4 Flooding

This chapter addresses the DGRs for the assessment of flooding impacts relating to the project. The DGRs and the section in which they are addressed are presented in **Table 1-1**.

4.1 Existing environment

4.1.1 Overview

The project traverses the Broughton Creek floodplain in the north, crosses a number of local ephemeral drainage lines through the hills between Tomlins Road and Tindalls Lane, then crosses the floodplain a second time near the confluence of Bundewallah, Connollys and Broughton Mill Creeks. It passes to the north of Berry before crossing a series of ephemeral creek lines between Berry and Jaspers Brush.

Named creeks and tributaries in the vicinity of the project area are shown on **Figure 1-1** and include (from east to west):

- Broughton Creek.
- Broughton Mill Creek.
- Connollys Creek.
- Bundewallah Creek.
- Town Creek.
- Hitchcocks Lane Creek.

These creeks and tributaries are described in the following sections. There are also 14 minor unnamed waterway crossings that are traversed by the project that have been assessed as part of the project.

4.1.2 Broughton Creek

Broughton Creek and its tributaries drain the hills of the Cambewarra Range that lie north of the township of Berry as well as the broad flat floodplain that lies to the south of Berry. Broughton Creek flows south from Berry for approximately 8km before joining the Shoalhaven River.

The catchment area of Broughton Creek at Coolangatta Road (south of Berry) is approximately 104 square kilometres (SMEC, 2008). Natural forest and cleared pasture are typical of the catchment, with varying levels of development around the townships of Berry, Bundewallah, Foxground, Broughton, Broughton Vale and Broughton Village.

Broughton Creek drains across the northern side of the Shoalhaven floodplain. Agriculture is the major land use, with extensive areas utilised for dairy and cattle grazing. Downstream of the Berry Township, the terrain is flat and swampy. Tidal influence extends about 12 kilometres upstream from the Broughton Creek and Shoalhaven River confluence to the vicinity of the Coolangatta Road Bridge.

The upper reach of Broughton Creek meanders across the northern section of the project in a southerly then westerly direction then south again before flowing south of Berry and into the Shoalhaven River approximately five kilometres west of Shoalhaven Heads.

During larger flood events the banks of the upper Broughton Creek are overtopped with flood waters taking the shorter routes across the floodplains, returning to Broughton Creek some distance downstream.

The existing Princes Highway traverses the upper reach of Broughton Creek near Broughton Village. The project would pass just south of this location.

4.1.3 Berry township

Named creeks traversed by the project in the vicinity of Berry are shown on **Figure 1-1**.

Bundewallah Creek is located to the north of Berry and flows eastwards under a bridge at Woodhill Mountain Road to join Broughton Mill Creek. Broughton Mill Creek flows southwards from the confluence with Bundewallah Creek, under an existing bridge at the Princes Highway, then under a second bridge at the South Coast Railway Line. Downstream and to the east of Berry, Broughton Mill Creek flows into Broughton Creek.

Connollys Creek enters Bundewallah Creek upstream of the confluence with Broughton Mill Creek.

Town Creek (also referred to as Princess Creek) meanders eastwards through the Berry town centre, adjacent to Princess Street, before joining Broughton Mill Creek.

Connollys Creek, Bundewallah Creek, Broughton Mill Creek and Town Creek are the main sources of flooding in Berry. Town Creek in particular presents a flood risk to a significant number of properties within Berry.

According to Cardno (2012) the existing Princes Highway is overtopped at the locations listed in **Table 4-1** during the ARI events indicated. During the 100 year ARI event, the crossings at Broughton Mill Creek, Town Creek and Hitchcocks Lane Creek and Tributary all experience overtopping.

Table 4-1: Existing overtopping of Princes Highway

	ARI event			
Waterway	**2 year**	**5 year**	**20 year**	**100 year**
Broughton Mill Creek	Overtops	Overtops	Overtops	Overtops
Town Creek			Overtops	Overtops
Hitchcocks Lane Creek	Overtops	Overtops	Overtops	Overtops
Hitchcocks Lane Tributary				Overtops

4.1.4 Available data

Previous flood studies

A number of studies have been carried out for the Broughton Creek and wider Shoalhaven River catchments. These studies provide useful background information to understanding the nature of flooding across the study area and include:

- Broughton Creek Floodplain Risk Management Study and Plan (Cardno, 2012).
- Lower Shoalhaven River Floodplain Management Study & Plan: Climate Change Assessment (WMAwater, 2011).
- Broughton Creek Flood Study (SMEC Australia Pty Ltd, 2008).
- Lower Shoalhaven River Floodplain Risk Management Study and Plan (Webb McKeown & Associates, 2008).
- Lower Shoalhaven River Flood Study (Public Works Department, 1990).

As part of the route selection process for the Gerringong to Bomaderry Princes Highway Upgrade, Maunsell (now AECOM) produced indicative 100 year ARI flood extents as shown in **Figure 4-1** (Maunsell, 2008). The upgrade falls within the indicative 100 year ARI flood extent in a number of places.

Property survey

As part of the Broughton Creek Floodplain Risk Management Study (Cardno, 2012), a floor level survey was conducted in 2010 on properties in Berry that were identified as being affected by the Probable Maximum Flood (PMF). This survey data has been used to assess the potential impacts of the project on properties within Berry.

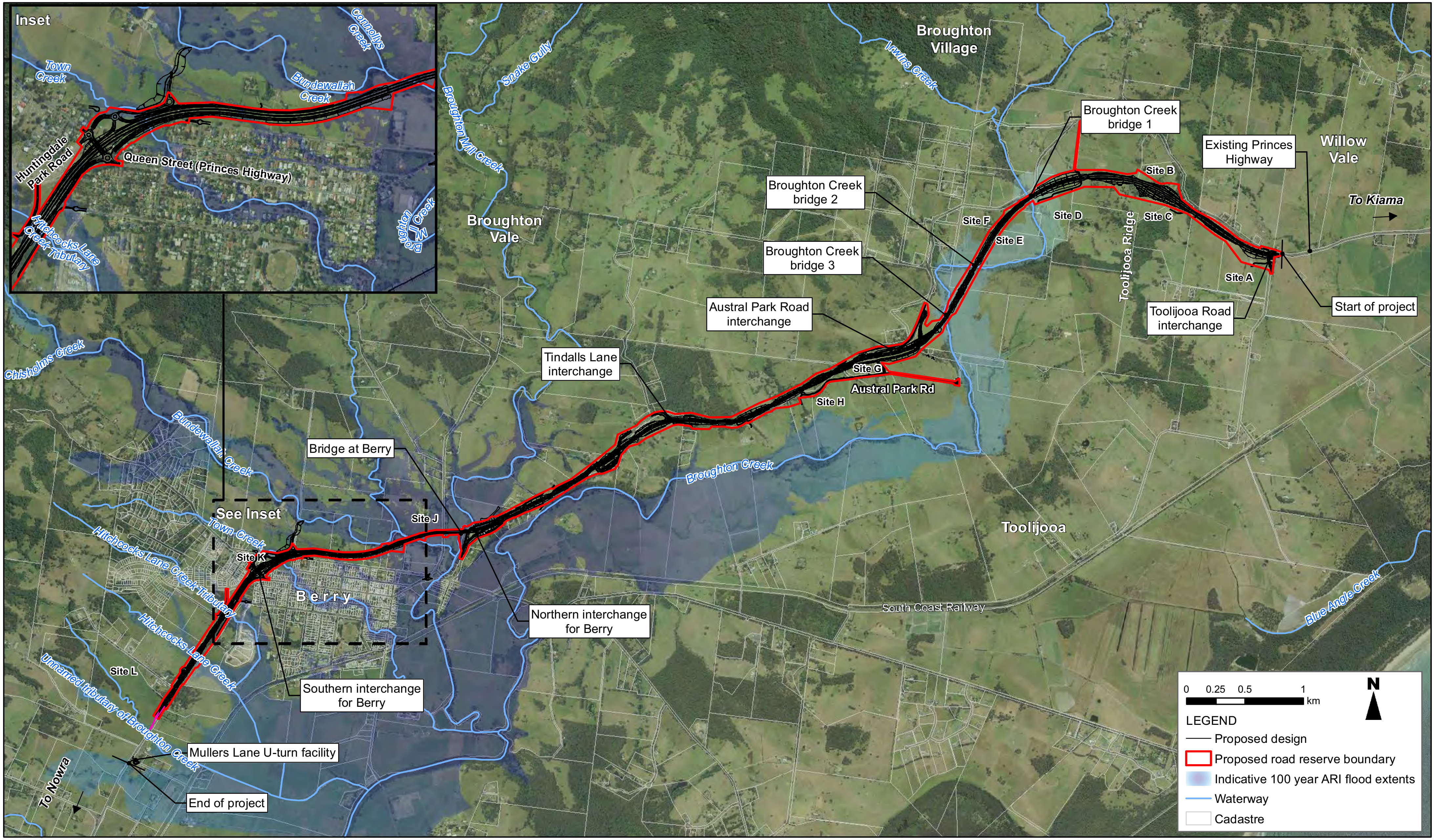

Figure 4-1 Indicative floodplain locations

Source: AECOM (2012), Cardno (2011), LPMA (2011)

4.2 Assessment of potential flooding impacts

4.2.1 Overview

As nominated by the DGRs, consideration has been given to potential flood impacts on upstream and downstream infrastructure and receivers due to the project. Waterways that could potentially be impacted by the project include:

- Broughton Creek (three crossings).
- Connollys Creek / Bundewallah Creek / Broughton Mill Creek (one crossing at Berry).
- Town Creek.
- Hitchcocks Lane Creek.
- Numerous unnamed tributaries to the above creeks.

The location of the highway with respect to the floodplain is an important consideration in the design and construction of the proposed works. Flooding of the highway can restrict access, cause damage and pose a safety risk. Conversely, any works within the floodplain are likely to change existing flood behaviour with the potential for adverse impacts on the surrounding environment. It has therefore been necessary to carry out an assessment of project related flood impacts. This assessment is outlined in the following sections.

4.2.2 Assessment approach

Hydrologic and hydraulic modelling and assessment has been carried out to better understand the flooding characteristics of the creeks and waterways traversed by the project under both existing and proposed conditions. This information has been used to quantify impacts and thus make informed decisions on managing the flood risks to the project and users as well as impacts on the surrounding environment.

The wider area around the alignment (except around the township of Berry) is generally zoned as rural and/or agricultural according to the Shoalhaven City Council and Kiama Municipal Council Local Environmental Plans. There is no indication at this stage that the existing land use patterns would change significantly in future. The flood impact assessment described in this section has therefore been based on the existing catchment characteristics.

Hydrologic and hydraulic modelling

The flood assessment has involved the development of hydrologic and hydraulic modelling approaches to suit the nature and extent of the waterways traversed by the project.

The assessment of the major crossing of the Broughton Mill Creek / Bundewallah Creek / Connollys Creek floodplain immediately north of Berry was carried out using the XP RAFTS and TUFLOW models developed for the Broughton Creek Floodplain Risk Management Study and Plan (Cardno, 2012). Other waterway crossings were assessed using the Probabilistic Rational Method (PRM) and a combination of HEC-RAS 1D modelling and culvert hydraulic calculations.

Hydrologic modelling

For Broughton Mill Creek, hydrologic modelling was carried out using the XP RAFTS rainfall runoff routing model to derive inflow hydrographs for the TUFLOW hydraulic model. For this purpose the XP RAFTS model constructed and used in the Broughton Creek Floodplain Risk Management Study and Plan (Cardno, 2012) and the Broughton Creek Flood Study (SMEC, 2008) was adopted. The model was used to derive inflows for the 100 year ARI and PMF events.

Flow results obtained from the XP RAFTS/TUFLOW flood models have been compared against PRM estimates and a summary of 100 year ARI flows is provided in **Table 4-2**. The flow result is reported at a location downstream of the project corridor at the convergence of Broughton Mill, Bundewallah and Connollys Creek. The peak flow from the XP RAFTS/TUFLOW model compares reasonably well, with the PRM flow being 11 per cent higher.

Table 4-2: Comparison of TUFLOW and PRM 100 year ARI flows

Waterway	TUFLOW	PRM
Broughton Mill Creek [1]	947	850 [2]

Notes

1. *Approximately 350m downstream of Berry Bridge .*
2. *For comparative purposes PRM estimate presented here is based on no allowance for climate change and is therefore less than the PRM estimate given in* ***Table 4-3****.*

For the remaining waterway crossings PRM was used to estimate peak flows. The PRM is based on data from 308 gauged catchments and is applicable to small to medium rural catchments in eastern NSW. The PRM was therefore considered appropriate for application to the present assessment.

In accordance with design criteria established for the project, provisions for potential future climate changes were made by increasing all rainfall intensities by six per cent (DECC, 2007).

For catchments where the PRM was used the PMF flow was approximated by multiplying the 100 year ARI PRM flow by five.

