Latrobe Council

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Hydro Tasmania

MINIMISING FLOOD RISK IN LATROBE

Hydraulic modelling and levee options assessment

1 June 2018

Prepared by Hydro-Electric Corporation
ABN48 072 377 158

t/a Entura 89 Cambridge Park Drive,
Cambridge TAS 7170 Australia

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Client contact	Jonathan Magor
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Executive summary

The severity of the June 2016 flood event and its impact on Latrobe established a high level of concern amongst Councillors, residents and commercial property owners regarding the flood protection of the Latrobe township. Latrobe is one of the earliest settlements along the north west coast of Tasmania and has a number of heritage buildings and future development options that may be affected by flooding.

Entura was engaged by Latrobe Council to conduct a structural flood protection option assessment for Latrobe township based on the 2016 flood event. The assessment is part of the project "Minimising Flood Risk in Latrobe and Surrounding Areas" under the Natural Disaster Resilience Grants Program (NDRGP).

Work was shared between Entura modellers and engineers (Mersey River flooding and levee bank concepts) and Council engineers (Kings Creek flood mitigation options).

The June 2016 flood was estimated to have a flood frequency circa 0.33% AEP (ie. 300 years ARI) though this estimate has large confidence bounds and is therefore difficult to define accurately. The 2016 flood levels were considered appropriate for the design of Mersey River flood protection options and is generally consistent with newly emerging Australian standards which recognise that design standards need to be considered on a case by case basis taking into account the health and safety risks of residents, the priority of assets to be protected, and other factors. Protection from the 2016 flood is likely to be the acceptable level of service the community will accept.

This study adopted 1% AEP design event for flood mitigation option assessment for Kings Creek inflows, in conjunction with the observed water levels along Mersey River during the 2016 flood event.

Kings Creek flooding

Modelling of Kings Creek was conducted by the Council with model validation completed by Entura using separate software packages and assumptions. A high degree of confidence is assigned to the model results that show:

- A 1% AEP flood event in Kings Creek can be contained within the existing channel in the CBD for frequent water levels in Mersey. This is consistent with findings in the HECEC (1994) Latrobe Floodplain Study.
- When levels in Mersey River are above 4.5 mAHD backflow starts to cause some flooding from Kings Creek into the CBD.
- Sheean Walk represents a natural drainage point for high flood water levels from Kings Creek (ie. for flood levels in Kings Creek above 5.8mAHD, some flow will naturally be diverted over Sheean Walk toward Mersey River)

Options for enhancing or constructing additional upstream detention storage in Kings Creek catchment were investigated. The aim was to reduce the volume and peak flow rates in Kings Creek at the location of over-bank flow near the CBD. The investigations found that:

- The existing detention storage on Kings Creek is designed for 1% AEP and expansion of this capacity would not effectively reduce peak flows in the CBD for the design event.

- A new detention storage could be built on Latrobe Creek near the hospital, but would only reduce flood levels in the CBD by approximately 100 mm at up to 20 dwellings in the CBD.
- A new detention basin cannot, by itself, protect the CBD from Kings Lane design floods with high levels in Mersey.
- Approximately 1 m high levees along Kings Creek (700 m) and Kobie Lane (200 m) would prevent inundation of the CBD under the adopted design flood conditions.
- Any levee for Kings Creek will need to incorporate an emergency spillway for flood events, rarer than the levee design event.
- A potential location for a spillway is at or near Sheean Walk utilizing the local topography to drain water away towards the Mersey River, but will require lowering of the walkway.
- Some local engineering works may be required to facilitate effective operation and reduce the impacts of spillway flows.
- A combined option of 300 mm lower levees and a detention storage is unlikely to be cost-effective or improve amenity.

In addition to levee works it is recommended that:

- Regular maintenance of the Kings Creek channel is undertaken to maintain its flood carrying capacity and reduce any impacts from debris and obstructions.

Mersey River flooding

A combined 1D/2D hydraulic model of the Mersey River was constructed and calibrated to assess the main mechanisms of riverine flooding and to identify potential flood mitigation options for Latrobe. The model extends from 5 km upstream of Latrobe to the Mersey River estuary, 7 km downstream of Latrobe.

Surveyed flood levels were able to be replicated within ±0.3 m accuracy which is considered satisfactory for flood mitigation option assessment. Sensitivity analysis showed that downstream tidal levels, bridge blockages and other factors do not significantly change the model results.

Modelling shows that:

- The major flood mechanism is inundation of properties at 20-42 Gilbert Street and overtopping of Gilbert Street just upstream of the Mersey River bridge.
- Minor road overtopping also occurs downstream of the Mersey River bridge, opposite 1-5 Gilbert Street, over a road length of 120 m.
- Areas downstream of Last Street are impacted by backflow from Mersey River.
- Areas east of Victor Street are impacted by backflow through Kings Creek channel and Kings Creek inflows.
- Kings Creek inflows increase flood levels east of Victor Street, within 100 m from the creek channel, by 50-300 mm.

Eight (8) flood mitigation options were developed and tested using the model in consultation with Council based on assessment of flooding mechanisms and possible future Council works. Each concept was evaluated against a number of criteria, as part of a high level cost benefit analysis. Criteria including:

- The potential reduction in flood damage
- Cost of construction
- Feasibility of construction, and
- Impact on surrounding areas.

No impact on water levels in surrounding rural areas was evident from any of the levee options tested. This is consistent with hydraulic principles and professional judgment given the relatively minor reductions in flood storage from levee construction compared with the very wide floodplain in the lower Mersey River.

Short-listed options

Following discussions with the Council, numerous flood protection alternatives, for flooding from both Mersey River and Kings Creek, were combined into four (4) short-listed options A, B, C and D.

Preliminary plans depicting these options are shown in the last **Appendix K**.

Option A is the most cost-effective option for riverine flooding and simply consists of a 350 m long flood barrier behind houses at 20-42 Gilbert Street. This option would approximately halve the damages experienced during the 2016 event, but is not a comprehensive solution for the whole township. A 350 m permanent concrete flood wall behind houses at 20-42 Gilbert Street is estimated to cost $650,650 (including 30% contingency).

Option B would protect all properties in Latrobe township for the 2016 event and would require:

1. A 350 m long flood barrier behind houses at 20-42 Gilbert Street. This barrier should be a permanent structure given that it prevents the major flooding mechanism. A concrete wall is recommendable due its small footprint. A section of the wall adjacent to Mersey River, south of the bridge, could be a glass wall, include murals or be integrated into the landscape (e.g. tree plantings) to improve visual amenity.
2. A 550 m long flood barrier downstream the Mersey River Bridge, along Gilbert Street, River Road and Last Street. This flood barrier can be shortened if some of the affected houses are flood-proofed.
3. Minor flood-proofing of houses at 46-70 and 45-87 Gilbert Street, which are influenced by backflow from Mersey River and Kings Creek inflows.

The cost of this option is estimated to be $2,383,810 (including 30% contingency).

If a flood barrier along River Rd is adopted, local drainage and outlets at the corner with Last Street should be taken into consideration during the detailed design of the project. Furthermore, breakout areas in Kings Creek that divert flows via Sheean Walk toward the barrier at River Rd should be addressed with a permanent blockage of this diversion (eg. raising of Sheean Walk lowest point by 500mm).

Option C could protect 60 properties (out of 70 affected) for the 2016 event at an estimated cost of estimated as $4,450,160 (including 30% contingency). This option would require:

1. A 350 m flood barrier behind houses at 20-42 Gilbert Street
2. A 150 m long flood barrier downstream the Mersey River Bridge, along Gilbert Street. Properties along River Road and Last Street cannot be protected in this options, as Kings Creek

inflow are diverted through the existing drain located parallel to Last Street. The existing drain is likely to require significant increase in capacity.

3. A 200m long and approximately 1 m high flood barrier along Kobie Lane.
4. Enlargement of Victor Street Bridge opening and provision of water impermeable handrails up to the height of 5.8 mAHD.
5. 700 m long flood barriers approximately 1 m high along the left and right banks of Kings Creek upstream of Victor Street. This length includes barriers and miscellaneous work to prevent surcharge between buildings located between Gilbert and Victor Street.
6. Modification of Sheean Walk to be able to cater for flow diversion from Kings Creek. This may include excavations – up to 0.5m depth; provision of flood barriers on the southern side of the walk; new culvert in front of 10, Victor Street and enlargement of the existing drain between Victor Street and River Rd.
7. Kings Creek embankment stabilisation from Sheehan Walk to Gilbert Street based on completed works at Kings Park. It needs to be part of this project as it can't be done once the walls are built

Option D is the same as Option C, but includes several emergency spillways and/or fuse plugs along Kings Creek levee and Kobie Lane levee, instead of Sheean Walk modifications. This option will need detailed hazard assessment during detailed design for flood events rarer than the chosen design standard (i.e. when levee overtops). Detail design should ensure that levee failure hazards do not exceed existing hazard conditions (i.e. without levees).

Both options C and D include a modified upgrade of Victor Street Bridge.

Summary of the costs and benefits of flood mitigation works is presented in the following Table.

	Cost (+30%)	**Flood mitigation effect**	**Comment**
OPTION A	$0.65 million	Could halve damages for the event similar to 2016; 21 houses saved; 15 houses significant reduction in damage	Not a comprehensive solution, but has the best benefit-cost ratio.
OPTION B	$2.4 million	Comprehensive flood protection; 70 houses saved	May require installing house flood-proofing barriers with short notice.
OPTION C	$4.5 million	~60 houses saved	~10 houses cannot be saved from Mersey River backflow downstream of the bridge, because this option needs to allow Kings Creek flood diversion through Sheean Walk

OPTION D	$4.5 million	Comprehensive flood protection; 70 houses saved	Comprehensive solution without need to divert flow to Sheean Walk. Risk to houses in the CBD for flood events rarer than design flood event.

All cost estimates exclude the purchase of land and resolving unusually complex internal drainage issues (if any) but include 30% contingency.

It should be noted that the cost and availability of: borrow materials, machinery, labour/ project management; design and feasibility studies, easements and/or the acquisition of land; resolving internal drainage issues and legislative costs can skew typical levee cost per linear meter significantly (Wollongong City Council, 2017). These issues would need to be considered during final design.

Preferred option

Option A has the lowest cost of the four short listed options. However, a major deficiency is that it only protects part of the Latrobe township from flooding. Council considers this unacceptable and inequitable for those outside that area and the future development of the town.

Option B is reliant on flood proofing and protecting existing homes, businesses and properties either before or during a flood event. Given the warning uncertainties about the Mersey River flooding depths and the short times of concentration for Kings Creek to peak this will be problematic. A further deficiency is that ongoing development of the town will be stifled, particularly in the area where flood protection of properties is necessary. Additionally, spills from Kings Creek exiting near Sheean Walk will have significant potential to divert waters towards properties that have previously been clear of flooding. Council advised that owners in such areas will see Option B as unacceptable and counterproductive.

Option C does not rely on flood proofing and protecting private properties in and around the CBD and the potential issues this introduces. The biggest deficiency is that spills from Kings Creek exiting near Sheean Walk will divert significant flow towards properties that have previously been clear of flooding. As a result, this option requires quite considerable changes to Sheean Walk and the current ambience and amenity provided by it. If progressed, Sheean Walk may effectively become a concrete lined open drain/walkway with box culverts at road crossings through to River Road. Additionally, this solution will most probably prevent a long downstream barrier in River Road, thereby not enabling properties in and around Last Street West to be protected from Mersey River backflow. This will require flood proofing and protecting properties in this vicinity thereby limiting future development and reliance on implementing protection measures proceeding and during a flood event. Council does not consider this a comprehensive or acceptable solution to the community.

Option D protects all developed properties from the modelled Mersey River floodwaters, in addition to increasing the flow capacity of Kings Creek by lowering friction losses and effectively raising the containment walls. It is considered the most desirable long-term solution as it does not rely on flood protecting properties prior to or during an event which is particularly problematic in relation in the flash flooding that may occur in Kings Creek if the Mersey River level was above 4.5m AHD. Public flood protection works are envisaged to be permanent and not reliant on personnel to deploy. This option allows for future development within the town and does not prevent extension of the existing

CBD area. Additionally, it identifies areas for localised drainage to pond on public land when waters 'outside' the levees are higher than those inside the walls and does not detract from Sheean Walk in any way. Detailed design will need to consider potential flow relief points and temporary works that may need to be deployed for events larger than the design flood.

Considering the above assessments Option D is recommended.

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1. Introduction

Latrobe has a long history of flooding stretching back to photographic and newspaper records from the 1880's of major floods in the main street. The June 2016 flood was particularly severe causing loss of life, stock losses and destroying long standing railway bridges and stream gauging stations.

The severity of the June 2016 flood event and its impact on Latrobe established a high level of concern amongst Councillors, residents and commercial property owners regarding the flood protection of the Latrobe township. Latrobe is one of the earliest settlements along the north west coast of Tasmania and has a number of heritage buildings and future development options that may be affected by flooding.

Latrobe Council secured a grant from the National Disaster Resilience Program (NDRGP) to deliver project "Minimising Flood Risk in Latrobe and Surrounding Areas". As part of the project, Entura was engaged by the Council to conduct structural flood protection option assessment for Latrobe township based on the 2016 flood event. Kings Creek flood mitigation options assessment was carried out conjointly by Council and Entura engineers. The scope of works presented in this report included:

- Flood mitigation options assessment for Kings Creek
- Hydrological analysis of Mersey River and establishment of the June 2016 food event inflow hydrograph
- Development of a suitable hydraulic model of the downstream reach of Mersey River for flood mitigation options assessment
- Development and assessment of structural flood mitigation options from Mersey River and Kings Creek

Traditional best practice principles in Australia have typically considered the 1% Annual Exceedance Probability (AEP) flood event as the design flood used for planning purposes, particularly for residential development in urban areas (CSIRO, 2000). But a previous flood study of the area (HECEC, 1994) has indicated that Latrobe is not flooded by the 1% AEP flood. Mersey River Flood Study (Entura, 2011) confirmed that Latrobe is not flooded for smaller "major" flood events, approximate magnitude of 3.33% AEP. This was the largest analysed event in the Mersey River Flood Study.

Newly emerging Australian standards now recognise that the adoption of flood design standards is more adequately considered on a case by case basis taking into account the health and safety risks of residents, the priority of assets to be protected, and other factors.

Given the high degree of concern regarding recent flooding, the historic nature of the township, and the potential impact on current and future development the 2016 flood levels have been used as the design standard in this instance for Mersey River flood mitigation assessment and 1% AEP design event for Kings Creek options.

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2. Kings Creek flood mitigation options assessment

2.1 Introduction

Kings Creek mitigation options assessment was conducted by Latrobe Council under Entura's guidance in order to develop local capacity and enhance links between local development plans and engineering standards.

2.2 Modelling

Modelling was conducted in 1-dimension (1D) in DRAINS software by the Council. The model included river cross-sections and major culverts and bridges. The stormwater network was not modelled as it was assumed that the network would be full under major flood conditions.

Upstream 1D hydraulic model boundaries were located 2 km from Latrobe CBD, on two creek branches, namely Kings Creek and Latrobe Creek. Hydrological model included catchments upstream of the existing basin and upstream of Hawkins Street, with total areas of 606ha and 1160ha respectively. Kings Creek flows from west to east and Latrobe Creek flows from north to south. Two branches meet 40 m south of Hawkins Street, between Moriarty Road and Bradshaw Street. The two reaches and the existing detention basin are shown in Figure 2.1.

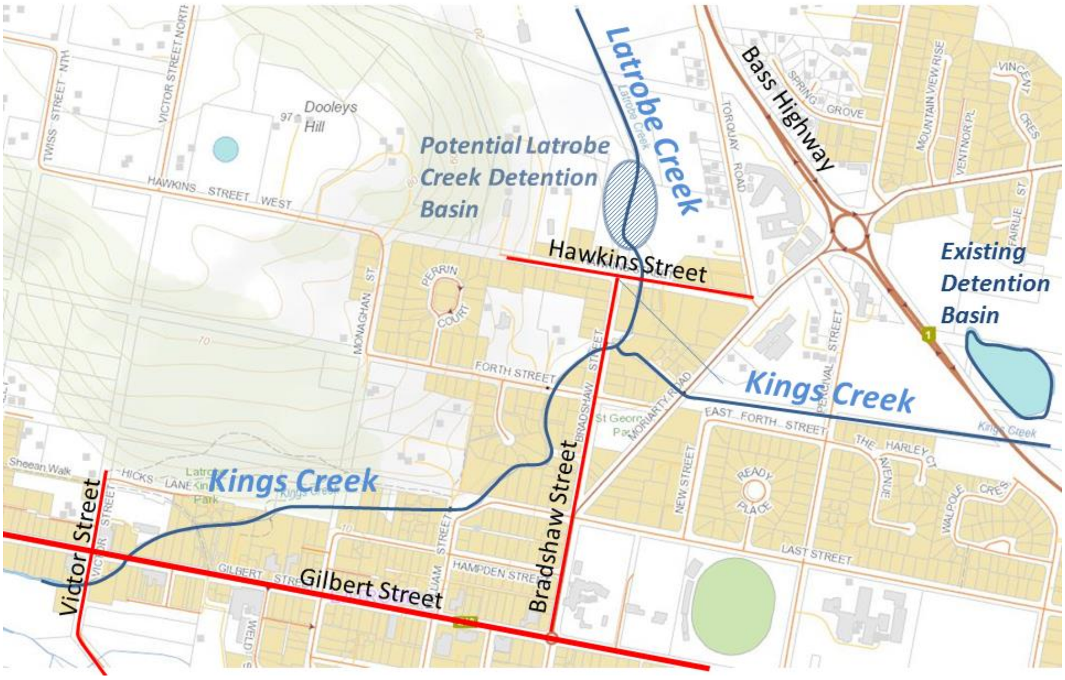

Figure 2.1: DRAINS hydraulic model extents

The downstream boundary condition for the model is the water level at the confluence of Kings Creek and Mersey River. The confluence is located 300 m west from Victor Street.

Topographic cross-sections were included in the model. For the CBD surveyed cross-sections were available, for the remaining areas cross-sections were extracted from LIDAR.

The existing detention pond was modelled as a node and its storage curve was extracted from topography.

Hydrological modelling was conducted in DRAINS concurrently with hydraulic modelling using the Australian Rainfall and Runoff initial-continuing loss method (ARR, 2016). Kings Creek catchment area was delineated into 21 catchments. Catchment physical characteristics, such as slope, area and imperviousness were adopted based on topographic and planning maps.

The following hydrological parameters were adopted from the ARR data hub (ARR, 2018):

- Initial losses (pervious) 14 mm
- Initial losses (impervious) 1 mm
- Continuous loses (pervious) 4.5 mm/h
- Continuous losses (impervious) 0 mm/h

2.3 Model validation

Independent model validation was conducted by Entura using 1D HEC-RAS modelling software, XPSWMM, and the combined 1D/2D MIKE FLOOD Mersey River model:

- Kings Creek channel, from Kings Park to Victor Street, was modelled in HEC-RAS to assess potential levee options in the CBD. The model used 15 cross sections from LIDAR.
- XPSWMM was used to assess a potential new detention basin on Latrobe Creek. The model included a storage node as the basin, outflow pipes and three (3) downstream cross sections. Inflows were modelled from a single upstream catchment of 1160 ha.
- The Mersey River model was used to validate floodplain modelling in the CBD. Details of Mersey River model are described in Section 4.

Mersey River floodplain grid in MIKE FLOOD was coarse to accurately model Kings Creek channel. Its purpose was to estimate water level variations in the CBD due to various creek inflows and high water levels in Mersey. In principle, the CBD serves as Kings Creek floodplain once water overtops its banks. Drainage of the Kings Creek floodplain occurs via Kings Creek itself, or via lower points in the landscape such as along Sheean Walk.

2.4 Current flood issues

2.4.1 Latrobe CBD

Modelling has shown that 1% AEP (Annual Exceedance Probability) flood event in Kings Creek can be contained within the existing channel in the CBD for normal and moderate flood levels in Mersey. This outcome corresponds to the findings in the earlier HECEC (1994) study.

For significant flood levels in Mersey, above 4.5 mAHD, some flooding starts to occur in the CBD due to a reduction in Kings Creek channel capacity caused by backflow from the Mersey River.

As a reference, based on Bureau of Meteorology (2018a; 2018b), major flood alert corresponds to 4.2 mAHD at Latrobe Mersey Bridge. Mersey River Flood Survey (Entura, 2011) estimated major alert on Mersey River at Kimberley as 3.33% AEP flood event.

It should be noted that flooding would occur in CBD even without Kings Creek inflow, for very large flood events in Mersey, such as the 2016 event. The extent of such flooding is shown in Appendix B.

