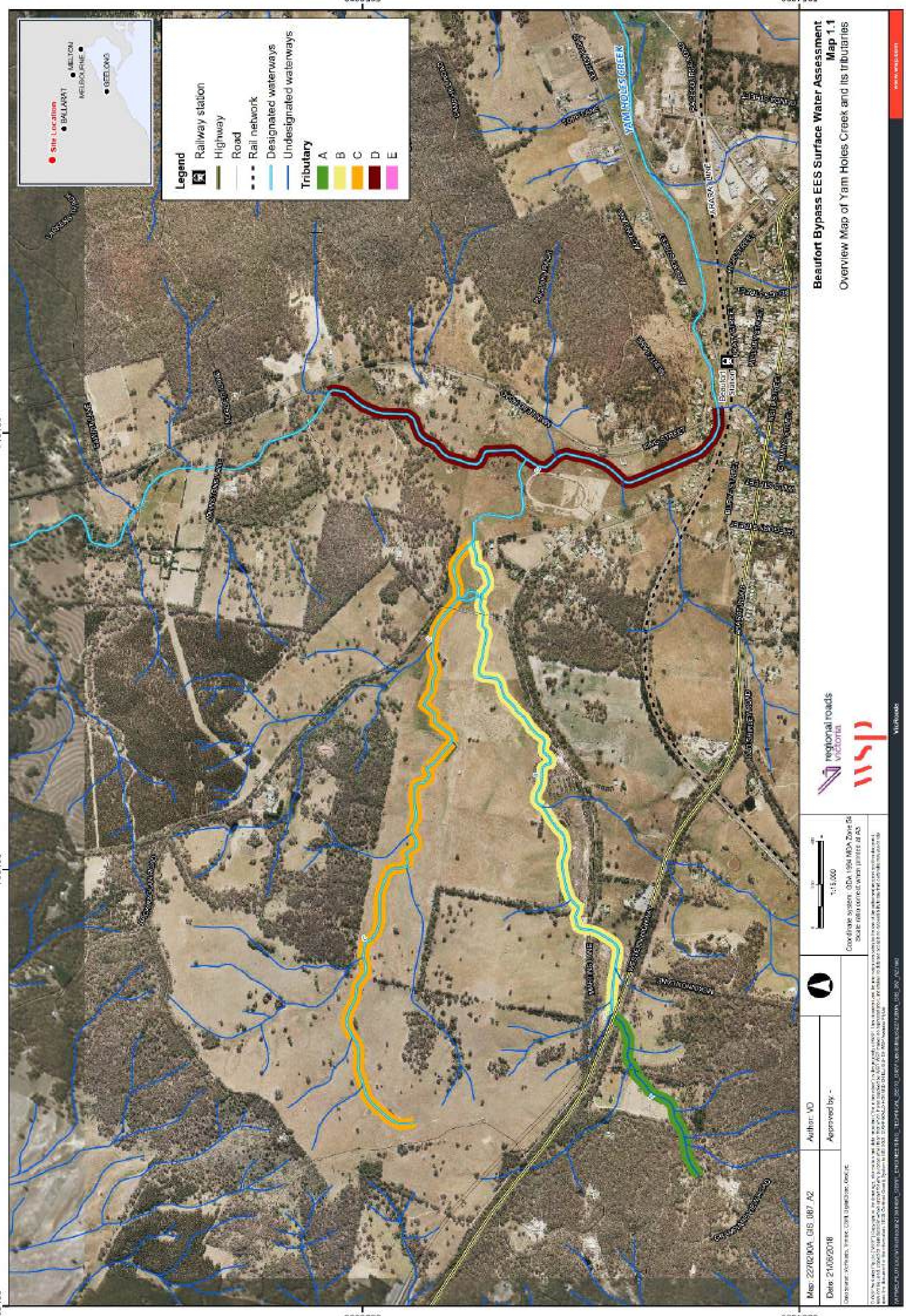


Figure 6.10 Yam Holes Creek Tributaries (Map 1.1)

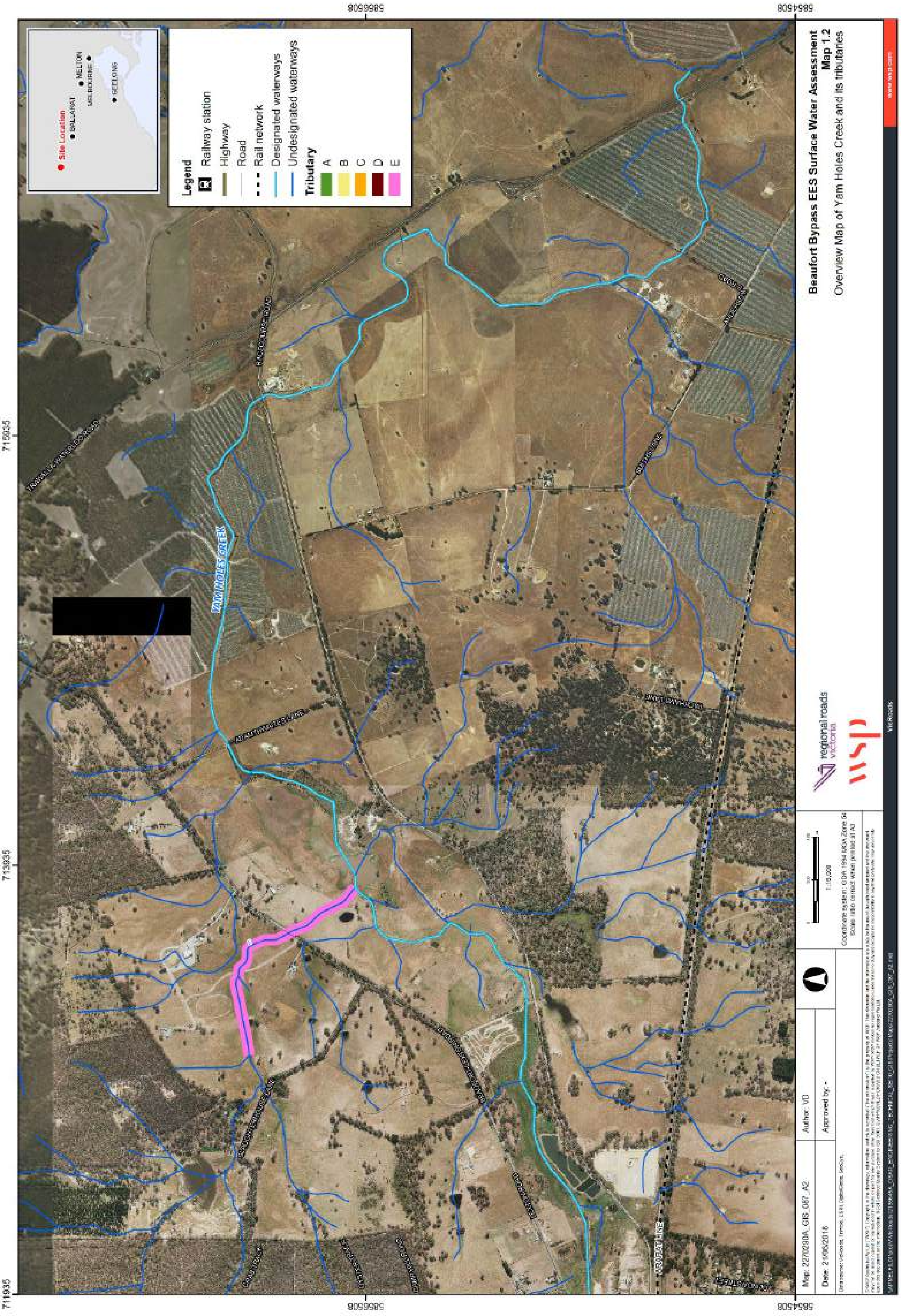


Figure 6.11 Yam Holes Creek Tributaries (Map 1.2)

6.4.1 TRIBUTARY A (LATITUDE -37.42391, LONGITUDE 143.34793)

This tributary is an un-designated, small ephemeral watercourse located approximately 4.2 km upstream of Yam Holes Creek (at King Street bridge). The catchment contributing runoff towards this tributary is located to the south of the Western Highway and is predominately a forest area. The tributary was dry on the day of the site visit.

Immediately upstream of the existing Western Highway, this tributary was realigned as part of the highway construction. The channel at this location is trapezoidal and rock lined with geotextile. The banks of the channel are graded at approximately 3H:1V with sparse grass vegetation (refer to Photo 6.1). Further upstream of the crossing with the Western Highway (and the slip road of the Western Highway), the channel is not well defined. The banks of the channel were not visible due to long grasses and rushes along upstream flow path (refer to Photo 6.2).

The upstream floodplain has gently sloping topography that directs runoff towards the flow path of the tributary. At the time of the site visit, vegetation in the floodplain comprise short grasses and exposed soil. The tree line of the forest area located further upstream in the catchment was visible from the Western Highway (refer to Photo 6.2).

The tributary flows under the slip road of Western Highway via 1.5 m×1.5 m box culverts (refer to Photo 6.3 and Photo 6.4).

Photo 6.1 Rock lined channel located upstream of box culvert at Western Highway

Photo 6.2 Floodplain looking upstream at west tie-in with Western Highway

Photo 6.3 Box culvert located at slip road of west tie-in with Western Highway

Photo 6.4 Box culvert at Western Highway

6.4.2 TRIBUTARY B (LATITUDE -37.41774, LONGITUDE 143.36895)

This tributary is a small ephemeral watercourse and a GHCMA Designated waterway (2-1/108-2). Bypass alignment option C0 and C2 intersect this tributary downstream of Back Raglan Road. The tributary converges with another tributary (reference Tributary C) approximately 375 m downstream of Back Raglan Road prior to flowing parallel to Main Lead Road and is named Yam Holes Creek at King Street bridge. The site photographs of the tributary were taken from Back Raglan Road. The catchment area contributing runoff to this tributary is located adjacent to Martin's Lane and south of the Western Highway. The catchment is rural and influenced by agricultural activity. Other land uses in the catchment include a forest area and rural housing.

The tributary conveys flows via two 700 mm diameter circular culverts beneath Back Raglan Road (refer to Photo 6.5). Immediately upstream of the culvert crossing at Back Raglan Road, uneven ground levels and overgrown vegetation indicates pooling and infiltration of runoff occurs prior to water levels reaching the invert level of the existing culverts. Upstream of Back Raglan Road, the flow path was difficult to view as there was no defined channel. The floodplain upstream of Back Raglan Road is open with vegetation coverage varying from overgrown grasses to overgrazed fields with exposed soil (refer to Photo 6.6).

Downstream of Back Raglan Road, the tributary meanders through the floodplain. The channel at this location shows signs of erosion with side slopes almost vertical or undercut. It was observed the base width of the tributary is approximately 1.5 m and side slope depths are greater than 1 m (refer to Photo 6.7). Neither the tributary bed or side slopes were vegetated downstream of Back Raglan Road. The floodplain downstream of Back Raglan Road is gently sloping towards the tributary with vegetation predominately comprising short grass cover (refer to Photo 6.8).

Photo 6.5 Circular culverts at Back Raglan Rd

Photo 6.6 Floodplain upstream of Back Raglan Rd

Photo 6.7 Channel downstream of Back Raglan Rd

Photo 6.8 Floodplain downstream of Back Raglan Road

6.4.3 TRIBUTARY C (LATITUDE -37.41638, LONGITUDE 143.36915)

This tributary is a small ephemeral watercourse and a GHCMA Designated waterway (2-2/108-2). This tributary converges with another tributary (reference Tributary B) approximately 375 m downstream of Back Raglan Road. The tributary then flows parallel to Main Lead Road and is named Yam Holes Creek at King Street bridge. All bypass alignment options intersect with this tributary either upstream or downstream of Back Raglan Road.

The catchment area contributing runoff to this tributary is located north of the current Western Highway alignment and west of Main Lead Road. The catchment is rural and influenced by agricultural activity. Other land uses in the catchment include a forest area and rural housing. The site photos of the tributary were taken at Back Raglan Road.

At the culvert crossing at Back Raglan Road, the upstream floodplain is open and, at the time of the site inspection, had no vegetation. A portion of the catchment located to the north of the overgrazed field comprises short grasses (refer Photo 6.9). The tributary at this location is an undefined channel that was dry during the site visit. Based on a review of maps, the flow path for this tributary is located within and to the north of the overgrazed field. The Back Raglan Road crossing of Tributary C at this location was very overgrown, in poor condition and was measured as a single span culvert (1.2 m wide×1 m high) (refer Photo 6.10).

The proposed A0 bypass alignment crosses this tributary approximately 460 m upstream of Back Raglan Road. Access to the tributary at this location was not possible the day of the site visit. The floodplain at this location is open and comprises short grass. A forest area with mature trees is near to the north of Alignment A0 (refer Photo 6.11).

Downstream of Back Raglan Road, the floodplain is also open and gently sloping with short grass vegetation. The flow path at this location is more defined although quite shallow and at the time of the site visit, was covered with dead vegetation and was dry (refer Photo 6.12).

Photo 6.9 Upstream flow path at Back Raglan Rd

Photo 6.10 Single span bridge at Back Raglan Rd

Photo 6.11 Approximate location of A0 bypass alignment (460 m upstream of Back Raglan Rd)

Photo 6.12 Floodplain and channel downstream of Back Raglan Road

6.4.4 TRIBUTARY D (PARALLEL TO MAIN LEAD ROAD)

The tributary located to the west and parallel to Main Lead Road is a GHCMA Designated waterway (-108-3). This tributary is named Yam Holes Creek at King Street bridge. The land use of the catchment area contributing runoff to this unnamed tributary is agricultural and includes the forested area of Camp Hill Reserve.

All bypass alignment options intersect this tributary. During the site visit, access to the tributary was not possible (no landowner permission), however, photographs of the floodplain at the location of the proposed bypass alignments were taken from the nearest access point.

At the proposed bypass alignment A0 and A1, the tributary channel meanders and is overgrown with long grasses and reeds. The floodplain is less open at this location and comprises short grasses, reeds and mature eucalyptus trees (refer to Photo 6.13 and Photo 6.14).

At the proposed bypass alignment C0 and C2, the floodplain is fenced and has an agricultural value. The topography of the floodplain is gently sloping, with no mature trees and vegetated with short to medium height grasses and rushes (refer to Photo 6.15).

Photo 6.13 Approximate floodplain at alignment A0 and A1 from Main Lead Road

Photo 6.14 Approximate floodplain at alignment A0 and A1 from Main Lead Road

Photo 6.15 Floodplain at proposed bypass alignment C0 and C2 at the riding track

6.4.5 TRIBUTARY E (LATITUDE -37.4103, LONGITUDE 143.41369)

This tributary is in the sub-catchment of 'Yam Holes Creek downstream of Beaufort' and is not a Designated waterway. The tributary intersects Beaufort-Lexton Road and converges with Yam Holes Creek approximately 385 m downstream of Beaufort-Lexton Road. Bypass alignment options A0 and A1 intersect with this tributary upstream of Beaufort-Lexton Road.

Much of the catchment area contributing runoff to this tributary is located to the north and west of Beaufort-Lexton Road. The catchment is rural and influenced by agricultural activity and includes forest areas.

At the Beaufort-Lexton Road bridge, the upstream and downstream floodplain comprise agricultural land, gently sloping topography and vegetated with predominately short to medium grass with very few mature trees. The tributary is a shallow flow path and overgrown with medium height grasses (refer to Photo 6.16 and Photo 6.17).

The bridge crossing at Beaufort-Lexton Road is a single span bridge (3.5 m wide×1.1 m high) (refer to Photo 6.18).

Photo 6.16 Floodplain upstream of Beaufort-Lexton Road

Photo 6.17 Floodplain and channel downstream of Beaufort-Lexton Road

Photo 6.18 Upstream face of circular culverts at Beaufort-Lexton

6.4.6 YAM HOLES CREEK (DOWNSTREAM OF BEAUFORT TOWN)

All bypass alignments intersect Yam Holes Creek in the sub-catchment of Yam Holes Creek downstream of Beaufort. Yam Holes Creek is a GHCMA Designated waterway (-10-108) and was dry at the time of the site visit.

Access to Yam Holes Creek to view the characteristics of the channel and floodplain was limited to two locations; Beaufort Blue Light Motorcycle Club and Racecourse Road.

Bypass alignment C0 intersects Yam Holes Creek at the Blue Light Motorcycle Club. The upstream floodplain at this location comprises dense vegetation on both sides of the creek. The geometry of the channel is trapezoidal with shallow side slopes connecting the creek to the floodplain. The channel bed and side slopes are vegetated with short grass, refer to Photo 6.19.

Downstream of the Blue Light Motorcycle Club access road, a v-notch weir is in the channel of Yam Holes Creek. The downstream floodplain at this location is open and vegetated with short grasses, refer to Photo 6.20.

Photo 6.19 Yam Holes Creek upstream of Blue Light Motorcycle Club access road

Photo 6.20 Yam Holes Creek upstream of Blue Light Motorcycle Club access road

A view of the catchment at the nearest location to Yam Holes Creek intersecting the bypass alignments A0 and A1 was taken from Racecourse Road. The catchment at this location is open with very few mature trees or dense vegetation. The topography is gently sloping with short to medium height grass vegetation cover, refer to Photo 6.21.

At the intersection of Yam Holes Creek at Racecourse Road, the upstream channel is well defined with an approximate base width of 1.5 m and depth of 1 m (based on observations); refer to Photo 6.22. The channel was not vegetated on the base or side slopes and does not appear to grade evenly. The channel meanders in the upstream floodplain with low points in the channel bed that would allow water to pool. The floodplain upstream at this location is also gently sloping with short to medium height vegetation. Further upstream Yam Holes Creek flows through a forest area/tree plantation.