Catchment areas for each proposed watercourse crossing have been defined using 1:25,000 topographic maps and available survey in the vicinity of the highway. The contours used to define these catchment areas were at minimum 10 metre intervals supplemented where available with aerial photogrammetric survey and detailed field survey.

Catchment layouts and identifiers are as shown in **Figure 4-2** and design flow estimates are listed in **Table 4-3**.

Table 4-3: PRM design flow estimates for major transverse drainage infrastructure

Catch ID	Waterway	Design chainage	Catchment area	1 year ARI	5 year ARI	10 year ARI	50 year ARI	100 year ARI
			(ha)	(m^3/s)				
LB	Unnamed Ephemeral	9000	4	0.5	1.3	1.6	2.3	2.7
KA	Unnamed Ephemeral	9840	66	5.8	15	19	28	32
K	Broughton Creek	9950	2781	106	276	358	557	646
LA	Unnamed Ephemeral	10500	6	0.8	2.1	2.2	3.8	4.3
L	Broughton Creek	10700	2869	108	283	366	570	661
M	Broughton Creek	11200	3197	117	306	396	618	715

Catch ID	Waterway	Design chainage	Catchment area	1 year ARI	5 year ARI	10 year ARI	50 year ARI	100 year ARI
			(ha)	(m^3/s)				
N	Unnamed Ephemeral	11900	7	1.0	2.3	2.9	4.2	4.8
O	Unnamed Ephemeral	12150	7	1.0	2.3	2.9	4.2	4.8
P	Unnamed Ephemeral	12310	6	0.8	1.9	2.4	3.5	4.1
Q	Unnamed Ephemeral	12770	106	8.4	21	27	41	48
R	Unnamed Ephemeral	13320	15	1.7	4.2	5.3	7.8	9.0
S	Unnamed Ephemeral	13580	21	2.3	5.6	7.1	11	12
TC	Unnamed Ephemeral	14150	1	0.12	0.29	0.34	0.51	0.6
TA	Unnamed Ephemeral	14420	3	0.5	1.2	1.6	2.3	2.6
TB*	Unnamed Ephemeral	14500	1	0.15	0.36	0.45	0.64	0.73
T	Broughton Mill/ Connollys Creek	16000	4286	146	383	497	775	896**
W	Town Creek	17450	85	7.0	17.8	22.6	34.2	39.5
XA	Duck Pond ephemeral	17950	4.4	0.6	1.6	1.7	2.8	3.2
X	Tributary to Hitchcocks Lane Creek	18100	75	6.5	16.3	20.7	31.2	36.0
Y	Hitchcocks Lane Creek	18550	68	6.0	15.0	1.1	28.7	33.1
Z	Unnamed Ephemeral	19150	4	0.6	1.5	1.8	2.6	3.0

Catchment TB has not been shown on* ***Figure 4-2* *for clarity reasons*

***TUFLOW 100yr ARI flow of 959m^3/s at Broughton Mill Creek has been used in the hydraulic impact analysis.*

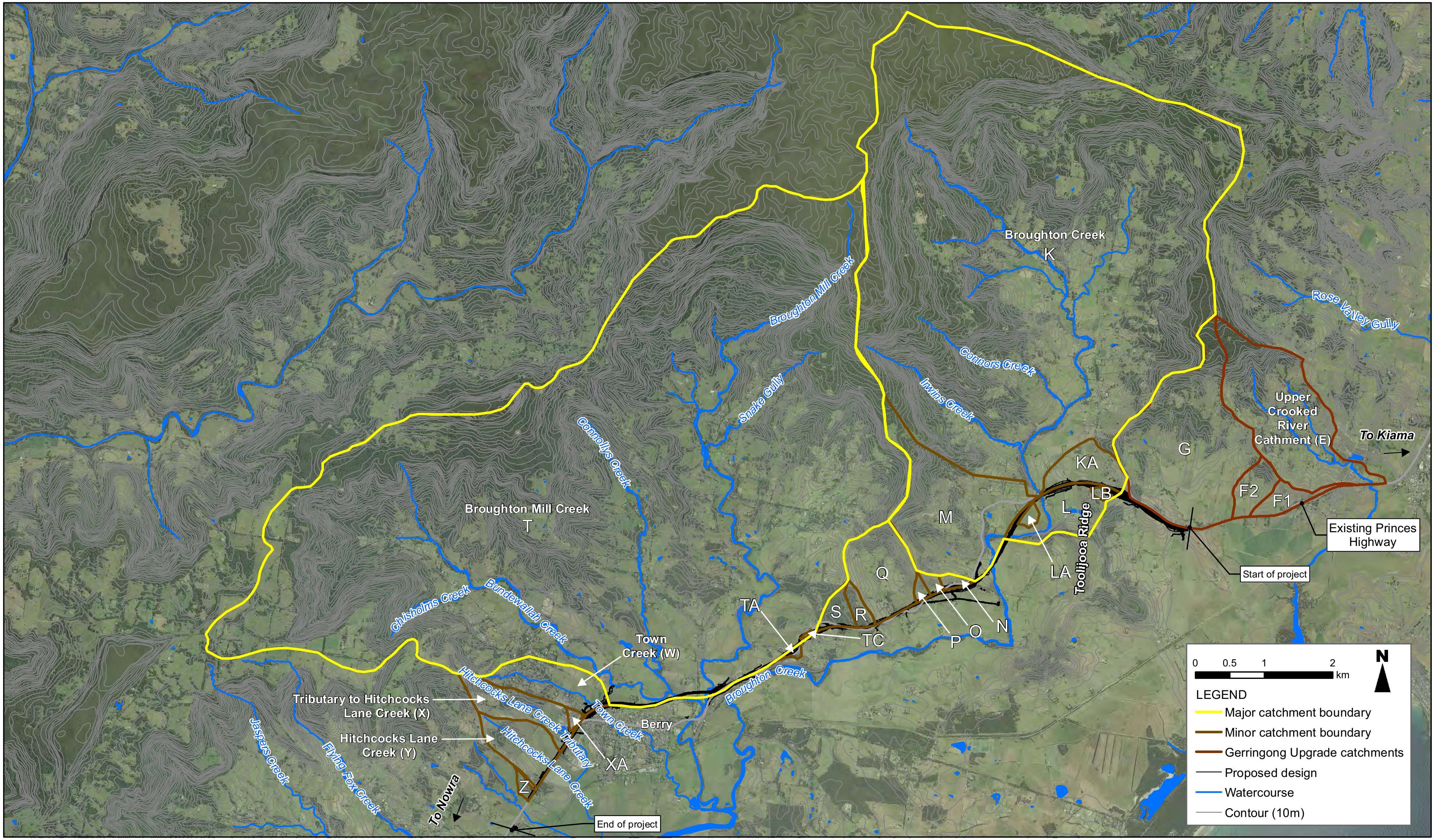

Figure 4-2 Catchment map

Source: AECOM(2012), LPMA (2011)

Note 1: See Table 4.3 for catchment information

Note 2: Gerringong Upgrade Catchments G,E,F2 and F1 Outside Project Area (shown for information only)

Note 3: Catchment TB has not been shown on the figure for clarity reasons

Hydraulic modelling

Flood levels, depths and velocities were determined from a range of detailed hydraulic analyses.

For the Broughton Mill Creek floodplain in the vicinity of Berry (including Bundewallah Creek, Connollys Creek and Town Creek) the TUFLOW 2D model established for the Broughton Creek Floodplain Risk Management Study and Plan (Cardno, 2012) was used as the basis. The Cardno TUFLOW model covers an area of approximately 9 square kilometres covering Berry and its immediate surrounds and is based on a three metres by three metres grid to define the ground topography. The downstream (southern) model limit is approximately 300 metres south of the South Coast railway line.

To assess the impacts of the project on flood behaviour the base model representing existing conditions was modified by adding the road design to the ground definition. For the purposes of concept design, nominal bridge piers were modelled and found to have relatively minor and localised impacts on flood levels and velocities. These impacts would need to be considered in more detail in future investigation or design development stages.

Inflow hydrographs derived from the XP RAFTS hydrologic model were applied to the upstream extents of the TUFLOW model. Rainfall was also applied directly to the 2D grid over the TUFLOW model extent which is consistent with the approach adopted for the Broughton Creek Floodplain Risk Management Study and Plan (Cardno, 2012).

The three bridge crossings of Broughton Creek to the north of the project, as well as Hitchcocks Lane Creek and Tributary were modelled using the HEC RAS 1D model. The remaining waterway crossings were modelled using either Bentley Culvert master or HY-8 culvert hydraulic software packages.

4.2.3 Proposed flood and drainage works summary

Culverts

Culverts along the project have been sized to provide 100 year ARI flood immunity to the highway and to minimise flood level impacts upstream or downstream of the crossings.

The proposed transverse drainage infrastructure for major culvert crossings is summarised in **Table 4-4** and the locations are shown in **Figure 4-3a** to **Figure 4-3b**.

Table 4-4: Proposed culvert summary

Crossing name	Design chainage (m)	Design flow (m^3/s)	Type	Size (mm)	Comments
LB	9030	2.7	Pipe	1x1500	Existing culvert drop structure
KA	9840	32	Pipe	4x1800	Goes through northern abutment of Broughton Creek bridge 1
LA	10500	N/A	Box	1x4600x3000	Oversized to provide vehicular access
N	11900	4.8	Pipe	2x1500	Three pipe segments joined by two large drop structures, to provide drainage under main carriageway and secondary roads on each side
O	12150	4.8	Pipe	2x1500	Existing pond at inlet
P	12310	4.1	Pipe	3x1500	Extend existing pipe and install two new pipes
Q	12770	48	Pipe	7x1800	A minimal water level impact is desirable due to upstream property (Existing 3x1500mm RCP)
R	13320	9.0	Pipe	2x1500	
S	13580	12.1	Pipe	2x1500	
TC	14150	0.6	Pipe	1x1500	
TA	14420	2.6	Pipe	1x1500	
TB	14560	0.7	Pipe	1x1500	
XA	17950	3.23	Pipe	1x1500	
X	18100	36.0	Pipe	4x1800	
Y	18550	33.1	Pipe	3x1800	
Z	19150	2.0	Pipe	1x1500	

Figure 4 - 3a : Location of proposed major culverts

Source: AECOM (2012), LPMA (2011)

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Figure 4 - 3b : Location of proposed major culverts

Source: AECOM (2012), LPMA (2011)

Path: P:\60021933_G2B\4_Tech_work_area\4.7_GIS\Maps_20120806_DKennewell\Centred_121030\Fig 4a_d_02_G053_Culverts_DDP_121030.mxd 31/10/2012

Bridges

Three bridge crossings are proposed over Broughton Creek and one bridge over the confluence of Connollys Creek, Bundewallah Creek and Broughton Mill Creek as shown in **Figure 1.1** and in **Table 4-5**. The proposed bridge works have been designed to minimise impacts on the existing flood regime upstream and downstream properties and to provide a suitable level of freeboard to the 100 year ARI flood level.

Table 4-5: Proposed bridge summary

Crossing name	Design Chainage (m)	Design flow (m^3/s)	Indicative Size (m)	Comments
K	9950	646	122m length, 4 spans	Broughton Creek bridge 1
L	10700	661	76m length, 3 spans	Broughton Creek bridge 2
M	11200	715	200m length, 6 spans	Broughton Creek bridge 3
T	16000	896	600m length, 19 spans	Bridge at Berry

At crossing K the project runs just to the south and downstream of the existing Princes Highway. The existing bridge over Broughton Creek would be retained. The proposed new bridge over Broughton Creek at this location (Broughton Creek bridge 1) would consist of four spans with 1.5 metre piers (total bridge span of 122 metres). In order to comply with the vertical alignment road design criteria, the road level at the proposed Broughton Creek bridge 1 has been set significantly higher than 100 year ARI flood levels. The piers would be placed outside the main creek channels.

The second bridge over Broughton Creek (Broughton Creek bridge 2) would be located approximately one kilometre downstream of Broughton Creek bridge 1 (along the main channel centreline). The proposed bridge consists of three spans with 1.5 metre piers (total bridge span 76 metres). The abutments of the bridge would be located to allow for on-grade access tracks to pass underneath on each side of the existing river banks, together with a reasonable allowance for overbank flow under the bridge. The road level at the proposed Broughton Creek bridge 2 has been set to comply with the vertical alignment road design criteria. The piers would be placed outside the main creek channel.

The third bridge over Broughton Creek would be located approximately 600 metres downstream of Broughton Creek bridge 2 (along the main channel centreline). The road level at the proposed Broughton Creek bridge 3 has been set significantly higher than 100 year ARI flood levels in order to comply with vertical alignment road design criteria. The proposed Broughton Creek bridge 3 would consist of six spans with 1.5 metre piers (total bridge span 200 metres). The lowest (underside) edge of the modelled bridge is at the northern abutment.