2.4.2 Percival Street

Kings Creek channel was known to be under-capacity for 1% AEP floods between Percival Street and Moriarty Road as described in HECEC (1994) which recommended channel enlargement. However, construction of the detention basin in 2002 has since occurred.

As per Council's recommendation, this study does not cover flooding issues in this particular area.

Council currently manages this issue using building approvals that require house floor elevations above 1% AEP.

2.5 Potential mitigation options

Potential mitigation options for Kings Creek flooding in the CBD are to:

- increase flood storage capacity in the upstream catchment areas to regulate flows through the constrained channels in the township, and/or
- contain flood within the channel in the CDB using levees

These solutions can be achieved by either of the following options:

- augmenting the existing flood detention storage adjacent to the Bass Highway,
- installation of gates to control flows out of the existing detention storage,
- establishing additional flood detention storage upstream of the current detention storage and in and around the town
- Levee along the King Creek channel in the affected areas

2.6 Design flood event

Traditional best practice principles in Australia have typically considered the 1% AEP flood event as the default design flood used for planning purposes, particularly for residential development in urban areas (CSIRO, 2000). However, the selection of an appropriate design flood event requires more careful consideration taking into account factors such as the resilience of the local community to flooding, recent history of flooding including loss of life and flood damage, the location and security of key infrastructure such as hospitals, cultural and historic heritage, emergency management, entrance and egress from flood prone sites, and other factors.

For the purposes of this study, the adopted design flood event for Kings Creek flood mitigation options assessment is based on:

- 1% AEP Kings Creek inflows
- 5.5 mAHD water level in Mersey River based on the 2016 flood event.

The joint probability of such event is a much rarer event than 1% AEP. However, the analysis of joint probabilities is complex in this situation, is beyond the scope of this study, and is unlikely to change the outcome of the study due to the nature and extent of flooding from Kings Creek.

2.7 Mitigation options comparison

2.7.1 Improving the existing flood detention storage

DRAINS modelling confirmed that the maximum capacity of the existing detention pond is equivalent to the 1% AEP flood event.

Running the model with and without the detention basin in place shows that the pond decreases peak flows from 13.5 m^3/s to 6 m^3/s for a 6 hour duration, 1% AEP storm which is considered critical for this catchment. Inflow and outflow hydrographs are shown in Figure 2.2.

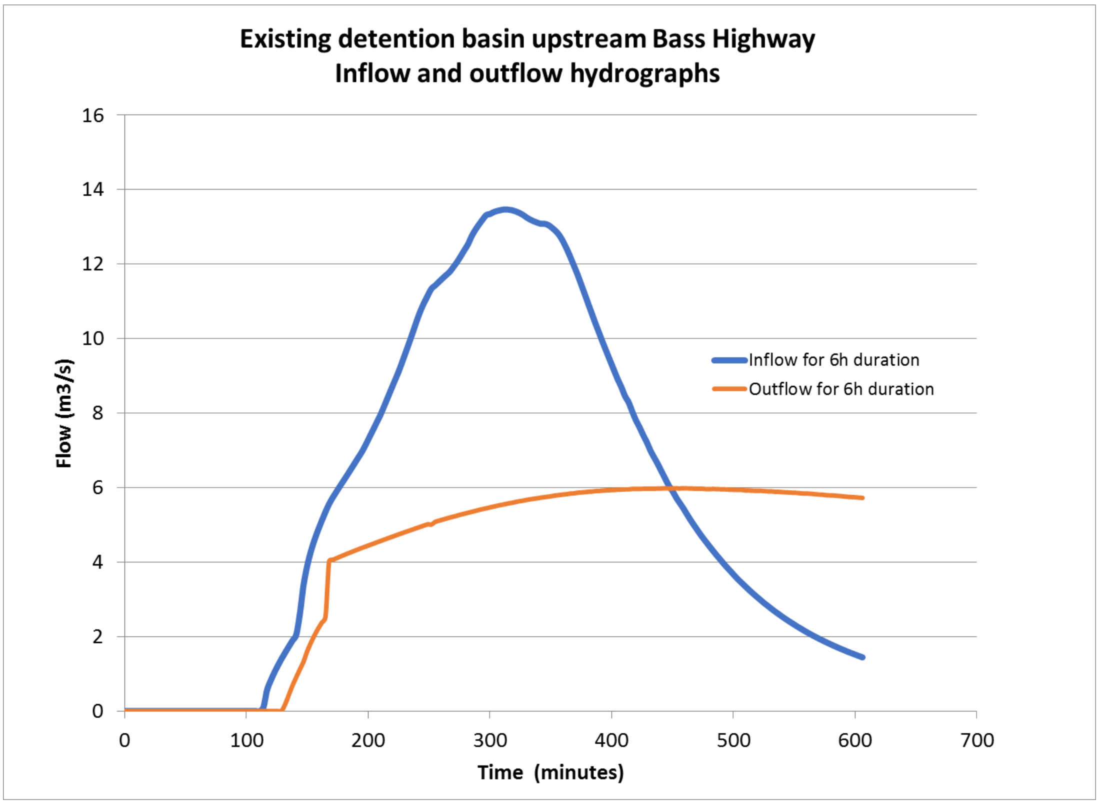

Figure 2.2: Inflow and outflow hydrographs for existing King Creek detention basin

The performance of the existing flood detention basin could be improved by:

- increasing its storage capacity with additional excavations, or
- installing gates to reduce outflows.

However, the potential to further decrease the peak discharge below 6 m^3/s is limited. The catchment area of the existing basin is 606 ha, while the total catchment area of Latrobe Creek, which is a Kings Creek tributary downstream of the existing basin, is 1160 ha. Total catchment area of Kings Creek (upstream of Mersey River) is 1800 ha. Hence, the existing basin attenuates flow from only approximately 30% of the total catchment area.

Augmenting storage capacity by excavation is generally more expensive that building dam walls; and the installation of gates on the existing basin would decrease its design capacity below 1% AEP.

Consequently, it was concluded that a new detention basin, which would attenuate peak flow from Latrobe Creek, would be more beneficial than augmentation of the existing pond.

2.7.2 Additional flood detention storage

Modelling has shown that the majority of Kings Creek inflow into the CBD is from Latrobe Creek catchment upstream of Hawkins Street. Current detention basin effectively halves peak flow from Kings Creek catchment upstream of the confluence with Latrobe Creek.

Ideally, any new detention pond should be located in relatively flat area, on land owned by Latrobe Council, with as much of the catchment as possible located upstream of the basin location.

The site that satisfies these criteria is found north of Hawkins Street and west from Mersey Hospital.

To produce a reduction in peak flood discharge similar to that achieved at the existing detention pond would require a detention storage volume of approximately 100 ML at this site. However, the optimal detention basin capacity is limited by topography, Council owned land boundaries and construction costs.

Taking site constraints into consideration, effective flood attenuation can be achieved through:

- Establishing a pond through the construction of a 2.5 m high embankment over a length of 130 m.
- Installing twin 1.2 m diameter outflow pipes in the embankment to constrain releases

Inflow and outflow hydrographs are shown in Figure 2.3. Peak inflow to the detention storage is estimated to be 24 m3/s with peak outflow estimated as 16 m^3/s.

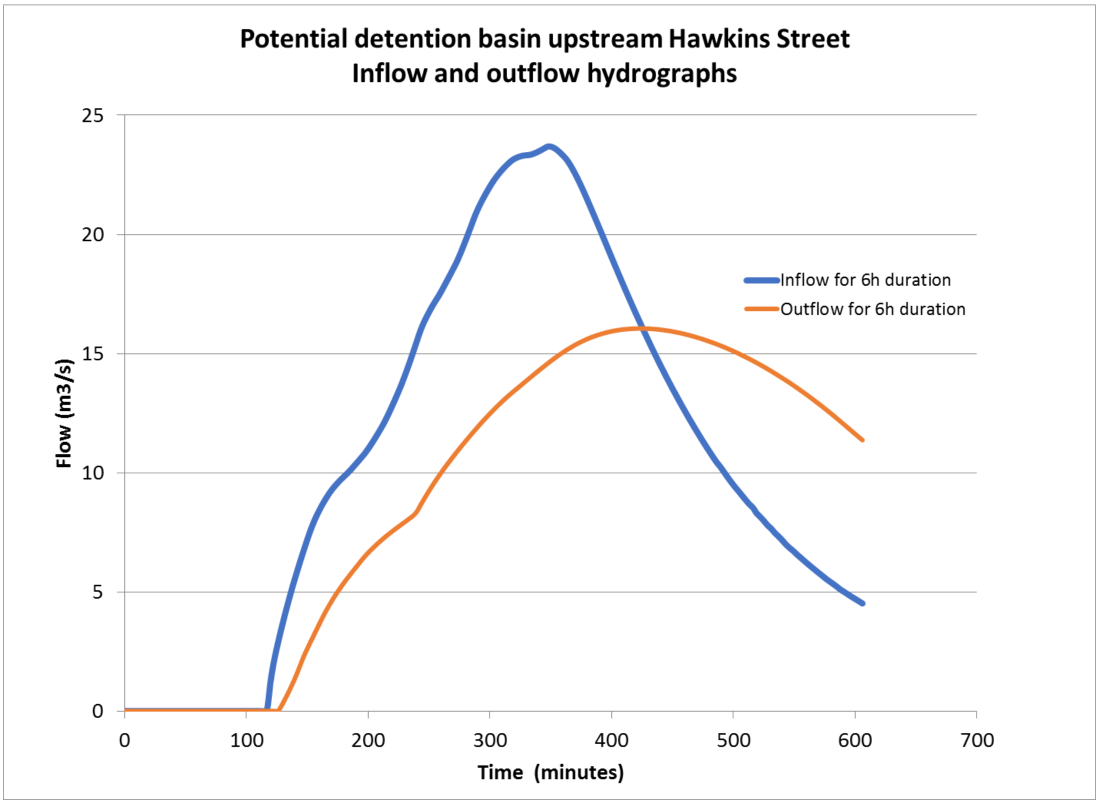

Figure 2.3: Inflow and outflow hydroraph for new detention basin

Construction costs for the basin are estimated as $250,000 (±30%) as detailed in **Appendix I**.

It is assumed that embankment will be a simple concrete weir, in order to allow for safe overflow during flood events beyond the design level.

An earthen embankment was considered, but it would need to incorporate a separate concrete spillway to cater for inflows rarer than 1% AEP; it would need to be constructed higher than a concrete weir to allow for sufficient head over the spillway; and it would be a more complex design than a simple concrete weir.

2.7.3 Levee along Kings Creek channel

An alternative to reducing the peak discharge from the catchment into the CBD is to construct a levee along segments of Kings Creek channel that might be over-topped during floods. Assessment of water gradients along Kings Creek indicates that a levee approximately 1 m high and 700 m long could achieve effective flood protection. This option corresponds to Option 6 analysed in Section 6.

2.8 Options effectiveness

2.8.1 Additional flood detention storage

The MIKE FLOOD Mersey River model (see Section 4) with water levels in the Mersey set at 5.5 mAHD was used to test the effectiveness of additional Kings Creek flood detention storage.

The model was run for two cases: without and with a detention pond. Flood hydrographs from DRAINS model were inserted into MIKE FLOOD model at Kings Park to simulate two cases.

Model results show that the new detention basin may decrease water levels in the CBD by only 100 mm and is unlikely to significantly reduce flood damages. A total of 20 properties could have marginally reduced damages for an event similar to the 2016 flood.

General stage damage curves are shown in Figure 2.4. The difference in structural damage for 100 mm flood level difference is insignificant. Such water level differences may cause higher content damage, but total content value is lower than structure cost, and is usually insured. Nevertheless, damage curves may disguise enormous variation in individual cases and uncertainty about their true value (Emergency Management Australia, 2003).

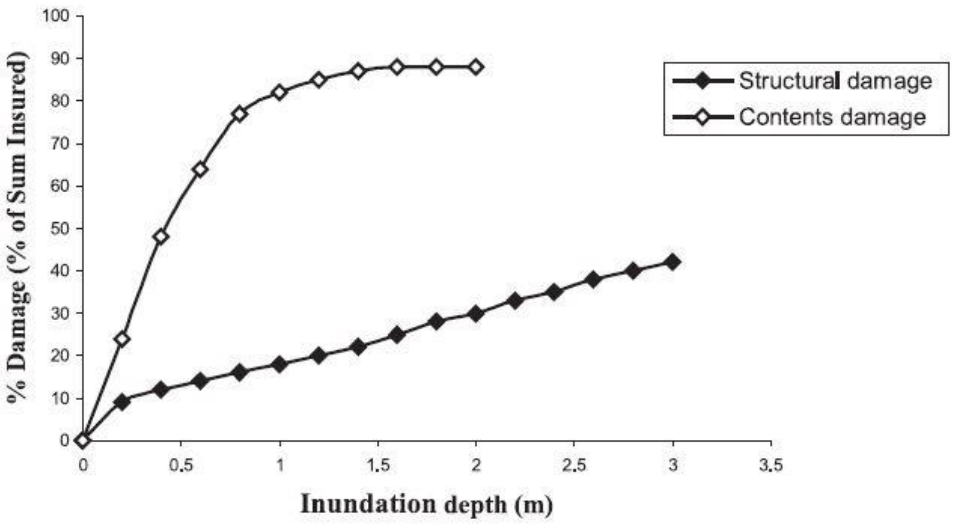

Figure 2.4: Stage Damage Curve (Emergency Management Australia, 2003))

It is concluded that it is unlikely that a detention basin will be a cost-effective option of reducing Kings Creek flooding.

2.8.2 Levee along Kings Creek

Under some very rare flood events, water levels in Kings Creek may exceed the channel capacity and over-top the banks. This includes flooding from the Mersey River only without any flood waters from Kings Creek. Sheean Walk and adjacent low topography provides a natural flood diversion which drains some flood waters back towards the Mersey River when water levels exceed 5.8 mAHD[1].

Using levees to constrain flood waters to the Kings Creek channel will reduce overbank water storage and lead to an increase in the 1% AEP water level in the Creek. A levee approximately 700 mm high could be used to protect the town, but as discussed in the next Section, a levee approximately 1 m high would provide additional protection equivalent to an upstream detention storage on Latrobe Creek as well as some freeboard. It would protect around 23 properties from flooding.

[1] In fact water will begin to move along Sheean Walk from 5.5 mAHD but will pond until the high point in the Walk (5.8 mAHD) is exceeded before it begins to drain towards the Mersey in an uncontrolled manner.

A 1 m high, 700 m long levee along Kings Creek would be combined with a 200 m levee along Kobie Lane to further protect properties from Mersey River flooding[2].

For flood events rarer than the levee design event, an emergency spillway is required to pass excess flows avoiding breaches that could cause significant damage. If Sheean Walk is adopted as an emergency spillway, it would need to be significantly modified and lowered.

The final height and cost of levees needs to be developed during detailed design taking into account engineering works on Sheean Walk. The cost estimates provided in this report are considered appropriately conservative and include a 30% contingency allowance.

2.8.3 Levee in conjunction additional detention storage

As indicated above, constraining Kings Creek via levee banks will reduce the flood capacity of the channel and will lead to an increase in water levels within the Creek for any nominated over-bank flow event. The efficacy of utilising levees in combination with an upstream detention storage was therefore investigated.

DRAINS and HEC-RAS models were run for the following two scenarios:

- Levee along Kings Creek for existing conditions and 5.5 mAHD water level in Mersey
- Levee along Kings Creek with detention basin and 5.5 mAHD water level in Mersey

Model results indicate that the creation of a detention pond on Latrobe Creek would decrease water levels in Kings Creek by 300 mm.

The same level of flood protection could be achieved by simply increasing the Kings Creek levee height by 300 mm.

The marginal costs of an additional 300 mm of levee construction are likely to be substantially lower than the costs of constructing a new detention basin.

2.9 Sensitivity analysis

Sensitivity analysis was conducted in HEC-RAS for the following:

- Three (3) levels in Mersey
- Two (2) Manning's roughness coefficients, 0.03 and 0.05, which correspond to "clean channel" and "channel with weeds and stones"

The analysis assumed a flood wall or levee along the Kings Creek banks and was run under steady state flow conditions (i.e. constant inflows).

Results of the analysis, 80 m upstream of Gilbert Street, are shown in Table 2.5.

[2] Mersey River flooding and comprehensive solutions are discussed in following sections of this report.

			Level in Mersey					
			5.5mAHD		5mAHD		4.5mAHD	
Flow (m3/s)	Description	Maning's n	Clean channel	Channel with Weeds and stones	Clean channel	Channel with Weeds and stones	Clean channel	Channel with Weeds and stones
32	1% AEP without detention basin		5.83	5.99	5.45	5.74	5.28	5.63
22.5	1% AEP with detention basin		5.64	5.75	5.25	5.46	4.95	5.29
15	approx. 10% AEP		5.57	5.62	5.1	5.23	4.72	4.98
10	approx. 50% AEP		5.53	5.56	5.05	5.11	4.58	4.75
5	N/A AEP		5.51	5.52	5.01	5.03	4.52	4.57

Table 2.5: Sensitivity analysis – levels in Kings Creek, 80m upstream of Gilbert St

The analysis indicates that:

- Kings Creek can overtop banks at 4.5 mAHD levels in Mersey for 1% AEP inflow at Kings Creek. 5 mAHD is the lowest natural bank level north of Gilbert Street.
- Regular maintenance of the Kings Creek channel is beneficial in reducing water levels.

2.10 Conclusions

There are a number of approaches that could be adopted to reduce the impact of flooding from Kings Creek in Latrobe CBD. Two “structural” flood mitigation options – levees and channel maintenance - were found to be feasible and are not interdependent.

The most cost-effective option is construction of levees along Kings Creek with a potential emergency diversion at Sheean Walk. This option includes a levee at Kobie Lane, to protect the CBD from high water levels in the Mersey River. Engineering works along Sheean Walk and adjacent low points in the topography will need to be investigated to minimise any incremental impacts from flooding.

Regular maintenance of the Kings Creek channel is also recommended to ensure any debris and obstructions are removed from the creek.

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3. Mersey River hydrological assessment

3.1 Catchment summary

The Mersey River catchment covers some 1,900 km² in northern Tasmania. Rainfall in the catchment varies from about 900 mm per year in the north, to over 2,700 mm in the highlands in the south of the catchment. Flows in the Mersey River are significantly affected by the presence of two dams, Rowallan Dam and Parangana Dam owned and operated by Hydro Tasmania (Entura, 2011).

3.2 Hydrological analysis

The flood frequency curve for Mersey River just upstream of Latrobe was reviewed in light of recent flooding and the annual exceedance probability of the June 2016 flood event was estimated as 0.33% AEP (ie. 300 years ARI). The recorded hydrograph at the Mersey River at Shale Road gauge was used as the input to the hydraulic analysis.

To review and reproduce the flood frequency curve, flood data and methodology was compared with Latrobe Study (HECEC, 1994) and Entura (2011) and updated where required.

HECEC (1994) derived annual maximum flows based on the following assumptions:

- Mersey River at Shale Rd is the site location for the frequency analysis. It is located upstream of Latrobe Bridge but its catchment area is almost the same.
- Where measured record is not available (1921 to 1963), annual maximum flow peaks from Mersey at Kimberley were transposed to Shale Rd.
- Prior to 1966 the Shale Rd flood peaks were reduced by applying a constant factor of 0.73, based on an analysis to represent post dam conditions (i.e. conditions following the construction of the Mersey River Hydropower Development).
- From 1966 – 1992 the measured flood peaks at Shale Rd were used.

For the present study, the following data and methodological changes were made:

- Mersey River at Kimberley flood peaks were reduced by approximately 17% across the whole historic record due to a rating change in the 1990's.
- Mersey River at Kimberley annual peak flows have been used for the pre dam period prior to the commencement of the Shale Rd gauging station. The peak flows have been area scaled to Shale Rd (a factor of 1.13). The flows have been scaled down to represent post dam conditions using the same scaling factor as in the 1993 flood report.
- Data has been extracted from the Bureau of Meteorology's "Water Data Online" service to obtain the recent record for Mersey River at Shale Rd up to 2017. The extracted data shows no change in historical values when compared to the 1993 report.
- It is believed that the Shale Rd flood peak estimate of 2001 m^3/s for 1970 is far too high. The concurrent peak flow at the Liena gauge is approximately 900 m^3/s and at Kimberley the peak flow is 1170 m^3/s. These peak flows are comparable to the 2016 flood where Shale Rd has

been given an estimate of 1200 m^3/s. Therefore the Kimberley flood peak has been transposed to Shale Rd for the 1970 flood event based on a linear regression between flood events at the two sites, providing an increase of 8% to Kimberley flows resulting in an estimate of 1270 m^3/s.

