canal is situated on an alluvial floodplain consisting of agricultural production land.

This waterway tends to be very sparsely vegetated, comprising mainly grasses and weeds, with very little overstorey growth. The channel has been heavily modified to improve drainage.

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

Plate 4-27 shows Tuckombil Canal looking downstream at the project crossing. There is a concrete weir immediately (five metres) downstream of the existing Pacific Highway bridge, which is unable to be seen in this photograph. The weir prevents saltwater intrusion for agricultural extractions from the waterway.

Plate 4-26 Tuckombil Canal looking downstream

McDonalds Creek

McDonalds Creek is a minor waterway north of Woodburn which drains east--west into the Richmond River. The adjacent land generally comprises forested valley floors and flats, and alluvial flood plain.

The creek is well-vegetated with good stands of native trees and shrubs growing along the edges and vicinity, which contributes to river health and the stability of banks.

This creek is likely to engage with the floodplain in relatively small flow events. To instigate a change in channel form or for considerable erosion to occur, McDonalds Creek would need to experience flooding of the order two year ARI or greater.

Plate 4-27 shows McDonalds Creek near the existing Pacific Highway crossing, about one kilometre south-west of the project crossing.

Plate 4-27 McDonalds Creek looking upstream

Eversons Creek

Eversons Creek is a minor waterway east of Broadwater which drains north into the Richmond River. The adjacent land generally comprises forested valley floors and flats, and alluvial flood plain.

The creek is well-vegetated with good stands of native trees and shrubs growing along the edges and vicinity, which contributes to river health and the stability of banks.

This creek is likely to engage with the floodplain in relatively small flow events. To instigate a change in channel form or for considerable erosion to occur, Eversons Creek would need to experience flooding of the order two year ARI or greater.

The project embankment does not cross Eversons Creek, but does encroach significantly on the waterway. Plate 4-28 shows Eversons Creek about 100 metres south of where the creek enters the project boundary.

Plate 4-28 Eversons Creek looking downstream

Mid Richmond River

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

The waterway appears stable, however may have the potential for later erosion or potentially slumping. There are generally narrow strips and pockets of native vegetation along the edges of the waterway which contribute to river health and the stability of banks.

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

- Bank slumping due to floodplain saturation may occur in all flood events
- For flood events greater than five year ARI, localised channel erosion and slumping may occur
- For events greater than 20 year ARI bank erosion causing channel change is possible.

Plate 4-29 shows the Richmond River near Broadwater, about 1.5 kilometres upstream of the project crossing.

Plate 4-29 Mid Richmond River near Broadwater