The bridge at Berry consists of 19 spans with 1.5 metre piers (total bridge span of 600 metres). The lowest (underside) edge of the modelled bridge is at the southern abutment. The road level in the north is set by geometric road design requirements and is considerably higher than the 100 year ARI peak flood level. The road level at the southern end of the bridge is dictated by the 100 year ARI flood level. As a mitigation measure for visual impacts of the bridge, the piers would be spaced to meet aesthetic requirements. This may result in some piers being located within Bundewallah Creek.

Appropriate scour protection would be provided to the bridge abutments and piers where velocities have the potential to cause scour. Further detailed modelling of the bridges would be carried out as part of the detailed design phase of the project.

Diversion of Town Creek

The presence of the proposed alignment around the northern side of Berry presents an opportunity to mitigate the existing flash flooding of Town Creek within Berry. Runoff from the Town Creek catchment (catchment W) north of the highway would be rerouted by a diversion channel passing through culverts under Rawlings Lane into Bundewallah Creek and then into Broughton Creek downstream (see **Figure 2-1** for the diversion channel location).

The diversion channel and culverts under Rawlings Lane would be sized to have adequate capacity to fully convey the 100 year ARI peak flow with appropriate freeboard.

4.2.4 Impacts at Broughton Creek

Flood level impacts along Broughton Creek are summarised in **Table 4-6** and shown in **Figure 4-4, Figure 4-5** and **Figure 4-6**.

Table 4-6: Summary of proposed bridge impacts

Crossing name	Design chainage (m)	Figure reference	Upstream Water Level impact 100 year ARI (m)	Comments
Broughton Creek bridge 1	9950	Figure 4-4	0.4m	Existing Princes Highway flood immunity would be reduced. Flood immune access provided by the project. No other structures affected. Impacts limited to pasture.
Broughton Creek bridge 2	10700	Figure 4-5	0.3m	Impacts are limited to pasture. No structures affected. No change in extent of floodplain due to steep sides of floodplain.
Broughton Creek bridge 3	11200	Figure 4-6	Localised increases due to piers and redistribution of flows. 0.1m	Impacts mitigated by the embankment between bridges 2 and 3 acting to divert flow to Bridge 3

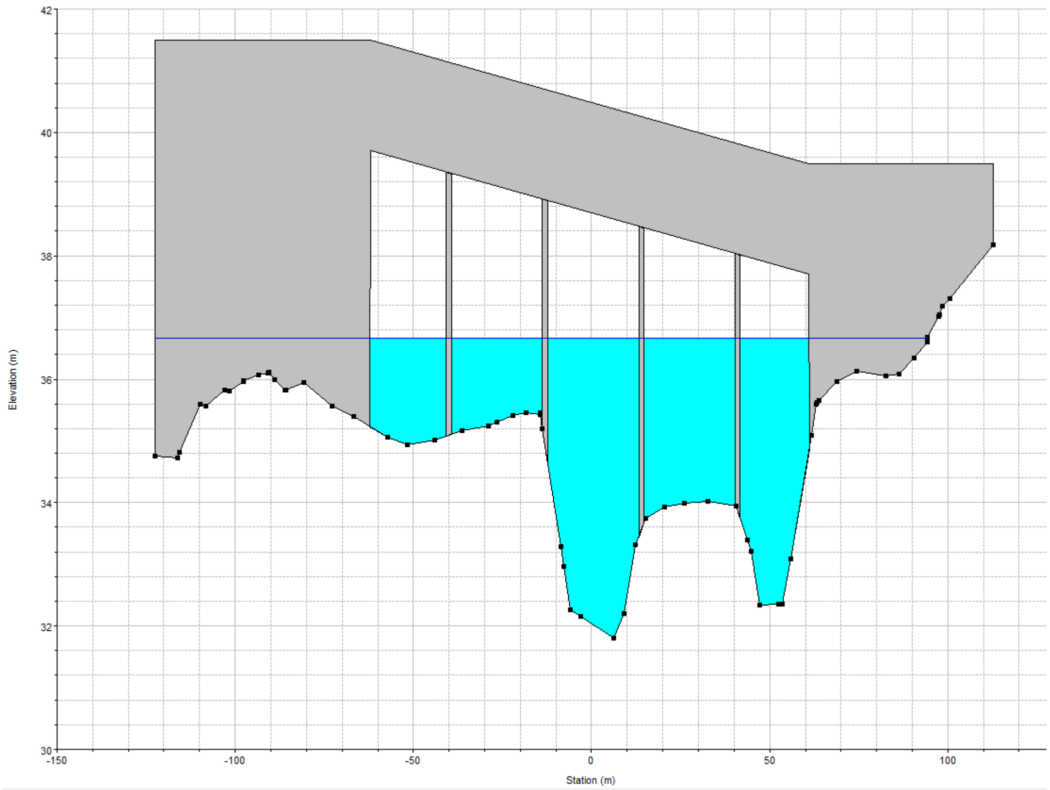

Figure 4-4: 100 year ARI design peak flood level at Broughton Creek bridge 1

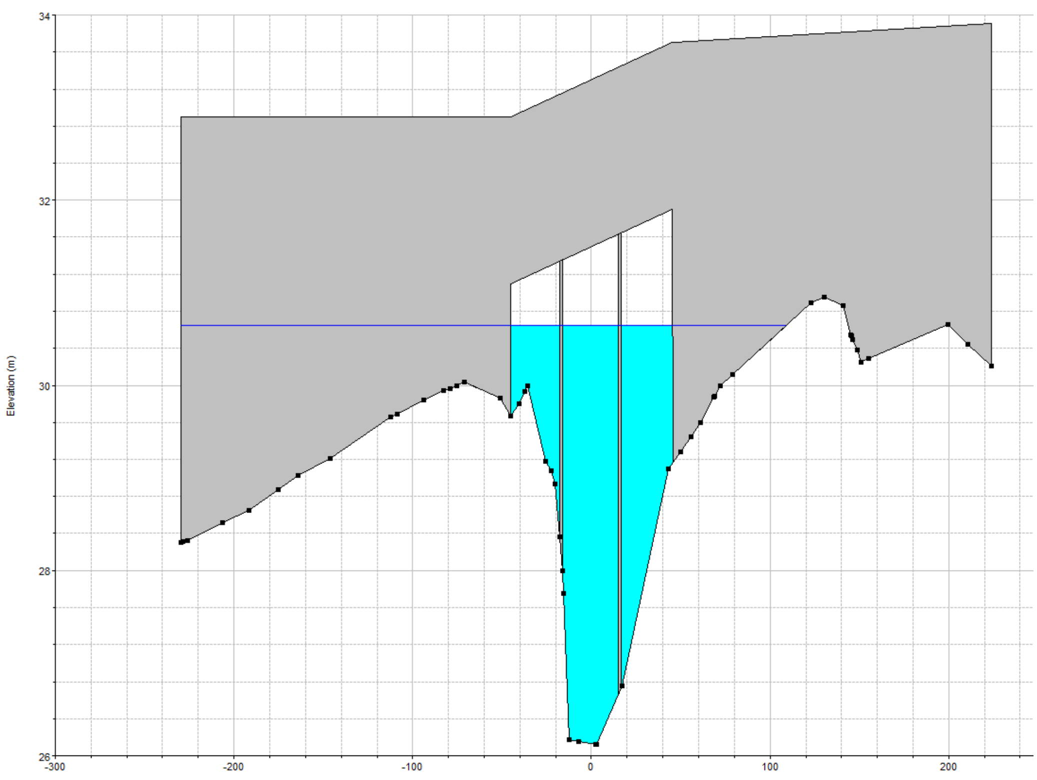

Figure 4-5: 100 year ARI design peak flood level at Broughton Creek bridge 2

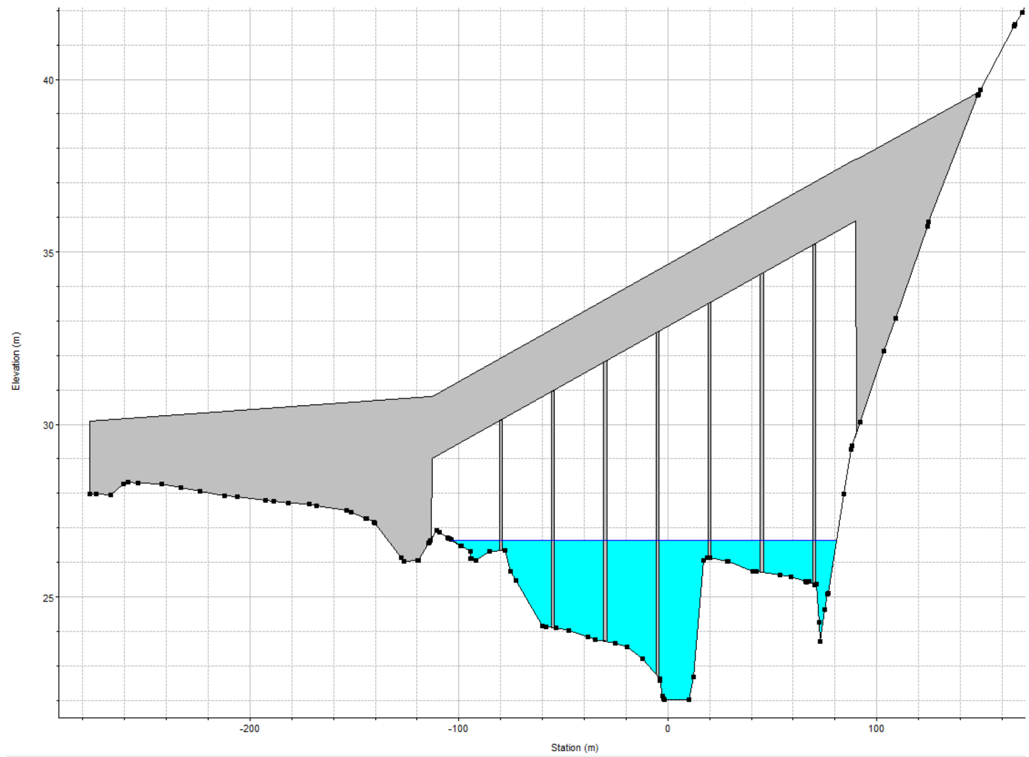

Figure 4-6: 100 year ARI design peak flood level at Broughton Creek bridge 3

Hydraulic modelling indicates that flows would be contained within the Broughton Creek banks for design flood events below the five year ARI. Above the five year ARI flood event, flood waters would overtop the left bank and flow across the floodplain eventually rejoining Broughton Creek further downstream. Under existing conditions the overland flow follows the general flowpaths shown in **Figure 4-7**. The proposed embankment across the floodplain would change the distribution of overland and in channel flows between the three proposed bridges on the upper Broughton Creek.

Between Broughton Creek bridges 2 and 3 the proposed embankment would effectively split this overbank flow into two paths (see **Figure 4-8**) on the eastern and western side of the alignment respectively. This creates three mechanisms by which the proposed works would impact on flood levels.

Firstly, the separated flow caused by the embankment would produce turbulence and energy loss that would increase flood levels upstream. Secondly, the placement of fill within the floodplain would potentially reduce the floodplain's storage capacity. This second mechanism is deemed relatively insignificant due to the large width of the floodplain. The third is that the overland flow distribution across the floodplain would be altered with more flow along the eastern side of the alignment. This could increase flood levels upstream of Broughton Creek bridge 2 and along the eastern side of the embankment between bridges 2 and 3.

The area that could be subjected to water level impacts due to these mechanisms is highlighted in **Figure 4-8**. The impacts are expected to be less than 0.3 metres in a 100 year ARI event and would be limited to agricultural land use areas and would not impact any structures or access. Due to the steep slopes at the edge of the floodplain, the impacts would not result in any significant increase in the 100 year ARI flood extent.