- The same scaling factor applied to the 2016 flood results in a peak of 1280 m^3/s. This was selected over the Shale Rd peak flow with the assumption that the significant magnitude of observed rainfalls in the lower catchment would cause an increase in the flood peak downstream of Kimberley.
- A Log Pearson Type 3 distribution was used to fit the flood frequency, and events lower than 100 m^3/s (five events) were removed to improve the fit at the upper end of the curve.

The two highest flood events in 2016 and 1970 significantly influence the shape of the flood frequency curve. The following notes relate to these two flood events:

- Comparisons between Mersey River at Liena and Mersey River at Kimberley records suggest that the 1970 and 2016 floods are very similar in magnitude. They are also the largest on record by a considerable margin.
- During June 2016 the catchment rainfall downstream of Liena was significant at an average of approximately 200 mm. With a downstream catchment area of 900 km^2, this suggests that the flood peak at Shale Rd could be even greater in magnitude than the estimated 1280 m^3/s.
- During the hydraulic analysis this should be taken into consideration and the flood hydrograph scaled if necessary to achieve a match of flood depths throughout Latrobe.

The use of the historic flood information (pre 1921) was reviewed but not included in the development of the flood frequency curve. Some notes related to the historical notes are provided below:

- Latrobe Study (HECEC, 1994) and Entura (2011) contained documented information on historical floods in the town dating back to the early 1800's.
- These have been excluded from the flood frequency analysis due to the lack of exact reference data for the largest documented floods. Specific reference points have been provided for some floods but these are assumed to be far lower in magnitude than the 1970 and 2016 floods. It was deemed to be outside of the scope of this study to undertake the timely exercise of estimating peak flow rates for these documented historical floods.
- September 1884 could be the largest flood in documented history. The documentation states that "Business premises in Gilbert St 6' deep in water". A check of the 2016 flood depths along Gilbert St showed a range from 2'- 4'. What is not clear from this information is whether the 6' depths were relative to the road height (which is the case for the 2016 flood depths used for comparison), or at business floor levels that are below the road. Also it is not specific about where on Gilbert St these depths were witnessed.
- December 1916 shows information which suggests it was larger in magnitude to the 1929 flood by up to 1 foot. The 1929 flood has a recorded peak of 820 m^3/s (pre Mersey scheme). A flood in 1923 with less historical information recorded a larger peak of 945 m^3/s.

Figure 3.1 shows the derived flood frequency curve for Mersey River just upstream of Latrobe.

Figure 3.2 shows the flood hydrograph shaped used to represent the 2016 flood event.

In summary, there is considerable uncertainty regarding the exact magnitude of the flood hydrograph in the Mersey River during June 2016 with various factors required to account of differences in area and rainfall contributing to the peak flow at Latrobe. The current best estimate of the probability of the June 2016 peak flow at Latrobe is 0.33% AEP.

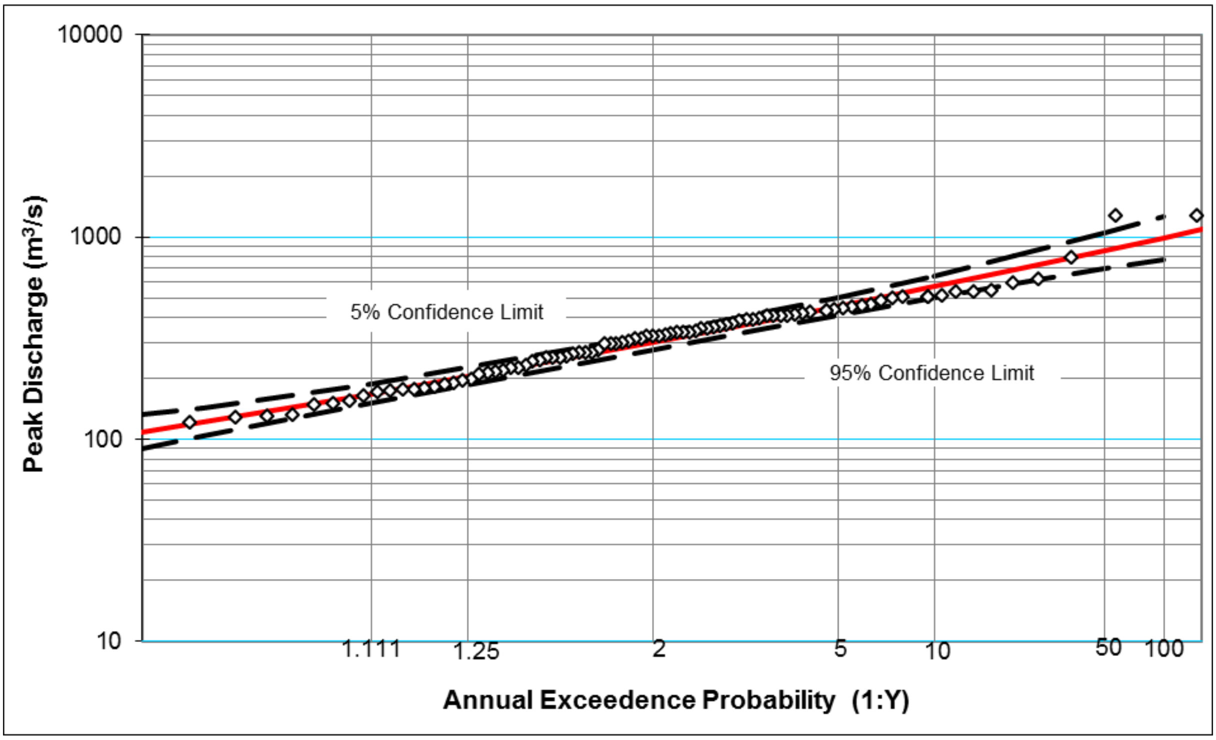

Figure 3.1: Flood frequency curve at Mersey River at Shale Rd (just upstream of Latrobe Bridge)

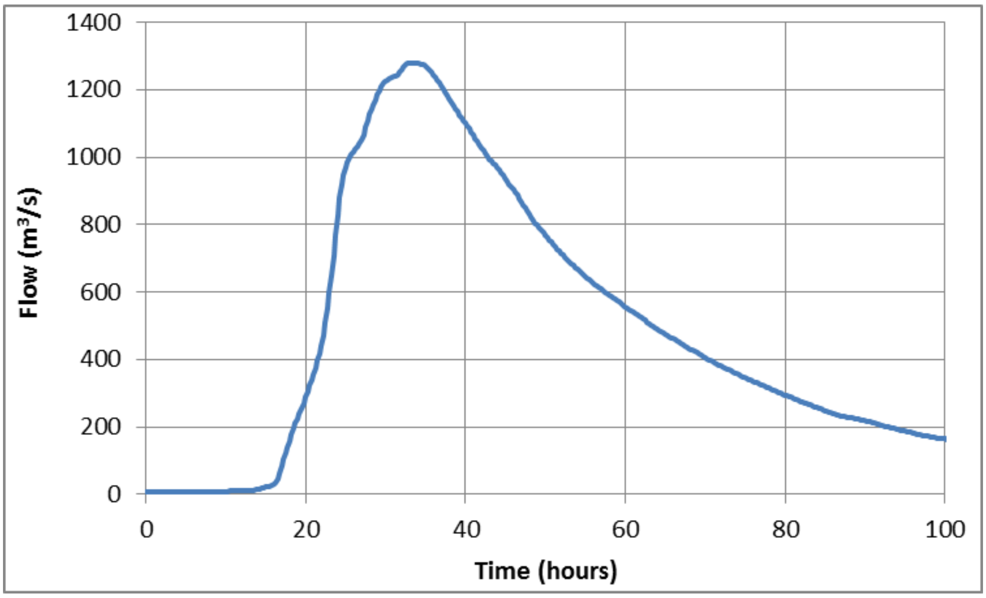

Figure 3.2: Flood hydrograph used as input upstream of Mersey River at Latrobe Bridge

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4. Mersey River hydraulic model

4.1 Model set-up

A hydraulic model was developed using the MIKE FLOOD (version 2014) software package which combines both the MIKE 11 (1 dimensional – 1D) and MIKE 21 (2 dimensional - 2D) software packages within a single model.

The model extends from 5 km upstream of Latrobe to the Mersey River estuary 7 km downstream of Latrobe. The Mersey River and its floodplain was modelled in 2D and major bridges and culverts along Frogmore Lane were modelled in MIKE11. Approximately 3.6 km of Mersey River estuary was modelled in MIKE 11 and linked at the downstream end of the 2D Mike 21 model.

The extents of the hydraulic modelling domain are shown in Figure 4.1.

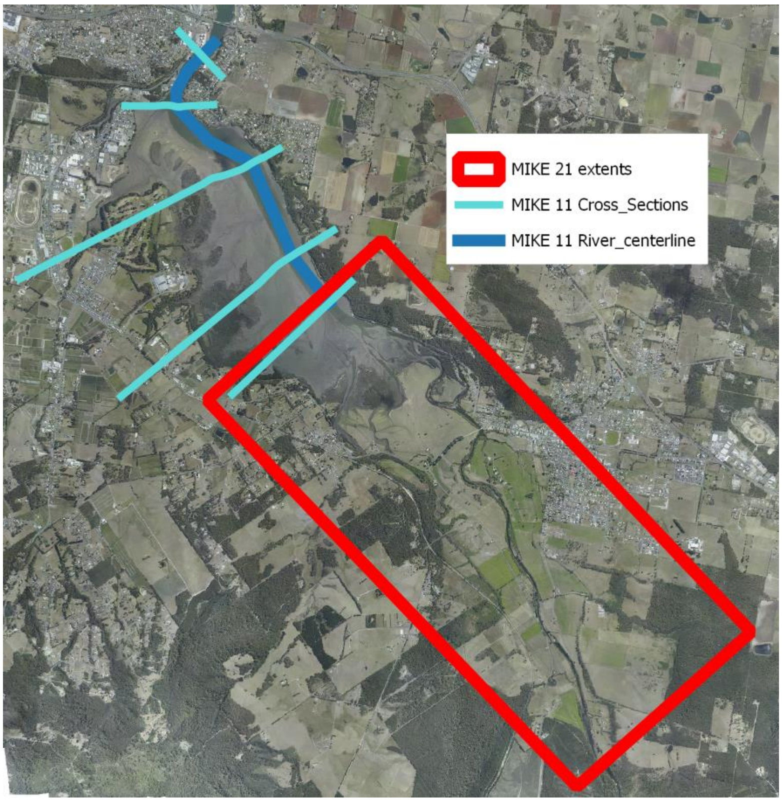

Figure 4.1: Mersey River hydraulic model extents

4.1.1 Floodplain DEM

A 5 m grid size was used for the MIKE 21 model, using 0.1 m contour data from LiDAR. This grid size was chosen for the purpose of maximising the accuracy of the model, while respecting the resolution of the input data, model size and required computation time.

4.1.2 Hydraulic Structures

The following three bridges and two culverts of interest were modelled in MIKE 11:

- Mersey River Bridge – SG-1997
- Mersey River Flood Opening No.1 – SG 1999
- Mersey River Flood Opening No.2 – SG 267
- Culvert upstream Ballahoo Creek Culvert
- Ballahaloo Creek Culvert

The relevant data regarding bridges was obtained from Department of State Growth. Ballahoo Creek Culvert details were obtained by site measurement.

4.1.3 Inflows

The 2016 flood event hydrograph developed in the hydrological analysis was inserted at the upstream boundary of the model.

4.1.4 Downstream Model Boundary

The downstream boundary of the hydraulic model is the Mersey River estuary. Tide levels, as a time series during the 2016 flood event, were obtained from the Bureau of Meteorology (BoM).

4.1.5 Roughness and Manning's Values

The Manning's n value for culverts and bridges was adopted as 0.013.

The roughness and equivalent Manning's n values for the MIKE 21 grid were based on land use information obtained from The Australian Collaborative Land Use and Management Program (ACLUMP, 2017). The adopted values are shown in Table 4.1. These values have been successfully used for similar flood mapping projects in Australia and New Zealand.

Table 4.1: Adopted roughness values

Land Type	Roughness Manning's M	Equivalent Manning's 'n'
Dairy sheds and yards	18	0.06
Degraded land	10	0.10
Grazing modified pastures	20	0.05
Marsh/wetland	25	0.04
Other minimal use	16	0.06
Residual native cover	21	0.05

Rural residential without agriculture	15	0.07
Urban residential	6	0.17
River	35	0.03

4.1.6 Link Structures

Links were established within the hydraulic model to transfer flow between the MIKE 11 structures and the MIKE 21 grid. The standard (E) link details, used for all the links, is summarised in Table 4.2 below.

Table 4.2: Standard (E) link details

Parameter	Value	Comment
Momentum factor	1	Full momentum transfer through the link
Extrapolation Factor	0	
Depth Adjustment	Yes	Depths in MIKE 21 adjusted accordingly to depths in MIKE 11
Smoothing factor	1	Smoothing level of values from MIKE 21 to MIKE 11 (range 0-1)

4.1.7 Other Parameters

Other critical parameters used within the MIKE FLOOD model are provided below:

- calculation time-step: 0.25 s.
- flooding and drying enabled.
- drying depth: 0.02m.
- flooding depth: 0.03m.
- eddy viscosity: 1.25 m^2/s.

4.2 Model Calibration

Flood levels gathered after the 2016 event were obtained from Latrobe Council and served to calibrate the model. A map showing measured levels is shown in **Appendix A**. This **Appendix** also shows maps with surveyed floor levels (Entura, 2011). Surveyed floor levels are useful in assessing effectiveness of mitigation measures.

Initial calibration was conducted by adjusting Manning's n in the floodplain and bridge openings. However, utilising hydrographs with peak flow of 1280 m^3/s from the hydrological analysis couldn't achieve observed levels in the township.

Particular difficulty during model calibration was replication of the apparent steep drop in water level between Cotton Street and the Mersey River bridge. Surveyed flood levels at Cotton Street are 6.2 mAHD and at the bridge 5.3 mAHD. In order to increase energy loss between two locations, Manning's M value was increased to 10 for "Rural residential without agriculture" which is landuse category between the bridge and Cottons Street.

These model adjustments were not sufficient to reproduce surveyed water levels. Consequently, inflow hydrographs was scaled and the final calibrated hydraulic model, with 1790 m^3/s peak inflow, was able to replicate observed flood levels with ±0.3m accuracy in Latrobe township.

Some modelled flood levels in areas around Kings Creek are lower than observed. These levels cannot be explained by backflow from Mersey River and are likely due to the coincident flooding in Kings Creek. Observed water levels around Kings Creek were above 6 mAHD at a few locations, while in the areas south (i.e. upstream in the Mersey River floodplain) observed water levels were below 6 mAHD.

The calibrated model is considered fit for the purpose of assessing remediation of main stream Mersey River flooding. However, the model should not be used for areas further than 3 km south of Latrobe township. Calibration was unable to replicate observed levels over the whole modelling domain and areas 3 km south of the CBD had modeled levels 0.5 m higher than observed.

4.3 Model Runs

The final calibrated hydraulic model results for the June 2016 flood event are shown in **Appendix B.**

4.4 Discussion of flooding mechanism

Flood velocity vectors, presented in Figure 4.2, show that the major flooding is caused by road overtopping at 20-42 Gilbert Street.

Essentially, Frogmore Lane, Mersey Bridge and 20-42, Gilbert Street form a long weir over the Mersey River floodplain. Flooding in Latrobe, north of Gilbert Street, occurs when this long weir starts overtopping at Gilbert Street. Some sections of Frogmore Lane, west of Latrobe CBD, start overtopping before Gilbert Street.

Minor road overtopping occurs downstream of the bridge, opposite 1-5 Gilbert Street, over a road length of 120 m.

Areas downstream of Last Street are impacted by backflow effect from Mersey River.

Areas adjacent to Kings Creek, east from Victor Street are impacted by reverse flow through Kings Creek channel and Kings Creek inflow.

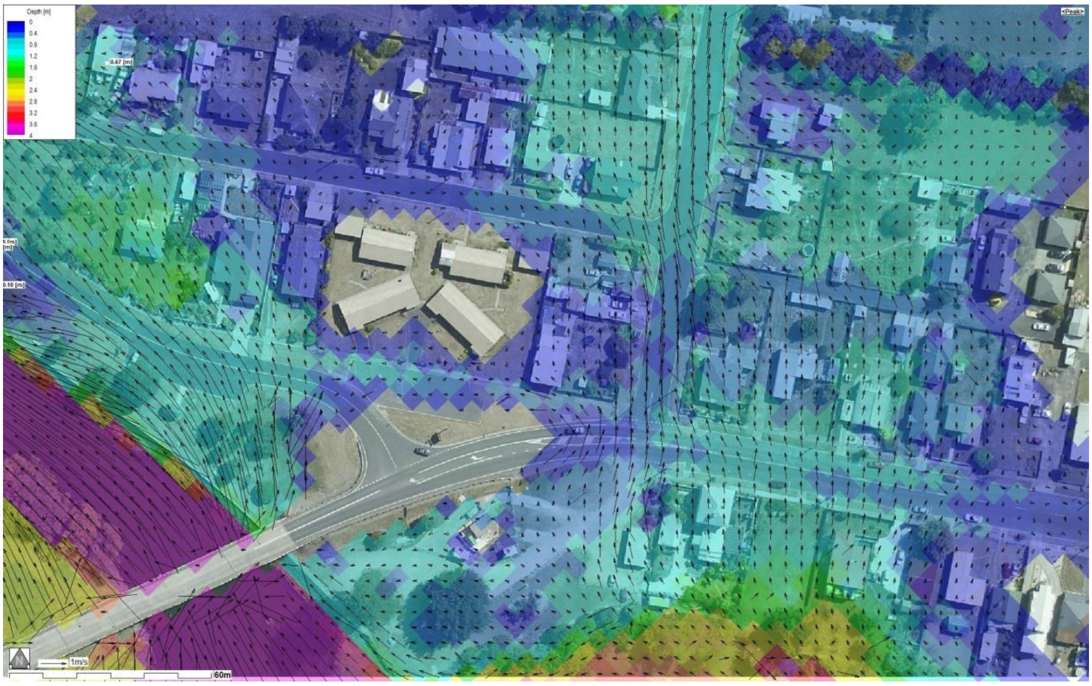

Figure 4.2: Mersey River flooding mechanisms at Latrobe

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5. Sensitivity analysis for Mersey River model

A sensitivity analysis was carried out for the 2016 event to estimate and illustrate impact of following factors which are relevant to model calibration:

- Manning's n
- Bridge blockage
- Downstream boundary condition (tidal level)
- Kings Creek inflows

5.1 Manning's n

A model run was completed using the originally envisaged Manning's n value, described in Section 4.1.5.

The major change was at Mersey River right-bank floodplain, south of Latrobe, which landuse is classified as "rural residential without agriculture".

The sensitivity analyses showed reduction in flood levels by 100 mm at Latrobe Township, which is insignificant in terms of the model accuracy and calibration.

5.2 Bridge blockage

AR&R (Ball et al, 2016) recommends assuming a maximum blockage of 20%, for a large bridge. However, a blockage of 50% was assumed as the 1D model cross-sections south and north of the Mersey River bridge[3] were estimated based on LiDAR (i.e. not survey) and to provide a conservative analysis of model sensitivity for illustrative purposes.

The results showed a maximum water level increase of 100 mm, upstream of the bridge and in Latrobe Township.

5.3 Downstream boundary condition

The model was unable to replicate the observed water level of 3.7 mAHD opposite Pig Island. Modelled water levels at this location were 3 mAHD with high Mersey inflows and observed tide levels adopted from BoM.

Consequently, a sensitivity analysis was conducted to assess the potential impact of errors in the adopted tidal levels (i.e. downstream boundary condition). The model was run with a constant downstream water level of 3.6 mAHD which is slightly below the observed level opposite Pig Island.

[3] These cross-sections served to link 1D and 2D models. Bridge opening area is limited by these cross-sections and dimensions of piers and superstructure. Number and dimension of piers, and dimension of superstructure was modelled based on the drawings obtained from Department of State Growth.

The model results show that high downstream water levels only influence flood levels up to the Mersey River Bridge. Areas north of the Bridge are not influenced by such high downstream water levels (i.e. tides) due to the hydraulic control at that location (i.e. bridge constriction and overtopping of Frogmore Lane).

The results of this sensitivity analysis correspond with the finding in HECEC (1994) that concluded that flood levels in the Mersey River upstream of Pig Island are insensitive to normal tidal variations.

5.4 Kings Creek flows[4]

Kings Creek flows may locally influence the flooded area in Latrobe. Based on anecdotal evidence, flow in Kings Creek during the 2016 event were “normal”, probably in the range of 63% to 50% AEP.

A regional flood frequency analysis was conducted using the latest model (ARR, 2017) and is shown in Table 5.1. The analysis indicates Kings Creek inflows to be around 10 m^3/s for a 50% AEP event with wide confidence limits.