Photo 6.21 Yam Holes Creek floodplain at the bypass alignments A0 and A1

Photo 6.22 Yam Holes Creek and floodplain upstream of Racecourse Road

Downstream of Racecourse Road, Yam Holes Creek is a shallow watercourse, trapezoidal in geometry and with a base width of approximately 1.5 m (based on observations). The banks of the creek are overgrown with medium vegetation. The channel is not vegetated on the base or side slopes and meanders through the floodplain. The floodplain downstream of Racecourse Road has short to medium vegetation cover with a large spoil mound located adjacent to Yam Holes Creek, refer to Photo 6.23 and Photo 6.24.

Photo 6.23 Yam Holes Creek bridge crossing at Racecourse Road

Photo 6.24 Yam Holes Creek and floodplain downstream of Racecourse Road

6.5 HYDROLOGIC ASSESSMENT

A calibrated RORB rainfall-runoff model for Yam Holes Creek to Beaufort was developed for the Beaufort Flood Study by Water Technology (2008). This model was used as the basis for hydrologic modelling of the study area. The RORB model was used to estimate the flood hydrographs at different locations within the study area.

RORB, originally developed by Monash University, is a general runoff and streamflow routing program used to calculate flood hydrographs from rainfall and other channel inputs. It subtracts losses from rainfall to produce rainfall-excess and routes this through catchment storage to produce runoff hydrographs at any location. It can be used both for the calculation of design hydrographs and for model calibration by fitting to rainfall and runoff data of recorded events. The model is spatially distributed, nonlinear, and applicable to both urban and rural catchments (Laurenson et al, 2010).

Given the lack of streamflow data for the Yam Holes Creek catchment (refer to Section 6.3), two RORB models were developed for the Beaufort Flood Study by Water Technology (2008). Water Technology initially developed a model of Mount Emu Creek to run several calibration events to allow selection of model routing parameters (Kc and m) and loss parameters (initial loss and continuing loss). The Mount Emu Creek model was calibrated using streamflow data for Mount Emu Creek at Mena Park (Station No. 236213), refer to Section 6.3.2. Subsequently, a RORB model for Yam Holes Creek to Beaufort was developed, drawing on scaled parameters from the Mount Emu Creek model calibration.

The 2008 Beaufort Flood Study notes that despite the effort applied to the hydrologic analysis, considerable uncertainty remains in the adoption of appropriate RORB model parameters for the Yam Holes Creek catchment. This is due to the imprecise nature of the parameter selection approach. However, it is considered that the calibration process for the Mount Emu Creek model has provided a reasonable basis for runoff generation process within the Mount Emu and Yam Holes Creek catchments. The calibrated model parameters from the Beaufort Flood Study are provided in Table 6.3.

Table 6.3 Calibrated RORB model parameters for Yam Holes Creek (adopted from Beaufort Flood Study, Water Technology, 2008)

PARAMETER	VALUE
Kc (empirical coefficient applicable to the catchment)	8.8
M (measure of catchment non-linearity)	0.8
Initial loss	19.75 mm
Continuing loss	1.0 mm/hr

The RORB model of Yam Holes Creek (Water Technology, 2008) was made available for this assessment. The original model ends just past the township of Beaufort and does not cover the Yam Holes Creek waterway crossings of the proposed alignment options downstream of Beaufort. The catchment of the original model was therefore extended downstream to the confluence of Mount Emu Creek as part of this assessment. A sub catchment plan showing the original and extended RORB model network is provided in Figure 6.12.

No additional hydrometric stations, that could be used in the model calibration, are within the extended catchment. Therefore, the same hydrologic parameters in Table 6.3 were used in the extended RORB model. This assumes the hydrologic characteristics of the extended catchment is largely similar to the original catchment used for calibration.

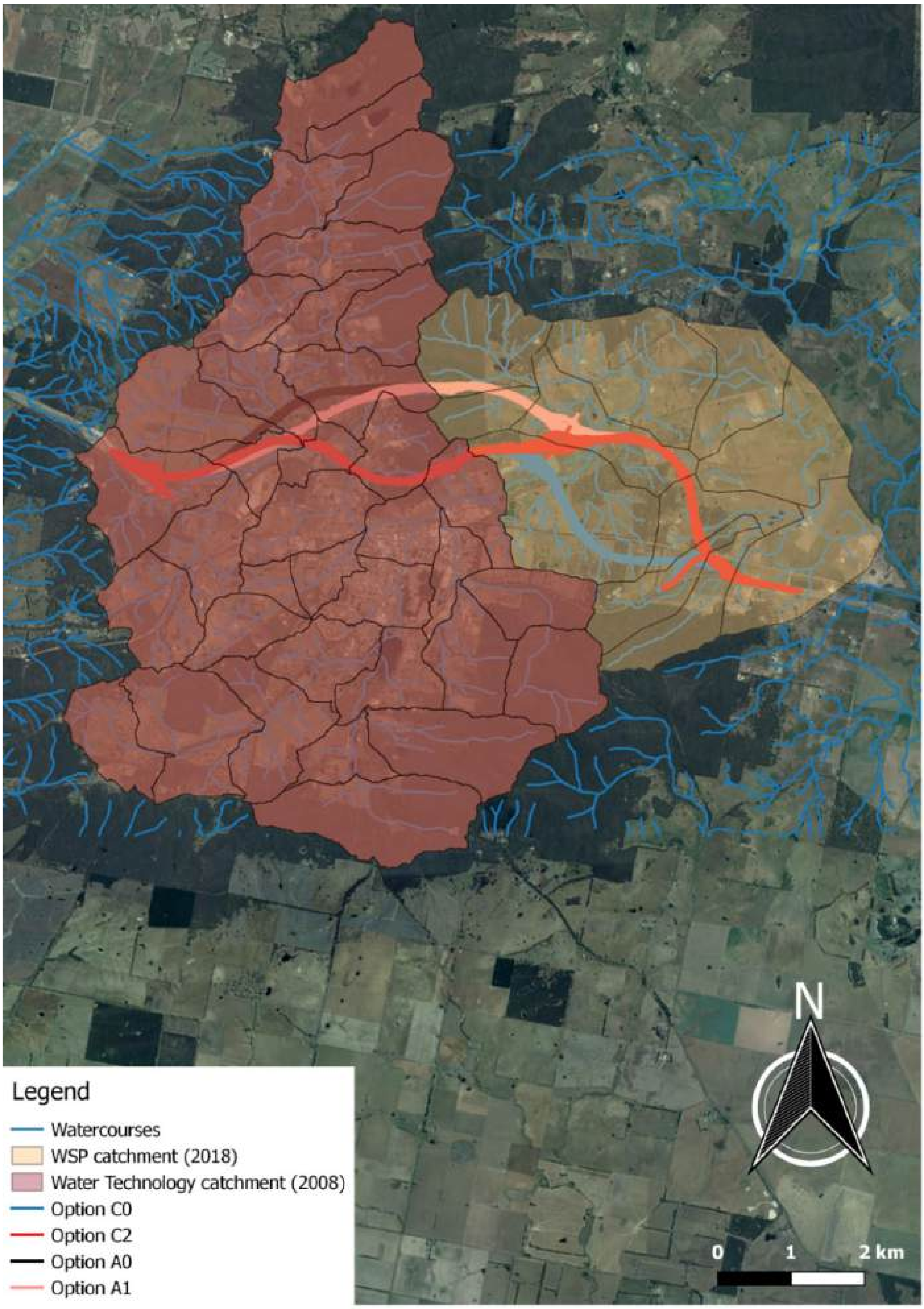


Figure 6.12 Yam Holes Creek sub catchment plan for the extended RORB model

The extended RORB model was used to estimate existing peak flow rates at the Yam Holes Creek waterway crossings of the proposed alignment options. Peak flow rates for the 1% AEP 6-hour duration storm event are summarised in Table 6.4.

Table 6.4 Base case peak flows at major waterway crossing locations of proposed alignments

KEY CROSSING (REFER TO MAPS 8.1 AND 8.2 IN APPENDIX A)	1% AEP PEAK FLOW (m^3/s)			
	Option A0	Option A1	Option C0	Option C2
Sub-catchment - Yam Holes Creek upstream of Beaufort				
Tributary C	9.2	13.2	–	–
Tributary D	32.7	32.7	38.2	38.2
Sub-catchment Yam Holes Creek downstream of Beaufort				
Yam Holes Creek	146.7	146.7	141.7	146.7

6.6 FLOODING

6.6.1 PLANNING OVERLAYS

Yam Holes Creek and its tributaries at Beaufort have planning overlays of FO and LSIO. These planning overlays identify waterways that have major flow paths, high flood hazard areas and the floodplain extent of the 1% AEP. The definitions and objectives of FO and LSIO are presented in Table 5.2.

In the sub-catchment Yam Holes Creek to Beaufort, bypass alignment Options C0 and C2 intersect the FO and LSIO between Main Lead Road and Back Raglan Road for approximate 1.3 km (following the centre line of the un-named tributaries of Yam Holes Creek).

In the sub-catchment Yam Holes Creek downstream of Beaufort, the bypass alignment Option C0 intersects the FO and LSIO at Yam Holes Creek located at the Blue Light Motorcycle Club for an approximate length of 480 m (following the centre line of Yam Holes Creek and the un-named tributary).

All four bypass alignment options require embankments to be constructed to convey the road across the FO and LSIO areas, refer to Map 2 in Appendix A.

6.6.2 REVIEW OF PREVIOUS FLOOD MODEL

Two previous hydraulic modelling studies were carried out in Beaufort namely:

- Beaufort Flood Study (Water Technology, 2008)
- Railway and Cumberland Creek Culverts (Water Technology, 2012).

The Beaufort Flood Study (Water Technology, 2008) was initiated by the GHCMA and Pyrenees Shire Council in response to concern over uncertainties in understanding and definition of flood risk for the Beaufort township. The study provided information on flood levels and flood risk within the Beaufort township.

As part of the 2012 study, the Pyrenees Shire Council was provided with a set of design drawings for proposed culvert upgrades for the railway line as well as a proposed floodway and culvert for Cumberland Creek at Racecourse Road. These structures were assessed by Water Technology to determine their effectiveness in reducing flood levels upstream of the railway.

A summary of the review of the above modelling studies is provided in Appendix B.

6.6.3 BEAUFORT BYPASS FLOOD MODEL

To investigate the potential impacts of the proposed bypass alignments, a flood model of Yam Holes Creek and its tributaries was developed. The flood model was used to establish the base case (pre-Beaufort Bypass) flood extent for the 1 EY, 10% AEP and 1% AEP events.

As well as establishing the base case, the hydraulic model was used to estimate flood impacts for each bypass alignment option and the preferred option. The results of the flood impact assessments are provided in Sections 7 and 9.

This section summarises the key inputs and results from the base case model (existing conditions). A technical memorandum summarising the modelling approach, assumptions and limitations has been provided in Appendix C.

6.6.3.1 HYDRAULIC MODEL

The model includes the tributaries contributing flow to Yam Holes Creek located north of the Western Highway, Yam Holes Creek and its tributaries in the township of Beaufort and Yam Holes Creek downstream of Beaufort township. The downstream model extent is approximately 890 m upstream from the crossing of Yam Holes Creek and Racecourse Road, and approximately 4.7 km upstream from the confluence between Yam Holes Creek and Mount Emu Creek.

The land use in the study area beyond the township of Beaufort comprises of agricultural land, forested areas and rural settlements. Within Beaufort township land use comprises residential, commercial and industrial zoning. All Beaufort alignment options cross the V/Line rail to the east of Beaufort township.

The existing infrastructure data included in the base case model are the elevation and dimensions of road and railway embankments, bridges and culverts were derived from VicRoads' database, feature survey, data embedded in the Beaufort flood model (Water Technology, 2008), the railway line upgrade culvert (Water Technology, 2012) and the data surveyed during site visits.

Verification of the hydraulic model was carried out against the 2008 Water Technology flood model at Beaufort.

6.6.3.2 HYDROLOGY

The RORB hydrology model characterised the catchment's reaction to rainfall and estimated peak flows in the study area for different AEPs. Hydrographs corresponding to the critical storm events were used as local boundary conditions in the hydraulic model.

Details of the RORB hydrology model are presented in Section 6.5.

6.6.3.3 BASE CASE (EXISTING CONDITIONS) RESULTS

The two-dimensional hydraulic model produced results for the 1 EY, 10% and 1% AEP flood depth, flood velocity, flood duration and flood hazard (velocity × depth) for the base case. These results are shown on maps in Appendix A.

The base case flood model suggests in the west of the Beaufort township, out of bank flooding is occurring particularly along Main Lead Road, King Street, Back Raglan Road and Jackson Street.

Downstream of Beaufort township, Yam Holes Creek has an extensive floodplain, with water depths at the bypass crossings varying from between 1.34 m (for Bypass A0, A1 and C2) to 1.5 m (for Bypass C0). The Yam Holes Creek 1% AEP floodplain extends approximately:

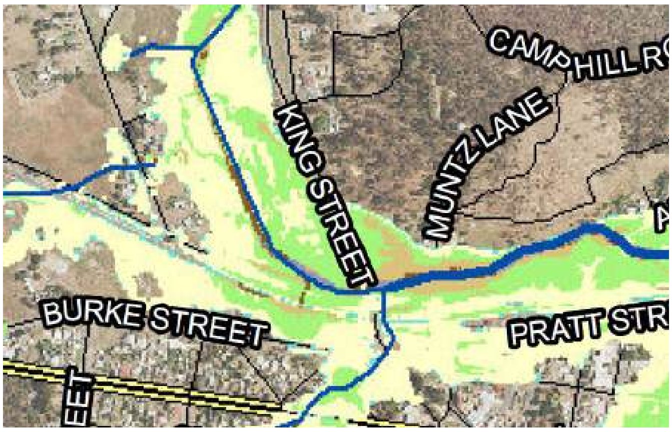
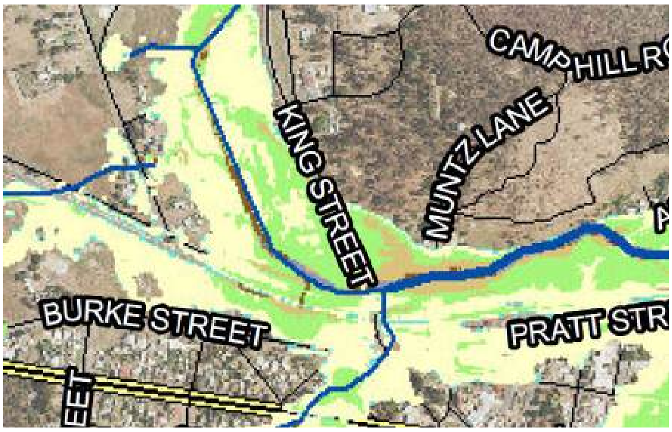
- 750 m at the intersection of Bypass A0 and A1
- 810 m at Bypass C2 crossing; and
- 300 m at Bypass C0 crossing.

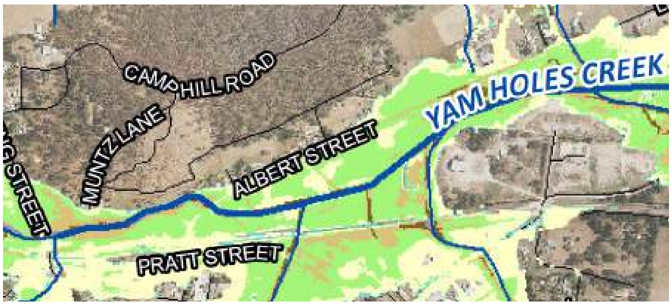
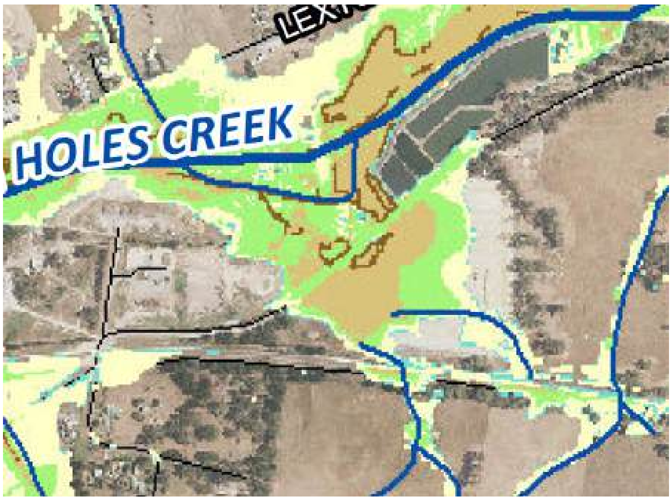
Between the bypass alignment options crossings with Yam Holes Creek and the downstream boundary of the model, the floodplain generally maintains its width, which is characteristic of the open gently grading topography. Flooding of Beaufort-Lexton Road and Racecourse Road is occurring during the 1% AEP event.

A summary of the maximum flood depths and flood lengths is provided in Table 6.5. The flood depth values provided in Table 6.5 are rounded to one decimal place, while total flood lengths are rounded to nearest 5 metres.

Flooding conditions at the Beaufort township were previously reported in the 2008 Water Technology Report and are not discussed further in this report.