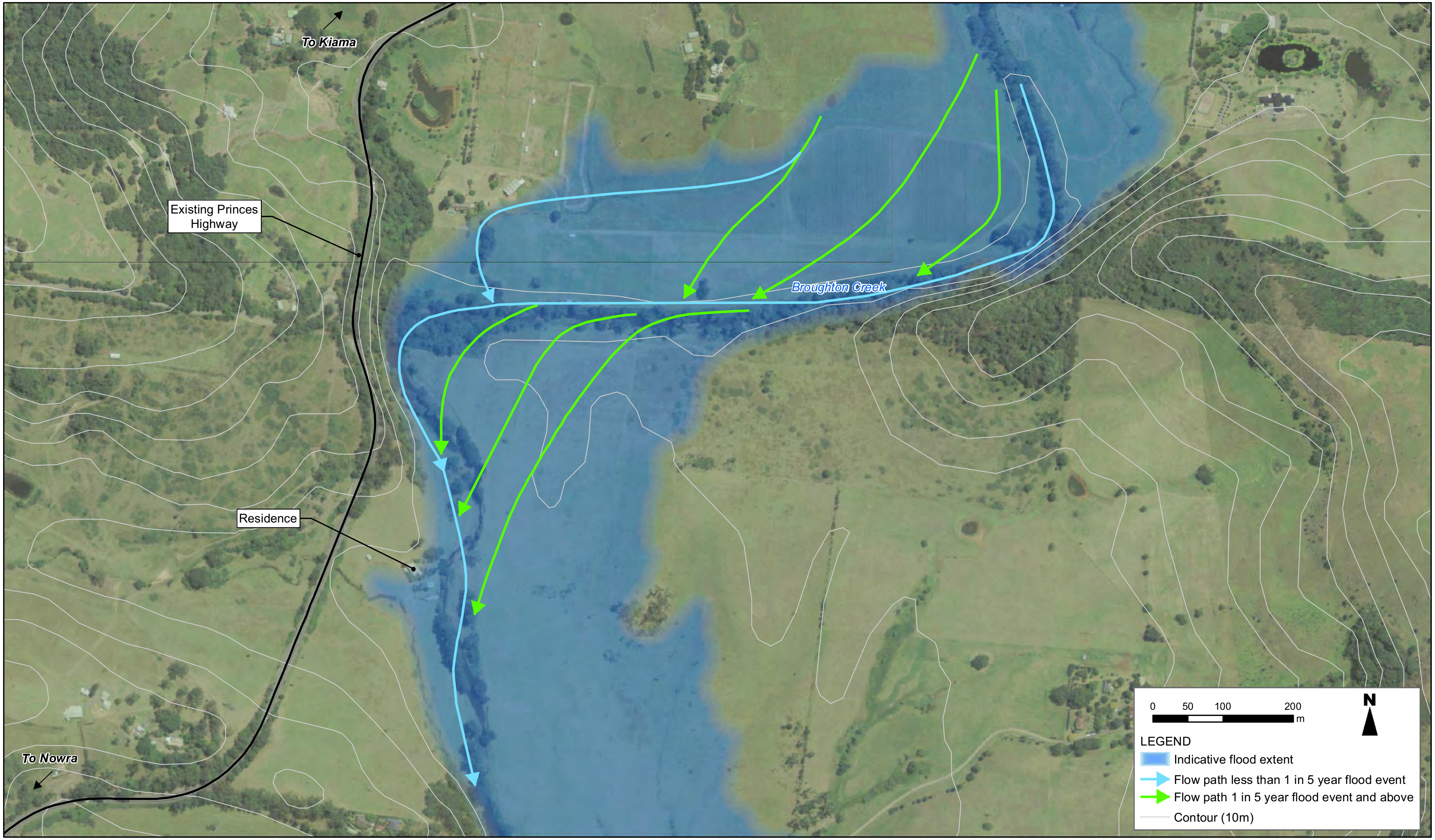

Figure 4-7 Broughton Creek overbank flowpaths

Source: AECOM (2007), LPMA (2011)

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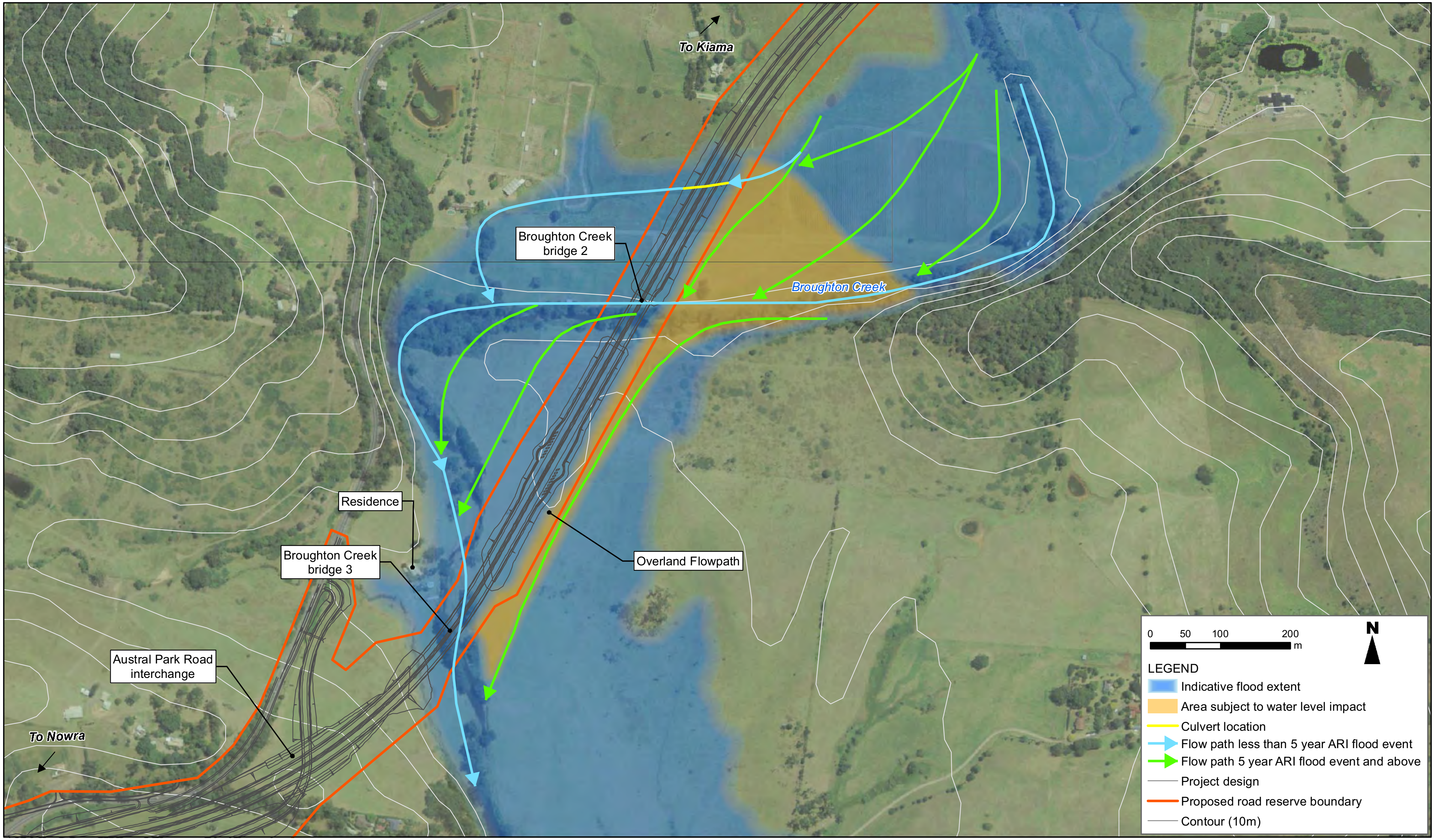

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Figure 4-8 Broughton Creek overbank flowpaths

Source: AECOM (2007), LPMA (2011)

On the western side of the embankment upstream of Broughton Creek bridge 3, flood level impacts are expected to be minimal because more flow would be diverted along the eastern side of the embankment. However, the proposed road embankment will change the flow paths across the floodplain on the western side of the embankment and could have localised impacts to properties along Broughton Creek where flows are redistributed.

A small tributary flows across the property just upstream of Broughton Creek bridge 3 and joins Broughton Creek approximately 200 metres downstream of the bridge. The works associated with the proposed interchange with the existing Princes Highway could affect the flow patterns of this tributary and, depending on the redistribution of flows either side of the embankment (between Broughton Creek bridges 2 and 3) this could cause localised flood impacts to the property upstream of bridge 3. The maximum impact immediately upstream of the bridge is estimated up to 0.1 metres but the impact at the residence itself is likely to be less.

The suggested modelling approach during the detailed design phase include 2- dimensional modelling of the floodplain to accurately determine the flow split around the southern abutment of Broughton Creek bridge 2 during major flood events. Depending on the amount of flow that would be conveyed along the embankment, appropriate works for a controlled overland flowpath and scour protection would be designed to minimise erosion and flood impacts.

4.2.5 Impacts at Berry Township

The project traverses the broad floodplain at the confluence of Broughton Mill Creek, Bundewallah Creek and Connollys Creek immediately north of Berry. Existing 100 year ARI flood depths and extent for this area are shown in **Figure 4-9**.

The proposed works will involve the diversion of Town Creek along the north of the proposed highway alignment to discharge into Bundewallah Creek, upstream of Connollys Creek. The proposed works will also involve the construction of highway embankment across part of the floodplain. Flood modelling of the proposed works has been used to identify potential impacts on the surrounding environment, set minimum waterway opening requirements and minimum design levels for the highway and associated infrastructure. Flood depths and extent under proposed conditions for the 100 year ARI event are shown in **Figure 4-10**. Corresponding relative changes in flood levels are shown in **Figure 4-11** and described below.

The flood modelling and assessment has shown that there will be an increase in flood levels upstream (north) of the alignment, due largely to a reduction in waterway area from the highway works encroaching across the floodplain as well as the increased in flows associated with the diversion of Town Creek.

From **Figure 4-11** it is evident that at the southern end of the bridge at Berry, where the abutment extends approximately 200 metres into the existing 100 year ARI flood extent, some localised flood impacts up to 0.3 metres would be expected upstream during the 100 year ARI event. Immediately downstream of the southern abutment, including some areas along North Street, flood levels would be reduced.

Immediately downstream of the proposed there would be an increase in flood levels, due to the concentration of flows through the bridge openings combined with the additional flows from Town Creek.

There would be minimal flood level impacts along the Town Creek diversion route as the channel would be sized to convey the 100 year ARI flow. Box culverts would convey the 100 year ARI flow under Rawlings Lane without overtopping.

An assessment has been made of properties that are potentially affected by the proposed works. Floor level survey information has been used to undertake a review of those properties that may experience adverse flood impacts as a result of the proposed highway upgrade as well as those that will be better off.

Potential increases in flood levels

The flood impact summary in **Table 4-7** includes 11 properties that are potentially affected by changes in flood level as a result of the project. Corresponding flood impact mapping is shown in **Figure 4-11**.

Properties 1, 2 and 3

Properties 1, 2 and 3 are located upstream of the project. Increases in flood levels at these properties are predominantly a function of the reduction in available waterway area across the floodplain. The model results show an increase in 100 year ARI flood level at property 1 of 0.06 metres and 0.08 metres at properties 2 and 3. This would result in a reduction in freeboard at these properties. Properties 1 and 2 would still have in excess of 0.5 metre freeboard. However the freeboard at property 3 would be reduced from 0.18 metres (existing) to 0.11 metres (proposed).

Properties 4 and 5

Properties 4 and 5 are located immediately downstream of the project. The properties are impacted by a combination of the diverted flows from Town Creek together with a greater concentration of flow through the constricted bridge opening. It would therefore be difficult to fully offset the impacts on these properties without removing or reducing the diversion of Town Creek.

No detailed floor level or ground level data are available for property 4. The modelled depth of flooding suggests the property experiences significant inundation around the building. Floor level survey is required to confirm the susceptibility of building floor level to flooding.

Floor level survey for property 5 shows the building is elevated over 3 metres above the 100 year ARI flood level. Consequently, the nominal 0.03 metre increase in flood levels is not significant in the context of the impact.

Properties 6, 7, 8, 9 and 11

Properties 6, 7, 8, 9 and 11 are located further downstream of the proposed road alignment. The nominal impacts at these properties (typically 0.03 metres or less) would be primarily due to the diversion of flows from Town Creek. The increase in flood levels at these properties is considered minor relative to the existing level of above floor inundation. Consequently, no additional local flood mitigation measures are expected to be required. This would however be subject to detailed design development.

Property 10

Property 10, the sports amenities building at the Berry sportsground and the Camp Quality Memorial Park, is located immediately downstream of the southern bridge abutment. Relative flood level impacts based on the current concept design are negligible or minor.

Potential reductions in flood levels

The diversion of Town Creek will provide a significant benefit to properties within Berry that currently experience flooding. The existing portion of Town Creek flowing through the town of Berry (south of the project) would experience a lowering of 100 year ARI flood levels of in excess of one metre as indicated on **Figure 4-12**. The property impacts table in **Appendix A** shows the reduction in flood levels affectation and increases in freeboard at these properties. The tabulated results show over 80 properties will have a measurable reduction in flood level. Of these, there are nine properties that experience above floor inundation in a 100 year ARI event under existing conditions that would become flood free under the post highway scenario (albeit with relatively small freeboard).

It is evident from the above assessment that the proposed diversion of Town Creek flows provides a significant benefit in reducing flooding through Berry. This needs to be considered in the context of evaluating any adverse impacts on properties and developing appropriate mitigation measures.

Changes in flood behaviour for more frequent events

The proposed works will impact flood levels during events more frequent than 100 year ARI through the same mechanisms as described above. Generally, the increases and reductions in flood levels will be of a smaller magnitude during more frequent flood events.