Table 5.1: Kings Creek Flood frequency estimation

AEP (%)	Discharge (m^3/s)	Lower Confidence Limit (5%) (m^3/s)	Upper Confidence Limit (95%) (m^3/s)
50	10.0	4.51	22.6
20	13.5	6.06	30.1
10	15.8	6.14	40.2
5	18.1	5.87	53.6
2	21.2	5.40	76.9
1	23.5	5.02	98.2

The hydraulic model of Latrobe was run with constant Kings Creek inflow of 10 m3/s to illustrate the impact of local Kings Creek inflows. Steady state flow was adopted in order to coincide

Flood inundation and water level difference maps are shown in **Appendix C**. The results shown that Kings Creek inflow is likely to impact areas within 100 m from the Kings Creek channel between 45-87 Gilbert Street. Water level increased between 50 mm and 300 mm for inflow of 10 m^3/s in Kings Creek.

Also, the results of the sensitivity analysis correspond more closely to observed water levels at 45-87 Gilbert Street. The result shows a breakout area at Sheean Walk, downstream of the unit at 5/1 Hicks Lane, which occurred during the 2016 event.

[4] NB: This analysis was conducted prior to Kings Creek flood mitigation assessment reported in Section 2. It includes steady state (i.e. constant) inflows into the model to model coincident flooding with high levels in Mersey. This approach is conservative and may overestimate the impacts of Kings Creek inflows. The analysis is for illustrative purposes – to examine potential extents that are influenced by Kings Creek inflow. The sensitivity analysis conducted in Section 2 uses a constant level in Mersey and flood hydrographs in Kings Creek and is considered more accurate.

It should be noted that this model cannot accurately assess Kings Creek floodplain and potential breakout areas due to relatively large grid cell size. Local mounds on Kings Creek banks were not modelled and the grid cell size of 5 m is unsuitable for such small creek.

5.5 Discussion

Potential variability in the adopted Manning's n, Bridge blockage and downstream boundary conditions do not significantly change results and do not impact on the major Mersey River flooding mechanism in Latrobe - overtopping of Gilbert Street. The water level difference is within 100 mm and within the model accuracy of +/- 0.3 m.

Kings Creek inflows increase local flood levels, within 100 m from the creek and these inflows do not alter the mitigation option assessment for Mersey River flooding. Given the uncertainty with Kings Creek inflows, proposed mitigation measures for main stream flooding adopted the flood inundation boundaries based on the observed water levels during the 2016 flood event.

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6. Flood mitigation options assessment

6.1 Structural mitigation options

Traditionally, flood mitigation is divided into structural and non-structural options. Options assessment in this study focused on the structural options.

Flood mitigation options for Latrobe were developed based on the assessment of flooding mechanisms and Council's recommendation. Effectiveness of each option was evaluated using the 2016 flood event.

The following eight (8) options were identified and assessed:

Option 1. 350 m long levee running parallel to the right bank (i.e. North bank) of Kings Creek up to Victor Street, behind houses at 20-42 Gilbert Street

Option 2. 600 m long levee running along Gilbert and River Road, downstream of the bridge. This levee was assessed in combination with short levee. Total length of levee is 950 m.

Option 3. 850 m long levee running parallel to the left right bank (i.e. North bank) of Kings Creek and crossing the creek at Victor Street and continuing parallel to Cotton Street. This levee will have opening on Kings Creek.

Option 4. 850 m long levee running south the Kings Creek and continuing parallel to Cotton Street. This levee option has opening on Kings Creek.

Option 5. 850 m long levee running south the Kings Creek and continuing parallel to Cotton Street. This option is the same as Option 4, but does not have opening on Kings Creek and will require pumping of Kings Creek inflows over the levee.

Option 6. Same as option 2, but with Kings Creek channel isolated from flooding into the CBD. Kings Creek isolation would require more than 1,000 m long levees/flood barriers and large culverts between Gilbert and Victor Street. These levees will run along Kings Creek banks, and along Kobie Lane.

This option was run with <u>constant</u> Kings Creek inflow of 20 m^3/s, which corresponds to 2% AEP.[5] This is a conservative approach as flood volumes from Kings Creek are deliberately over-estimated in an attempt to mimic the joint flood event of peak Kings Creek inflow with the highest water level in Mersey River.

Option 7. Same as option 5, but with Kings Creek channel isolated from flooding into the CBD. This would require a 1,000 m long levee along Kings Creek banks and large culverts between Gilbert and Victor Street. Consistent with Option 6, this option was run with a constant Kings Creek inflow of 20 m^3/s, which corresponds to 2% AEP.

[5] This inflow was arbitrarily selected to illustrate impact from Kings Creek inflows.

Option 8. Reducing Bridge superstructure to 0.5 m heights instead of current 1.8 m.

Levee alignments for options 1-7 are shown in **Appendix D**, as part of modelling results. Option 8 is not included in the Appendix as the effect is insignificant.

6.2 Options evaluation

The MIKE FLOOD hydraulic model was updated to include each levee option and run for the June 2016 flood event. The flood map results from each run are shown in **Appendix D**. Levees were modelled as a “glass wall” (a levee of infinite height) to avoid iterative model runs to determine the levee height required to prevent overtopping.

Each option was evaluated at high level against a number of criteria, such as potential reduction in flood damage, cost of construction, feasibility of construction and impact on surrounding areas. Tabulated assessment and assumptions are shown in **Appendix E**

It should be noted that the purpose of high-level cost-benefit analysis was to compare options relative to each other. Therefore, various assumptions, such as damages or discount rate were simplified. Damages at individual properties were unavailable and were, therefore, assumed based on average insurance claims.

Option 1 is The most cost effective as a relatively short barrier prevents the main flooding mechanism described in Section 4.4.

Option 2 protects areas as per Option 1, and additionally protects several houses from reverse flow from Mersey River downstream of the bridge.

Option 3 provides minimal improvement in flood protection compared with Option 1 due to reverse flow from Mersey River up the Kings Creek. Water levels are reduced by 100 mm behind the levee.

Option 4 does not provide any benefit due to reverse flow from Mersey River. This option does not address major flooding mechanism.

Option 5 will require:

- flap gates on Kings Creek crossing to prevent reverse flow from Mersey River, and
- pumps to discharge Kings Creek inflow from the upstream side of the levee into the Mersey River when high water levels in the Mersey River close tide flaps/valves

Compared to Option 1, Option 5 provides additional flood protection benefits for 20-30 houses at 46-70 and 58-87 Gilbert Street.

The pump station costing has assumed 10 m^3/s capacity is required to address inflows from Kings Creek.

It is more cost effective to flood-proof affected houses east from Victor Street than to construct a levee with pump station and flap gates.

Council has expressed an aspiration to allow future development of land south of the Latrobe CBD and Options 6 and 7 are provided for illustrative purposes for such potential case.

Land reclamation would create land that can be developed subject to appropriate controls so that it is not reliant on flood protection measures such as levees, barrier walls or flood gates. It adds value to the town and is important for the future expansion of Latrobe's commercial area. Current CBD is along Gilbert Street and is 150 m wide due to floodplain restriction to growth. Development would aid street connectivity, parking and reduce traffic congestion at Gilbert St.

Option 6, similar to Option 5, provides additional benefit for several houses at 46-70 and 58-87 Gilbert Street. However, isolating Kings Creek channel to protect existing housing in the CBD, is not cost effective solution and carries a flooding risk from rare flood events in Kings Creek.

Isolating Kings Creek channel will require an emergency flow diversion (i.e. emergency spillway) to safely pass the extreme flood flows (i.e. above design flow) in a controlled manner. The spillway may be located along Sheean Walk and will prevent water levels from overtopping the levee along Kings Creek and causing structural damage of the levee and in the CBD.

As an alternative to Sheean Walk, emergency spillways and/or fuse plugs could be located on the left bank levee (i.e. south bank) of Kings Creek and provide controlled spill into the CBD and toward Kobie Lane levee, which would also require an emergency spillway. This would require careful design.

Height of the levee along Kings Creek will depend on the adopted design flood event for the emergency spillway(s), but will be at least 1 m above current banks, based on the preliminary assessment.

The full benefits associated with Option 7 need to be analysed in conjunction with benefits from land reclamation that are beyond the scope of this study. However, if this area is developed it appears sensible to integrate flood management as part of the planning by establishing road heights/minor embankments to effectively extend the main levee system, and to adopt appropriate building floor levels.

Option 8 reduces water by 100 mm upstream of the bridge and proves limited benefits. This option does not address the major mainstream flooding mechanism described in Section 4.4.

6.3 Impact on surrounding areas

Option 1 increases water levels in vicinity of the levee and increase water levels at several houses at 45-56 Gilbert Street by 50 mm. Water level difference for option 1 is shown in Appendix F.

Option 2 does not affect additional houses compared to Option 1. However, local drainage and outlets at Last Street should be taken into consideration during design stage of the project.

Options 3, 4 and 5 do not impact any houses.

Option 5 shows that a levee which blocks significant part of floodplain does not impact water levels significantly 500 m upstream from the levee – 500 m upstream of the levee increase in water levels is 40 mm. This is indicative that changes to levee alignments and/or land reclamation would not negatively impact surrounding areas.

6.4 Impact of Kings Creek inflow

Option 2 was run with Kings Creek inflow of 10 m3/s and showed that some flooding occurs downstream breakout location at 5/1 Hicks Lane, along Sheean Walk toward River Rd. This should be addressed if option 2 is adopted, in order to prevent ponding behind the downstream levee at River Rd.

7. Short-listed options

7.1 Preamble

Following discussions with the Council, numerous flood protection alternatives were combined into four (4) short-listed options**, namely option A, B, C and D.**

A preliminary plan depicting the proposed comprehensive option are shown in **Appendix K**.

The mitigation options present a combination of financial and non-financial benefits including wider social and economic benefits to the community that can be taken into consideration during the development of final flood mitigation proposals.

7.2 Option A

Option A includes 350 m long flood barrier behind houses at 20-42 Gilbert Street. This option would approximately halve the damages experienced during the 2016 event.

7.3 Option B

Mersey River flood options assessment indicated that Option 2 and flood-proofing of houses at 45-87, Gilbert Street can protect houses in Latrobe from floods similar to the 2016 event. This option could also protect affected properties from Kings Creek inflows.

The levee downstream of the Mersey River bridge would need to be 600 m long to protect all houses affected by backflow from Mersey River. However, a shorter structure can protect the majority of the houses. It is possible to use different flood barriers types for various sections of the levee to maximize cost effectiveness and utility. A demountable barrier can reduce cost, but requires assembling on short notice. A glass wall is expensive, but addresses visual amenity.

Considering potential costs, benefits and levee footprints, the following comprehensive mitigation option has been developed and is classified as Option B:

1. A 350 m permanent flood barrier behind houses at 20-42, Gilbert Street, which will address the major flooding mechanism described in Section 4.4. This barrier can be a concrete wall due to its small footprint. Section of the wall adjacent to Mersey River, south of the bridge, can be a glass wall, due to visual amenities.
2. A 540 m long flood barrier downstream the Mersey River Bridge, opposite 1-5, Gilbert Street and along River Road and Last Street. This levee alignment indicates shorter barrier compared to option 2 analysed in the previous Section. It should be noted that 400 m of this barrier protects 7 houses located below 4 mAHD. This section of flood barrier can be replaced with house flood-proofing or demountable barrier. A concrete wall has been adopted for this

barrier for cost estimates based on the acceptability of the solution to the local community, but an earth levee is a feasible solution for some sections. [6]

3. Prevention of breakout areas in Kings Creek that diverts flow via Sheean Walk toward River Rd.
4. Flood-proofing of houses at 46-70 and 45-87, Gilbert Street, which are influenced by reverse flow from Mersey River and Kings Creek inflows.

An overview of levee types and typical cost is shown in **Appendix G**.

An overview of house flood-proofing options is shown in **Appendix H**.

Flood proofing of houses may prove problematic due to short times for Kings Creek to peak, the reliance on proactive action by land holders, and short warning times for property owners to implement measures. Council has reinforced that the community expects a permanent resounding solution and Option D is developed as another comprehensive alternative.

7.4 Option C

Option C could protect 60 properties (out of 70 affected) during the 2016 event and would require:

1. A 350 m flood barrier behind houses at 20-42 Gilbert Street
2. A 150 m long flood barrier downstream the Mersey River Bridge, along Gilbert Street. Properties along River Road Last Street cannot be protected in this option, as Kings Creek inflows are diverted through the existing drain located parallel to Last Street.
3. A 200 m long flood barrier along Kobie Lane. Height of the barrier is approximately 1m.
4. Enlargement of Victor Street Bridge opening and provision of water impermeable handrails up to the height of 5.8 mAHD.
5. 700 m long flood barriers along left and right Kings Creek banks upstream of Victor Street. Height of the barriers is approximately 1 m. This length includes barriers and miscellaneous work that shall prevent surcharge between structures located between Gilbert and Victor Street.
6. Modification of Sheean Walk to be able to cater for flow diversion from Kings Creek. This may include excavations – up to 0.5 m depth; provision of flood barriers on the southern side; new culvert in front of 10 Victor Street and enlargement of the existing drain between Victor Street and River Rd.
7. Kings Creek embankment stabilisation from Sheehan Walk to Gilbert Street based on completed works at Kings Park. It needs to be part of this project as it can’t be done once the walls are built.

7.5 Option D

Option D is the same as Option C, but includes several emergency spillways and/or fuse plugs along Kings Creek levee and Kobie Lane levee, instead of Sheean Walk modifications. A fuse plug is a collapsible section of the levee installed to breach in controlled manner during emergency. While it

[6] The local community expects a comprehensive solution which would protect all properties with a permanent mitigation options and this barrier is costed as such, although demountable barrier and/or house flood-proofing may be more cost-effective.

can reduce levee height for design event (compared to spillway), it may require better maintenance than a spillway.

This option will need hazard assessment during detailed design for events rarer than design event (ie. when levee overtops). Detail design should ensure that hazards for such rare events with proposed levees do not exceed existing hazard conditions (ie. without levees) for the same rare events.

7.6 Levee heights

Levee heights will depend on levee alignment and design elevation. Exact levee alignment shall be set during detailed design. Recommended levee elevation is based on the higher of modelled and observed levels during the June 2016 event. Preliminary adopted freeboard is 0.3 m, but should be evaluated during detailed design.

7.6.1 Floodwall behind houses at 20-42 Gilbert Street

For the short levee behind houses at 20-42 Gilbert Street, the highest elevation of the observed and modelled levels is 5.5 mAHD. With a 0.3 m freeboard, the recommended top of the levee should be set at 5.8 mAHD. Elevation should be kept constant along the levee, as modelled results show 200 mm water level difference along the levee. Based on the preliminary alignment assessment, the height of the levee will vary between 0.5 m and 2.5 m above ground surface. The longitudinal profile of the ground elevation along the short levee is shown in Figure 7.1.

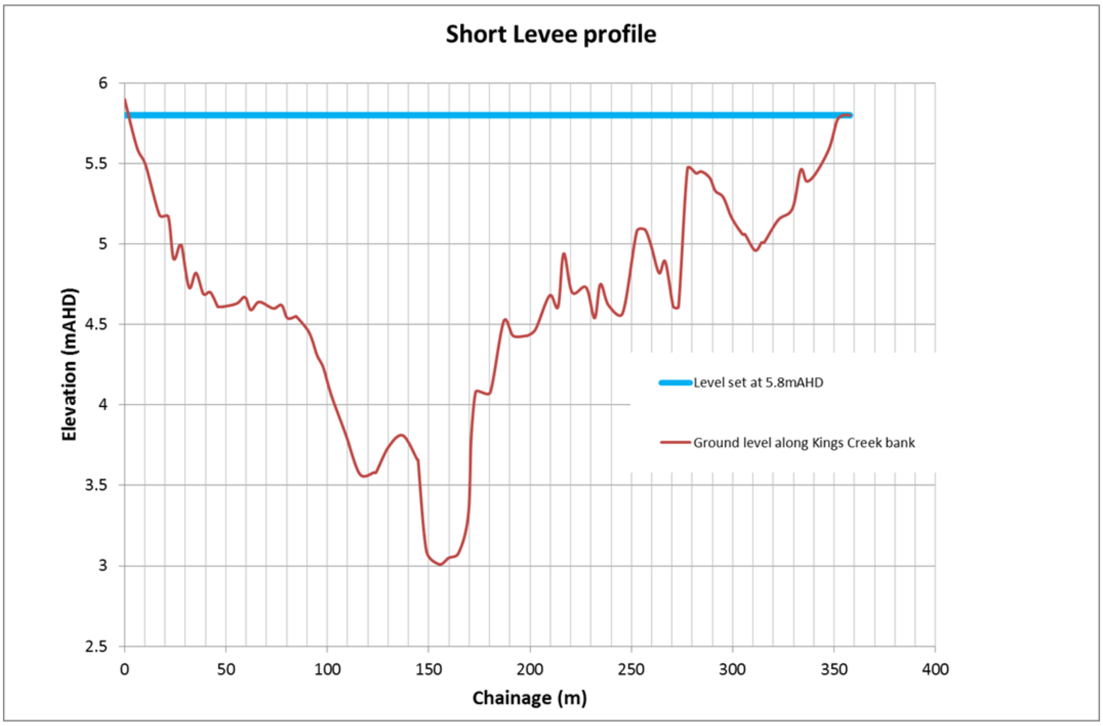

Figure 7.1: Longitudinal profile of the short levee along Kings Creek bank

7.6.2 Levee downstream of the Mersey Bridge

Water surface elevations along the levee downstream of the Mersey Bridge are shown in Figure 7.2. The estimated height of the levee varies between 0.5 m and 1.5 m, depending on location and based on preliminary route assessment along Gilbert Street, River Rd and Last Street.

The Figure shows two water surface elevations. The higher elevation is based on observed water level at one location opposite Pig Island. The lower elevation is based on the calibrated model, which was unable to replicate high downstream water levels. Levee design may be significantly higher if the observed level is adopted. Therefore, a detailed feasibility on levee length and height should be conducted prior to design, taking into consideration uncertainty in level observations and potential benefits in saving 7 houses located below 4 mAHD.

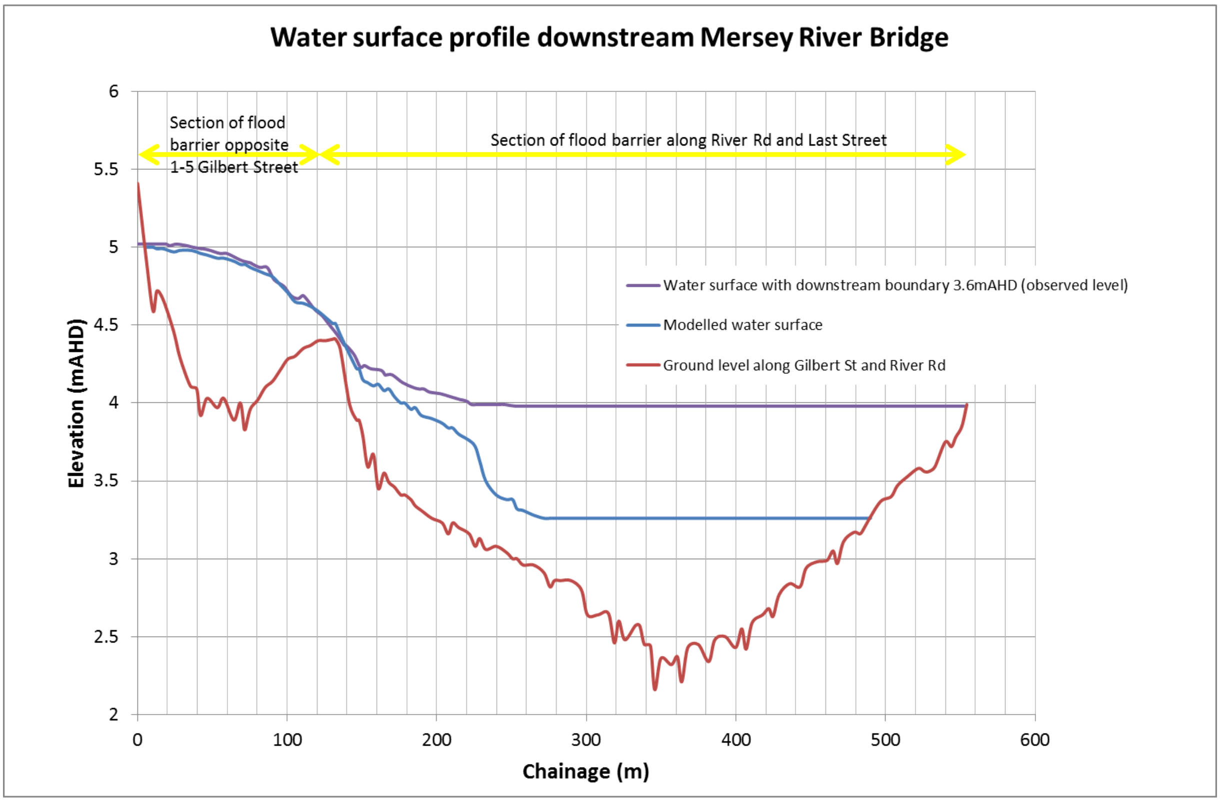

Figure 7.2: Water Surface profile downstream Mersey River Bridge

7.6.3 Kobie Lane levee (Option C)

Longitudinal profile of the ground elevation along Kobie Lane levee is shown in Figure 7.3. Top of the levee is the same as short levee, behind houses at 20-42 Gilbert Street, at 5.8 mAHD. The final location selected would need to consider any benefit in providing informal detention storage for local drainage above the Kobie Lane Road extension.