Table 6.5 Flood depths at existing roads upstream and downstream of Beaufort

ROAD	1% AEP MAX FLOOD DEPTH	TOTAL 1% AEP FLOOD LENGTH	LOCATION
Back Raglan Road	0.9 m	315 m	
King Street	0.4 m	200 m	
Jackson Street	1.1 m	160 m	

ROAD	1% AEP MAX FLOOD DEPTH	TOTAL 1% AEP FLOOD LENGTH	LOCATION
Beaufort-Lexton Road	1.2 m	1200 m	
Racecourse Road	0.9 m	470 m	

6.7 WATER QUALITY

6.7.1 GHCMA SURFACE WATER MONITORING SITES

GHCMA has an ongoing sampling regime at 20 sites throughout the Glenelg Hopkins Basin as part of the Victorian Water Monitoring Partnership. The GHCMA do not have monitoring sites within the Yam Holes Creek catchment. However, there are three monitoring sites in the wider Glenelg Hopkins Basin where there are event samplers that are triggered during high rainfall events. This data provides a general context of water quality within the wider region and provides a comparison to the SEPP (Waters) environmental quality objectives. These samplers are located in the:

- Glenelg River at Dartmoor (Station 238206) (Latitude -37.92, Longitude 141.28)
- Grangeburn at Morgiana (Station 238219) (Latitude -37.71, Longitude 141.83)
- Wannon River at Henty (Station 238228) (Latitude -37.65, Longitude 141.51).

Figure 6.13 presents the locations of these surface water quality monitoring stations in the wider Glenelg Hopkins Basin. The GHCMA do not have an ongoing water quality sampling regime at Yam Holes Creek or Mount Emu Creek. Other sources of stream water quality data, such as Pyrenees Shire Council water quality sampling (refer to Section 6.7.2) and the Index of Stream Condition Report ISC3 (refer to Section 6.7.3) are used to provide an indication of the existing catchment water quality conditions.

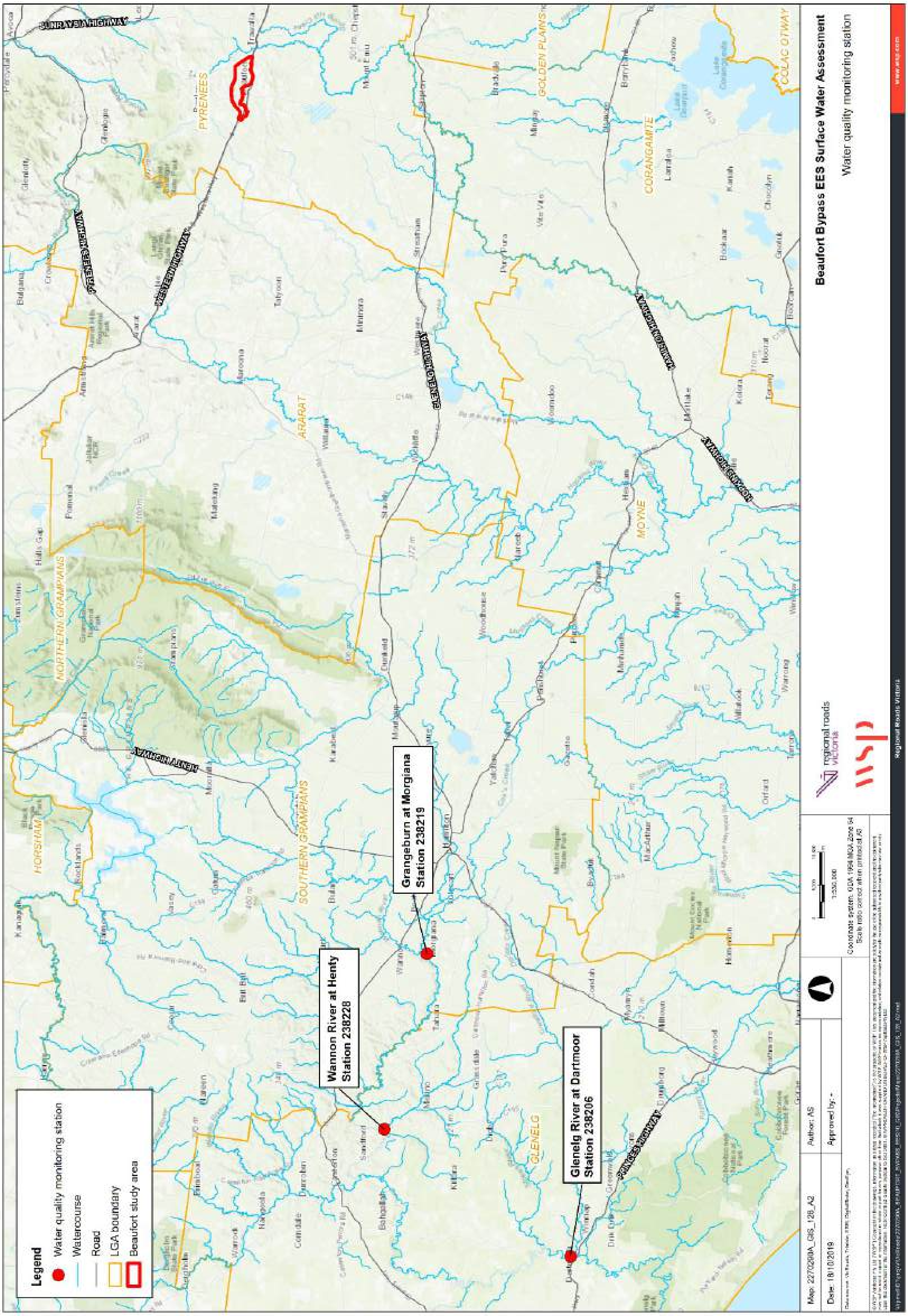


Figure 6.13 GHCMA water quality monitoring stations

Water quality summary statistics for monitoring undertaken in 2015 are available from DELWP for the Glenelg River at Dartmoor and Wannon River at Henty stations and are summarised in Table 6.6 and Table 6.7, respectively. The stations water quality monitoring results were compared to SEPP (Waters) environmental quality indicators and objectives, provided in Table 4.2. Cells highlighted in green indicate SEPP (Waters) environmental quality objectives were met, while cells highlighted in red indicate SEPP (Waters) environmental quality objectives were not met.

Table 6.6 Water quality percentiles for 2015 – Glenelg River at Dartmoor (Station 238206)

PARAMETER	COUNT	MIN	10%	25%	50%	75%	90%	MAX
Acidity/Alkalinity (pH)	12	7.7	7.8	7.8	7.9	7.93	8	8
Dissolved Oxygen (ppm)	12	7.9	8.02	8.5	8.85	9.65	10.07	10.5
Water Temperature (°C)	12	9.2	11.2	11.6	15.9	17.9	21	21.6
Turbidity (NTU)	12	3.1	3.4	4.4	5.7	7.4	10.5	17.4
Conductivity (µS/cm)	12	1920	1952	2112.5	2235	2652.5	2987	3260
Colour (True Filtered) (PCU)	12	2	16.2	19.5	26.5	35	53.9	75
Total Suspended Solids (mg/l)	12	4	5.1	6	6.5	9.25	20.8	22
Nitrate + nitrite as N – total (mg/l)	12	0.17	0.217	0.4225	0.66	0.7975	0.982	1
Kjeldahl Nitrogen (mg/l)	12	0.01	0.465	0.525	0.565	0.705	0.789	0.8
Total Phosphorus as P (mg/l)	12	0.01	0.01	0.02	0.02	0.02	0.03	0.03
Filtered Reactive Phosphorus (mg/l)	12	0.003	0.003	0.003	0.003	0.004	0.0049	0.005

Table 6.7 Water quality percentiles for 2015 – Wannon River at Henty (Station 238228)

PARAMETER	COUNT	MIN	10%	25%	50%	75%	90%	MAX
Acidity/Alkalinity (pH)	12	7.8	7.9	7.98	8.05	8.23	8.3	8.3
Dissolved Oxygen (ppm)	12	5.9	6.81	7.275	9.75	11.125	11.68	12.6
Water Temperature (°C)	12	8.5	10.8	11.5	14.8	18.2	19.8	20.7
Turbidity (NTU)	12	3.4	4.3	4.8	5.9	7.2	8.1	10.3
Conductivity (µS/cm)	12	4480	4537	4622.5	4895	5580	5739	5900
Colour (True Filtered) (PCU)	11	2	30	31	35	42.5	48	56
Total Suspended Solids (mg/l)	11	2	2	5.5	8	9.5	11	14
Nitrate + nitrite as N – total (mg/l)	11	0.003	0.003	0.003	0.003	0.0045	0.011	0.015
Kjeldahl Nitrogen (mg/l)	11	0.6	0.61	0.635	0.67	0.905	1.1	1.5
Total Phosphorus as P (mg/l)	11	0.02	0.02	0.02	0.03	0.03	0.04	0.09
Filtered Reactive Phosphorus (mg/l)	11	0.003	0.003	0.003	0.003	0.003	0.004	0.007
Arsenic as – total (mg/l)	11	0.001	0.001	0.001	0.001	0.0015	0.002	0.002
Chromium as Cr – total (mg/l)	11	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Copper as Cu – total (mg/l)	11	0.001	0.001	0.001	0.001	0.001	0.001	0.001

PARAMETER	COUNT	MIN	10%	25%	50%	75%	90%	MAX
Lead as Pb – total (mg/l)	11	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Mercury as Hg – total (mg/l)	11	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Nickel as Ni – total (mg/l)	11	0.001	0.001	0.001	0.002	0.002	0.002	0.002
Zinc as Zn – total (mg/l)	11	0.001	0.001	0.001	0.001	0.004	0.007	0.018

Time series plots of electrical conductivity (EC) and discharge daily maximum monitoring data for the Glenelg River at Dartmoor, Grangeburn at Morgiana, and Wannon River at Henty stations are provided in Figure 6.14, Figure 6.15 and Figure 6.16 respectively. In general, there is a trend with all three monitoring stations that EC and discharge have an inverse relationship, i.e. EC increases for low flows. This is likely due to the disconnected pools and less flushing of the channel system in low flow conditions.

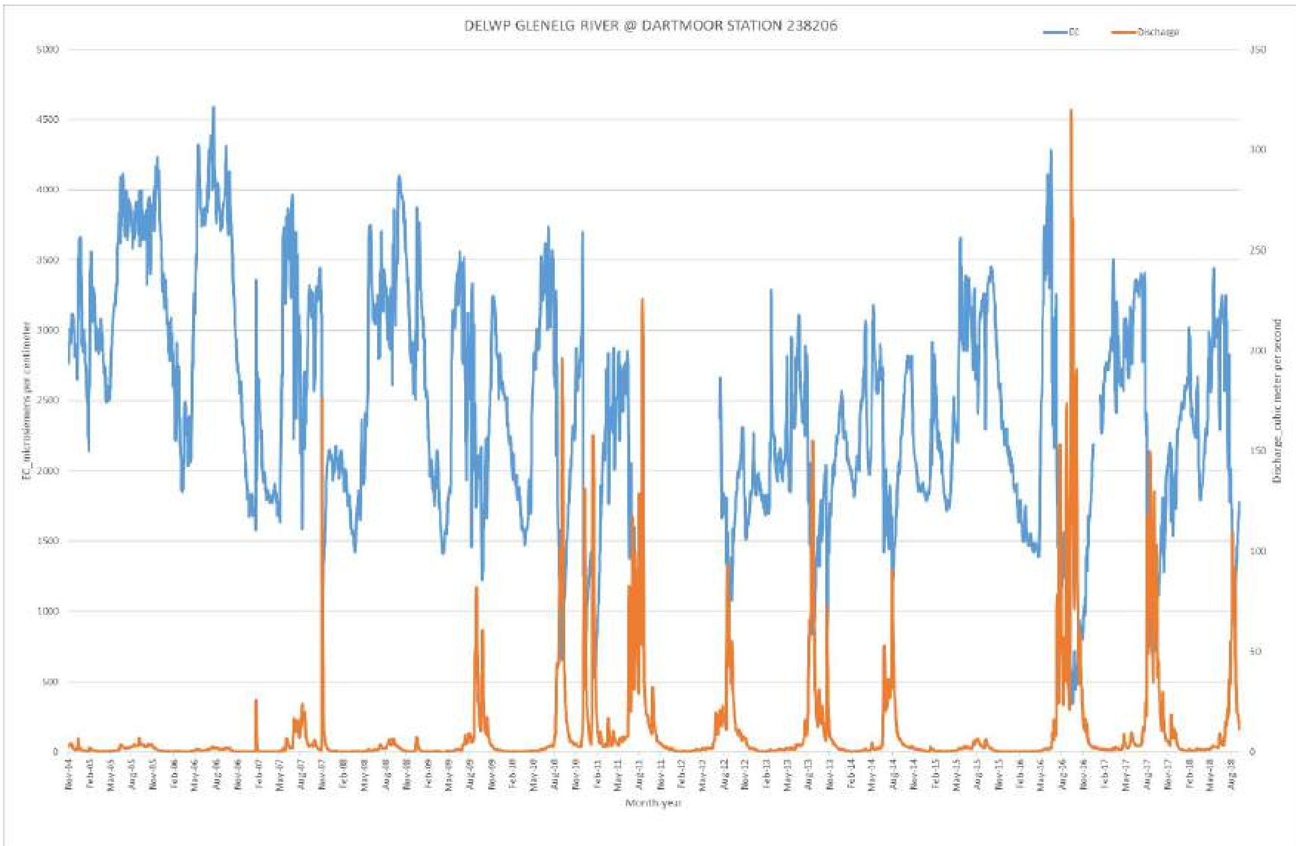


Figure 6.14 Electrical conductivity and discharge time series plot – Glenelg River at Dartmoor (Station 238206)

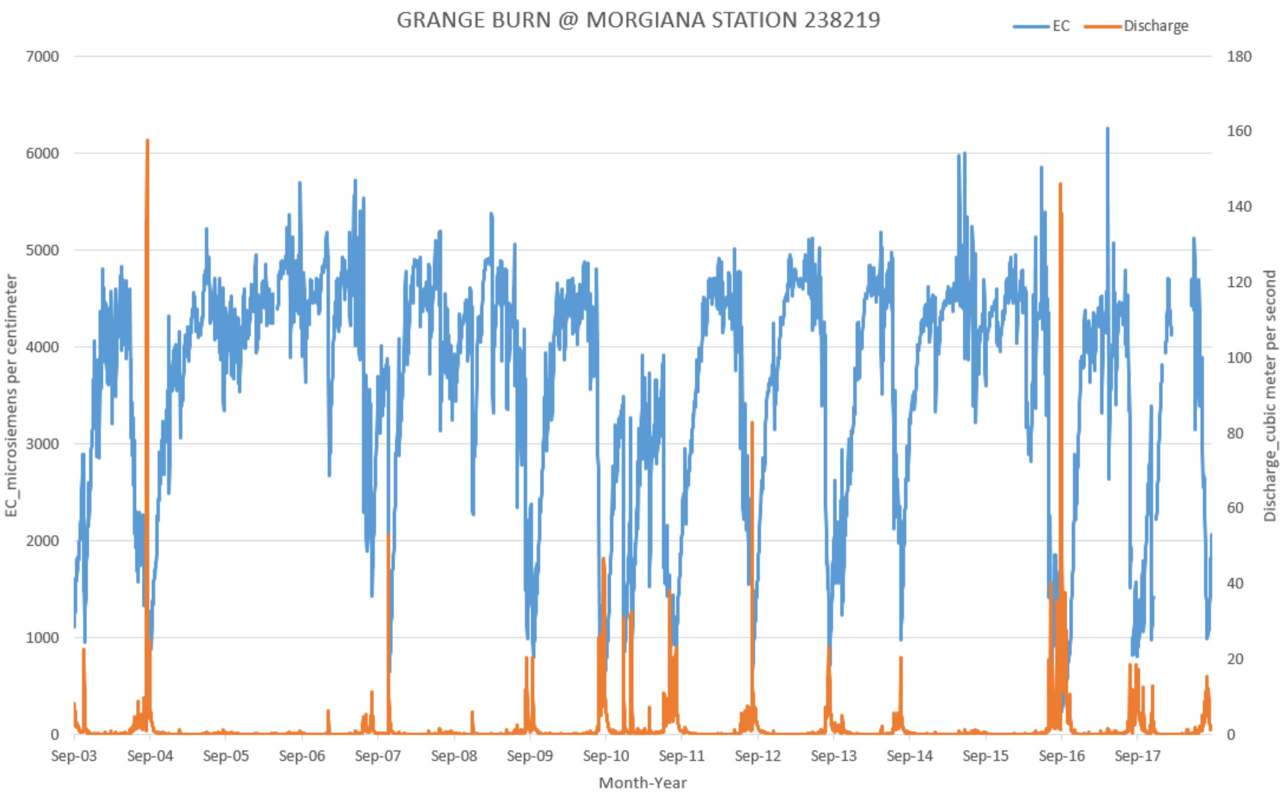


Figure 6.15 Electrical conductivity and discharge time series plot – Grangeburn at Morgiana (Station 238219)