The proposed embankment at the southern end of the bridge at Berry would encroach on the flooded area to a lesser extent during more frequent flood events. This would result in relatively smaller impacts due to constriction of the floodplain and, subsequently, more frequent flood events will have a reduced flood impact relative to the 100 year ARI event.

The diversion of flows from Town Creek to Bundewallah Creek would result in changes to the behaviour of more frequent flood events similar to those described in the 100 year ARI assessment, however the impacts would be of a relatively smaller magnitude as a consequence of the smaller flow rates.

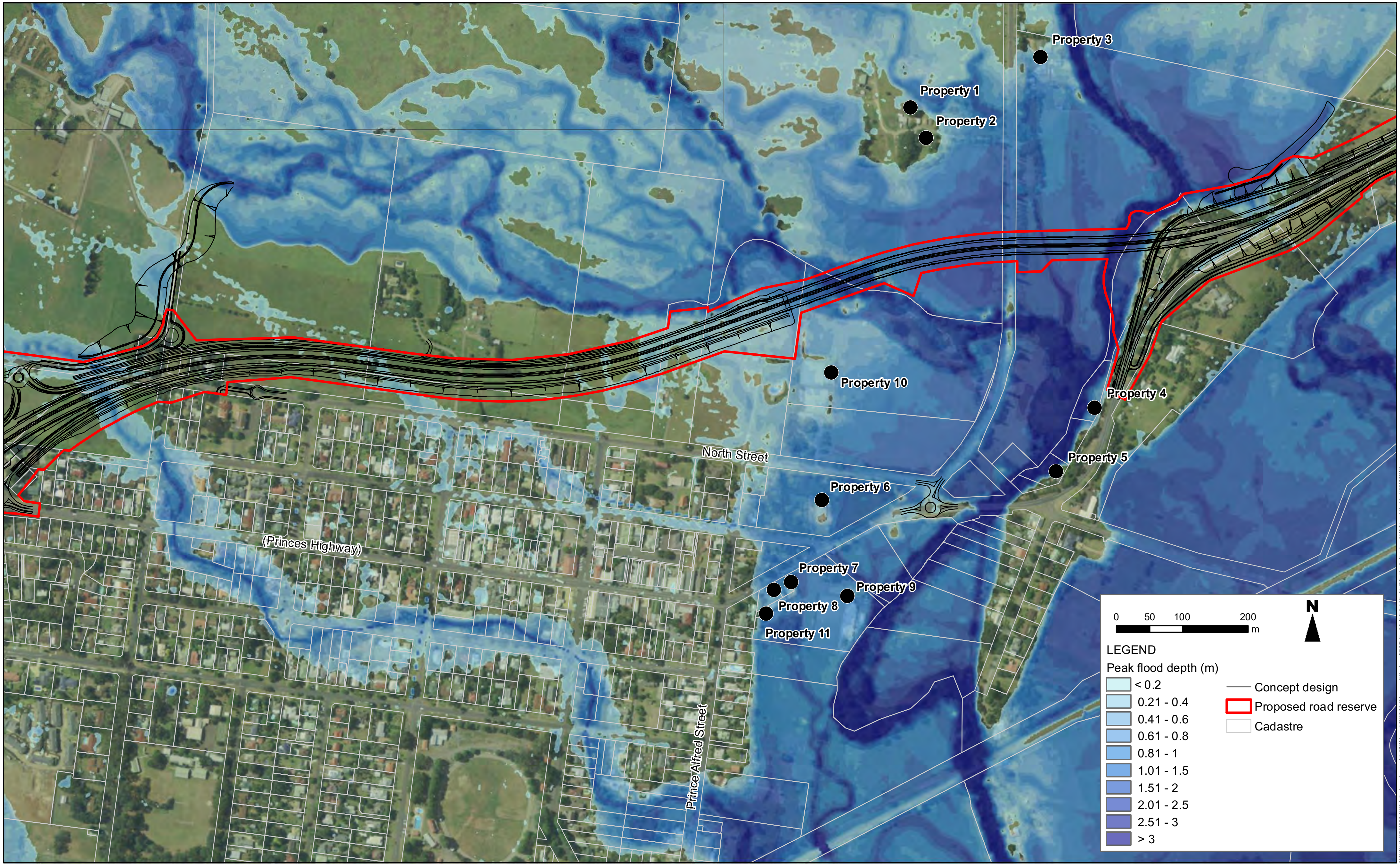

Figure 4-9 Berry Township –100 year ARI peak flood depths – existing conditions

Source: AECOM (2012), Cardno (2011)

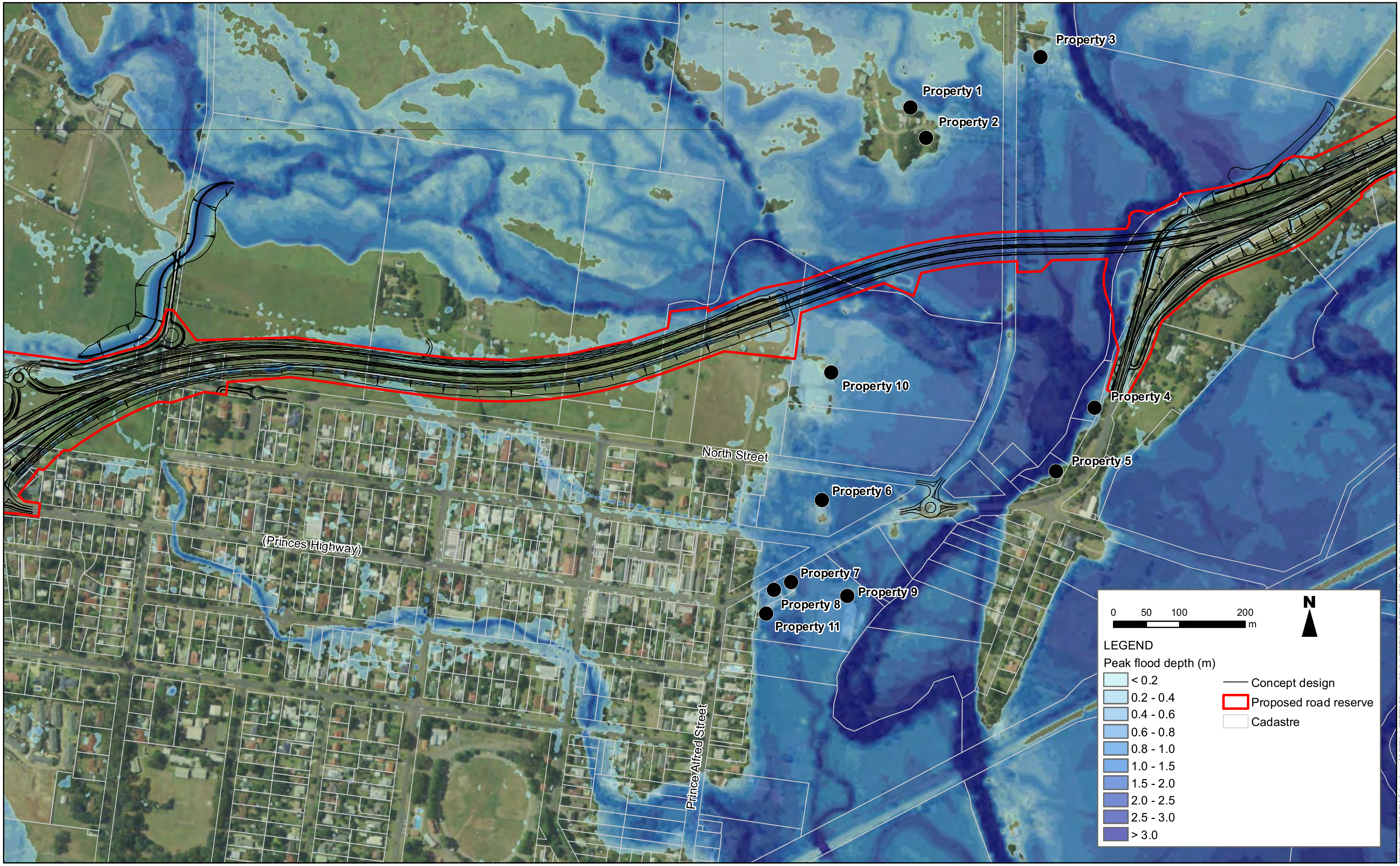

Figure 4-10 Berry Township –100 year ARI peak flood depths – proposed conditions

Source: AECOM (2012), Cardno (2011)

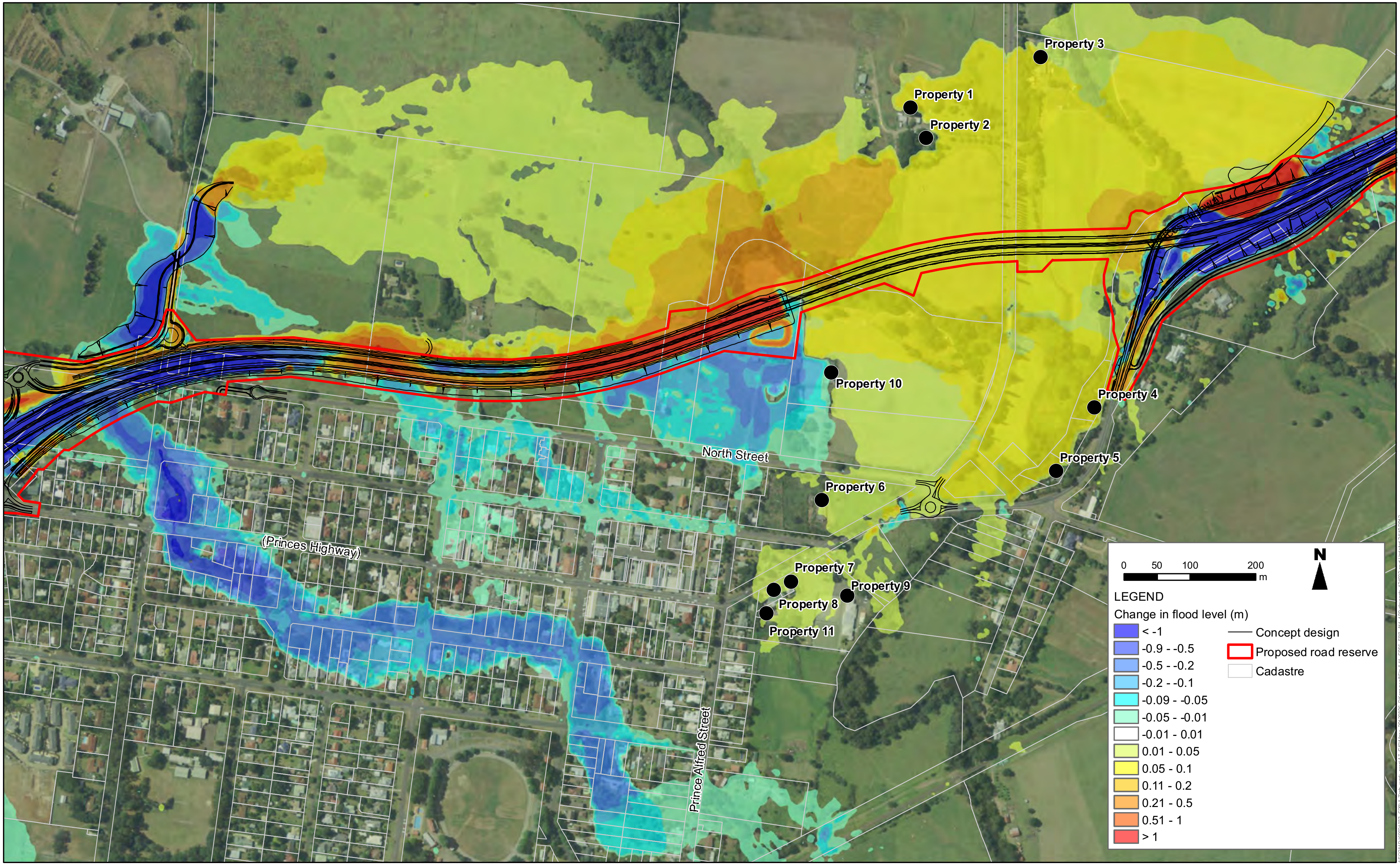

Figure 4-11 Berry Township –100 year ARI change in flood level

Source: AECOM (2012), Cardno (2011)

Notes

- A positive relative impact represents an increase in flood level under proposed conditions relative to existing condtions. A change in flood level of +/- 0.01m is considered to be within the level of accuracy of the model and to have neglible or no impact
- Relative flood level impacts shown along the alignment (within the project corridor) are a function of the direct rainfall on grid hydraulic modelling approach and are a fuction of the relative height between the existing ground and design surface. Impacts indicated in these areas are confined to works within the Proposed Road Corridor.
- The direct rainfall on grid approach can also lead to localised "noise" in flood level results in areas outside the corridor. These isolated pockets of impacts are an artefact of the flood modelling approach rather than a quantifiable impact from the Proposed works.