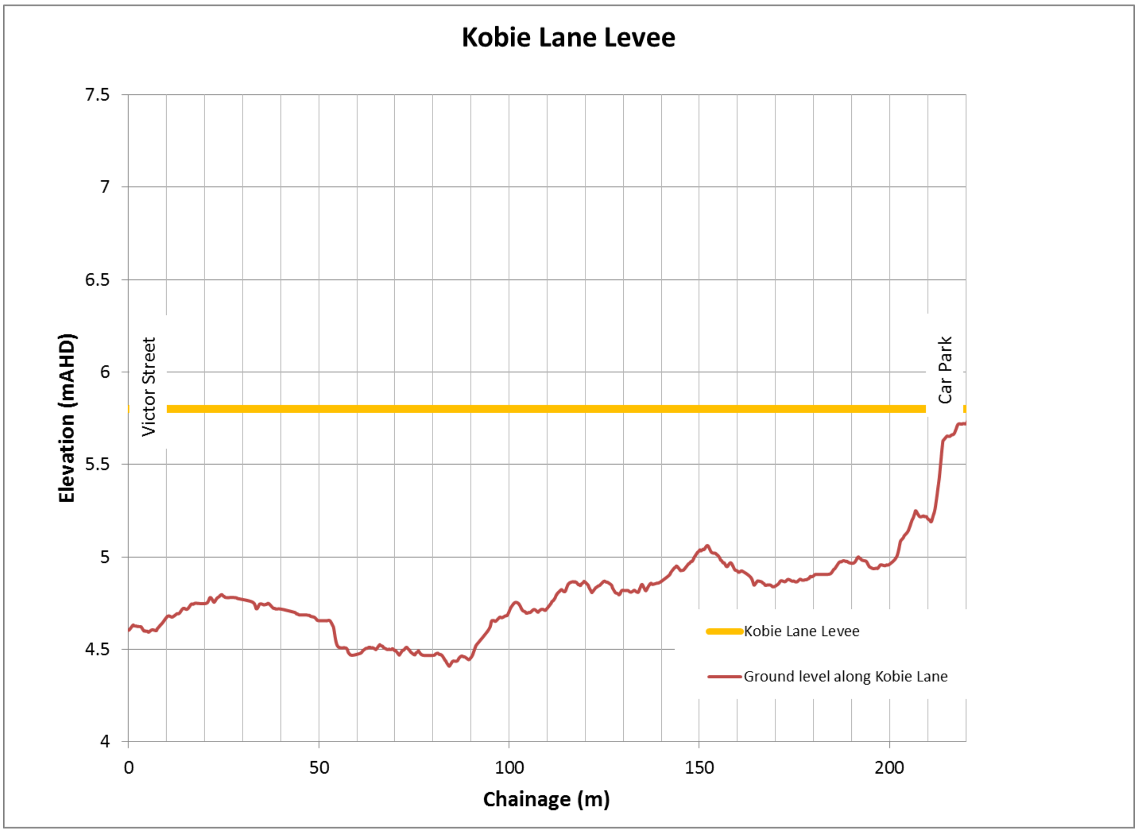

Figure 7.3: Kobie Lane Levee

7.6.4 Kings Creek levee

Levee along Kings Creek left bank (bank looking downstream) is shown in Figure 7.4 and along right bank in Figure 7.5. Approximate average levee height is 1 m. Level at Sheean Walk emergency spillway shall be balanced against required discharge and cost of the levee (i.e. levee height). The level may be set below 1% AEP water level in Kings Creek in order to reduce levee costs. Spillways capacity depends on available head and spillway width.

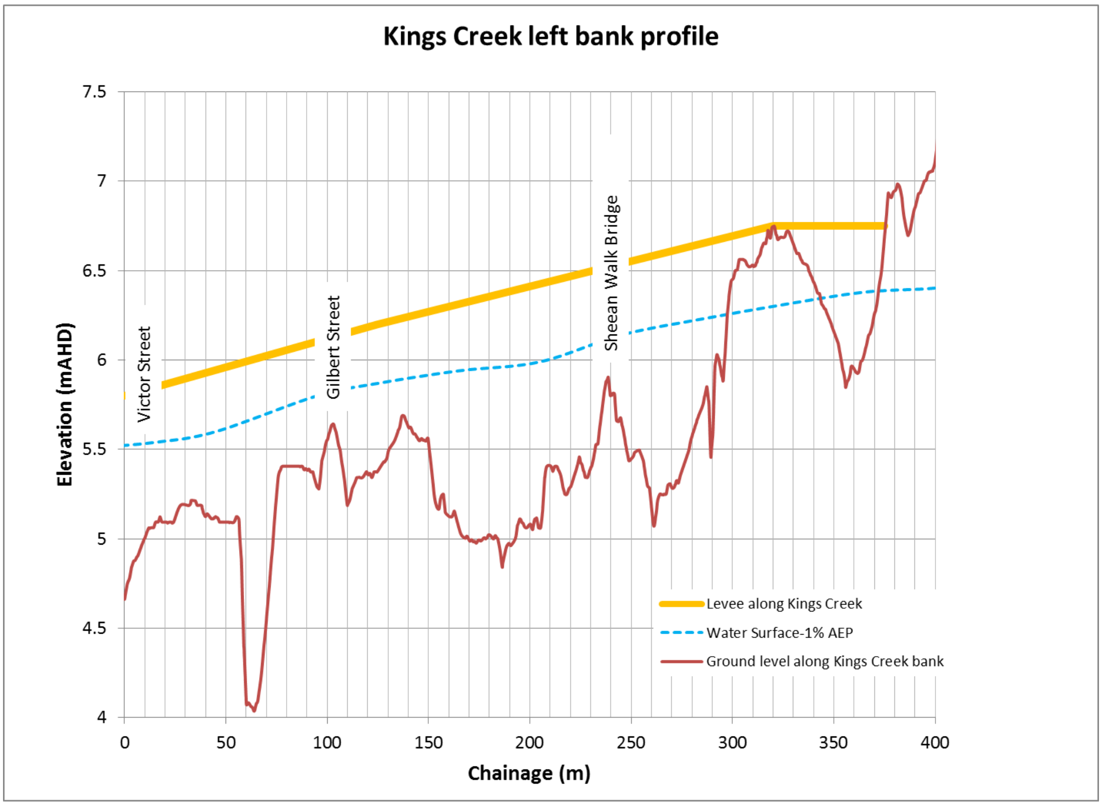

Figure 7.4: Kings Creek left bank profile

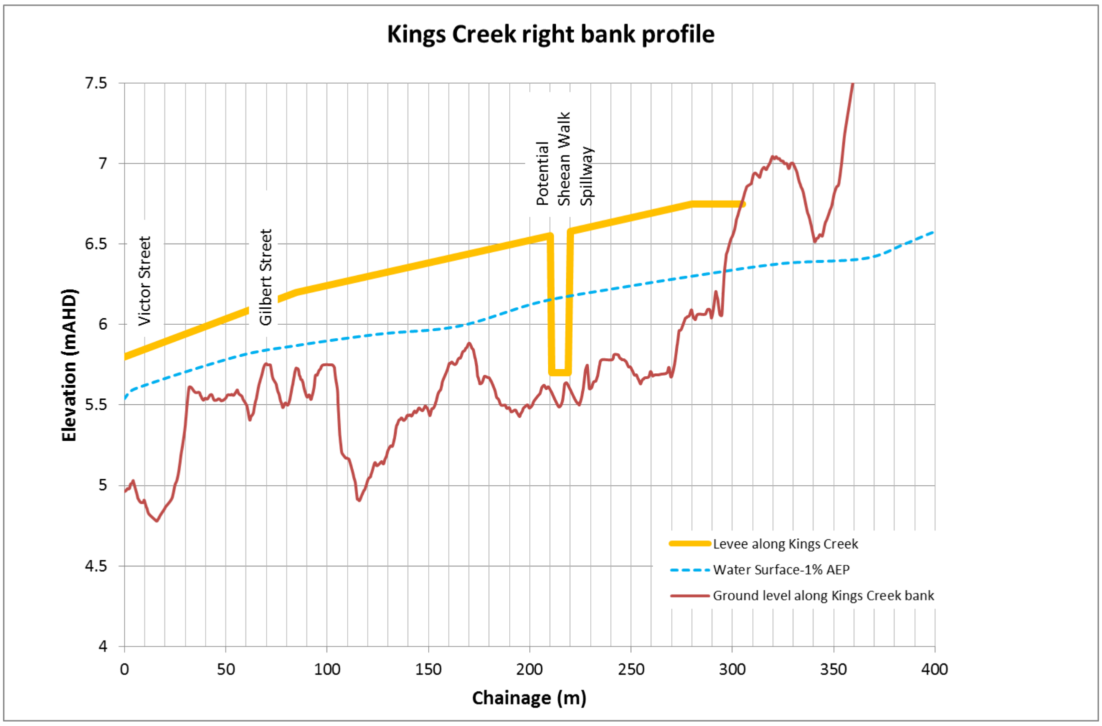

Figure 7.5: Kings Creek right bank profile

7.7 Sheean Walk flow diversion

The initial alignment of Sheean Walk and the adjacent low lying topography is a potential relief point for flood waters. As discussed in Section 2.8.2 any levee constructed along Kings Creek will need to consider an emergency spill.

A longitudinal profile along Sheean Walk, between Old Railway Bridge and Victor Street, is shown in Figure 7.6. It shows potential excavation to provide for a diversion channel. A culvert would be required to convey flows under Victor Street.

As a reference, a 10 m wide rectangular channel with 1 m depth and 0.0033 m/m slope (0.5 m/150 m), in good condition, can convey 20 m^3/s (Fang, 2000). Slope was adopted from the longitudinal profile. An efficient channel shape is likely to be trapezoidal (or have similar characteristics), but details for rectangular are provided for simplicity. Careful consideration would need to be given to how to convey such flow within Sheean walk whilst maintaining s similar ambience at other time.

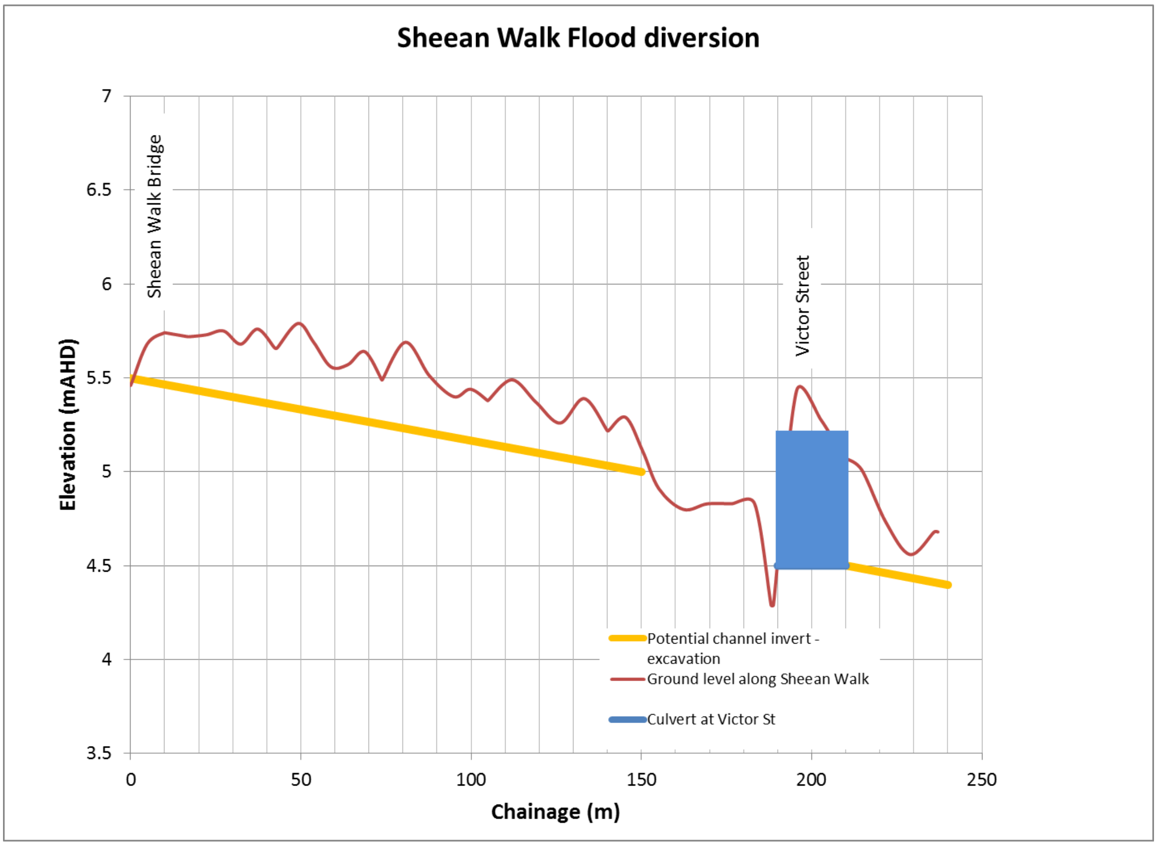

Figure 7.6: Sheean Walk flow diversion

7.8 Cost estimates

Table 7.1 below provides a summary of the costs and flood mitigation effects of the various short-listed options.

Option A would provide the highest level of benefit for the cost incurred.

Options C and D include Victor Street Bridge upgrade and embankment stabilisation.

Table 7.1: Cost summary

	Cost (+30%)	Flood mitigation effect	Comment
OPTION A	$0.65 million	Could halves damages for the event similar to 2016; 21 houses saved; 15 houses significant reduction in damage	Not a comprehensive solution, but has the best benefit-cost ratio.
OPTION B	$2.4 million	Comprehensive flood protection; 70 houses saved	May require installing house flood-proofing barriers with short notice. Relies on property owners being present.
OPTION C	$4.5 million	~60 houses saved	~10 houses cannot be saved from Mersey River backflow downstream of the bridge, because this option needs to allow Kings Creek flood diversion through Sheean Walk
OPTION D	$4.5 million	Comprehensive flood protection; 70 houses saved	Comprehensive solution without need to divert flow to Sheean Walk. Risk to houses in the CBD for flood events rarer than design flood event.

It should be noted that the cost and availability of: borrow materials, machinery, labour/ project management; design and feasibility studies, easements and/or the acquisition of land; resolving internal drainage issues and legislative costs can skew typical cost per linear meter significantly (Wollongong City Council, 2017).

7.9 Preferred options

Option A has the lowest cost of the four short listed options. However, a major deficiency is that it only protects part of the Latrobe township from flooding. Council considers this unacceptable and inequitable for those outside that area and the future development of the town.

Option B is reliant on flood proofing and protecting existing homes, businesses and properties either before or during a flood event. Given the warning uncertainties about the Mersey River flooding depths and the short times of concentration for Kings Creek to peak this will be problematic. A further deficiency is that ongoing development of the town will be stifled, particularly in the area where flood protection of properties is necessary. Additionally, spills from Kings Creek exiting near Sheean Walk will have significant potential to divert waters towards properties that have previously been clear of flooding. Council advised that owners in such areas will see Option B as unacceptable and counterproductive.

Option C does not rely on flood proofing and protecting private properties in and around the CBD and the potential issues this introduces. The biggest deficiency is that spills from Kings Creek exiting near Sheean Walk will divert significant flow towards properties that have previously been clear of flooding. As a result, this option requires quite considerable changes to Sheean Walk and the current ambience and amenity provided by it. If progressed, Sheean Walk may effectively become a concrete lined open drain/walkway with box culverts at road crossings through to River Road. Additionally, this solution will most probably prevent a long downstream barrier in River Road, thereby not enabling properties in and around Last Street West to be protected from Mersey River backflow. This will require flood proofing and protecting properties in this vicinity thereby limiting future development and reliance on implementing protection measures proceeding and during a flood event. Council does not consider this a comprehensive or acceptable solution to the community.

Option D protects all developed properties from the modelled Mersey River floodwaters, in addition to increasing the flow capacity of Kings Creek by lowering friction losses and effectively raising the containment walls. It is considered the most desirable long-term solution as it does not rely on flood protecting properties prior to or during an event which is particularly problematic in relation in the flash flooding that may occur in Kings Creek if the Mersey River level was above 4.5m AHD. Public flood protection works are envisaged to be permanent and not reliant on personnel to deploy. This option allows for future development within the town and does not prevent extension of the existing CBD area. Additionally, it identifies areas for localised drainage to pond on public land when waters 'outside' the levees are higher than those inside the walls and does not detract from Sheean Walk in any way. Detailed design will need to consider potential flow relief points and temporary works that may need to be deployed for events larger than the design flood.

Considering the above assessments Option D is recommended.

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8. Conclusions

Entura conducted structural flood protection option assessment for Latrobe township based on the June 2016 flood event from Mersey River and 1% AEP inflow from Kings Creek.

Kings Creek flood mitigation options assessment was conducted using DRAINS, XPSWMM and HEC-RAS modelling packages.

Mersey River hydraulic model was calibrated to reproduce water levels for the 2016 event and eight (8) flood mitigation options were assessed using the model.

Each option was evaluated using a high level cost-benefit analysis.

Following discussions with the Council, numerous alternatives that provide flood protection from Mersey River and Kings Creek were combined into four (4) short-listed options**.**

The most cost effective option A is a 350m long flood barrier behind houses at 20-42 Gilbert Street. This option would approximately halve damages during the 2016 event. Option A is not a comprehensive flood protection solution for the town.

Remaining short-listed options include:

- A barrier downstream of Mersey Bridge and house flood-proofing west of Victor Street (named Option B),
- A short barrier downstream of Mersey Bridge and flood barriers along Kings Creek and Kobie Lane, with an emergency spillway at Sheean Walk (named Option C)
- The same as the previous option C, but includes several emergency spillways and/or fuse plugs along Kings Creek levee instead of one spillway at Sheean Walk (named option D).

Cost of the 350m permanent concrete flood wall behind houses at 20-42 Gilbert Street is estimated to be $650,650 (including 30% contingency). Estimated cost of other solutions including contingency is between $2.4 million and $4.5 million.

The formulation of an acceptable and comprehensive flood mitigation option for Latrobe will be subject to the costs and benefits of the various solutions discussed in this report as well as consideration of the wider social and economic benefits for the community .

Preliminary assessment, taking into consideration community expectation, recommends Option D.

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9. Glossary

The following glossary was adopted from Flood Victoria (2018). Relevant items used in the report are summarised in the glossary.