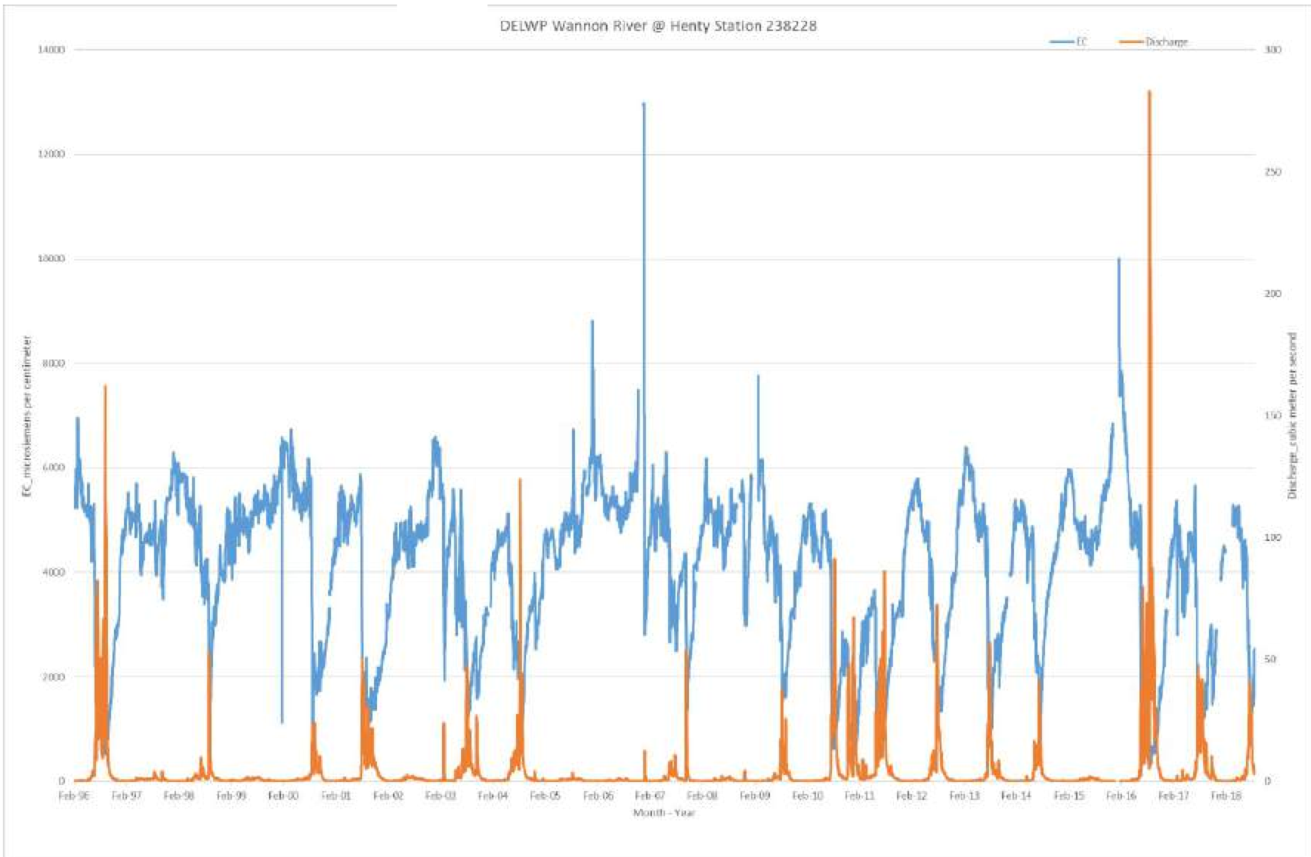


Figure 6.16 Electrical conductivity and discharge time series plot – Wannon River at Henty (Station 238228)

6.7.2 PYRENEES SHIRE COUNCIL SURFACE WATER MONITORING SITES

While there is a lack of ongoing water quality monitoring at Beaufort to establish a baseline trends for Yam Holes Creek, Pyrenees Shire Council have two surface water sampling locations on Yam Holes Creek directly upstream and downstream of the Beaufort Landfill located at 125 Racecourse Road, Beaufort. Sampling and analysis at these stations is undertaken on a bi-annual basis as part of Pyrenees Shire Council's due diligence environmental compliance for the Landfill. Monarc Environmental issued a report *Summary of Monitoring Results for Groundwater and Surface Water at Beaufort Landfill* to Pyrenees Shire Council, dated March 2018.

Surface water monitoring results taken in 2016, 2017 and 2018 were provided and are summarised in Table 6.8.

These water quality values are provided as they are the only data source for water quality in the Yam Holes Creek catchment. These values provide a general indication of Yam Holes Creek waterway health. However, the purpose of sampling at Yam Holes creek was to address due diligence environmental compliance rather than specifically assess SEPP (Waters) objectives. Hence, the data set collected is not sufficient for a direct comparison against the SEPP water quality objectives.

Table 6.8 Water quality monitoring results on Yam Holes Creek at Beaufort Landfill

SAMPLE DATE / SEPP	TOTAL NITROGEN (UG/L)	DO (% SATURATION)	TURBIDITY (NTU)	ELECTRICAL CONDUCTIVITY (µS/CM)	PH
	75th percentile	Max	75th percentile	75th percentile	75th percentile
SEPP Targets for Central Foothills and Coastal Plains	≤1,050	130	≤15	≤2,000	≤8.0
Sampling Location YH2					
15-02-2018	Dry	Dry	Dry	Dry	Dry
29-11-2017	Not Tested	40.7	60	2250	6.88
23-08-2017	1600	164.9	24	3480	7.71
07-07-2016	Not Tested	7.98	Not Tested	Not Tested	7.73
Sampling Location YH1					
15-02-2018	3100	113.6	40	8020	8.95
29-11-2017	not tested	48.2	50	462	6.6
23-08-2017	67800	121.9	24	941	7.9
07-07-2016	not tested	61.9	not tested	415	7.03

6.7.3 STREAM CONDITION

River condition in Victoria is assessed using the Index of Stream Condition (ISC). The ISC measures the environmental condition of river reaches. The Index of Stream Condition – The Third Benchmark of Victorian River Condition ('ISC3') (DEPI, 2013) report provides a summary of river health for major rivers and streams in Victoria using data collected over a six-year period from 2004–2010.

The condition of waterways in the Glenelg Hopkins region varies from excellent to very poor, reflecting the level of modification of the waterway and types of use. Waterways in near natural condition with high environmental values are generally in national and state parks and have good waterway health condition. Highly modified waterways are typically in urban areas or areas of intensive agriculture have poorer waterway health condition. These waterways often support economic values and recreational activities (DEPI, 2013).

ISC3 results showed that stream condition varied considerably between the three basins in the region, with streams in the Glenelg basin being in best condition. Both the Glenelg and Portland basins had the majority of their stream length in moderate condition (68 per cent and 84 per cent respectively). The majority of stream length in the Hopkins basin was in poor condition (38 per cent) or very poor condition (56 per cent). This result is generally due to modified flow regimes, degraded riparian vegetation, poor bank condition and low water quality resulted from elevated nutrients and salinity. It should be noted that the assessment coincided with a drought period, which was particularly severe in the Glenelg Hopkins region. These conditions impacted on several measures of the ISC, in particular water quality and hydrology.

The ISC Report, classified the reach of Mount Emu Creek near Beaufort as very poor. The Mount Emu Creek reach (ID 22), received a total ISC score of 18. The ISC score comprised Hydrology (1), Physical Form (7), Streamside Zone (4), Water Quality (not available) and Aquatic Life (4). The condition of Yam Holes Creek was not assessed (DEPI, 2013).

6.8 WETLANDS

Details of surveys and assessments of the wetlands located in the study area are presented in the EES Appendix C: *Flora and fauna impact assessment*, WSP 2021. The wetlands within the study area were categorised into high, moderate and low value based on EES Appendix C: *Flora and fauna impact assessment*, WSP 2021. The definition of these categories are:

- High value – Seasonal Herbaceous Wetlands (Freshwater) of the Temperate Lowland Plain (EPBC Act listed community and mapped by WSP Flora and Fauna specialist). Theses wetlands are listed as critically endangered ecological communities under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. There are overlaps between the Seasonal Herbaceous Wetlands (Freshwater) and the wetland Ecological Vegetation Classes (EVCs) (mapped by WSP Flora and Fauna specialists).
- Moderate value – All other areas mapped as wetland EVCs (mapped by WSP Flora and Fauna specialist).
- Low value – Areas mapped as 'Wetland Current' by DELWP, however mapping by WSP Flora and Fauna specialist show these areas are without wetland EVCs, i.e. no native vegetation.

High, moderate and low value wetlands are presented in Figure 6.17 and found in the following general locations:

- within the unnamed tributary of Yam Holes Creek between Martins Lane and Western Highway
- within the unnamed tributary of Yam Holes Creek north of Martins Lane
- within the unnamed tributary of Yam Holes Creek to the west of King Street
- extensive areas along the Yam Holes Creek and valley between Racecourse Road and Beaufort-Lexton Road
- south of Racecourse Road and within the Snow Gums Bushland Reserve
- within the unnamed tributaries of Yam Holes Creek north of Smiths Lane.

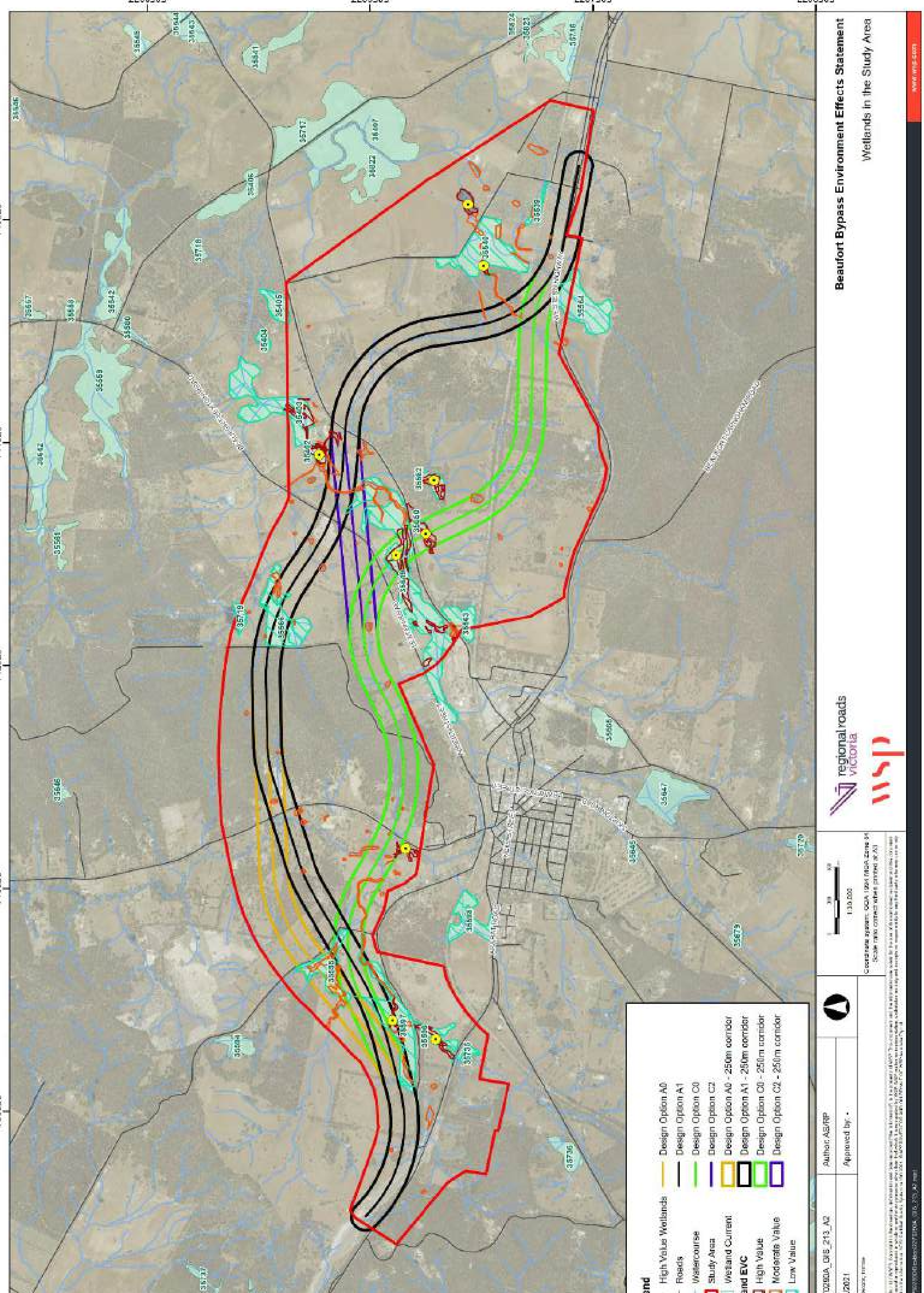


Figure 6.17 Study area wetlands

A list of the wetlands and summary of the high value wetland characteristics as sourced from the EES Appendix C: *Flora and fauna impact assessment*, WSP 2021 is presented in Table 6.9.

It should be noted that, for the Stage 2 assessment of the preferred alignment, all wetlands in the DELWP mapping database that are located within the area of influence of the project were considered in the impact assessment, regardless of classification or level of importance.

Table 6.9 Description of wetland characteristics

WETLAND CURRENT ID	HIGH VALUE WETLAND NUMBER	WETLAND CHARACTERISTICS
35402	Wetland 1	— At least 3/4 full in Summer 2015, 2016, 2017. Flooded in September 2016. — Likely surface water fed, possibly fed from pivot irrigator nearby. — Deepest point ~2 m.
35403	–	— Shallow wetland/floodplain along channelised part of Yam Holes Creek. — Seasonal wetland likely surface water fed with overflow from creek in flood events and sewer treatment plant from pivot irrigators. — Mostly a dry area rather than seasonal wetland with damp areas constrained to the drainage line.
35404	–	— Seasonal wetland likely surface water fed. — Not assessed in field as this is outside study area.
35405	–	— Seasonal wetland likely surface water fed. — Not assessed in field as is outside study area.
35539	–	— Seasonal wetland likely surface water fed. — Mostly a dry area rather than seasonal wetland.
35540	Wetland 5	— Flooded in September 2016. Half to ¾ full in Spring 2017. — Seasonal wetland likely surface water fed.
35540	Wetland 9	— Flooded in September 2016. — Seasonal wetland likely surface water fed.
35562	Wetland 3	— Shallow wetland, mostly dry in November 2015, full flooded in September 2016, in drawdown in Spring 2017. — Seasonal wetland likely surface water fed. — Deepest point ~0.5 m.
35563	–	— Sewer Treatment Plant was expanded across half of this wetland in 2014–15. — Part of wetland extent susceptible to salinity.
35564	–	— Seasonal wetland likely surface water fed. — Partially assessed in field as most of this wetland is outside study area. — Mostly a dry area rather than seasonal wetland.
35566	–	— Mostly a dry area rather than seasonal wetland with damp areas constrained to the drainage line.

WETLAND CURRENT ID	HIGH VALUE WETLAND NUMBER	WETLAND CHARACTERISTICS
35595	–	— Mostly a damp area rather than seasonal wetland.
35596	Wetland 8	— Flooded in September 2016. — Seasonal wetland likely surface water fed. — Surrounding area susceptible to salinity.
35597	Wetland 7	— Dry in 2015. Flooded in September 2016. Half to ¾ full in Spring 2017. Dry in January 2018. — Seasonal wetland likely surface water fed. — Surrounding area susceptible to salinity. — Deepest point ~0.2 m.
35649	Wetland 4	— Shallow wetland/floodplain along channelised part of Yam Holes Creek. — Flooded in September 2016. Very shallow to damp soil in Summer 2017. — Seasonal wetland likely surface water fed with overflow from creek in flood events.
35650	Wetland 2	— Mostly dry in November 2015, full in Spring/Summer 2016 and 2017. — Seasonal wetland likely surface water fed. — Deepest point ~1.5 m.
35719	–	— Created dam
35735	–	— Seasonal wetland likely surface water fed. — Mostly a dry area rather than seasonal wetland, possibly upstream part of wetland 35595 cut for the development of the Western Highway.
–	Wetland 6	— Dry in 2015. Flooded in September 2016. Half to ¾ full in Spring 2017. — Seasonal wetland likely surface water fed. — Deepest point ~0.2 m.

The surface water impact assessments for the wetlands are presented in Sections 7.2 and 9.2.8.

7 INITIAL ASSESSMENT OF FOUR ALIGNMENT OPTIONS

7.1 FLOODPLAIN IMPACT ASSESSMENT

The floodplain impact assessment considers how the bypass alignment options perform against the project objective for surface water:

To protect catchment values, water quality, stream flows and floodway capacity, as well as to avoid impacts on protected beneficial uses to the extent practicable.

The scoping requirements for the Beaufort Bypass Project EES identified the assessment measures to consider:

- identify potential effects of alternatives on surface water environments especially in relation to run-off impacts on water quality and flood flows.

The scoping requirements also identified:

- undertake assessment (modelling) of the hydrology of the study area to inform concept design(s) to minimise the impacts of the proposed project
- identify potential and proposed design alternatives and mitigation measures which could avoid or minimise effects on catchment functions and values, in particular for creeks and other surface water environments
- identify the potential risks at waterway crossings and storage of top soil in flood plains
- identify potential and proposed design alternatives and mitigation measures which have the least environmental impact.

The base case (existing conditions) hydraulic model was updated to incorporate the four bypass alignment options, A0, A1, C0 and C2. This section provides an initial high level review of the interaction between the 1% AEP floodplain and the bypass alignment options based on the results of initial flood modelling.

The details of the flood modelling are provided in Appendix C.

7.1.1 BYPASS ALIGNMENT OPTIONS MODELLED

The functional design of the bypass alignment options including horizontal and vertical geometry of batter extent and earthworks was provided for this assessment. The functional design at this stage of assessing the four bypass options did not include a preliminary estimate of bridges or culvert structures.

For the purpose of the model, the proposed bypass options modelled with gaps at the location of the watercourse crossings to estimate the minimum crossing length, which resulted in 100 mm, or less, flood level increase upstream of the crossing location. The predicted flood impacts were assessed by comparing the base case model depths to the proposed flood depths for each bypass option. This high-level assessment achieved the key result of identifying the relative extent of watercourse, floodplain and wetland interaction for the different bypass options. The results from this assessment conservatively estimate the number and size of culverts at each crossing on the civil design drawings. This high-level modelling approach was combined with additional qualitative assessments to consider the potential for direct disturbance of mapped wetland areas; the potential for direct disturbance of mapped 1% AEP floodplain areas; the number of waterway crossings required; the extents of the 1% AEP floodplain at each waterway crossing; and other hydraulic attributes of the waterway crossings. The approach was sufficient to inform the option selection process, following which the preferred option was subject to further design development and a comprehensive modelling analysis of flood regime impacts (refer to Section 9 of this report for the detailed assessment of the preferred option).