Table 4-7: Summary of flood levels and relative impacts at property buildings – 100 year ARI event

Property		Survey Note 1		Existing Conditions		Concept Design								
						Concept Design 100 yr flood level at property (mAHD)			Change in flood level (m) Note 4			Freeboard to floor level (m)		
#	Address	Floor level (mAHD)	Ground level (mAHD)	100 year ARI flood level at property (mAHD)	Free-board to floor level (m) Note 3	Concept Design	Arrangement 1	Arrangement 2	Concept Design	Arrangement 1	Arrangement 2	Concept Design	Arrangement 1	Arrangement 2
1	59 Woodhill Mountain Rd	11.15	11.06	10.56	0.59	10.62	10.62	10.62	0.06	0.06	0.06	0.53	0.53	0.53
2	59 Woodhill Mountain Rd	11.29	10.90	10.45	0.84	10.53	10.49	10.48	0.08	0.04	0.03	0.76	0.80	0.81
3	76 Woodhill Mountain Rd	10.69	10.85	10.51	0.18	10.58	10.55	10.54	0.08	0.04	0.03	0.11	0.14	0.15
4	29a Princes Hwy	No data	9.8 Note 2	10.12	No data	10.17	10.17	10.16	0.05	0.05	0.03	No data		
5	15 Princes Hwy	13.85	13.56	10.27	3.58	10.30	10.30	10.29	0.03	0.03	0.02	3.55	3.55	3.56
6	152 North St	9.46	8.18	9.09	0.37	9.10	9.11	9.10	0.01	0.02	0.01	0.36	0.35	0.36
7	134 Princes Hwy	7.84	7.02	8.17	-0.33	8.19	8.19	8.18	0.01	0.02	0.01	-0.35	-0.35	-0.34
8	132 Princes Hwy	7.24	7.25	8.18	-0.94	8.20	8.20	8.19	0.01	0.02	0.01	-0.96	-0.96	-0.95
9	140 Princes Hwy (Berry Bowling Club)	7.51	6.55	7.87	-0.36	7.89	7.89	7.89	0.01	0.01	0.02	-0.38	-0.38	-0.38
10	Lot 1 North Street (Camp Quality Park sport amenities)	9.64	9.39	9.83	-0.19	9.82	9.86	9.86	-0.01	0.03	0.03	-0.18	-0.22	-0.22
11	Lot 1 Princes Hwy	7.51	6.92	7.60	-0.09	7.62	7.61	7.61	0.02	0.01	0.01	0.11	0.10	0.10

Notes

1. *Floor and Ground Level survey carried out by Peter Smith & Co for Shoalhaven City Council as part of the Broughton Creek Floodplain Risk Management Study. Except for Properties 1 and 2, which was carried out by RMS.*
2. *No floor level data available for Property 4. Ground levels approximated from flood model DTM.*
3. *A negative freeboard represents the depth of above floor inundation.*
4. *A positive relative impact represents an increase in flood level under proposed conditions relative to existing conditions. A change in flood level of +/-0.01m is considered to be within the level of accuracy of the model and is considered to have negligible or no impact*

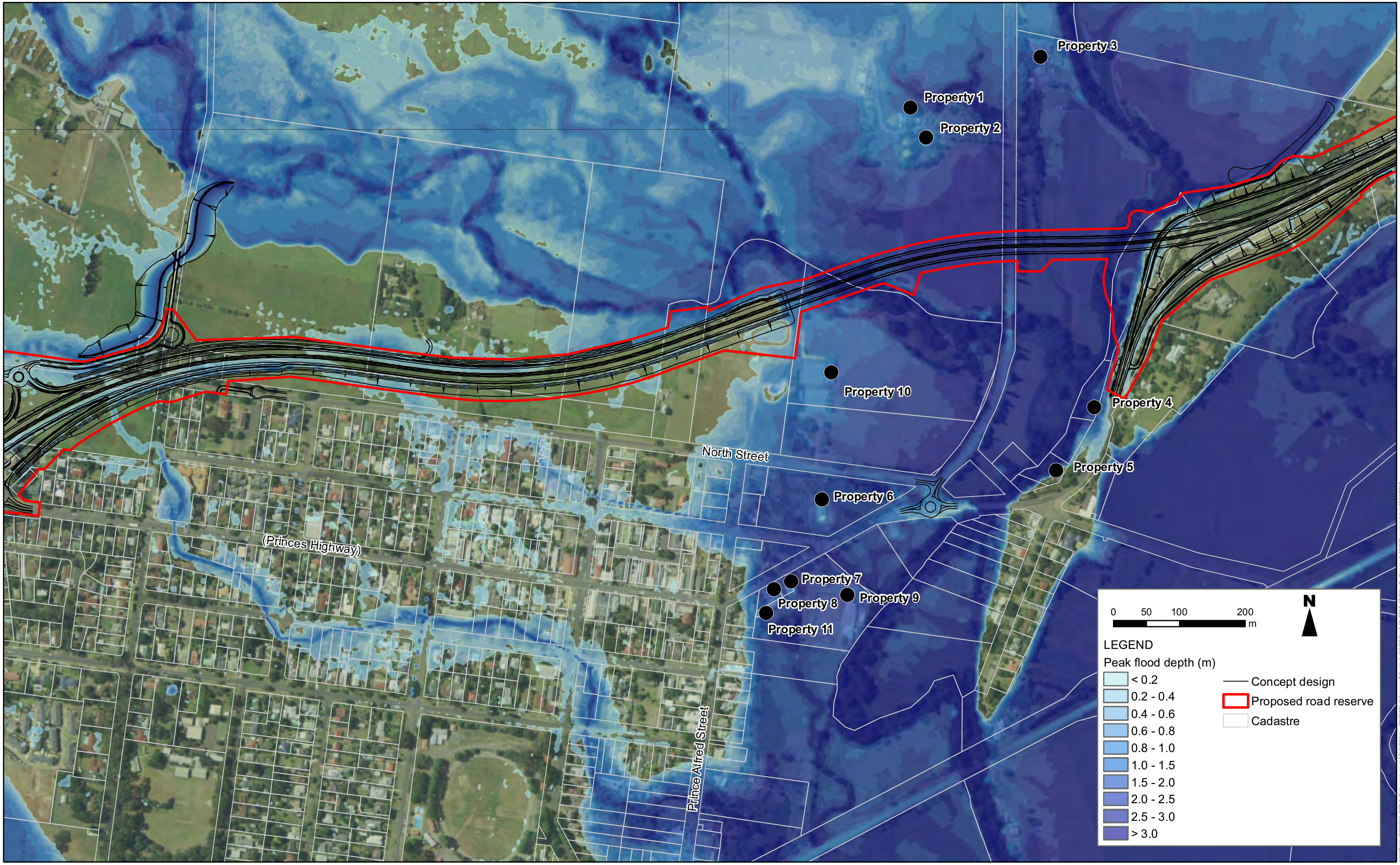

Figure 4-12 Berry Township – PMF peak flood depths – proposed conditions

Source: AECOM (2012), Cardno (2011)

4.2.6 Regional flood impacts during the Probable Maximum Flood

The preceding sections have dealt with local flood impacts around the individual drainage structures. However, flooding on a wider scale has to be considered for emergency planning purposes and impacts on critical infrastructure. The potential flood impacts during the PMF along the proposed route alignment have therefore been investigated. This assessment also serves to identify potential worst case impacts.

The proposed road embankment has the potential to block flood waters. The road could be overtopped by about three metres between Broughton Creek bridges 1 and 2 during the PMF. The raised road embankment could increase flood levels up to two metres above existing levels during the PMF upstream of Broughton Creek bridge 1, and up to two metres at Broughton Creek bridge 2. While there is no critical infrastructure upstream of these bridges, dwellings on private properties could be affected. The project would not adversely affect evacuation routes as the existing highway in this location is already overtopped during a PMF under existing conditions. Flood impacts at Broughton Creek bridge 3 would be mitigated by the large bridge waterway openings and high elevation of the bridge above the floodplain.

The drainage crossings through the middle reaches between the Broughton Creek crossings and Berry convey much smaller flows and impacts in the PMF would be localised and not affect critical infrastructure.

At Berry, the project would be located north of the current highway. This would reduce the flood risk to the main part of the town of Berry as well as some access routes, such as the South Coast Rail Line. There would be an increase in PMF flood level of approximately 0.2 metres at the north of bridge at Berry. Directly north of the western abutment, the flood level would increase approximately 0.6 metres. Downstream of bridge at Berry, the increase would generally be 0.1 - 0.15 metres. The change in flood levels for the PMF event are shown in **Figure 4-13**.

The diversion channel for Town Creek would provide flood relief to much of the Berry township by diverting water upstream of the upgraded alignment toward Bundewallah Creek. Therefore properties within the town of Berry would experience a reduction in flood level of up to 0.9 metres.

Due to the nature of the terrain at Hitchcocks Lane tributary the flood impacts during the PMF would likely be limited to the area between the highway alignment and Huntingdale Park. The proposed road level at this location is approximately three metres above the existing road level and the flood impacts could extend as far as the northern boundary of the property through which the creek runs.

The project would have adverse flood impacts during a PMF. However, it would also reduce the flood risk to the township of Berry and critical infrastructure and evacuation routes should not be affected.

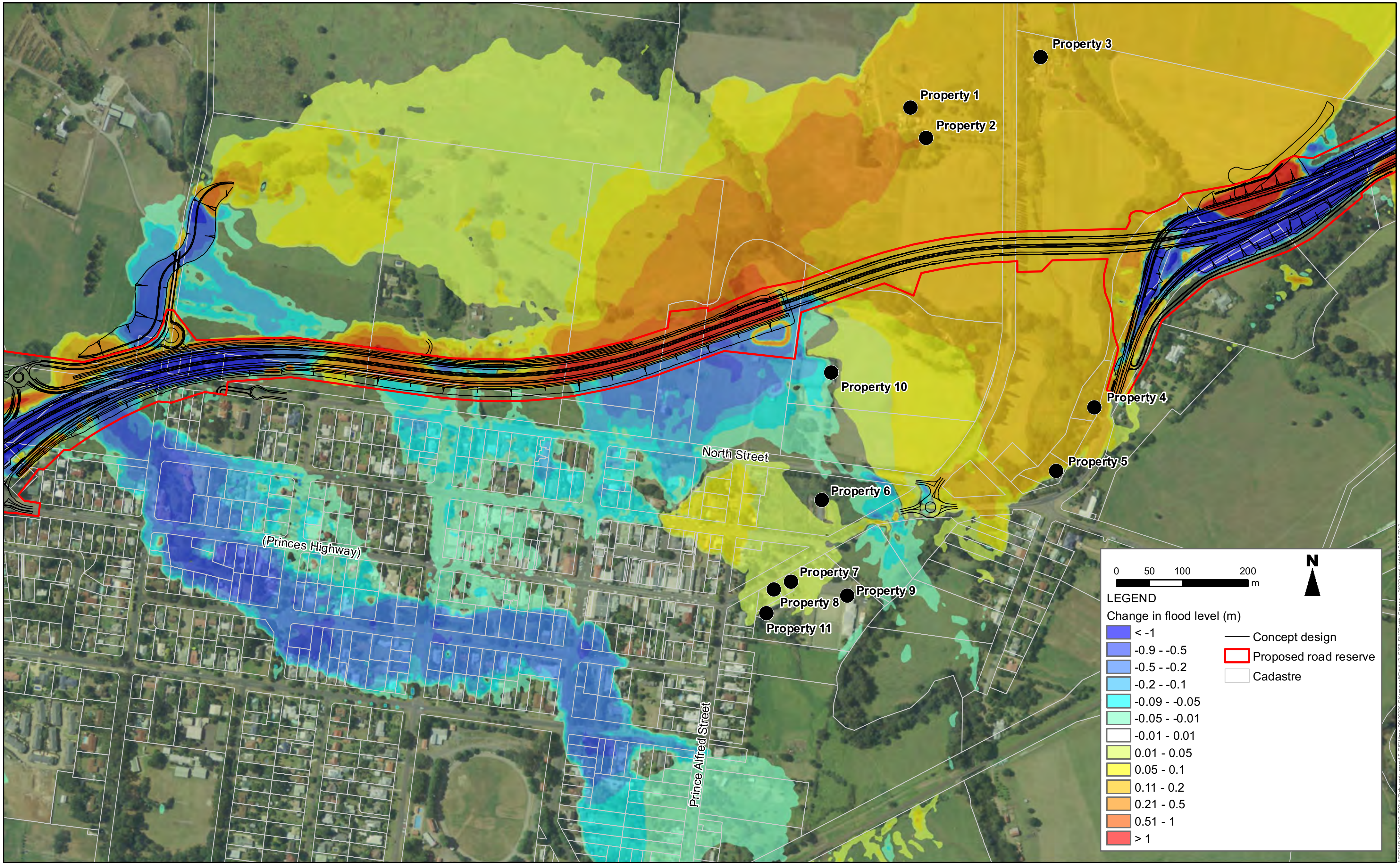

Figure 4-13 Berry Township – PMF change in flood level

Notes

- A positive relative impact represents an increase in flood level under proposed conditions relative to existing condtions. A change in flood level of +/- 0.01m is considered to be within the level of accuracy of the model and to have neglible or no impact
- Relative flood level impacts shown along the alignment (within the project corridor) are a function of the direct rainfall on grid hydraulic modelling approach and are a fuction of the relative height between the existing ground and design surface. Impacts indicated in these areas are confined to works within the Proposed Road Corridor.
- The direct rainfall on grid approach can also lead to localised "noise" in flood level results in areas outside the corridor. These isolated pockets of impacts are an artefact of the flood modelling approach rather than a quantifiable impact from the Proposed works.