Term	Explanation
Annual Exceedance Probability (AEP)	the likelihood of occurrence of a flood of given size or larger occurring in any one year. AEP is expressed as a percentage (%) and may be expressed as the reciprocal of ARI (Average Recurrence Interval). For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% risk (ie, a risk of one-in-20) of a peak flood discharge of 500 m^3/s or larger occurring in any one year (see also Average Recurrence Interval).
Australian Height Datum (AHD)	the adopted national height datum that generally relates to height above mean sea level. Elevation is in metres.
Average Recurrence Interval (ARI)	the likelihood of occurrence, expressed in terms of the long-term average number of years, between flood events as large as or larger than the design flood event. For example, floods with a discharge as large as or larger than the 100-year ARI flood will occur on average once every 100-years. ARI is related to AEP and Odds of Flooding as follows: ARI in years equals the reciprocal of AEP expressed in terms of chance. For example, a 1% AEP flood has a chance of occurrence in any year of 0.01, and an associated ARI of 100 years. The Odds of Flooding are equal to the ARI in years. Therefore the 100 year ARI flood is also the 100:1 flood (see also Annual Exceedance Probability).
Catchment	the area of land draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Consequence of flooding	a qualitative or quantitative description of the outcome of a flood event in terms of loss, injury, disadvantage or gain.
Design flood (or Flood Standard)	a flood of known magnitude or average recurrence interval, or a historic event which is selected for land use planning, emergency planning and engineering design purposes. The selection should be based on an understanding of flood behaviour and associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Note that the design flood does not define the maximum extent of land liable to flooding, which is defined by the Probable Maximum Flood (PMF).
Flood Damage	the tangible and intangible costs of flooding. Tangible costs are quantified in monetary terms (eg, damage to goods and possessions, loss of income

	or services in the flood aftermath). Intangible damages represent the increased levels of physical, emotional and mental health problems suffered by flood affected people and attributed to a flooding episode. Intangible damages are difficult to quantify in monetary terms.
Flood Hazard	potential for loss or damage to property or harm to persons due to flooding.
Flood Proofing	a combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
Flood Storage Area	those parts of the floodplain with available water volume which would temporarily store floodwater to be later discharged as the flood recedes. These parts of the floodplain are important for the attenuation of a flood and reduction of its severity during the passage of a flood.
Flood Study	a study to determine and document the nature of flooding for an area. It usually includes a review of history of flooding; and for detailed studies an understanding of flood velocity, depth, frequency and extent, and an understanding of flood damages.
Flood Warning	flood warning involves the timely collection, interpretation and dissemination of flood information before and during a flood event to enable the community to respond effectively to the flood threat. The BoM is responsible for collecting rainfall and stream flow data, operating flood prediction models and preparing and issuing flood warnings to the media, key agencies and other bodies for non-flash flooding situations. The VICSES is responsible for delivering flood warnings to specific municipal council contacts, as well as transmitting any other flood warning identified in the MEMP. Municipal councils are responsible for disseminating flood warnings to the local community, local authorities and other local bodies for flash flooding and non-flash flooding situations.
Floodplain	area of land adjacent to a creek, river, estuary, lake, dam or artificial channel which is subject to inundation by the Probable Maximum Flood (PMF).
Floodplain Management Measures (or risk treatments)	the full range of techniques available to prevent or reduce flood risk, damage, human suffering and disruption. A measure (or risk treatment) to mitigate the impacts of flooding may include structural and non-structural works such as: a levee, a diversion channel, house raising, flood warning and emergency management arrangements, installation of bridges, channel widening, etc.
Freeboard	a factor of safety above design flood levels, typically used in relation to the setting of floor levels, and levee crest heights. It is usually expressed as a height above the design flood level. Freeboard tends to compensate for flood prediction uncertainties and for factors which increase flood levels, such as a wave action, localised hydraulic effects, settlement of levees. It should not be relied upon to provide protection for events larger than the design flood.

Fuse Plug	A collapsible concrete, steel or sand filled section that is designed to fail in a way that sacrificially protects the remainder of a dam or levee under extreme flood conditions.
Hydraulics	the study of water flow; in particular flow parameters such as water surface height, water depth, duration and velocity across a floodplain and/or river or stream.
Hydrology	the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Level of Flood Risk	the combination of likelihood of flooding and consequence of flooding to produce a level of flood risk.
Likelihood of Flooding	a quantitative or qualitative description of the likelihood that a specified event will occur. The likelihood of occurrence of flooding can be measured in terms of Annual Exceedance Probability (AEP) or Average Recurrence Interval (ARI).
Minor, Moderate and Major Flooding	both the VICSES and BoM use the following definitions in flood warnings to give a general indication of the type of problems expected with a flood: *Minor Flooding:* causes inconvenience such as closing of minor roads and the submergence of low level bridges. *Moderate Flooding* low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic bridges may be covered. *Major Flooding*: extensive rural areas and/or appreciable urban areas are flooded, with properties and towns isolated.
Peak Discharge (Flow)	the maximum discharge occurring during a flood event.
Probability	a quantitative measure of the likelihood of occurrence of an event. It normally reflects the relative frequency of or expectation that an event will occur, and is usually expressed as a percentage, eg the probability of throwing a given number by rolling a dice is 1 in 6, or 16.7%.
Risk	the chance of something happening that will have an impact upon objectives. It is measured in terms of consequence and likelihood.
Spillway	A section of a dam or levee that is designed to safely pass flood flows that exceed the design flood capacity of the structure
Strategic Levee	urban or rural levees generally considered to protect important areas or assets from a broader regional viewpoint. They will generally protect significant urban areas or large rural areas which are mainly highly productive. They could also protect single properties, yet have significant adverse flooding effects on a large number of other properties. They may control potentially undesirable river breakaways or realignments.

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Appendices

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A Observed water levels and surveyed floor levels

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Mersey River Flood Mitigation Options Assessment

Observered water levels during 2016 flood event

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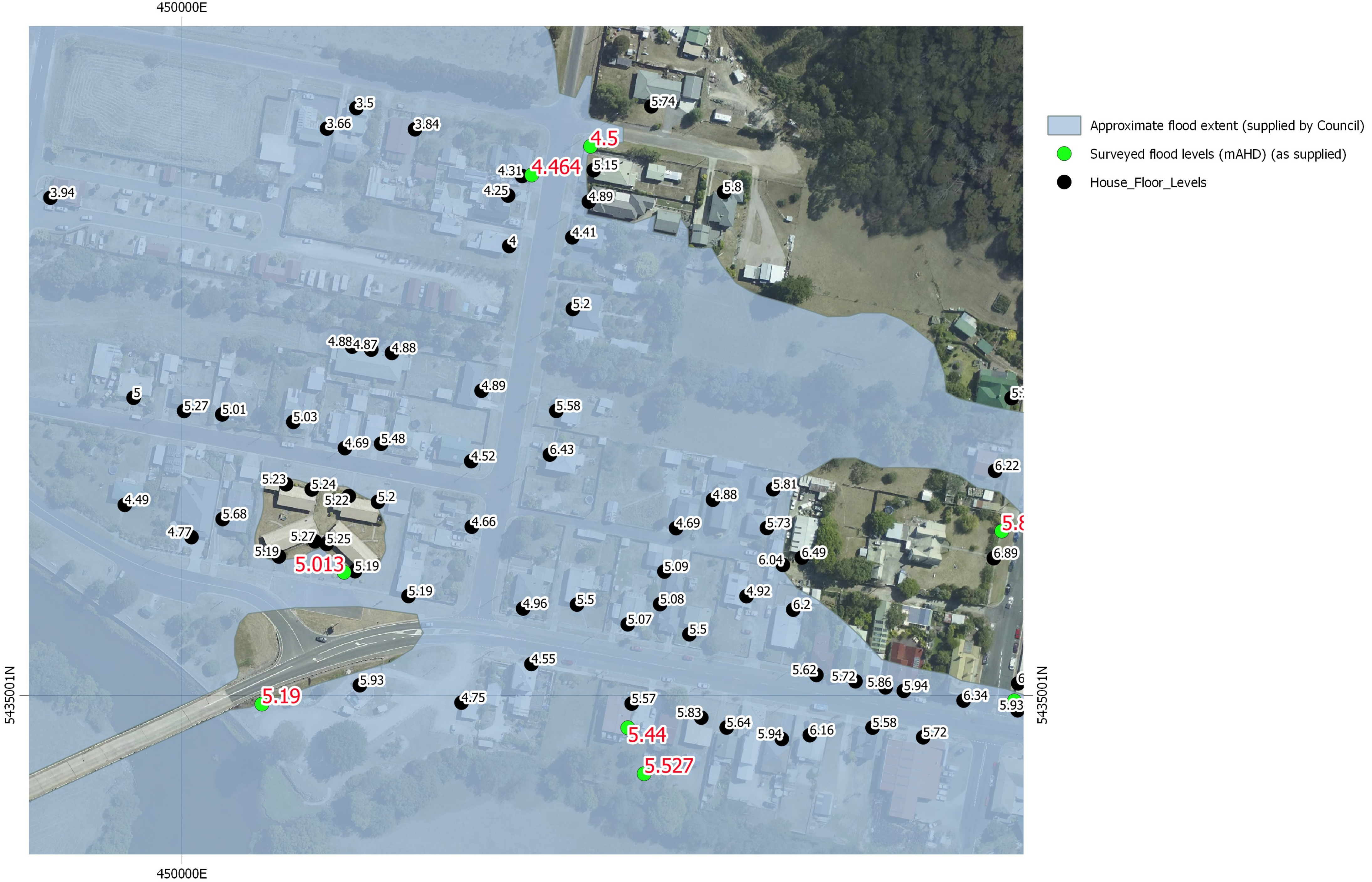

Mersey River Flood Mitigation Options Assessment

Floor levels and observed flood levels during 2016 flood event (West of Victor St)

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0 20 40 m

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Mersey River Flood Mitigation Options Assessment

Floor levels and observed flood levels during 2016 flood event (East of Victor St)

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B Calibrated model results

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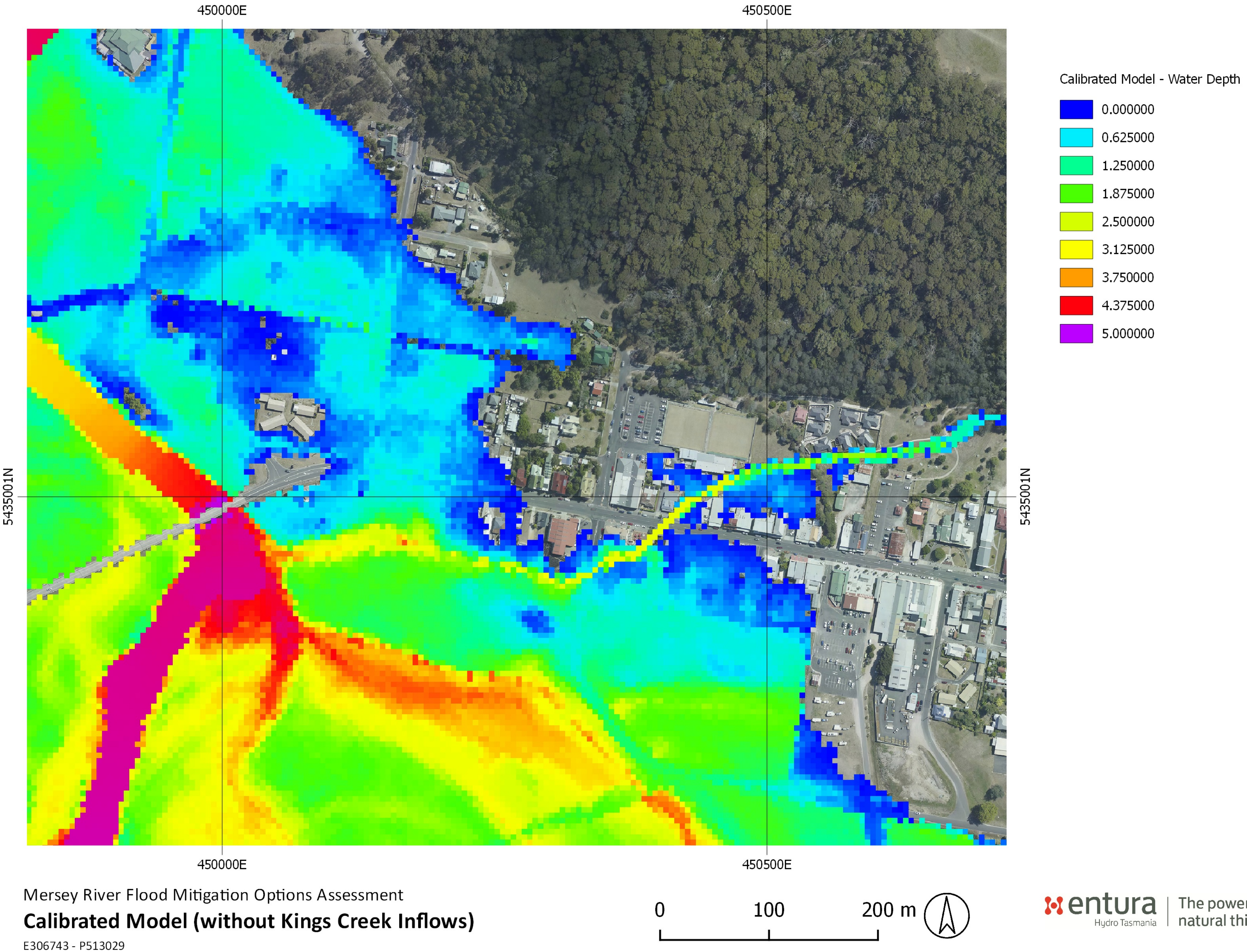

Mersey River Flood Mitigation Options Assessment

Calibrated Model (without Kings Creek Inflows)

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C Sensitivity analysis – Impact of Kings Creek Inflows and flood inundation maps with Kings Creek inflow

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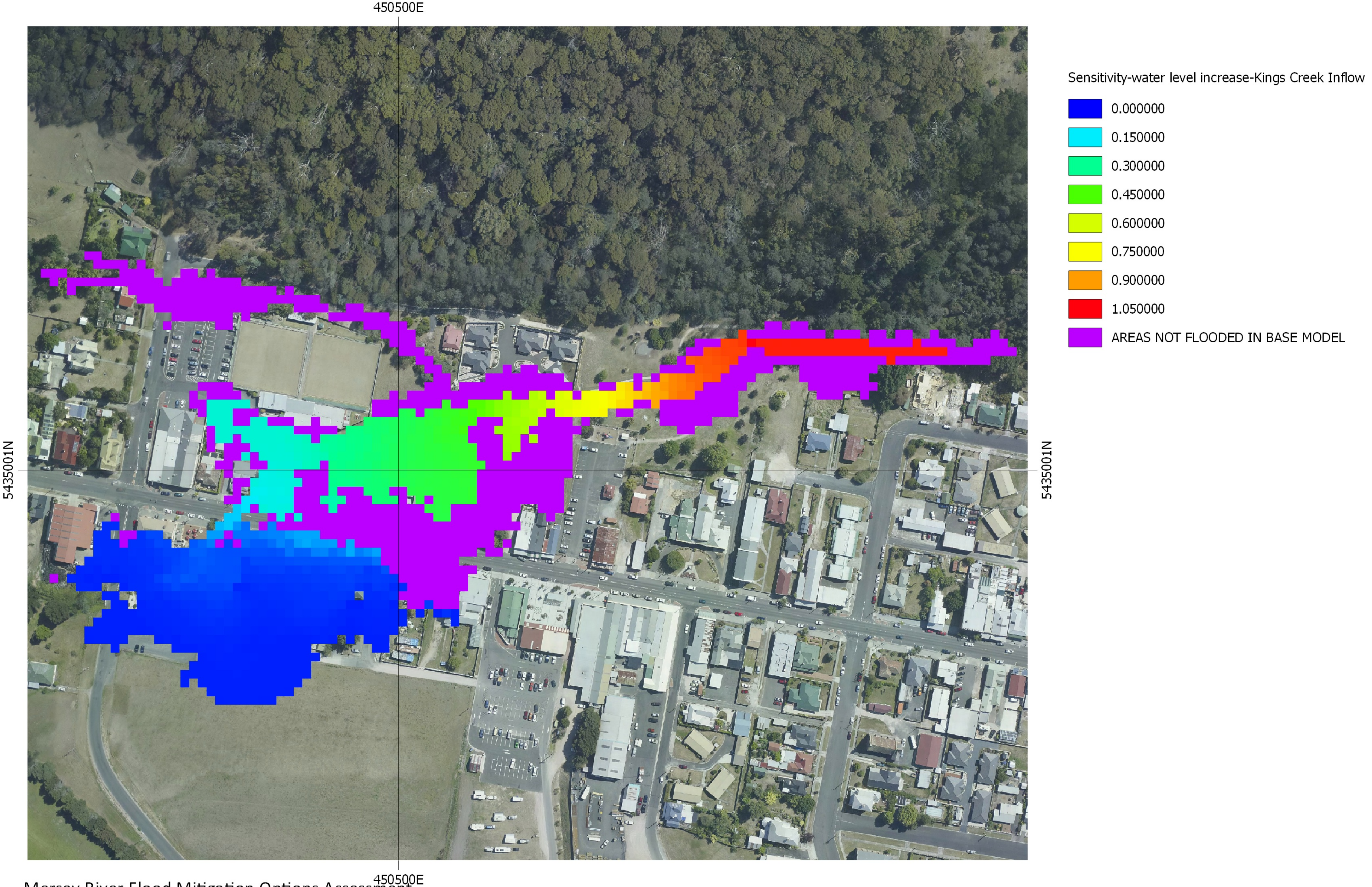

Mersey River Flood Mitigation Options Assessment

Increase in water levels due to constant King Creek inflow of 10m3/s

Map of water level difference (in comparision to base model)

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0 50 100 m

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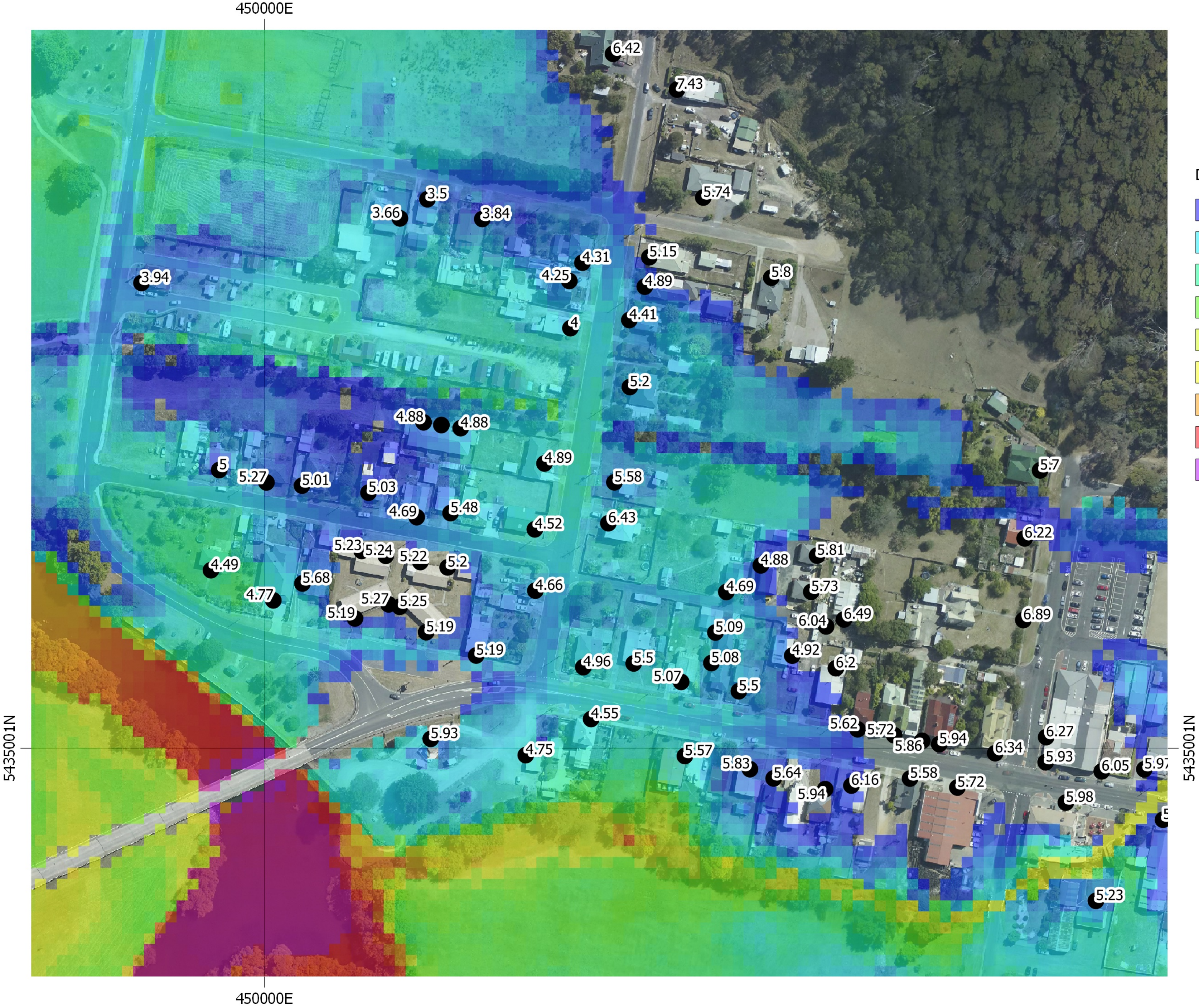

House_Floor_Levels

Dephts-Base model with Kings Creek inflow (10m3/s)

- 0.000000
- 0.625000
- 1.250000
- 1.875000
- 2.500000
- 3.125000
- 3.750000
- 4.375000
- 5.000000

Mersey River Flood Mitigation Options Assessment

Floor levels and modelled depths (West of Victor St)