7.1.2 FLOODPLAIN IMPACTS

The bypass alignment options with the earthworks models for each option overlain on the baseline 1% AEP flood extent and depth map. The following provides an initial comparison of the options with respect to waterway crossings:

- To the west of the study area, bypass alignment Options A0 and A1 involve less interaction with floodplains than bypass alignment Options C0 and C2. The ‘A’ options generally cross waterways and floodplains perpendicular to the flow direction, while the ‘C’ options are located over a significant floodplain and cross the floodplain further downstream, where it is more extensive. Option A0 has more crossings but these are located further upstream in the floodplains so would involve less extensive crossings than the other options.
- To the east of the project area the bypass alignment options are similar with all options crossing Yam Holes Creek floodplain. Option C0 crosses the Yam Holes Creek floodplain further upstream and would involve a less extensive crossing than the other bypass alignment options.

7.1.3 FLOODPLAIN IMPACTS WITH 100MM FLOOD DEPTH INCREASE – ‘A’ OPTIONS

Based on the initial flood modelling, the required waterway crossing widths (for significant crossings only, not including small culverts required to connect up minor drainage lines across the alignment) are as indicated in Table 7.1 and Figure 7.1. This shows that the alignment options have very similar total waterway crossing widths, with Option A0 needing more but shorter structures.

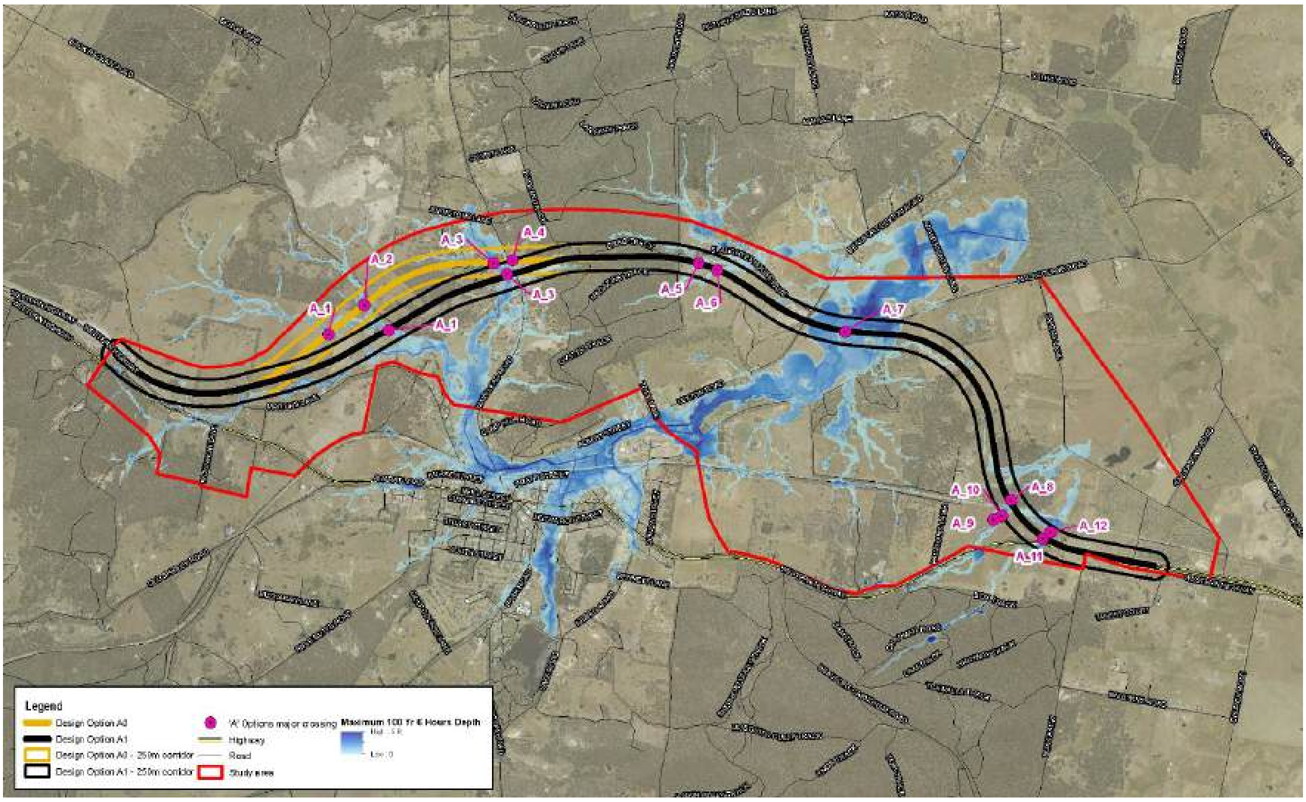


Figure 7.1 Overview of ‘A’ Options and major watercourse crossings based on 1% AEP floodplain

Table 7.1 Indicative significant waterway crossing lengths for 'A' Options

CROSSING NUMBER	OPTION A0 WATERCOURSE CROSSING WIDTH (METRES)	OPTION A1 WATERCOURSE CROSSING WIDTH (METRES)
1	45	110
2	20	n/a
3	90	50
4	10	n/a
5	25	35
6	65	65
7	610	610
8	30	30
9	20	20
10	30	30
11	20	20
12	25	25
TOTALS	**990**	**995**

7.1.4 FLOODPLAIN IMPACTS WITH 100 MM FLOOD DEPTH INCREASE – ‘C’ OPTIONS

Significant waterway crossings would also be required at the eastern portion of both ‘C’ options as presented in Figure 7.2 and Table 7.2. Option C2 would involve a similar crossing width to the ‘A’ options at Yam Holes Creek of 700 m, with an average 1% AEP depth of the waterway of 600 mm at the crossing. Option C0 would require a shorter crossing at Yam Holes Creek of approximately 400 m in width and with an average 1% AEP depth of 400 mm at the crossing.

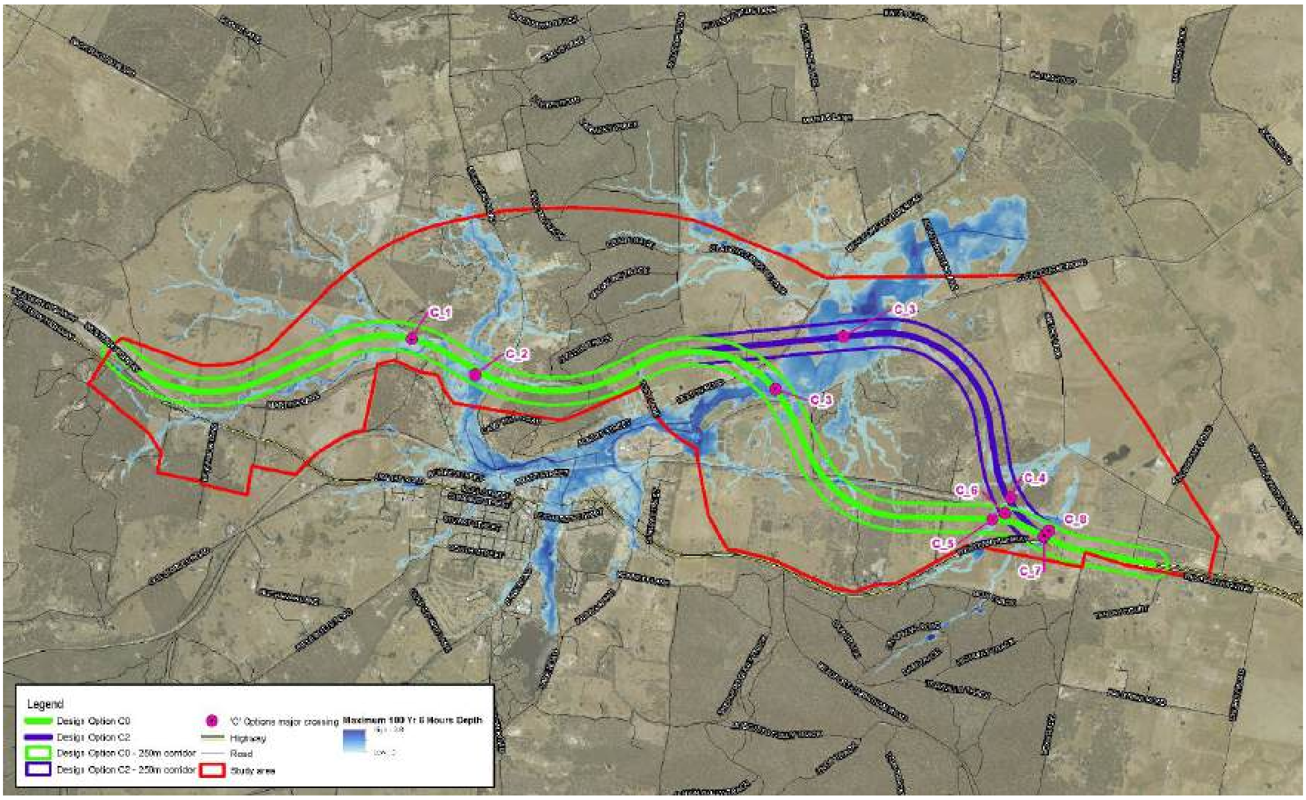


Figure 7.2 Overview of ‘C’ Options and major watercourse crossings based on 1% AEP floodplain

Table 7.2 Indicative significant waterway crossing widths for ‘C’ Options

CROSSING NUMBER	OPTION C0 WATERCOURSE CROSSING WIDTH (METRES)	OPTION C2 WATERCOURSE CROSSING WIDTH (METRES)
1	325	325
2	455	455
3	405	570
4	90	30
5	20	20
6	85	30
7	–	20
8	–	25
TOTALS	**1380**	**1475**

7.1.5 FLOODPLAIN IMPACT ON 1% AEP BASE CASE – OPTION A0

Option A0 comprises 11.2 km of dual carriageway and passes through the State Forest north of the Camp Hill summit. Interchanges are located near the west tie-in with the existing Western Highway and at Beaufort-Lexton Road. A slip lane is located at the east tie-in with the existing Western Highway.

Table 7.3 summarises the results of the floodplain impact for bypass alignment Option A0 for the 1% AEP flood event. The flood impact maps for Option A0 are presented in Appendix A, Maps 9.1 and 9.2.

Table 7.3 Assessment criteria for Beaufort Bypass Option A0

ASSESSMENT CRITERIA	KEY ASSESSMENT OUTPUTS
Number and type of waterway crossings	16
Number and location of designated waterway crossings	Option A0 crosses 3 designated waterways within the project area: **1** Yam Holes Creek **2** Tributary of Yam Holes Creek to the south of Back Raglan Road **3** Tributary of Yam Holes Creek to the west of Main Lead Road.
Greatest 1% AEP flood depth intersecting bypass alignment option	Tributary of Yam Holes Creek to the northwest of Racecourse Rd has a 1340 mm flood depth.
Max flood width at Yam Holes Creek crossing (1% AEP base case) assuming zero increase in flood levels	750 m
The length of alignment within the 1% AEP base case floodplain*	The lengths of A0 alignment within the 1% AEP inundation area are as follows: **1** 860 m, Yam Holes Creek **2** 332 m, Tributary of Yam Holes Creek to the south of Back Raglan Road **3** 115 m, Tributary of Yam Holes Creek to the west of Main Lead Road.
Total watercourse crossing length allowing 100 mm or less flood level increase	990 m
Yam Holes Creek crossing length allowing 100 mm or less flood level increase	610 m
Yam Holes Creek crossing average 1% AEP depth allowing 100 mm or less flood level increase	600 mm
The extent of ground disturbing works within 50 m of watercourse	The extent of ground distributing works within 50 m of watercourse for 1% AEP event are as follows: **1** 9 ha, Yam Holes Creek **2** 1.6 ha, Tributary of Yam Holes Creek to the south of Back Raglan Road **3** 1 ha, Tributary of Yam Holes Creek to the west of Main Lead Road.
All crossing perpendicular to direction of flow	Yes

*Crossing lengths are estimated for significant structures such as large box culverts or bridges. Lengths do not include minor single pipe/small box culvert crossings that will be required for minor drainage lines and overland flow paths.

7.1.6 FLOODPLAIN IMPACT ON 1% AEP BASE CASE – OPTION A1

Bypass alignment Option A1 comprises 11.1 km of dual carriageway. The alignment option is located south of A0 bypass alignment and joins the alignment of A1 bypass east of Main Lead Road. Interchanges are located near the west tie-in with the existing Western Highway and at Beaufort-Lexton Road. A slip lane is located at the east tie-in with the existing Western Highway.

Table 7.4 presents the assessment criteria for Beaufort Bypass Option A1 based on the Base Case 1% AEP event for the critical storm duration. The flood impact maps for Option A1 are presented in Appendix A, Maps 10.1 and 10.2.

Table 7.4 Assessment criteria for Beaufort Bypass Alignment Option A1

ASSESSMENT CRITERIA	KEY ASSESSMENT OUTPUTS
Number and type of waterway crossings	16
Number and location of designated waterway crossings	Option A1 crosses 3 designated waterways within the project area: **1** Yam Holes Creek **2** Tributary of Yam Holes Creek to the south of Back Raglan Road **3** Tributary of Yam Holes Creek to the west of Main Lead Road.
Greatest 1% AEP flood depth intersecting bypass alignment option	Tributary of Yam Holes Creek to the northwest of Racecourse Rd has a 1340 mm flood depth.
Max flood width at Yam Holes Creek crossing (1% AEP base case) assuming zero increase in flood levels	750 m
The length of alignment within the 1% AEP base case floodplain*	The length of A1 alignment within the 1% AEP inundation area are as follows: **1** 860 m, Yam Holes Creek **2** 85 m, Tributary of Yam Holes Creek to the south of Back Raglan Road **3** 230 m, Tributary of Yam Holes Creek to the west of Main Lead Road.
Total watercourse crossing length allowing 100 mm or less flood level increase	835 m
Yam Holes Creek crossing length allowing 100 mm or less flood level increase	610 m
Yam Holes Creek crossing average 1% AEP depth allowing 100 mm or less flood level increase	600 mm
The extent of ground disturbing works within 50 m of watercourse	The extent of ground distributing works within 50 m of watercourse for 1% AEP event are as follows: **1** 9 ha, Yam Holes Creek **2** 0.85 ha, Tributary of Yam Holes Creek to the south of Back Raglan Road **3** 2.6 ha, Tributary of Yam Holes Creek to the northwest of Main Lead Road.
All crossing perpendicular to direction of flow	Yes.

*Crossing lengths are estimated for significant structures such as large box culverts or bridges. Lengths do not include minor single pipe/small box culvert crossings that will be required for minor drainage lines and overland flow paths.

7.1.7 FLOODPLAIN IMPACT ON 1% AEP BASE CASE – OPTION C0

Bypass alignment Option C0 comprises 10.6 km of dual carriageway. The alignment follows the A0 bypass alignment from the west tie-in before deviating at Back Raglan Road in an easterly direction almost parallel to the existing Western Highway. The option passes adjacent to the north of the Camp Hill summit before turning southeast and re-joining the existing Western Highway at the eastern tie-in. Bridges will pass over Back Raglan Road, Main Lead Road and Racecourse Road and the Melbourne-Ararat rail line.

Table 7.5 presents the assessment criteria for Beaufort Bypass Option C0 based on the existing 1% AEP event for the critical storm duration. The flood impact maps for Option C0 are presented in Appendix A, Maps 11.1 and 11.2.

Table 7.5 Assessment criteria for Beaufort Bypass Alignment Option C0

ASSESSMENT CRITERIA	KEY ASSESSMENT OUTPUTS
Number and type of waterway crossings	14
Number and location of designated waterway crossings	Option C0 crosses 3 designated waterways within the project area: **1** Yam Holes Creek **2** Tributary of Yam Holes Creek to the south of Back Raglan Road **3** Tributary of Yam Holes Creek to the west of Main Lead Road.
Greatest 1% AEP flood depth intersecting bypass alignment option	Yam Holes Creek located between Racecourse Rd and Beaufort-Lexton Road has a 1500 mm flood depth.
Max flood width at Yam Holes Creek crossing (1% AEP base case) assuming zero increase in flood levels	300 m
The length of alignment within the 1% AEP base case floodplain*	The length of C0 alignment within the 1% AEP inundated area are as follows: **1** 300 m, Yam Holes Creek **2** 900 m, Tributary of Yam Holes Creek to the south of Back Raglan Road **3** 350 m, Tributary of Yam Holes Creek to the west of Main Lead Road.
Total watercourse crossing length allowing 100 mm or less flood level increase	1380 m
Yam Holes Creek crossing length allowing 100 mm or less flood level increase	495 m
Yam Holes Creek crossing average 1% AEP depth allowing 100 mm or less flood level increase	400 mm
The extent of ground disturbing works within 50 m of watercourse	The extent of ground distributing works within 50 m of watercourse for 1% AEP are as follows: **1** 4 ha, Yam Holes Creek **2** 12.6 ha. Tributary of Yam Holes Creek to the south of Back Raglan Road **3** 2.9 ha, Tributary of Yam Holes Creek to the west of Main Lead Road.

ASSESSMENT CRITERIA	KEY ASSESSMENT OUTPUTS
All crossing perpendicular to direction of flow	No – Sections of alignment runs over GHCMA designated watercourse. Floodplain depth approximately 500 mm on average and floodplain width approximately 150 m on average. Total floodplain storage being displaced approximately 56,250 m^3.