Source: AECOM (2012), Cardno (2011)

4.2.7 Site compound and stockpile locations

Site compounds would be used to store plant and equipment and to provide parking and amenities for construction staff. Chemicals and fuels for construction would be stored in appropriately bunded storage areas in the compound site. The compound and stockpile sites would be subject to the site location criteria set out in the Stockpile Site Management Procedures (RTA, 2001).

The exact location of compound and stockpile sites is difficult to determine at this stage of project development and would be subject to change during the detailed design and construction stages. However, potential site compound locations have been identified and are described in **Chapter 4** of the environmental assessment. The site compounds would be located within the project corridor and adjacent lands.

The potential for flood impacts at site compounds and stockpiles would be assessed during the detailed design phase. This assessment would take into consideration factors such as the nature of the sites, the construction sequencing, the duration of operation of these sites and proximity to sensitive waterways.

4.2.8 Stock refuge

The project runs mainly through rural pastures and stock refuges on these rural floodplains are important to protect livestock. Floodwaters can affect livestock in several ways, including injury and drowning or damage to fodder reserves. Stock refuges in the event of flooding on the Broughton Creek floodplain would be maintained by the access road under Broughton Creek bridge 2. This provides a flood evacuation route for stock to walk to higher ground. This outcome could alternatively be achieved by providing mounds of fill within the floodplain, preferably located in fringe areas or at the base of the proposed highway embankment.

4.2.9 Worst case

A key aspect of the DGRs for this project is the provision of appropriate environmental management measures and design standards to minimise the potential risk of flood impacts. For the purposes of determining a worst case scenario in line with the DGRs it has been assumed that all drainage infrastructure (ie culverts, bridges and drains) could experience some form of blockage.

With existing drainage lines blocked, flood waters would follow new overland flowpaths where available, similar to the flood behaviour that might occur during the PMF. Concentrated flows through culverts or bridge openings that are partially blocked could result in increased flow velocities and lead to increased scour and erosion. This could not only affect ecosystems and cause local flood level impacts but could ultimately affect the structural integrity of the road infrastructure.

It is considered highly unlikely that all these measures could fail, and as such there is only a low risk of the worst case impacts occurring.

4.2.10 Climate change potential impacts

Climate change has the potential to alter rainfall and sea level conditions that lead to flooding of the creeks and waterways traversed by the project.

Scientific research into the potential impacts of climate change has been rapidly evolving over recent years. Latest research indicates that climate change is likely to result in more frequent and intense storms, but lower average annual rainfall. This has the potential to increase rainfall intensities for storms leading to increases in the frequency and magnitude of flooding to catchments and waterways in the vicinity of the project.

Research into sea level trends shows that over the period 1870 – 2001 global sea levels rose by 0.2 metres, with the current global rate of increase approximately twice the historical average (DECCW, 2009). Increased sea level rise has the potential to affect Shoalhaven River and Broughton Creek flooding south of Berry. However, the project lies outside the area of Broughton Creek and Shoalhaven River flooding and is therefore not influenced by sea level rise.

The Floodplain Risk Management Guideline Practical Consideration of Climate Change (DECC, 2007) provides estimated changes in rainfall intensities for the 1 in 40 year one day rainfall totals. With regard to the study area the predicted increase in rainfall intensity is plus seven per cent by 2030 and plus five per cent by 2070. On this basis the RMS have established design criteria providing an allowance for six per cent rainfall increase across the overall Gerringong to Bomaderry route alignment (including the project).

While there is general consensus regarding the overall trend of increased rainfall intensities and sea level rise, there is less consensus on the extent of these increases. For this reason the DECC 2007 Guideline recommends assessment of a range of rainfall and sea level scenarios to assess the sensitivity of the catchment to potential increases.

With regard to increase in peak rainfall and storm volume the DECC 2007 guideline recommend consideration of the following:

- Low level rainfall increase 10 per cent
- Medium level rainfall increase 20 per cent
- High level rainfall increase 30 per cent

It should be noted that under the DECC 2007 Guidelines, a high level rainfall increase of 30 per cent is recommended for consideration due to the level of uncertainty in rainfall projections and the implementation of a precautionary approach is recommended. However, on the basis of current research, it is generally acknowledged that a 30 per cent rainfall increase is on the conservative side.

In light of the above, the approach adopted to manage the potential impacts of climate change on flooding has involved:

- Adopting a six per cent increase in design rainfall intensities for design of transverse drainage structures; and
- Undertaking sensitivity analyses for increases in rainfall intensity of 10, 20 and 30 per cent.

Potential increases in rainfall intensities have been assessed as part of the hydrologic and hydraulic modelling of the project. A summary of the implications for 100 year ARI flood levels is provided below.

Potential climate change impacts at the bridge at Berry

Of the total project, the western abutment of the bridge at Berry has the least amount of freeboard provided for in the concept design. As such, flood levels at this location would be most vulnerable to climate change impacts.

Implications for flooding levels due to climate change were assessed for potential increases in rainfall intensity. Variations in rainfall on the local catchment were assessed by factoring the inflows to the TUFLOW model by 10 per cent, 20 per cent and 30 per cent to reflect the respective increases in rainfall intensity. Results of the scenarios assessed are shown in **Table 4-8.**

Table 4-8: Potential impact of climate change on 100 year ARI flood levels at Berry Bridge (metres)

Location	Base case 100yr design flood level (mAHD)	Increase in rainfall intensity		
		10 per cent	20 per cent	30 per cent
Western abutment of the bridge at Berry	11.22	0.05	0.09	0.13

The results show that for a 10 per cent increase in rainfall, the increase in flood level is approximately 0.05 metres. The upper bound of the sensitivity analysis (30 per cent increase in rainfall) would result in an increase in flood level of up to 0.13 metres.

In light of the above, the potential impacts due to climate change at some point in the future are at worst expected to reduce the freeboard which would normally be available. The changes are within the available freeboard provided at this location. On this basis no additional allowance for climate change is considered necessary.

Potential climate change impacts at Broughton Creek

The potential effects of climate change have been investigated at the three proposed bridges over Broughton Creek and the results are listed in **Table 4.9.**

Table 4-9: Potential impact of climate change on 100 year ARI flood levels at Broughton Creek (metres)

Location	Base case 100yr design flood level (mAHD)	Increase in rainfall intensity		
		10 per cent	20 per cent	30 per cent
Broughton Creek bridge 1	36.66	0.13	0.26	0.38
Broughton Creek bridge 2	30.65	0.14	0.28	0.43
Broughton Creek bridge 3	27.65	0.13	0.26	0.38

The results show that for a 10 per cent increase in rainfall, the increase in flood level is approximately 0.1 metres. For the conservative case of a 30 per cent increase in rainfall, the increase in flood level would be approximately 0.4 metres at the three bridges.

In light of the above, the potential impacts due to climate change at some point in the future are at worst expected to reduce the freeboard which would normally be available. The changes are within the available freeboard provided at this location. On this basis no additional allowance for climate change is considered necessary.

4.3 Environmental management measures

4.3.1 Waterway crossings

To minimise the project's potential impact on flooding and to minimise the potential impact of the proposed waterway crossings on the environment, appropriate mitigation measures would be implemented to mitigate flooding. The design of drainage structures would allow for the natural flow of floodwaters and existing overland flow paths to be maintained post-construction where possible.

In order to minimise impacts on flow behaviour culverts would be located and, sized to adequately convey the 100 year ARI runoff event (if on the main alignment) and designed to meet the RMS's design velocity criteria. However, it should be noted that the hydrology and hydraulics of the culverts would be refined during detailed design. Climate change would also be taken into account as discussed in Section 4.3.3.

Bridge configurations would be designed to maintain existing flow patterns as far as possible to minimise increases in flood levels and velocities around the bridge structures. Minimising the clearance footprint for embankments and maintaining clear passage of stream channels, would assist in mitigating the construction impacts on the various creeks within the project area. Piers would be placed outside the main creek channels where possible, and would be designed and orientated to minimise the generation of turbulence and subsequent bed and bank erosion. The intrusion of the bridge abutments into the 100 year ARI flood extent would be limited to minimise flood level impacts.

The need for scour protection at any bridge or culvert crossing would be minimised through appropriate design measures. However, some form of scour protection or energy dissipation would be necessary at those waterway crossings with high velocities to prevent excessive erosion and potential damage to structures. Scour protection measures would be installed along the bed and banks upstream and downstream of these waterway crossings where appropriate and in accordance with relevant design guidelines.

These management measures would be further refined during the detailed design stage.

Broughton Creek

The embankment between Broughton Creek bridge 2 and Broughton Creek bridge 3 may be subject to floodwaters flowing parallel to the alignment and, along the toe of the embankment. Suitable batter treatment needs to be designed to prevent failure of the embankment due to scour.

Further detailed modelling, combined with refinement of the bridge configurations would be carried out as part of the detailed design phase to minimise flood and scour impacts.

Bridge at Berry and Town Creek diversion

As a minimum, all water quality basins located on the floodplain should be constructed at or close to ground level or replaced with swales.

Provision would be made for adequate freeboard in the Town Creek diversion channel to prevent overtopping and scour protection provided where velocities are high.

The assessment outlined in Section 4.3.5 of this report has shown that 11 properties are potentially at risk of adverse flood impacts. This assessment is based on the concept design which is subject to change with any optimisation measures introduced during detailed design. During detailed design potential impacts would be confirmed and necessary mitigation measures developed accordingly. The current recommended mitigation approach for each property, based on the concept design, is outlined below (refer **Figure 4-11** for property locations).

Properties 1, 2 and 3

It is recommended that the implications of these impacts and possible local mitigation measures such as diversion swales, local bunding or flood proofing of buildings be discussed with the property owner.

Alternatively, impacts could be offset by increasing the waterway area across the floodplain. To gain an understanding of the extent of works required to offset impacts two additional design scenarios were run and these are also included in **Table 4-7**. These additional scenarios would involve:

- Arrangement 1 - removing the water quality basins that are located in the floodplain; pulling in the retaining wall at the eastern abutment to maintain the existing flowpath from the billabong at property 3; and creating an opening in the western abutment 30 metres long.
- Arrangement 2 – same as Arrangement 1 with an opening in the western abutment 60 metres long; culverts in the southern abutment and additional retaining wall in the northern abutment as per Arrangement 1. In either case, given the sensitive nature of flooding in this area, all basins on the floodplain should be constructed at or close to ground level and/or replaced with bunded swales.

Properties 4 and 5

Local mitigation works should be discussed and agreed with the owner of property 4 and would include consideration of measures such as diversion swales, local bunding or flood proofing of buildings.

Floor level survey for property 5 shows the building is elevated over three metres above the 100 year ARI flood level. Consequently, the nominal increase in flood levels is not significant in the context of the impacts.

However, appropriate property mitigation measures may be warranted to address the impacts (which are 0.05 metres or less) if these are considered to be unacceptable. Local mitigation works should be discussed with the property owner and would include measures such as diversion swales, local bunding or flood proofing of buildings.

Properties 6, 7, 8, 9 and 11

Properties 6, 7, 8, 9 and 11 are located further downstream of the proposed road alignment. The nominal impacts at these properties would be primarily due to the diversion of flows from Town Creek. The increase in flood levels at these properties is considered minor relative to the existing degree of flood potential or inundation. Consequently, no additional local flood mitigation measures are expected to be required. This would however be subject to detailed design development.

Property 10

Property 10, the sports amenities building for the Berry sportsground and Camp Quality Memorial Park, is located immediately downstream of the southern bridge abutment. Relative flood level impacts based on the current concept design are negligible or minor.

4.3.2 Ancillary facilities

To reduce the risk of flood damage (and potential contamination of waterways) ancillary chemical storage facilities would be located above the 100 year ARI flood level.

Stockpile sites and ancillary construction material facilities would be sited above the 100 year ARI flood level where possible, but may be located above the 20 year ARI flood level. Where storage would be required on the floodplain (for activities such as bridgeworks) appropriate mitigation measures would be implemented, such as bunds around materials and equipment would be designed and scour protection applied to mitigate flood impacts.