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0 20 40 m

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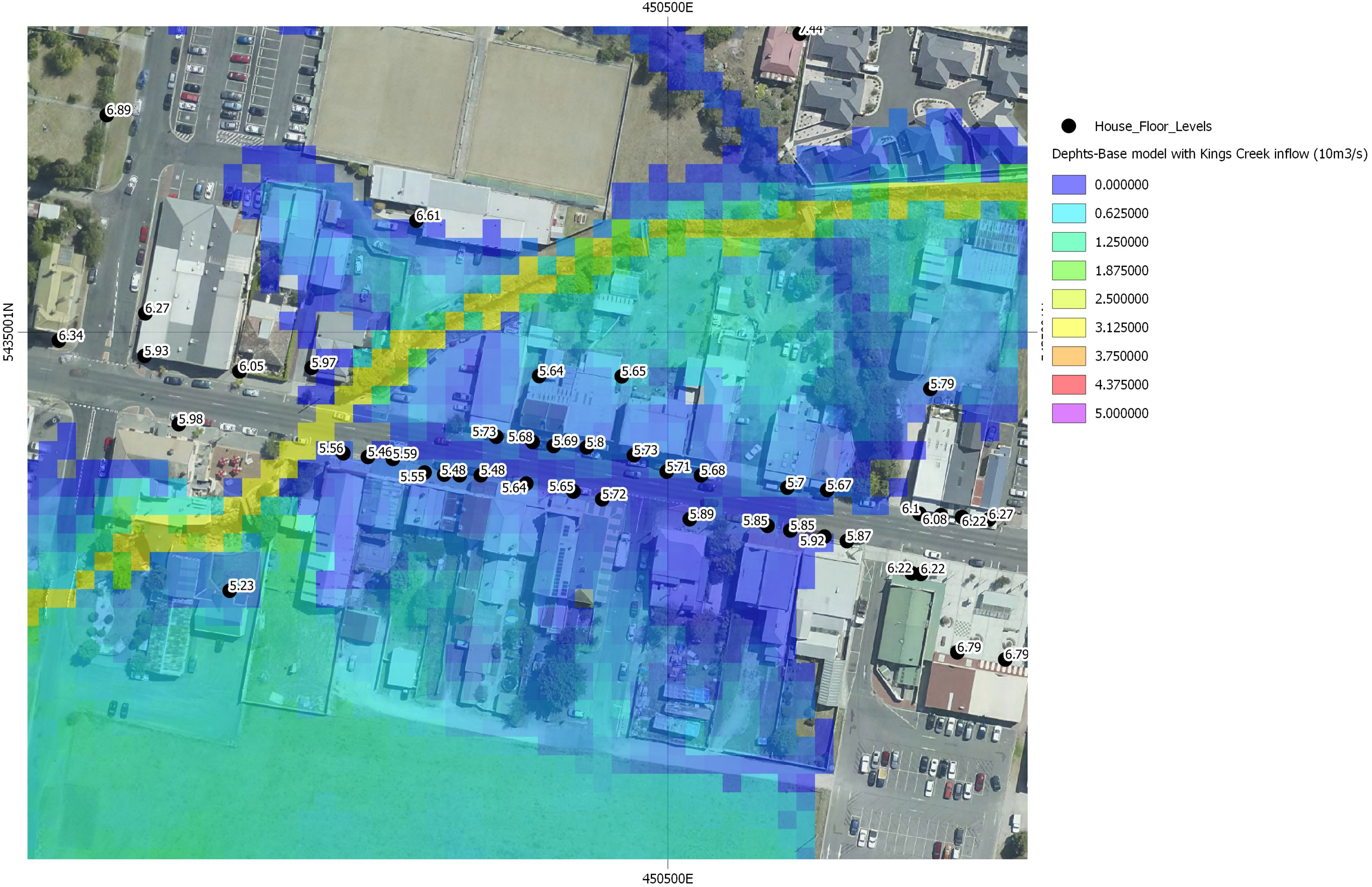

Mersey River Flood Mitigation Options Assessment

Floor levels and modelled depths (East of Victor St)

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D Mitigation options

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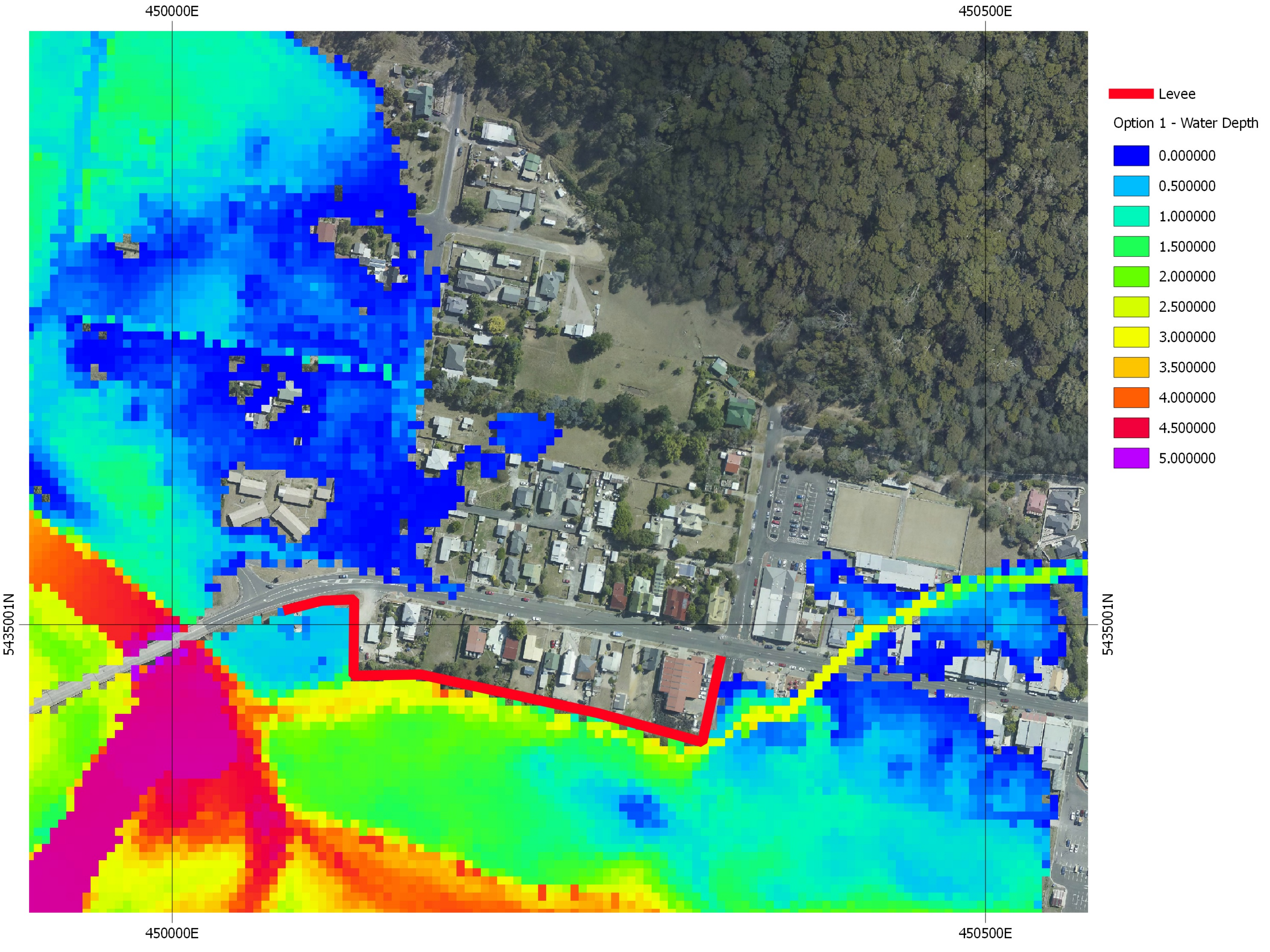

Mersey River Flood Mitigation Options Assessment

Option 1 - Short Levee behing houses at 20-42, Gilbert Street

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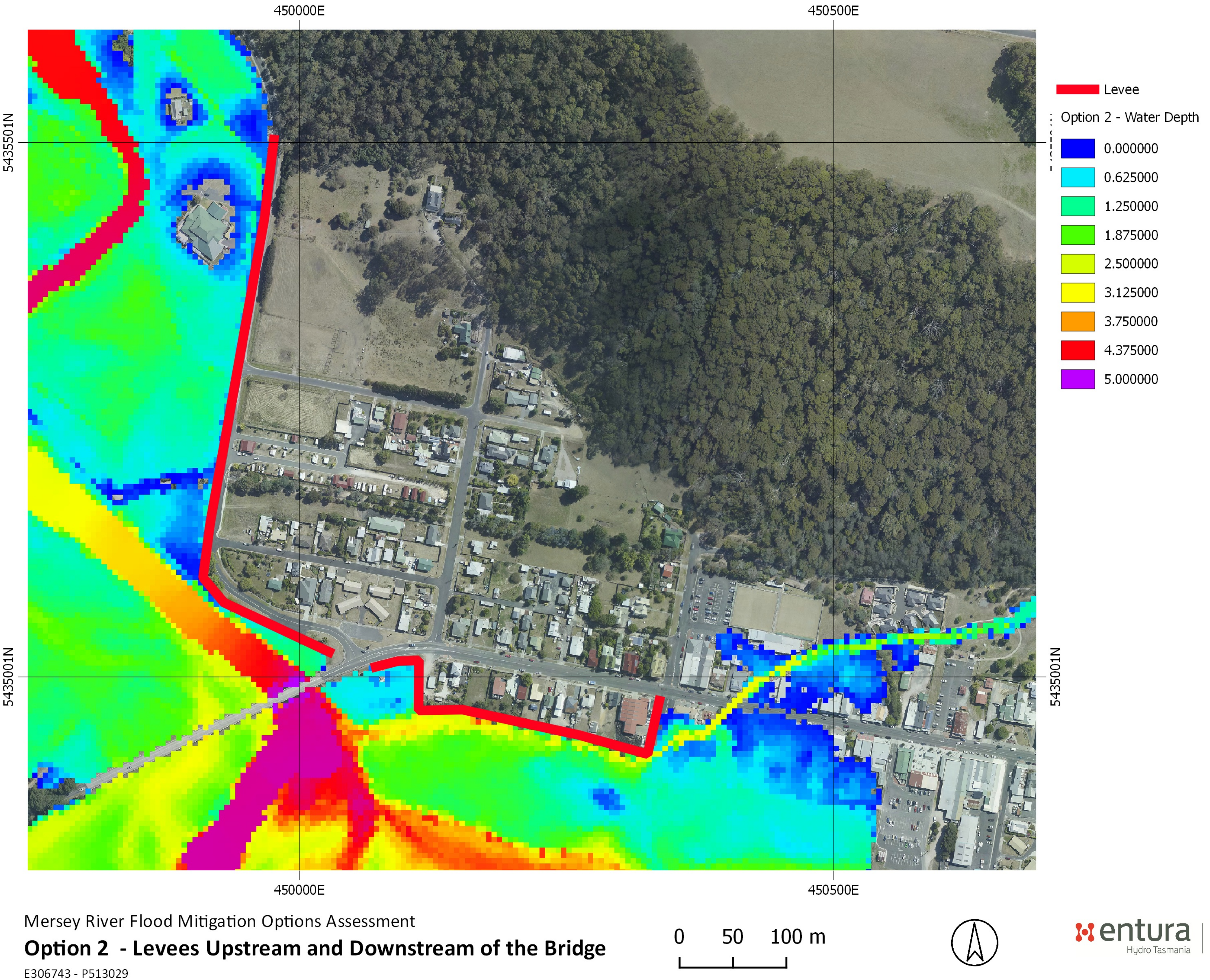

Mersey River Flood Mitigation Options Assessment

Option 2 - Levees Upstream and Downstream of the Bridge

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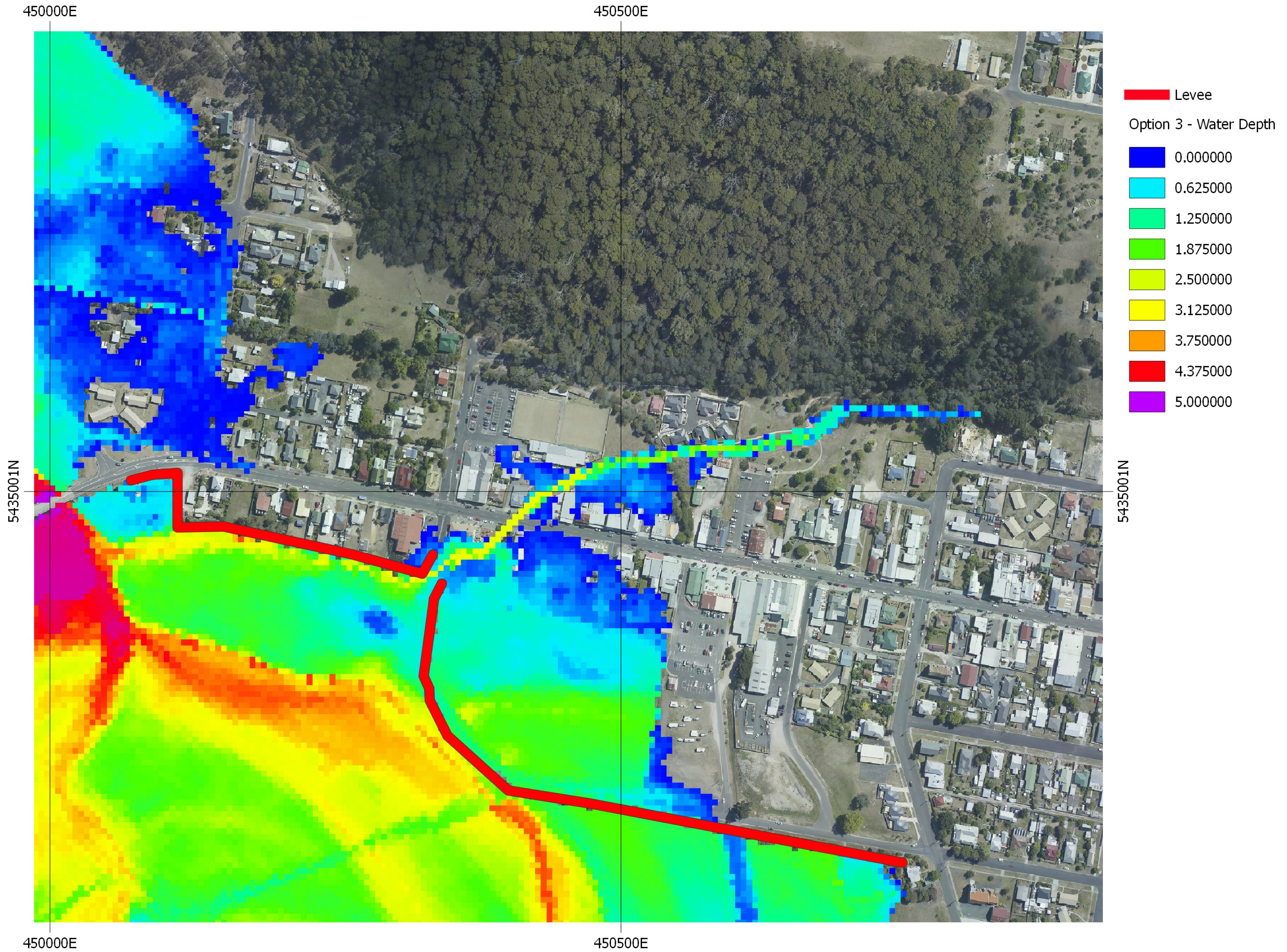

Mersey River Flood Mitigation Options Assessment

Option 3 -Levee across Cottons Street with opening on Kings Creek

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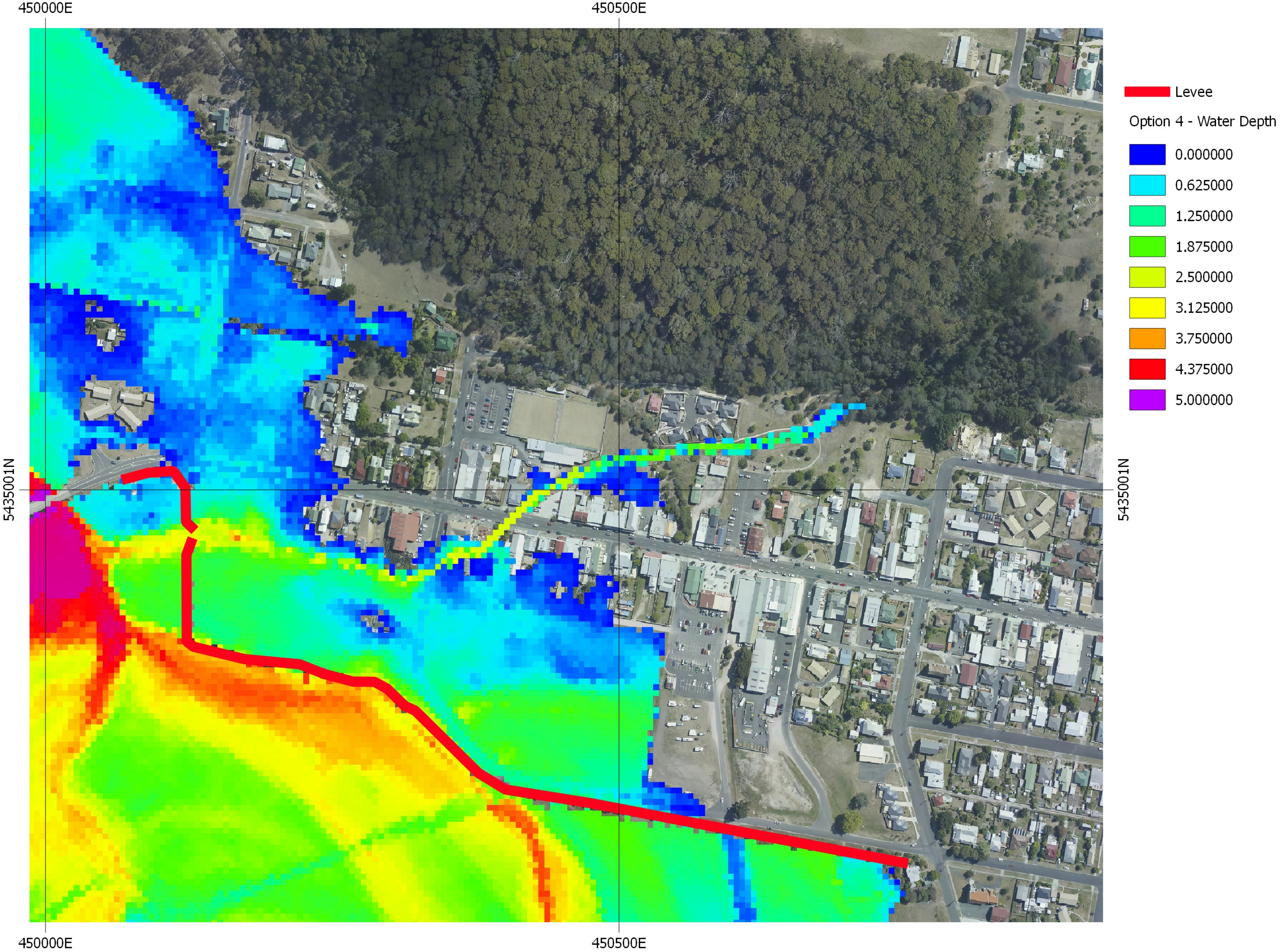

Mersey River Flood Mitigation Options Assessment

Option 4 - Levee south of Kings Creek and accross Cottons St with opening on Kings Creek