*Crossing lengths are estimated for significant structures such as large box culverts or bridges. Lengths do not include minor single pipe/small box culvert crossings that will be required for minor drainage lines and overland flow paths.

7.1.8 FLOODPLAIN IMPACT ON 1% AEP BASE CASE – OPTION C2

Bypass alignment Option C2 comprises 11 km of dual carriageway. The alignment follows the C0 bypass alignment from the west tie-in to Beaufort-Lexton Road, where it continues in an easterly direction. The alignment then joins the A0 alignment near Racecourse Road until the east tie-in with the existing Western Highway.

Table 7.6 presents the assessment criteria for Beaufort Bypass Option C2 based on the existing 1% AEP flood event for the critical storm duration. The flood impact maps for Option C2 are presented in Appendix A, Maps 12.1 and 12.2.

Table 7.6 Assessment criteria for Beaufort Bypass Alignment Option C2

ASSESSMENT CRITERIA	KEY ASSESSMENT OUTPUTS
Number and type of waterway crossings	16
Number and location of designated waterway crossings	The Option C2 crosses 3 designated water courses within the project area: 1 Yam Holes Creek 2 Tributary of Yam Holes Creek to the south of Back Raglan Road 3 Tributary of Yam Holes Creek to the west of Main Lead Road.
Greatest 1% AEP flood depth intersecting bypass alignment option	Tributary of Yam Holes Creek to north west of Racecourse Rd has a 1340 mm flood depth.
Max flood width at Yam Holes Creek crossing (1% AEP base case) assuming zero increase in flood levels	810 m
The length of alignment within the 1% AEP base case floodplain*	The length of C2 alignment within the 1% AEP storm are as follows: 1 900 m, Yam Holes Creek 2 900 m, Tributary of Yam Holes Creek to the south of Back Raglan Road 3 290 m, Tributary of Yam Holes Creek to the west of Main Lead Road.
Total watercourse crossing length allowing 100 mm or less flood level increase	1475 m
Yam Holes Creek crossing length allowing 100 mm or less flood level increase	570 m
Yam Holes Creek crossing average 1% AEP depth allowing 100 mm or less flood level increase	600 mm

ASSESSMENT CRITERIA	KEY ASSESSMENT OUTPUTS
The extent of ground disturbing works within 50 m of watercourse	The extent of ground distributing works within 50 m of watercourse for 1% AEP inundated area are as follows: **1** 9 ha, Yam Holes Creek **2** 12.6 ha, Tributary of Yam Holes Creek to the south of Back Raglan Road **3** 2.9 ha, Tributary of Yam Holes Creek to the west of Main Lead Road.
All crossing perpendicular to direction of flow	No – Sections of alignment runs over GHCMA designated watercourse. Floodplain depth approximately 500 mm on average and floodplain width approximately 150 m on average. Total floodplain storage being displaced approximately 56,250 m^3.

*Crossing lengths are estimated for significant structures such as large box culverts or bridges. Lengths do not include minor single pipe/small box culvert crossings that will be required for minor drainage lines and overland flow paths.

7.1.9 SUMMARY OF 1% AEP FLOODPLAIN ASSESSMENT

A summary table of the impacts on the 1% AEP floodplain is presented in Table 7.7.

Table 7.7 Summary of assessment

OBJECTIVE	OPTION A0	OPTION A1	OPTION C0	OPTION C2
Number and type of waterway crossings	16	16	14	16
Number and location of designated waterway crossings	3	3	3	3
Greatest 1% AEP flood depth intersecting bypass alignment option	1.34 m	1.34 m	1.5 m	1.34 m
Max flood width at Yam Holes Creek crossing (1% AEP base case) assuming zero increase in flood levels	750 m	750 m	300 m	810 m
Total length of alignment within the 1% AEP base case floodplain*	1307 m	1175 m	1550 m	2090 m
Total watercourse crossing length allowing 100 mm or less flood level increase	990 m	835 m	1380 m	1475 m
Yam Holes Creek crossing length allowing 100 mm or less flood level increase	610 m	610 m	495 m	570 m
Yam Holes Creek crossing average 1% AEP depth allowing 100 mm or less flood level increase	600 mm	600 mm	400 mm	600 mm
The extent of ground disturbing works within 50 m of watercourse	11.6 ha	12.45 ha	19.5 ha	24.5 ha
All crossing perpendicular to direction of flow	Yes	Yes	No	No

*Crossing lengths are estimated for significant structures such as large box culverts or bridges. Lengths do not include minor single pipe/small box culvert crossings that will be required for minor drainage lines and overland flow paths.

7.1.10 CONCLUSION

From Table 7.7 it is evident the A Options have the least interference with the existing 1% AEP flood area, while Option C0 requires the least number of waterway crossings and has the minimum cross-drainage width. Option A0 has the distinct advantage of minimum ground disturbing footprint required for construction of waterway crossings. However, its disturbed area is close to the disturbed area of Option A1.

While Options A1 and C0 are the options with minimum surface water impact, Option A1 has the least potential impact as the road embankment interference with the 1% AEP floodplain is minimum, and also waterways crossings are perpendicular to the direction of flow. Option A1 also has the second smallest required footprint for construction of waterway crossings.

The advantages of Option C0 is that it has the shortest crossing of Yam Holes Creek downstream of Beaufort.

Non-perpendicular crossings to a designated waterway was identified for both Option C0 and C2 alignments at between Back Raglan Road and Main Lead Road. The average 1% AEP floodplain depth at this location is approximately 500 mm.

Based on the above, Option A1 is considered to have the least surface water impacts when compared to the other 3 alignments; however, through undertaking the options selection process outlined in Section 4.7, Option C2 was preferred when all environmental, social and economic disciplines were considered holistically. A more detailed flood impact assessment for Option C2 is presented in Section 9.1.

7.2 WETLAND IMPACT ASSESSMENT

The Stage 1 surface water impact assessment of the high quality wetlands for each bypass alignment option includes:

- a hydraulic assessment of the changes to the 1% AEP flood level; and
- a qualitive assessment of the likely flow regime and water quality impacts based on the alignment options.

A summary of the surface water impacts to high quality wetlands are presented in Table 7.8 and Table 7.9. The locations of the high quality wetlands are provided in Figure 7.3 and in Map 13 Appendix A.

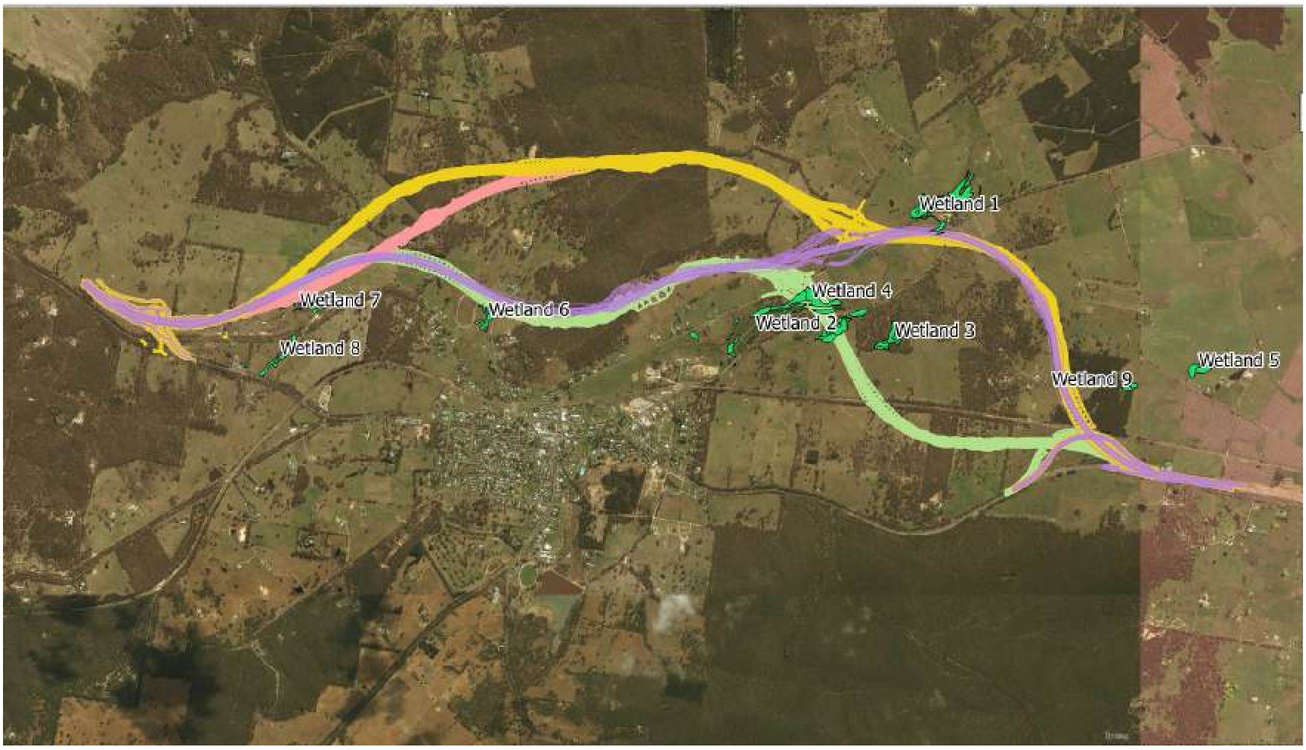


Figure 7.3 Location of high quality wetlands

Based on the assessment in Table 7.9 and Table 7.9, the ‘A’ options and C2 have the least impact to high quality wetlands. Bypass C0 is the least preferable option with significant direct impacts (i.e. direct encroachment of the road corridor within or over the wetland area) identified at wetlands 2, and 4.

As detailed in Section 8, Option C2 was preferred when all environmental, social and economic disciplines were considered holistically. A more detailed wetland impact assessment for Option C2 is presented in Section 9.2.8.

Table 7.8 Summary of direct impacts to wetlands

WETLAND	A0	A1	C0	C2
Areas of potential direct impacts on wetlands				
High quality	0.06	0.06	3.77	0.19
Moderate quality	1.10	1.19	1.31	1.45
Low quality	6.30	6.71	2.47	2.00
Grand Total	**7.46**	**7.96**	**7.55**	**3.65**

Table 7.9 Hydraulic and qualitive assessment of Surface Water impacts to high value wetlands

CRITERIA	WETLAND NUMBER								
	1	2	3	4	5	6	7	8	9
Bypass Alignment A0									
Changes to 1% AEP Flood Level (TUFLOW model results)	No	No	No	+ 40 mm	No	No	No	No	No
Road embankments directly overlays wetland boundary	Yes Approx. 0.026 ha impacted by embankment	No	No	No	No	No	No	No	No
Proposed cross drainage immediately upstream of wetland that provides direct connectivity with wetland	Yes Cross drainage on Yam Holes Creek (approx. 0.3 km upstream of wetland) and unnamed tributaries	No	No	No	Yes Cross drainage on unnamed tributary located 1.4 km upstream of wetland	Yes Cross drainage on unnamed tributary located 1.7 km upstream of wetland	Yes Direct connectivity with cross drainage on unnamed tributary located 1.4 km upstream of wetland	No	Yes Cross drainage on unnamed tributary approx. 0.5 km upstream of wetland
Road drainage outfall likely to be located immediately upstream of wetland (based on road gradient)	Yes	No	No	No	Yes	Yes	No	No	No

CRITERIA	WETLAND NUMBER								
	1	2	3	4	5	6	7	8	9
Changes to catchment surface and drainage pattern upstream of wetland due to alignment	Wetland is fed by Yam Holes Creek, total catchment area approx.87.8 km^2. Approx. 2% change to land use type and drainage characteristics of upstream catchment, as follows: — Area of catchment where existing overland flow patterns will be modified to directed flow within drainage channels associated with road corridor is approx. 0.59 km^2. — The area of land use type change (from general rural land to road pavement and embankment) associated with the A0 alignment is approx. 1.5 km^2.	No change.	No change.	Wetland is fed by Yam Holes Creek, total catchment area of approx.76 km^2. Approx. 2% change to land use type and drainage characteristics of upstream catchment, as follows: — Area of catchment where existing overland flow patterns will be modified to directed flow within drainage channels associated with road corridor is approx. 0.51 km^2. — The area of land use type change (from general rural land to road pavement and embankment) associated with the A0 alignment is approx. 1.02 km^2.	Wetland is fed by watercourse with an upstream catchment area of approx.5.9 km^2. Approx. 6% change to upstream catchment surface. change to land use type and drainage characteristics of upstream catchment, as follows: — The area of land use type change (from general rural land to road pavement and embankment) associated with the A0 alignment is approx. 0.35 km^2.	Wetland is fed by tributary of Yam Holes Creek with a total catchment area of approx.35.4 km^2. Approx. 4% change to land use type and drainage characteristics of upstream catchment, as follows: — Area of catchment where existing overland flow patterns will be modified to directed flow within drainage channels associated with road corridor is approx. 0.51 km^2. — The area of land use type change (from general rural land to road pavement and embankment) associated with the A0 alignment is approx. 0.80 km^2.	Wetland is fed by tributary of Yam Holes Creek with a total catchment area of approx.8.6 km^2. Approx. 8% change to land use type and drainage characteristics of upstream catchment, as follows: — Area of catchment where existing overland flow patterns will be modified to directed flow within drainage channels associated with road corridor is approx. 0.59 km^2. — The area of land use type change (from general rural land to road pavement and embankment) associated with the A0 alignment is approx. 0.41 km^2.	No change	Wetland is feed by watercourse with an upstream catchment area of approx.1.9 km^2. Approx. 5% change to land use type and drainage characteristics of upstream catchment, as follows: — The area of land use type change (from general rural land to road pavement and embankment) associated with the A0 alignment is approx. 0.09 km^2.

CRITERIA	WETLAND NUMBER								
	1	2	3	4	5	6	7	8	9
Primary flow path providing water to (overland flow and or watercourse) wetland altered. Assuming cross drainage at detail design to be appropriately sized to not impact downstream flow regime.	No Primary flow to wetland is Yam Holes Creek and its tributaries.	No	No	No	Yes Re-alignment of tributary upstream of wetland.	No	No	No	No Primary flow to wetland is a tributary of Yam Holes Creek.
Likely impact to wetland water quality from road drainage. Assume water quality treatment is provided (based on BPEMG and AGRD) prior to discharge.	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely
Likely impact to flow regime during operational phase (assuming cross drainage will be appropriately sized)	Unlikely	Unlikely	Unlikely	Unlikely	Likely	Unlikely	Unlikely	Unlikely	Unlikely
Summary of key impacts	Direct impact to wetland by A0 embankment. Low risk of indirect impacts to wetland. Indirect impacts include changes to the upstream catchment (2% change) and likely drainage outfall upstream of wetland.	No likely impacts.	No likely impacts.	No direct impact to wetland. Low risk of indirect impacts to wetland. Indirect impacts include changes to the upstream catchment area (2% change). The 1% AEP flood model indicates a 40 mm increase in water levels at the wetland.	No direct impact to wetland. Medium risk indirect impacts to wetland. Indirect impacts include changes to upstream catchment area (6% change), re-alignment of tributary that supplies flow to the wetland and likely drainage outfall upstream of wetland.	No direct impact to wetland. Low risk of indirect impacts. Indirect impacts include 4% change to upstream catchment area and likely drainage outfall upstream of wetland.	No direct impact to wetland. Medium risk of indirect impacts. Indirect impacts with 8% change to upstream catchment area.	No likely impacts.	No direct impact to wetland. Low risk of indirect impacts. Indirect impacts with 5% change to upstream catchment area.

CRITERIA	WETLAND NUMBER								
	1	2	3	4	5	6	7	8	9
Bypass Alignment A1									
Changes to 1% AEP Flood Level (TUFLOW model results)	No	No	No	+ 40 mm	No	No	No	No	No
Road embankments directly overlays wetland boundary	Yes Approx. 0.026 ha impacted by embankment	No	No	No	No	No	No	No	No
Proposed cross drainage immediately upstream of wetland that provides direct connectivity with wetland	Yes Cross drainage on Yam Holes Creek (approx. 0.3 km upstream of wetland) and unnamed tributaries	No	No	No	Yes Direct connectivity with cross drainage on unnamed approx. 1.4 km upstream of wetland	Yes Direct connectivity with cross drainage on unnamed approx. 1.4 km upstream of wetland	Yes Direct connectivity with cross drainage on unnamed tributary approx. 1.7 km upstream of wetland	No	Yes Cross drainage on unnamed tributary approx. 0.5 km upstream of wetland
Road drainage outfall likely to be located immediately upstream of wetland (based on road gradient)	Yes Low point in road alignment near Yam Holes Creek	No	No	No	Yes Low point in alignment near unnamed tributary	Yes	No	No	No

CRITERIA	WETLAND NUMBER								
	1	2	3	4	5	6	7	8	9
Changes to catchment surface and drainage pattern upstream of wetland due to alignment	Wetland is fed by Yam Holes Creek, total catchment area approx.87.8 km². Approx. 2% change to land use type and drainage characteristics of upstream catchment, as follows: — Area of catchment where existing overland flow patterns will be modified to directed flow within drainage channels associated with road corridor is approx. 0.8 km². — The area of land use type change (from general rural land to road pavement and embankment) associated with the A1 alignment is approx. 1.3 km².	No change.	No change.	Wetland is fed by Yam Holes Creek with a total catchment area of approx.76 km². Approx. 2% change to land use type and drainage characteristics of upstream catchment, as follows: — Area of catchment where existing overland flow patterns will be modified to directed flow within drainage channels associated with road corridor is approx. 0.72 km². — The area of land use type change (from general rural land to road pavement and embankment) associated with the A1 alignment is approx. 0.82 km².	Wetland is fed by watercourse with an upstream catchment area of approx.5.9 km². Approx. 6% change to land use type and drainage characteristics of upstream catchment, as follows: — The area of land use type change (from general rural land to road pavement and embankment) associated with the A1 alignment is approx. 0.35 km².	Wetland is fed by tributary of Yam Holes Creek with a total catchment area of approx.35.4 km². Approx. 4% change to land use type and drainage characteristics of upstream catchment, as follows: — Area of catchment where existing overland flow patterns will be modified to directed flow within drainage channels associated with road corridor is approx.0.72 km². — The area of land use type change (from general rural land to road pavement and embankment) associated with the A1 alignment is approx. 0.8 km².	Wetland is fed by tributary of Yam Holes Creek with a total catchment area of approx.8.6 km². Approx. 10% change to land use type and drainage characteristics of upstream catchment, as follows: — Area of catchment where existing overland flow patterns will be modified to directed flow within drainage channels associated with road corridor is approx. 0.42 km². — The area of land use type change (from general rural land to road pavement and embankment) associated with the A1 alignment is approx. 0.4 km².	No change	Wetland is feed by watercourse with an upstream catchment area of approx.1.9 km². Approx. 5% change to land use type and drainage characteristics of upstream catchment, as follows: — The area of land use type change (from general rural land to road pavement and embankment) associated with the A1 alignment is approx. 0.09 km².