In addition, the use of automatic weather stations (AWSs) would be considered to gather accurate and timely weather data and to facilitate weather warnings to construction contractors. AWSs are generally solar powered and record rainfall, wind speed and direction, temperature, relative humidity and dew point. The data is transferred to a remote server every 15 minutes over the 3G/4G telephone network. The data is then made available to RMS and contractors via the internet on an easy to navigate website. Information can also be sent to mobile phones by SMS. The AWSs can alert RMS staff and contactors of selected -predetermined weather conditions, such as when a site has received a certain rainfall amount in a day. This system can be used to mitigate potential adverse impacts of weather events.

4.3.3 Rehabilitation of waterways to pre-construction condition

Best practice management measures would be implemented during construction in accordance with applicable RMS QA specifications, Managing Urban Stormwater- Soils and Construction Volume 1 (Landcom, 2004) and Volume 2D – Main Road Construction (DECCW, 2008).

4.3.4 Climate change management measures

On the basis of the preceding assessment, the recommended measures to manage potential impacts due to climate change would involve:

- The provision of an appropriate freeboard of around 0.5 metres minimum for major bridge waterway crossings on Broughton Creek and Berry.
- The provision of a six per cent allowance for increased rainfall intensities. For minor waterway crossing culverts, additional impacts could feasibly be accommodated (if required) through future local adaptive measures such as culvert amplification and/or lifting the level of the highway.

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Appendix A

Assessment of creek property flood impacts - Berry

Assessment of creek property flood impacts - Berry

Property		100 year ARI Flood Level Note 1		Change in Flood Level Note 2	Floor level	Freeboard		Comment
Number	Street	Existing	Proposed			Existing	Proposed	
		(mAHD)	(mAHD)	(m)	(mAHD)	(m)	(m)	
110	North Street	15.00	14.97	-0.02	15.65	0.65	0.68	
112	North Street	14.92	14.81	-0.12	15.75	0.83	0.94	
114	North Street	14.89	14.77	-0.12	15.84	0.95	1.07	
118	North Street	14.40	14.30	-0.10	14.51	0.11	0.21	
120	North Street	14.04	13.96	-0.08	14.86	0.82	0.90	
122	North Street	13.90	13.83	-0.08	14.53	0.63	0.70	
124	North Street	13.84	13.80	-0.04	13.98	0.14	0.18	
124	North Street	13.86	13.79	-0.07	14.04	0.18	0.25	
124	North Street	13.86	13.82	-0.04	14.06	0.20	0.24	
126	North Street	13.55	13.49	-0.06	13.85	0.30	0.36	
126	North Street	13.55	13.49	-0.06	13.89	0.34	0.40	
126	North Street	13.19	13.17	-0.02	13.82	0.63	0.65	
126	North Street	13.33	13.30	-0.03	13.83	0.50	0.53	
126	North Street	13.45	13.42	-0.03	13.86	0.41	0.44	
130	North Street	13.08	12.95	-0.13	13.30	0.22	0.35	
130	North Street	12.82	12.69	-0.13	13.36	0.54	0.67	
138	North Street	12.13	12.12	-0.02	12.39	0.26	0.27	

Property		100 year ARI Flood Level Note 1		Change in Flood Level Note 2	Floor level	Freeboard		Comment
Number	Street	Existing	Proposed			Existing	Proposed	
0	North Street	12.17	12.17	-0.01	9.64	-2.53	-2.53	
150	North Street	11.99	11.87	-0.11	12.61	0.62	0.74	
2	Prince Alfred Street	8.79	8.75	-0.04	9.12	0.33	0.37	
7	Prince Alfred Street	8.99	8.95	-0.04	9.43	0.44	0.48	
67	Albert Street	11.22	11.17	-0.04	11.90	0.68	0.73	
10	Alexandra Street and Albert Street	11.42	11.35	-0.08	12.15	0.73	0.80	
62	Albert Street	11.85	11.81	-0.04	12.12	0.27	0.31	
0	Alexandra Street	11.98	11.96	-0.02	12.37	0.39	0.41	
65	Albert Street	12.12	12.07	-0.05	12.10	-0.02	0.03	Building no longer flooded
7	Alexandra Street	12.18	12.14	-0.04	12.70	0.52	0.56	
4	Alexandra Street	12.08	12.07	-0.02	12.20	0.12	0.13	
6	Alexandra Street	11.89	11.89	-0.01	12.49	0.60	0.60	
63	Albert Street	12.31	12.26	-0.04	12.51	0.20	0.25	
61	Albert Street	12.43	12.36	-0.07	12.82	0.39	0.46	
59	Albert Street	12.56	12.54	-0.02	13.23	0.67	0.69	
51	Albert Street	14.09	14.07	-0.02	14.49	0.40	0.42	
49	Albert Street	14.29	14.28	-0.01	14.78	0.49	0.50	
44	Albert Street	13.89	13.88	-0.01	14.44	0.55	0.56	
42	Albert Street	14.13	14.08	-0.04	14.53	0.40	0.45	

Property		100 year ARI Flood Level Note 1		Change in Flood Level Note 2	Floor level	Freeboard		Comment
Number	Street	Existing	Proposed			Existing	Proposed	
1	Albany Street	14.70	14.68	-0.01	15.87	1.17	1.19	
3	Albany Street	14.62	14.60	-0.02	15.19	0.57	0.59	
3a	Albany Street	14.57	14.56	-0.01	15.11	0.54	0.55	
18	Albert Street	17.98	17.96	-0.02	18.30	0.32	0.34	
4	Albert Street	17.98	17.96	-0.02	18.30	0.32	0.34	
2	Albert Street	18.11	17.73	-0.38	18.96	0.85	1.23	
2	Albert Street	18.10	17.77	-0.33	18.95	0.85	1.18	
2	Albert Street	18.12	17.98	-0.14	19.02	0.90	1.04	
2	Albert Street	18.13	17.96	-0.17	18.98	0.85	1.02	
2	Albert Street	18.02	17.97	-0.05	19.04	1.02	1.07	
2	Albert Street	17.98	17.94	-0.04	18.99	1.01	1.05	
2	Albert Street	17.99	17.67	-0.32	19.04	1.05	1.37	
2	Albert Street	18.01	17.71	-0.30	19.07	1.06	1.36	
3	Albert Street	18.31	18.30	-0.01	19.05	0.74	0.75	
1	Albert Street	18.23	18.21	-0.02	19.06	0.83	0.85	
64	Princess Street	9.82	9.51	-0.31	9.96	0.14	0.45	
66	Princess Street	9.69	9.59	-0.10	10.35	0.66	0.76	
15	Alexandra Street and Princess Street	10.23	10.11	-0.11	10.96	0.73	0.85	
61	Princess Street	10.50	10.24	-0.26	10.82	0.32	0.58	

Property Number	Street	100 year ARI Flood Level Note 1 Existing	Proposed	Change in Flood Level Note 2	Floor level	Freeboard Existing	Proposed	Comment
19	Alexandra Street	9.82	9.68	-0.14	10.42	0.60	0.74	
54	Princess Street	9.77	9.69	-0.09	11.78	2.01	2.09	
52	Princess Street	11.03	10.92	-0.11	11.89	0.86	0.97	
50	Princess Street	11.43	11.29	-0.14	12.07	0.64	0.78	
48	Princess Street	11.64	11.41	-0.24	12.04	0.40	0.63	
46	Princess Street	11.70	11.46	-0.24	12.13	0.43	0.67	
44	Princess Street	12.04	11.75	-0.28	12.45	0.41	0.70	
42	Princess Street	12.36	12.05	-0.31	12.26	-0.10	0.21	Building no longer flooded
11	Albany Street	12.48	12.42	-0.07	13.10	0.62	0.68	
13	Albany Street	12.64	12.54	-0.10	13.16	0.52	0.62	
15	Albany Street	12.55	12.52	-0.03	13.40	0.85	0.88	
36	Princess Street	12.96	12.87	-0.09	13.31	0.35	0.44	
34	Princess Street	13.29	13.04	-0.24	14.12	0.83	1.08	
33	Princess Street	13.64	13.62	-0.02	14.27	0.63	0.65	
26	Princess Street	13.65	13.33	-0.32	13.62	-0.03	0.29	Building no longer flooded
31	Princess Street	13.99	13.94	-0.05	14.62	0.63	0.68	
29	Princess Street	14.34	14.31	-0.04	14.59	0.25	0.28	
27	Princess Street	14.76	14.68	-0.08	15.04	0.28	0.36	
37	Edward street and Princess Street	14.88	14.55	-0.34	15.27	0.39	0.72	

Property		100 year ARI Flood Level Note 1		Change in Flood Level Note 2	Floor level	Freeboard		Comment
Number	Street	Existing	Proposed			Existing	Proposed	
33	Edward Street	15.53	15.11	-0.42	15.56	0.03	0.45	
19	Princess Street	15.92	15.81	-0.11	16.50	0.58	0.69	
17	Princess Street	16.21	16.21	-0.01	16.48	0.27	0.27	
51a	Victoria Street	13.54	13.33	-0.22	14.41	0.87	1.08	
53	Victoria Street	13.45	13.36	-0.08	14.16	0.71	0.80	
22	Alexandra Street and Victoria Street	9.46	9.11	-0.35	9.55	0.09	0.44	
66	Victoria Street	7.37	7.00	-0.37	7.65	0.28	0.65	
68	Victoria Street	8.70	8.42	-0.27	8.78	0.08	0.36	
87	Victoria Street	9.47	9.31	-0.15	9.57	0.10	0.26	
70	Victoria Street	8.98	8.95	-0.03	9.17	0.19	0.22	
35	Prince Alfred Street	6.97	6.95	-0.02	7.44	0.47	0.49	
43	Prince Alfred Street	6.96	6.94	-0.02	6.79	-0.17	-0.15	
45	Prince Alfred Street	6.96	6.94	-0.02	7.26	0.30	0.32	
80	Queen Street	11.30	11.30	-0.01	12.30	1.00	1.00	
46	Queen Street	15.99	15.76	-0.23	16.58	0.59	0.82	
44	Queen Street	16.44	16.34	-0.10	16.38	-0.06	0.04	Building no longer flooded
42	Queen Street	16.51	16.12	-0.39	16.35	-0.16	0.23	Building no longer flooded
40	Queen Street	16.61	16.16	-0.44	16.76	0.15	0.60	
38	Queen Street	16.62	16.17	-0.46	16.59	-0.03	0.42	Building no longer flooded

Property Number	Street	100 year ARI Flood Level Note 1 Existing	Proposed	Change in Flood Level Note 2	Floor level	Freeboard Existing	Proposed	Comment
36	Queen Street	17.44	17.38	-0.06	17.57	0.13	0.19	
24	Queen Street and George Street	17.93	16.89	-1.04	19.02	1.09	2.13	
24	Queen Street and George Street	17.93	17.21	-0.73	19.02	1.09	1.81	
24	Queen Street and George Street	17.96	17.40	-0.55	18.93	0.97	1.53	
24	Queen Street and George Street	17.96	17.42	-0.54	18.95	0.99	1.53	
35	Queen Street	17.82	17.60	-0.22	17.76	-0.06	0.16	Building no longer flooded
35	Queen Street	17.85	17.71	-0.14	17.77	-0.08	0.06	Building no longer flooded
35	Queen Street	17.87	17.64	-0.23	17.75	-0.12	0.11	Building no longer flooded
37	Queen Street	17.52	17.37	-0.14	17.83	0.31	0.46	
37	Queen Street	17.79	17.58	-0.21	18.07	0.28	0.49	
37	Queen Street	17.82	17.59	-0.23	18.10	0.28	0.51	
39	Queen Street	17.55	17.43	-0.12	17.63	0.08	0.20	
41	Queen Street	17.37	17.34	-0.03	17.49	0.12	0.15	
65	Queen Street	13.58	13.57	-0.01	14.39	0.81	0.82	
65	Queen Street	13.75	13.74	-0.01	14.32	0.57	0.58	
65	Queen Street	13.88	13.86	-0.02	14.25	0.37	0.39	
65	Queen Street	13.95	13.93	-0.03	14.29	0.34	0.36	
65	Queen Street	13.95	13.92	-0.03	14.31	0.36	0.39	
65	Queen Street	13.98	13.96	-0.02	14.30	0.32	0.34	

Property		100 year ARI Flood Level Note 1		Change in Flood Level Note 2	Floor level	Freeboard		Comment
Number	Street	Existing	Proposed			Existing	Proposed	
69	Queen Street	13.45	13.43	-0.02	13.78	0.33	0.35	
71	Queen Street	13.41	13.40	-0.01	13.89	0.48	0.49	

Notes 1. Flood level has been extracted from flood surface DTM at point location of floor level survey and may therefore be influenced by local features.

A positive relative impact represents an increase in flood level under proposed conditions relative to existing conditions.

2. A change in flood level of +/-0.01m is considered to be within the level of accuracy of the model and have negligible or no impact.

3. A negative freeboard represents the depth of above floor inundation.