CRITERIA	WETLAND NUMBER								
	1	2	3	4	5	6	7	8	9
Primary flow path providing water to (overland flow and or watercourse) wetland altered. Assuming cross drainage at detail design to be appropriately sized to not impact downstream flow regime.	No	No	No	No	Yes Re-alignment of tributary upstream of wetland.	No	No	No	No
Likely impact to wetland water quality from road drainage. Assume water quality treatment is provided (based on BPEMG and AGRD) prior to discharge.	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely	Unlikely
Likely impact to flow regime during operational phase (assuming cross drainage will be appropriately sized)	Unlikely	Unlikely	Unlikely	Unlikely	Likely	Unlikely	Unlikely	Unlikely	Unlikely
Summary of key impacts	Direct impact to wetland by A1 embankment. Low risk of indirect impact to wetland. Indirect impacts include changes to the upstream catchment (2% change) and likely drainage outfall upstream of wetland.	No likely impacts.	No likely impacts.	No direct impact to wetland. Low risk of indirect impact to wetland. Indirect impacts to upstream catchment area (2% change). The 1% AEP flood model indicates this may impact water levels at the wetland.	No direct impact to wetland. Medium risk of indirect impact to wetland. Indirect impacts include changes to upstream catchment area (6% change), re-alignment of tributary that supplies flow to the wetland and likely drainage outfall upstream of wetland.	No direct impact to wetland. Low risk of indirect impact to wetland. Indirect impacts with 4% change to upstream catchment area and likely drainage outfall upstream of wetland.	No direct impact to wetland. High risk of indirect impact to wetland. Indirect impacts with 10% change to upstream catchment area.	No likely impacts.	No direct impact to wetland. Low risk of indirect impact to wetland. Indirect impacts with 5% change to upstream catchment area.

CRITERIA	WETLAND NUMBER								
	1	2	3	4	5	6	7	8	9
Bypass Alignment C0									
Changes to 1% AEP Flood Level (TUFLOW model results)	No	No	No	-20 mm	No	-30 mm	No	No	No
Road embankments directly overlays wetland boundary	No	Yes Approx. 1.59 ha impacted by embankment	No	Yes Approx. 3.71 ha impacted by embankment	No	No	No	No	No
Proposed cross drainage immediately upstream of wetland that provides direct connectivity with wetland	Yes Yam Holes Creek located approx. 1.8 km upstream at wetland	Yes Cross drainage located over wetland	Yes Cross drainage of tributaries approx. 0.85 km upstream of wetland	Yes Cross drainage located over wetland	Yes Direct connectivity with cross drainage on unnamed tributary located 1.2 km upstream of wetland	Yes	Yes Direct connectivity with cross drainage on unnamed tributary located 1.4 km upstream of wetland	No	Yes Direct connectivity with cross drainage on unnamed tributary located 0.75 km upstream of wetland
Road drainage outfall likely to be located immediately upstream of wetland (based on road gradient)	Yes Road drainage outfall located approx. 1.8 km upstream of wetland	Yes	Yes Road drainage outfall to watercourse directly connected to tributary	Yes	No Runoff from outfall could be directed to tributary that bypasses wetland	Yes	No	No	No

CRITERIA	WETLAND NUMBER								
	1	2	3	4	5	6	7	8	9
Changes to catchment surface and drainage pattern upstream of wetland due to alignment	Wetland is fed by Yam Holes Creek, total catchment area approx.87.8 km^2. Approx. 3% change to land use type and drainage characteristics of upstream catchment, as follows: — Area of catchment where existing overland flow patterns will be modified to directed flow within drainage channels associated with road corridor is approx. 1.2 km^2. — The area of land use type change (from general rural land to road pavement and embankment) associated with the C0 alignment is approx. 1.5 km^2.	Wetland is feed by watercourse, upstream catchment area approx. 1.7 km^2. Road directly impacting wetland. No change to land use type and drainage characteristics of upstream catchment.	Wetland is fed by watercourse with an upstream catchment area of approx. 0.9 km^2. Approx. 18% change to land use type and drainage characteristics of upstream catchment, as follows: — The area of land use type change (from general rural land to road pavement and embankment) associated with the C0 alignment is approx. 0.16 km^2.	Wetland is fed by Yam Holes Creek with a total catchment area of approx. 76 km^2. Road directly impacting wetland. Approx. 3% change to land use type and drainage characteristics of upstream catchment, as follows: — Area of catchment where existing overland flow patterns will be modified to directed flow within drainage channels associated with road corridor is approx. 1.2 km^2.	Wetland is feed by watercourse with an upstream catchment area of approx. 5.9 km^2. Approx. 4% change to land use type and drainage characteristics of upstream catchment, as follows: — The area of land use type change (from general rural land to road pavement and embankment) associated with the C0 alignment is approx. 0.25 km^2.	Wetland is fed by tributary of Yam Holes Creek with a total catchment area of approx. 35.4 km^2. Approx. 4% change to land use type and drainage characteristics of upstream catchment, as follows: — Area of catchment where existing overland flow patterns will be modified to directed flow within drainage channels associated with road corridor is approx. 0.68 km^2. — The area of land use type change (from general rural land to road pavement and embankment) associated with the C0 alignment is approx. 0.73 km^2.	Wetland is fed by tributary of Yam Holes Creek with a total catchment area of approx. 8.6 km^2. Approx. 9% change to land use type and drainage characteristics of upstream catchment, as follows: — Area of catchment where existing overland flow patterns will be modified to directed flow within drainage channels associated with road corridor is approx. 0.35 km^2. — The area of land use type change (from general rural land to road pavement and embankment) associated with the C0 alignment is approx. 0.42 km^2.	No change	Wetland is feed by watercourse with an upstream catchment area of approx.1.9 km^2. Approx. 6% change to land use type and drainage characteristics of upstream catchment, as follows: — The area of land use type change (from general rural land to road pavement and embankment) associated with the C0 alignment is approx. 0.12 km^2.

CRITERIA	WETLAND NUMBER								
	1	2	3	4	5	6	7	8	9
				— The area of land use type change (from general rural land to road pavement and embankment) associated with the C0 alignment is approx. 1.2 km².					
Primary flow path providing water to (overland flow and or watercourse) wetland altered. Assuming cross drainage at detail design to be appropriately sized to not impact downstream flow regime.	No	Yes Cross drainage located over wetland	No	Yes Cross drainage located over wetland	No	No	No	No	No
Likely impact to wetland water quality from road drainage. Assume water quality treatment is provided (based on BPEMG and AGRD) prior to discharge.	Unlikely	Likely Alignment crosses over wetland.	Unlikely	Likely Alignment crosses over wetland	Unlikely	Likely Road embankment interfaces with wetland	Unlikely	Unlikely	Unlikely
Likely impact to flow regime during operational phase (assuming cross drainage will be appropriately sized)	Unlikely	Likely Large crossings will require modelling	Unlikely	Likely Large crossings will require modelling	Unlikely	Likely	Unlikely	Unlikely	Unlikely

CRITERIA	WETLAND NUMBER								
	1	2	3	4	5	6	7	8	9
Summary of Impacts	No direct impact to wetland. Low risk of indirect impact to wetland. Indirect impacts include changes to the upstream catchment (3% change) and likely drainage outfall upstream of wetland.	Direct impact to wetland by C0 embankment. Low risk of indirect impact to wetland. Indirect impacts are possible drainage outfall at wetland.	No direct impact to wetland. High risk of indirect impact to wetland. Indirect impacts to upstream catchment area (18% change) and likely drainage outfall upstream of wetland.	Direct impact to wetland by C0 embankment. Low risk of indirect impact to wetland. Indirect impacts to upstream catchment area (3% change) and likely drainage outfall upstream of wetland.	No direct impact to wetland. Low risk of indirect impact to wetland. Indirect impacts include changes to upstream catchment area (4% change) and likely drainage outfall upstream of wetland.	No direct impact to wetland. Low risk of indirect impact to wetland. Indirect impacts include changes to upstream catchment area (4% change) and likely drainage outfall upstream of wetland.	No direct impact to wetland. Medium risk of indirect impact to wetland. Indirect impacts include changes to upstream catchment area (9% change).	No likely impacts.	No direct impact to wetland. Medium risk of indirect impact to wetland. Indirect impacts include changes to upstream catchment area (6% change) and likely drainage outfall upstream of wetland.
Bypass Alignment C2									
Changes to 1% AEP Flood Level (TUFLOW model results)	No	No	No	+ 40 mm	No	-30 mm	No	No	No
Road embankments directly overlays wetland boundary	Yes Approx. 0.026 ha impacted by embankment	No	No	No	No	No	No	No	No
Proposed cross drainage immediately upstream of wetland that provides direct connectivity with wetland	Yes Cross drainage on Yam Holes Creek (approx. 0.3 km upstream of wetland) and unnamed tributaries	No	No	No	Yes Direct connectivity with cross drainage on unnamed watercourse approx. 1.4 km upstream of wetland	Yes Direct connectivity with cross drainage on unnamed watercourse < 0.1 km upstream of wetland	No	No	Yes Cross drainage on unnamed tributary approx. 0.5 km upstream of wetland
Road drainage outfall likely to be located immediately upstream of wetland (based on road gradient)	Yes Low point in road alignment near Yam Holes Creek	No	No	No	Yes Low point in alignment near unnamed tributary	Yes	No	No	Yes

CRITERIA	WETLAND NUMBER								
	1	2	3	4	5	6	7	8	9
Changes to catchment surface and drainage pattern upstream of wetland due to alignment	Wetland is fed by Yam Holes Creek with a total catchment area of approx. 87.8 km². Approx. 3% change to land use type and drainage characteristics of upstream catchment, as follows: — Area of catchment where existing overland flow patterns will be modified to directed flow within drainage channels associated with road corridor is approx. 1.1 km². — The area of land use type change (from general rural land to road pavement and embankment) associated with the C2 alignment is approx. 1.4 km².	No change.	No change.	Wetland is fed by Yam Holes Creek with a total catchment area of approx. 76 km². Approx. 3% change to land use type and drainage characteristics of upstream catchment, as follows: — Area of catchment where existing overland flow patterns will be modified to directed flow within drainage channels associated with road corridor is approx. 1.1 km². — The area of land use type change (from general rural land to road pavement and embankment) associated with the C2 alignment is approx. 0.98 km².	Wetland is fed by watercourse with an upstream catchment area of approx. 5.9 km². Approx. 6% change to land use type and drainage characteristics of upstream catchment, as follows: — The area of land use type change (from general rural land to road pavement and embankment) associated with the C2 alignment is approx. 0.35 km².	Wetland is fed by tributary of Yam Holes Creek with a total catchment area of approx. 35.4 km². Approx. 4% change to land use type and drainage characteristics of upstream catchment, as follows: — Area of catchment where existing overland flow patterns will be modified to directed flow within drainage channels associated with road corridor approx. 0.68 km². — The area of land use type change (from general rural land to road pavement and embankment) associated with the C2 alignment is approx. 0.73 km².	Wetland is fed by tributary of Yam Holes Creek with a total catchment area of approx. 8.6 km². Approx. 9% change to land use type and drainage characteristics of upstream catchment, as follows: — Area of catchment where existing overland flow patterns will be modified to directed flow within drainage channels associated with road corridor approx. 0.35 km². — The area of land use type change (from general rural land to road pavement and embankment) associated with the C2 alignment is approx. 0.42 km².	No change	Wetland is feed by watercourse with an upstream catchment area of approx. 1.9 km². Approx. 5% change to land use type and drainage characteristics of upstream catchment, as follows: — The area of land use type change (from general rural land to road pavement and embankment) associated with the C2 alignment is approx. 0.09 km².

CRITERIA	WETLAND NUMBER								
	1	2	3	4	5	6	7	8	9
Primary flow path providing water to (overland flow and or watercourse) wetland altered. Assuming cross drainage at detail design to be appropriately sized to not impact downstream flow regime.	No Primary flow to wetland is Yam Holes Creek and its tributaries.	No	No	No	Yes Re-alignment of tributary upstream of wetland.	No	No	No	No
Likely impact to wetland water quality from road drainage. Assume water quality treatment is provided (based on BPEMG and AGRD) prior to discharge.	Likely Road embankment interfaces with wetland.	Unlikely	Unlikely	Unlikely	Unlikely	Likely Road embankment interfaces with wetland.	Unlikely	Unlikely	Unlikely
Likely impact to flow regime during operational phase (assuming cross drainage will be appropriately sized)	Unlikely	Unlikely	Unlikely	Unlikely	Likely	Unlikely	Unlikely	Unlikely	Unlikely
Summary of key impacts	Direct impact to wetland by C2 embankment. Low risk of indirect impact to wetland. Indirect impacts include changes to the upstream catchment (3% change) and likely drainage outfall upstream of wetland.	No likely impacts.	No likely impacts.	No direct impact to wetland. Low risk of indirect impact to wetland. Indirect impacts to upstream catchment area (3% change). The 1% AEP flood model indicates this may impact water levels at the wetland.	No direct impact to wetland. Medium risk of indirect impact to wetland. Indirect impacts include changes to upstream catchment area (6% change) and likely drainage outfall upstream of wetland	No direct impact to wetland. Low risk of indirect impact to wetland. Indirect impacts include changes to upstream catchment area (4% change) and likely drainage outfall upstream of wetland. The 1% AEP flood model indicates changes to water levels at the wetland.	No direct impact to wetland. Medium risk of indirect impact to wetland. Indirect impacts include changes to upstream catchment area (9% change).	No likely impacts.	No direct impact to wetland. Low risk of indirect impact to wetland. Indirect impacts include changes to upstream catchment area (5% change) and likely drainage outfall upstream of wetland.

8 OPTIONS ASSESSMENT AND PREFERRED ALIGNMENT SELECTION

The options assessment completed for the project assessed alignment options A0, A1, C0 and C2 against the customised set of criteria summarised in Section 4.6. The results of the options assessment and sensitivity testing are detailed in Table 8.1. As well as the score for each alignment under each scenario, a colour coding has been applied to rank the performance of the options under each scenario as follows:

- best performing alignment option: Green
- second performing alignment option: Yellow
- third performing alignment option: Orange
- worst performing alignment option: Red.

Table 8.1 Combined alignment option scenario scoring

SCENARIO	ALIGNMENT A0	ALIGNMENT A1	ALIGNMENT C0	ALIGNMENT C2
Scenario 1	128	123	126	111
Scenario 2	18	22	20	27
Scenario 3	45.85	44.89	50.01	43.95
Scenario 4	81.03	77.59	93.98	74.12
Scenario 5	24.16	22.70	27.03	19.44
Scenario 6	47.74	42.69	56.16	35.49
Sensitivity Scenario 1	-6	-3	-5	9
Sensitivity Scenario 2	-3	2	-4	11
Sensitivity Scenario 3	-11	-6	-9	5

The alignment scoring scenarios outlined in Table 8.1 show that the best performing option is the C2 Alignment, while the worst performing options are the A0 and C0 Alignments. The primary drivers for this outcome were due to the C2 alignment having:

- the lowest amount of total native vegetation clearance
- the least impact on threatened vegetation communities identified under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) and *Flora and Fauna Guarantee Act 1988* (FFG Act)
- the least impact on wildlife corridors, particularly the core habitat areas
- the lowest amount of native vegetation with high conditions to be removed by Ecological Vegetation Class (EVC) Conservation Status
- the lowest potential impacts on known or registered sites of Aboriginal and historic heritage significance
- the smallest number of dwellings within 100 m, 200 m and 300 m of the alignment corridor.

Further detail on the options assessment process is provided in the EES *Attachment IV: Options assessment*.

9 IMPACT ASSESSMENT OF PREFERRED ALIGNMENT

This section presents the more detailed impact assessment undertaken for the preferred Option C2, which included more detailed hydraulic modelling of the C2 alignment and water quality modelling to determine stormwater treatment management measures required to treat runoff from the road corridor prior to discharge to the receiving environment.

The assessment assumes that best practice stormwater quality management measures will be required to treat runoff from the road corridor before release to the receiving environment.

9.1 KEY SURFACE WATER FEATURES AND DRAINAGE INFRASTRUCTURE FOR OPTION C2

Appendix E contains maps showing an overview of the key surface water features and drainage infrastructure for Option C2. The cross drainage infrastructure includes box culverts for most watercourse crossings and a combination of bridges and box culverts for the crossing of the Yam Holes Creek floodplain between Beaufort-Lexton Road and Racecourse Road, which has been identified as a sensitive ecological area. The list of cross drainage culverts and bridges is provided in Table 9.1 below:

Table 9.1 Cross drainage infrastructure for Option C2

CROSSING ID	STRUCTURE TYPE	STRUCTURE SIZE	STRUCTURE LENGTH (METRES)
C02_XD_B	Culvert	12 x 3.6 m wide x 1.2 m high	145
C02_XD_C_1	Culvert	18 x 3.6 m wide x 1.2 m high	125
C02_1	Culvert	5 x 3.6 m wide x 1.2 m high	289
C02_3	Culvert	4 x 3.6 m wide x 1.2 m high	111
C02_7	Culvert	7 x 3.6 m wide x 1.2 m high	106
C02_2_9	Culvert	9 x 3.6 m wide x 1.2 m high	32
C02_2_11	Culvert	9 x 3.6 m wide x 1.2 m high	150
C02_12	Culvert	8 x 2.7 m wide x 0.9 m high	176
C02_15	Culvert	7 x 3.6 m wide x 1.2 m high	186
C02_XD_C_2	Culvert	18 x 3.6 m wide x 1.2 m high	125
YH_West	Bridge	9 x 20 m spans	N/A
C02_XD_8_2	Culvert	20 x 3.6 m wide x 1.2 m high	90
YH_East	Bridge	10 x 20 m spans	N/A
C2_13	Culvert	4 x 2.7 m wide x 0.9 m high	30

As well as direct crossings of the main watercourses, the C2 alignment also runs along or over several minor watercourse which will need to be diverted along the road corridor before re-connecting to their original flow path further downstream. The locations of the channel realignments are shown in Appendix E and listed below in Table 9.2.

Table 9.2 Channel realignments for Option C2 (from west to east)

NO.	CHANNEL REALIGNMENT LENGTH (METRES)
1	230
2	640
3	685
4	525
5	235
6	425
7	45
8	730
9	410
10	225
TOTAL	**4,150**

The channel realignments and associated culvert/bridge crossings of the road corridor have been located to match existing topography and reduce the extent of clearing and excavation of the existing landscape. For example, the channel realignment north of the road corridor between Back Raglan Road and Main Lead Road has been located along the northern side of the road corridor rather than the southern side of the corridor to minimise the amount of cut that would be required to construct the channel and to locate the channel on the less populated side of the road corridor.

The maps also show locations where the road drainage system will discharge to the receiving environment and the area of the new road corridor that will drain to each location.

9.2 FLOODPLAIN IMPACT ASSESSMENT FOR OPTION C2

The methodology for the floodplain impact assessment is outlined in Section 4.5.2. Flood impact maps are provided in Appendix F. The impacts have been minimised as far as practical by testing numerous configurations of cross drainage structures, with the resulting designs listed in Table 9.1 above. The following sections describe the impacts on a range of flood parameters. Prior to detailed flood modelling the impacts to the hydrology regime were considered high. The assessment in Section 9 has tested a combination of culverts and bridges which are effective at managing flooding impacts with minor changes to flooding parameters outside the project corridor.

9.2.1 FLOOD LEVEL (AFFLUX) IMPACTS

Table 9.3 summarises the key afflux results for each event.

Table 9.3 Summary of key afflux results for Option C2

EVENT	APPENDIX F MAP REFERENCE	KEY AFFLUX IMPACTS
1 EY	DES_AFF_1EY_1 DES_AFF_1EY_2	Increases of up to 50 mm upstream of Yam Holes Creek western bridge extending approximately 500 m upstream. Localised increases of up to 200 mm immediately downstream of Yam Holes Creek western bridge. No buildings or local roads affected by afflux. Model instabilities cause apparent afflux around Racecourse Road, sewage treatment works and Wetland 35563 – these are not true impacts (see Section 9.2.6 for details).
10% AEP	DES_AFF_10AEP_1 DES_AFF_10AEP_2	Increases of up to 200 mm upstream of Yam Holes Creek bridges, reducing to 20 mm approximately 400 m upstream. Increases of up to 200 mm on Racecourse Road just upstream of Yam Holes Creek eastern bridge. No buildings affected by afflux. Model instabilities cause apparent afflux through Beaufort, sewage treatment works and Wetland 35563 – these are not true impacts (see Section 9.2.6 for details).
1% AEP	DES_AFF_1AEP_1 DES_AFF_1AEP_2	Increases of up to 300 mm upstream of Yam Holes Creek bridges, reducing to 20 mm approximately 600 m upstream. Increases of up to 300 mm on Racecourse Road just upstream of Yam Holes Creek eastern bridge. Increases of up to 20 mm downstream of Yam Holes Creek bridges extending approximately 200 m downstream. Increases of up to 20 mm extending up to 100 m upstream of road corridor in floodplain west of Main Lead Road. Localised increases of up to 100 mm along eastern side of Main Lead Road. No buildings affected by afflux. Model instabilities cause apparent afflux through Beaufort, sewage treatment works and Wetland 35563 – these are not true impacts (see Section 9.2.6 for details).

Flood level impacts during the construction and operational phase are largely contained within the existing floodplain for the 1 EY, 10%AEP and 1% AEP flood events. For the 1 EY and 10% AEP flood events, the impact from flood levels is considered low. For the 1% AEP, there are short duration localised impacts on the Western Highway at the west interchange, parcel 4~Q\PP2096 (220 Main Lead Road) and parcel 46~5\PP2096 (Beaufort-Lexton Road) where treated sewage irrigation ponds are currently located. The flood level impacts at these specific locations will be subject to further investigation and mitigation during the detailed design phase.

9.2.2 FLOOD VELOCITY IMPACTS

Table 9.4 summarises the key flood velocity impacts for each event.

Table 9.4 Summary of key flood velocity impacts for Option C2

EVENT	APPENDIX F MAP REFERENCE	KEY FLOOD VELOCITY IMPACTS
1 EY	DES_CHVEL_1EY_1 DES_CHVEL_1EY_2	Localised increases only around new drainage structures with increases contained within project boundary.
10% AEP	DES_CHVEL_10AEP_1 DES_CHVEL_10AEP_2	Localised increases only around new drainage structures with increases mainly contained within project boundary, some increases extend just beyond the boundary upstream and downstream of the Yam Hole Creek bridges.
1% AEP	DES_CHVEL_1AEP_1 DES_CHVEL_1AEP_2	Localised increases only around new drainage structures with increases mainly contained within project boundary, some increases extend just beyond the boundary upstream and downstream of the Yam Hole Creek bridges.

In areas of most change around the Yam Holes Creek bridges and within the area requiring channel realignments west of Main Lead Road, increases in velocity can be as high as 100%; however, in all cases the design case velocity values are below 2 m/s and are below 1.5 m/s in most areas of change. Erosion or scour is unlikely to occur for these velocity values in areas with well-established vegetation. The impact from increased flood velocities is therefore considered to be low for the operational phase.

9.2.3 FLOOD DURATION IMPACTS

Table 9.5 summarises the key flood duration impacts for each event.

Table 9.5 Summary of key flood duration afflux impacts for Option C2

EVENT	APPENDIX F MAP REFERENCE	KEY FLOOD DURATION IMPACTS
1 EY	DES_CHDUR_1EY_1 DES_CHDUR_1EY_2	Increases of up to 30% upstream and downstream of Yam Holes Creek western bridge extending approximately 200 m downstream. No buildings or local roads affected by increased duration.
10% AEP	DES_CHDUR_10AEP_1 DES_CHDUR_10AEP_2	Increases of up to 30% upstream and downstream of Yam Holes Creek bridges extending approximately 400 m upstream and 200 m downstream. Increased flood duration affects Racecourse Road just upstream of Yam Holes Creek eastern bridge.
1% AEP	DES_CHDUR_1AEP_1 DES_CHDUR_1AEP_2	Increases of up to 30% upstream and downstream of Yam Holes Creek bridges extending approximately 400 m upstream and 200 m downstream. Increased flood duration affects Racecourse Road just upstream of Yam Holes Creek eastern bridge.

For the critical storm events, the flooding durations around the Yam Holes Creek bridges are extended by up to 2.5 hours and flood durations are increased from approximately 8 hours to 10.5 hours. This increased duration impact is considered to be low as the longer flood durations are localised and of similar magnitude to existing flood durations.

9.2.4 FLOOD HAZARD IMPACTS

Table 9.6 summarises the key flood hazard impacts for each event.

Table 9.6 Summary of key flood hazard impacts for Option C2

EVENT	APPENDIX F MAP REFERENCE	FLOOD HAZARD IMPACTS
1 EY	DES_CHHAZ_1EY_1 DES_CHHAZ_1EY_2	No change in hazard outside project boundary
10% AEP	DES_CHHAZ_10AEP_1 DES_CHHAZ_10AEP_2	Increase in hazard (by 1 classification) approximately 200 m upstream of Yam Hole Creek bridges, affects land adjacent to Racecourse Road.
1% AEP	DES_CHHAZ_1AEP_1 DES_CHHAZ_1AEP_2	Increase in hazard (by 2 classifications) approximately 300 m upstream of Yam Hole Creek bridges, affects Racecourse Road.

Flood hazard impacts during the operational phase are largely contained within the existing floodplain for the 1 EY, 10% AEP and 1% AEP flood events. For the 1EY and 10% AEP flood events, the impact from increased flood hazard is low. For parcel 46~5\PP2096 (Beaufort-Lexton Road) where treated sewage irrigation ponds are currently located, the flood hazard impact will be subject to further investigation and mitigation during the detailed design phase.

9.2.5 EFFECTS OF HIGH CULVERT BLOCKAGE

The design case model assumes 20% blockage of culvert structures, as discussed in Section 4.5.2.2. A sensitivity test was undertaken on the 1% AEP event only using a higher culvert blockage factor of 50%. The afflux, velocity change and duration change maps for the 50% blockage scenario are presented in Appendix G.

When compared against the 1% AEP impact maps discussed in Sections 9.2.1 to 9.2.3, the higher blockage scenario shows no significant worsening of flood level, velocity or duration impacts. Changes to impacts are most noticeable upstream of the culverts west of Main Lead Road where afflux values increase outside the project boundary from 50 mm for the 20% blockage scenario to 200 mm for the 50% blockage scenario (comparing Map DES_AFF_1AEP_1 in Appendix F to Map DES_AFF_1AEP_1 in Appendix G). However, the area affected by the afflux remains similar in both scenarios.

The results show that the current design produces a similar level of impact under a high culvert blockage scenario and impacts are not sensitive to the blockage assumption.

9.2.6 EFFECTS OF CLIMATE CHANGE

The effects of climate change on the predicted flood impacts on adjacent land were determined by comparing the flood impact maps for the 1% AEP event with and without climate change allowance. The impact mapping comparison is summarised below in Table 9.7.

Table 9.7 Summary of effects of climate change on predicted flood impacts for the 1% AEP event

PARAMETER	WITHOUT CLIMATE CHANGE APPENDIX F MAP REFERENCE	WITH CLIMATE CHANGE APPENDIX F MAP REFERENCE	IMPACT COMPARISON
Afflux	DES_AFF_1AEP_1 DES_AFF_1AEP_2	DES_AFF_1AEPCC_1 DES_AFF_1AEPCC_2	Afflux increased by between 50 and 100 mm in impacted areas but no change to extent of impacted areas
Velocity change	DES_CHVEL_1AEP_1 DES_CHVEL_1AEP_2	DES_CHVEL_1AEPCC_1 DES_CHVEL_1AEPCC_2	No significant change or worsening of impact
Duration change	DES_CHDUR_1AEP_1 DES_CHDUR_1AEP_2	DES_CHDUR_1AEPCC_1 DES_CHDUR_1AEPCC_2	No significant change or worsening of impact
Hazard change	DES_CHHAZ_1AEP_1 DES_CHHAZ_1AEP_2	DES_CHHAZ_1AEPCC_1 DES_CHHAZ_1AEPCC_2	No significant change or worsening of impact

9.2.7 EFFECTS OF MODEL INSTABILITIES

The apparent afflux through Beaufort along Garibaldi Creek is generated by an instability in the flood model rather than a true impact of the project. A steep embankment immediately downstream of the model inflow boundary at Garibaldi Creek causes a fluctuation in the water surface level in the existing conditions model. These fluctuations in water levels propagate down Garibaldi Creek through Beaufort, stabilising only at the creek's confluence with Yam Holes Creek. Figure 9.1 below shows the instability in the existing conditions flood level time series (red line) which causes artificial fluctuations of approximately 150 mm in the time series. When compared against the design case model results, the fluctuations result in an artificial afflux prediction in the Garibaldi Creek portion of the model.

Such instabilities are common in flood models, particularly through urban areas where flow patterns are complex. The instability does not affect the accuracy of the flood model or its predictions of impacts in the rest of the model domain outside the Garibaldi Creek system.

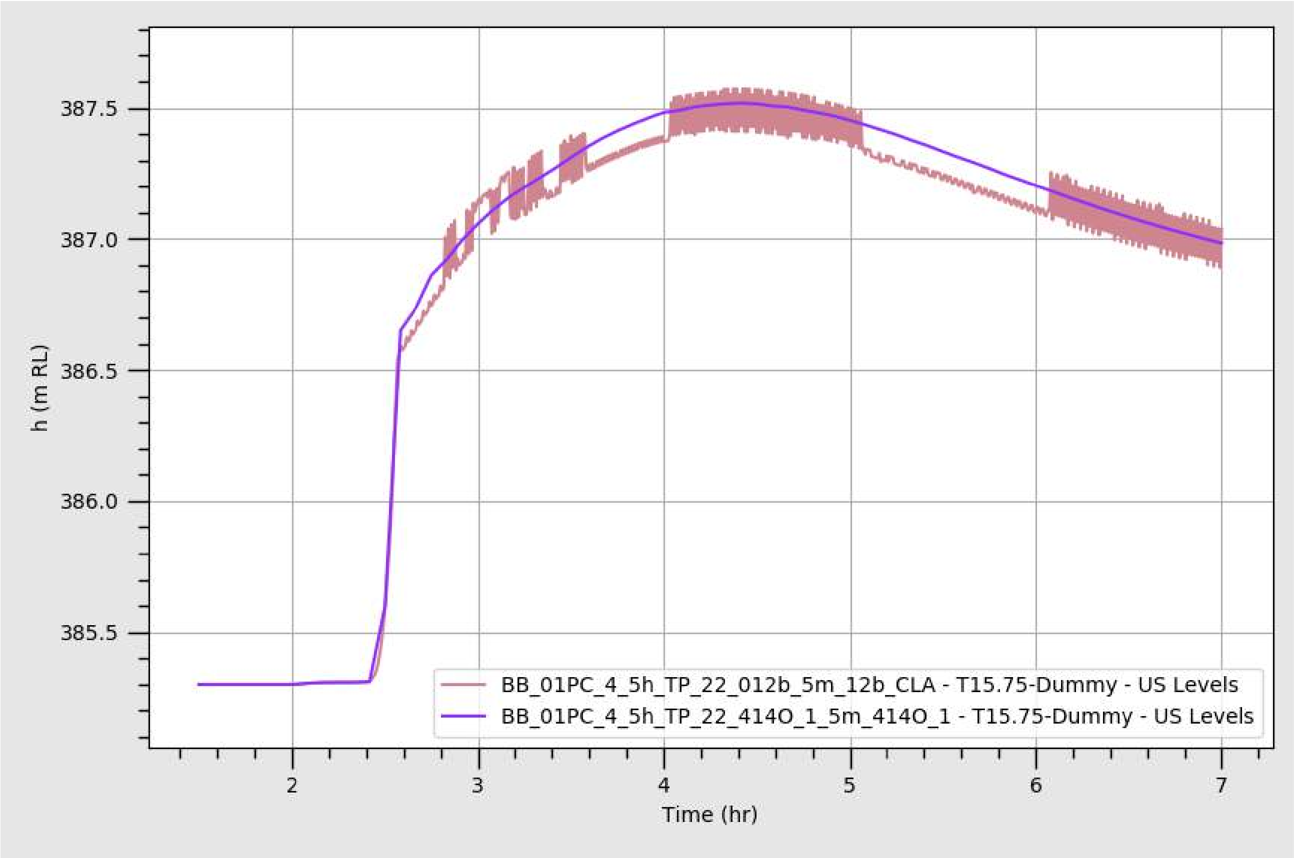


Figure 9.1 Example of existing conditions model instability in Garibaldi Creek through Beaufort

9.2.8 SUMMARY OF FLOOD IMPACTS

The impact mapping in Appendix F shows the detailed location and extent of impacts for each parameter (afflux, velocity change, duration change and hazard change). The maps show that the highest impacts (or change in parameters) occurs within the project boundary, with lesser impact and change outside the boundary. In addition, the mapping in Appendix F shows no significant new areas of land flooded outside the project boundary.

Outside the boundary the afflux is predominantly less than 100 mm with impacts localised to areas that experience significant depths of flooding in the baseline condition. Duration impacts are also localised, with flooding times in the affected areas increased by 2.5 hours or less. Changes to flood velocity and hazard are also minor and localised outside the project boundary, with the impact on these parameters occurring upstream of the Yam Holes Creek bridges.

Given that the majority of flood changes occur within the project boundary or within the existing floodplain, the impact on adjoining land uses is considered to be low, with the exception of impacts upstream of the Yam Holes Creek bridges and around Racecourse Road where some changes in flood behaviour are predicted upstream of the project boundary and along the road. At the next stage of design it is expected that these impacts can be reduced through a multi-disciplinary design approach to refining the design of the bridges and associated earthworks. Following further design optimisation of the bridges and reduction in impact, consultation with affected landowners on the impacts would then be undertaken to identify their sensitivities to changes in flood behaviour and the requirement to incorporate flood impact mitigation measures into the detailed design.