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0 50 100 m

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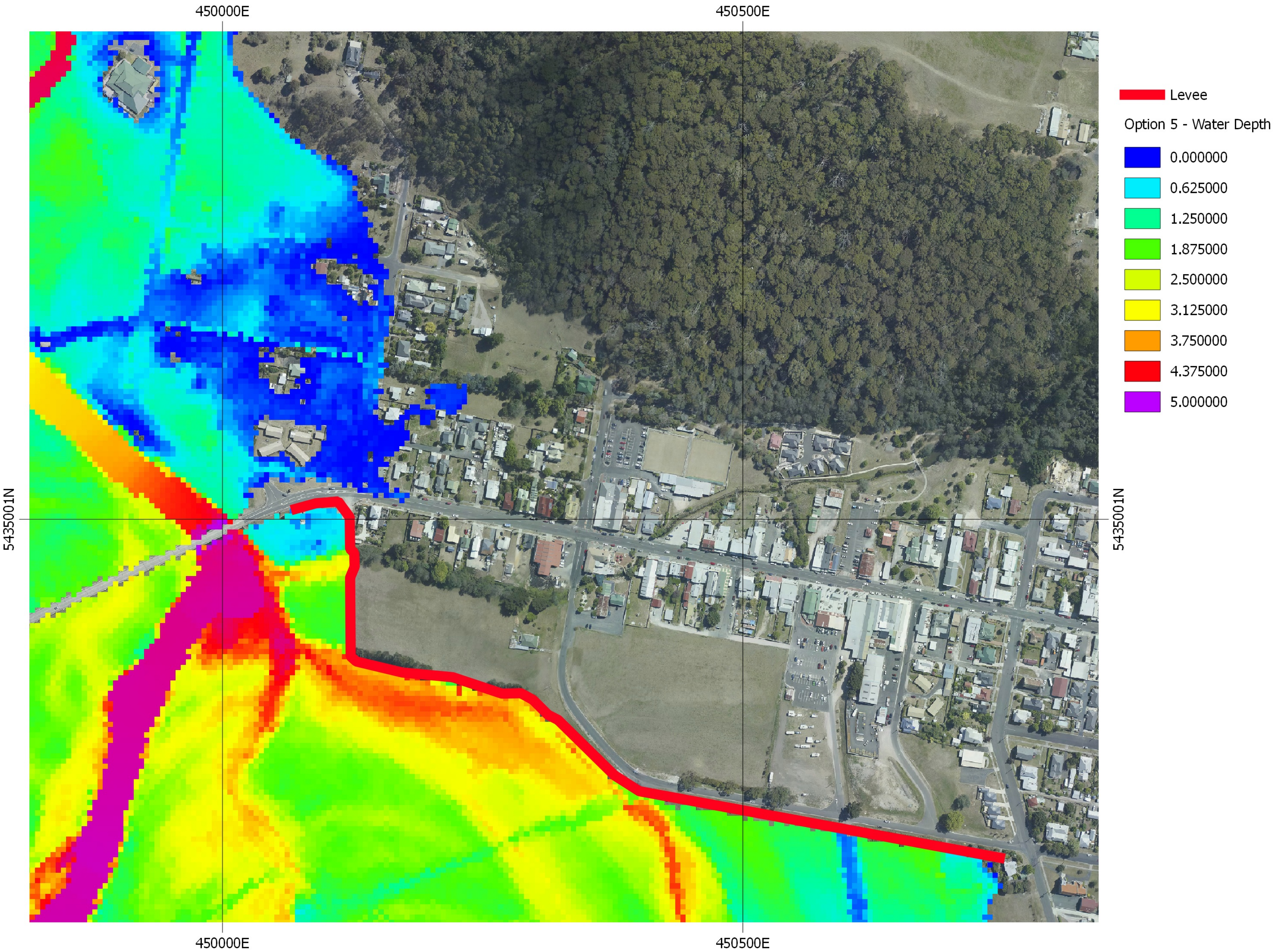

Mersey River Flood Mitigation Options Assessment

Option 5 - Levee South of Kings Creek with pumps and flap gates on Kings Creek

0 100 200 m

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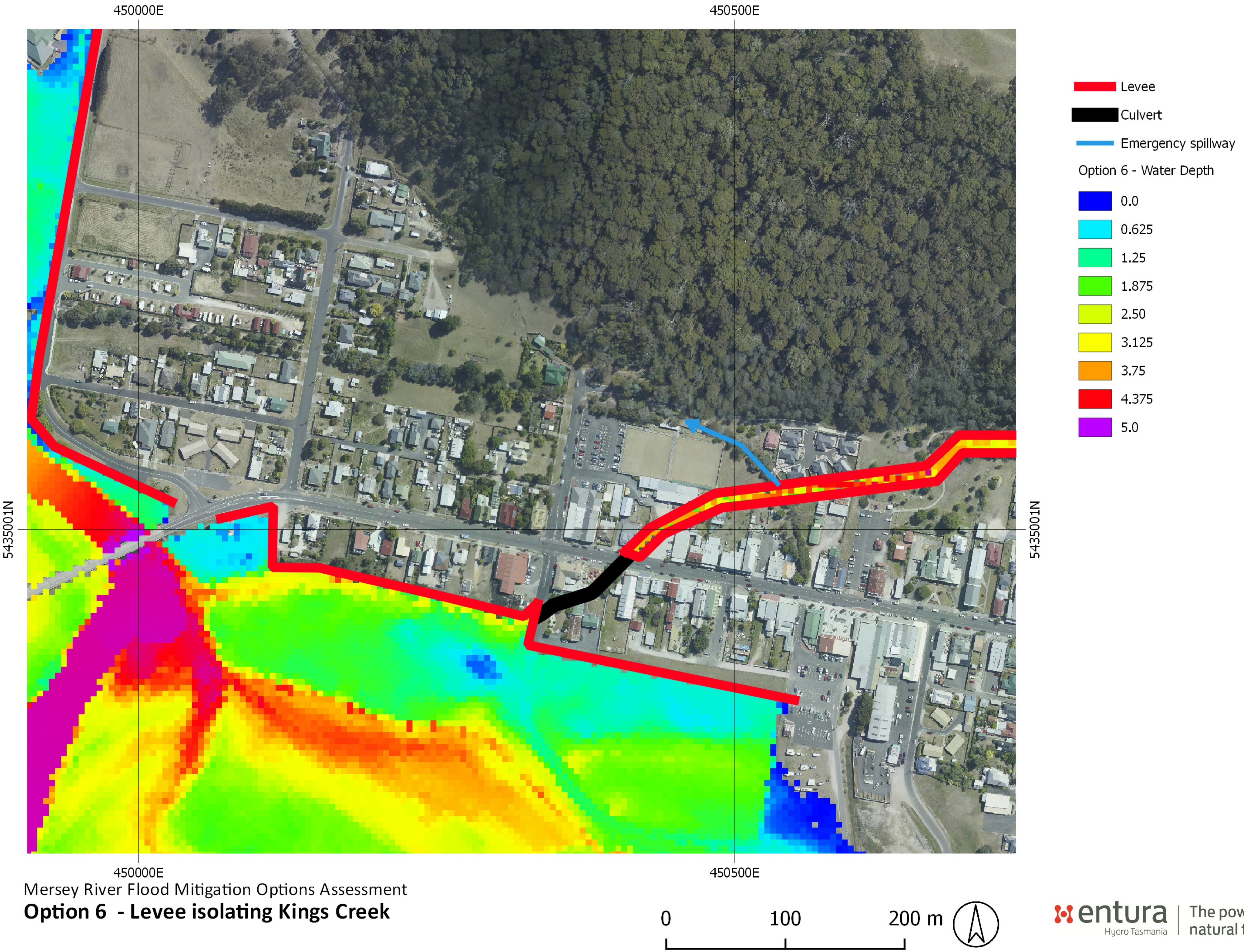

Mersey River Flood Mitigation Options Assessment

Option 6 - Levee isolating Kings Creek

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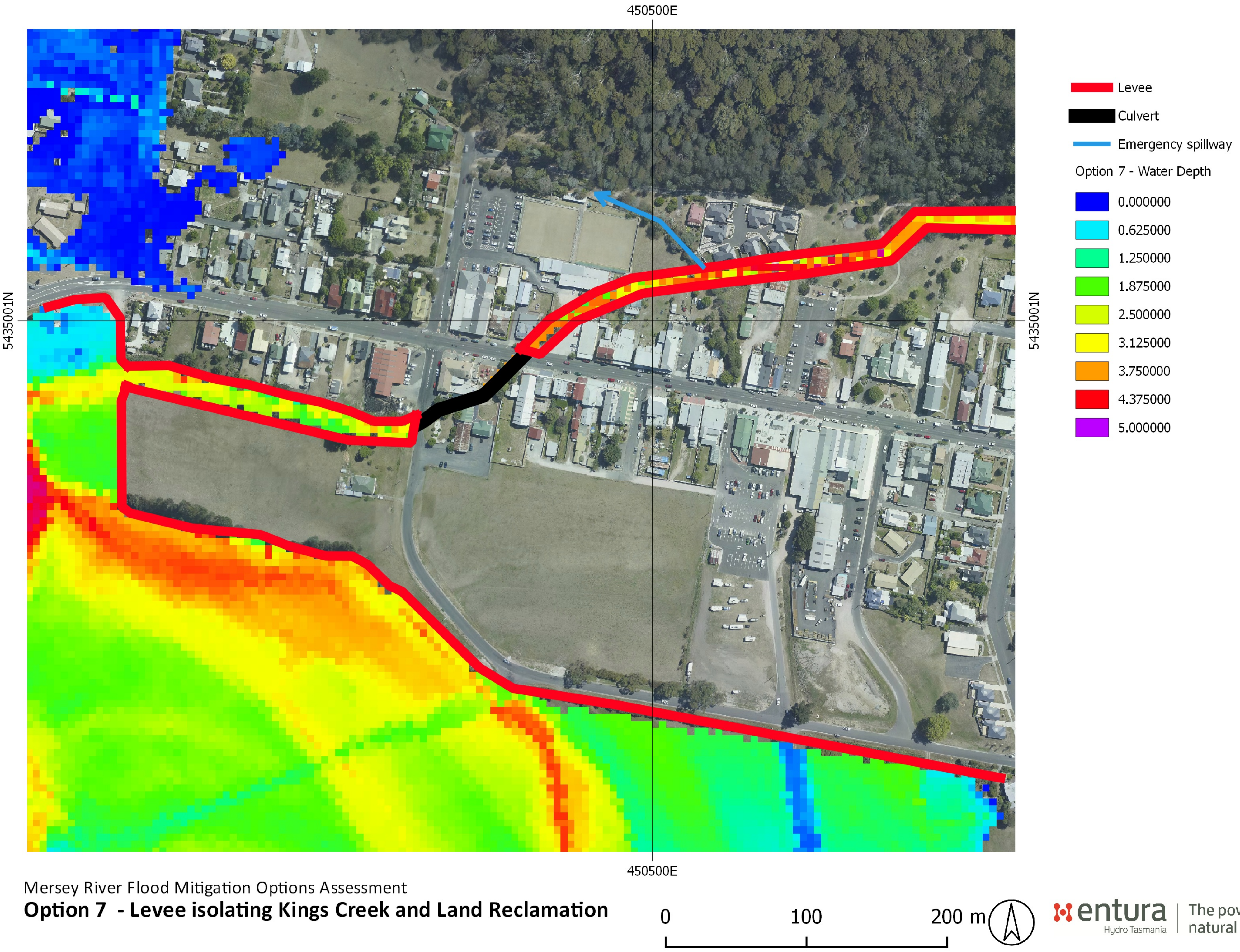

Mersey River Flood Mitigation Options Assessment

Option 7 - Levee isolating Kings Creek and Land Reclamation

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E Options evaluation

Assumptions:

1. Total of 70 properties damaged in Latrobe township.[7]
2. The averaging approach (AIDR, 2002) was assumed for cost of damages. It assumes an average loss per impacted dwelling, which is the simplest method recommended by AIDR (2002).

   Cost of damage is $20,000/property, which is 100% higher than the average insurance claim for the overall event which occurred in SEQ, NSW, VIC and TAS [8]. It assumes that damages in Latrobe were more severe than the average and that some properties were uninsured.

   These values do not account for differences in property values and damage levels across properties. This does not include public infrastructure damages , indirect and intangible losses.
3. Reduction in damage is 80%, for properties labelled as "significant reduction in damage". These properties have reduction in water depth from 0.3m to 0.7m and water depth is less than 0.3m with the corresponding mitigation measure.
4. For option 1, a concrete wall is assumed behind houses at 20-42 Gilbert Street. Cost of concrete wall was assumed as $1,300 per meter (Wollongong City Council. 2017).
5. For option 2: The same as option 1 plus cost of additional levee downstream of the Mersey River Bridge. Downstream levee was assumed as $1000/meter
6. For option 3: Cost of levee is assumed as $1,000 per meter (Wollongong City Council, 2017)
7. For option 4: Cost of levee is assumed as $1,000 per meter (Wollongong City Council, 2017)
8. For option 5:
   (a) Cost of levee is assumed as $1,000 per meter
   (b) Cost of pump station and flap valves: $600,000[9].
   (c) O&M costs for pump station: $100,000 over lifetime. [10]
9. O&M costs for levees are excluded from cost estimates.
10. For option 6: Cost of isolating Kings Creek channel by providing a levee and culverts is assumed as $1,000,000. This is likely underestimated cost, and will depend on design flood event for Kings Creek. Incremental benefit of this option, compared to option 2 is protection of 23

[7] Council identified 67 properties. Counting on the map identified 47 properties to be saved with option 2. 23 properties are assumed to be flood-proofed for option 7.

[8] Based on Insurance Council of Australia (ICA, 2017) estimated value of all claims was $421,696,229 (64% Domestic, 36% Commercial) for the overall event which occurred in SEQ, NSW, VIC and TAS. Total lodged claims were 46,363.

[9] 500kW pump station assumed to transfer 10m3/s flow over the levee.

[10] O&M costs Mechanical and electrical equipment has lower design lifespan (than civil infrastructure) and relatively higher O&M. Pumps would require replacement every 20-30 years and may be used only few times during their lifetime.

properties. Cost of flood-proofing these 23 houses will be significantly less than isolating Kings Creek and therefore, assumed cost of this option are irrelevant.

11. For comprehensive option:

    (a) Cost of house flood-proofing was assumed as $20,000 per property east of Victor Street. This is equal to assumed damage cost. A total of 23 houses assumed to be flood-proofed. Majority of houses are under water depths less than 0.5m. It is likely that few houses will have high flood-proofing costs and the remaining ones will require minor modifications.

    (b) Levee cost updated to 1,300 to provide consistency thought report with short-listed options. Options with various types of levees discarded. Planning and design costs (10% of total) added to cost-benefit analysis to provide consistency with

12. Discount rate equal to inflation (i.e. time value of money is not taken into consideration).

Notes:

- ***Purpose of high-level cost-benefit analysis was to compare option relative to each other.***
- ***Some assumptions are simplistic (eg. discount rate) and/or can have high margin of error (eg. damage costs, house flood-proofing).***

Option	Length of levee (m)	Cost of levee (±30%)	Costs of pumps and gate valves (including O&M)	Flood-proofing (no. of properties)	Total cost	Number of properties saved	Significant reduction in damage (no. of properties)	Benefit (total reduction of damage)	Benefit-cost ratio	Comments (risks and/or impact on surrounding areas)
OPTION 1	350	$455,000			$455,000	21	15	$660,000	1.45	Increase water levels at houses at 46-60 Gilbert Street by 50 mm. A number of properties remain unprotected
OPTION 2	950	$1,055,000			$1,055,000	47		$940,000	0.89	A number of properties remain unprotected
OPTION 3	850	$850,000			$855,000	21	15	$660,000	0.77	As above
OPTION 4	850	$850,000			$855,000	3	10	$200,000	0.23	

Option	Length of levee (m)	Cost of levee (±30%)	Costs of pumps and gate valves (including O&M)	Flood-proofing (no. of properties)	Total cost	Number of properties saved	Significant reduction in damage (no. of properties)	Benefit (total reduction of damage)	Benefit-cost ratio	Comments (risks and/or impact on surrounding areas)
OPTION 5	700	$850,000	$700,000		$1,550,000	44	15	$1,120,000	0.72	A risk of a joint event with high levels in Mersey and rarer AEPs in Kings Creek. It can be mitigated with an emergency spillway which will increase cost. A number of properties remain unprotected
OPTION 6	2000 *NB: Highly longer*	2,000,000 NB: *Not analysed in detail*			2,000,000	70	0	$1,400,000	0.7	A risk of rare AEPs in Kings Creek. It can be mitigated with an emergency spillway which will increase cost.
OPTION 7	Not analysed, as land reclamation is beyond scope of the study									A risk of rare AEPs in Kings Creek. It can be mitigated with an emergency spillway which will increase cost.

Option	Length of levee (m)	Cost of levee (±30%)	Costs of pumps and gate valves (including O&M)	Flood-proofing (no. of properties)	Total cost	Number of properties saved	Significant reduction in damage (no. of properties)	Benefit (total reduction of damage)	Benefit-cost ratio	Comments (risks and/or impact on surrounding areas)
OPTION 8	Not analysed, as there is no benefit									
COMPREHENSIVE SOLUTION – Modified Option 2 and flood-proofing remaining houses	890	$840,000		23	$1,850,000	70	0	$1,400,000	0.87	Planning and design costs (10% of total) included in costs in order to provide consistency with the cost provided in the Section 7.

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F Impact on surrounding areas – water level difference map for option 1

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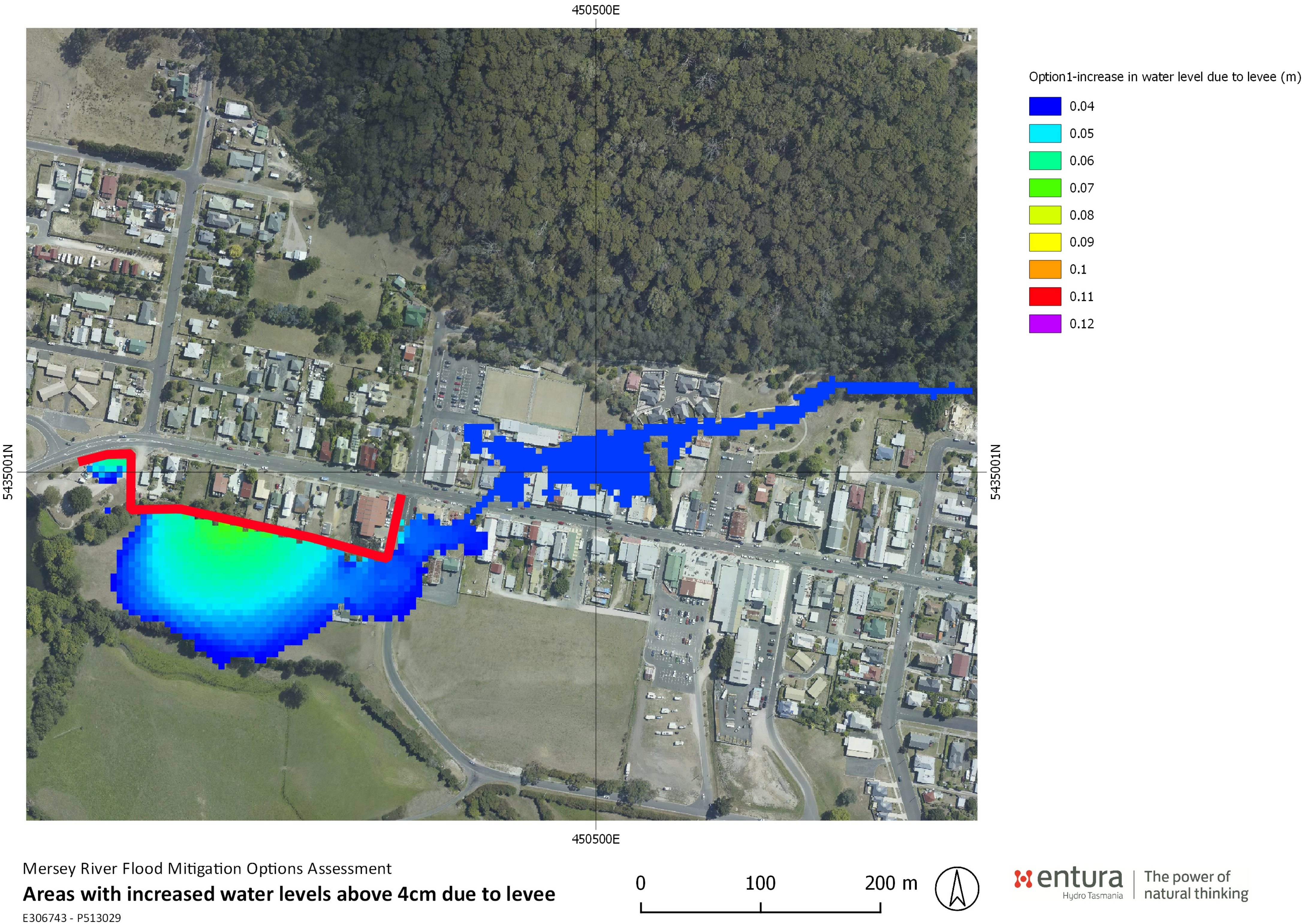

Mersey River Flood Mitigation Options Assessment

Areas with increased water levels above 4cm due to levee

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G Levee types and costs

Levees and floodwalls are types of permanent flood protection barriers. A levee is a compacted earthen structure and a floodwall is an engineered structure usually built of concrete, masonry, or a combination of both. In general, floodwalls are used when there is insufficient land to place an earthen levee up to the required level of protection.

Temporary barriers work with the same principles as permanent barriers, but can be removed, stored, and reused in subsequent flood events. Most of these barriers are meant to take the place of sandbags.

Indicative costs for various flood barrier options are shown in Table 10.1.

It should be noted that the cost and availability of: borrow materials, machinery, labour/ project management; design and feasibility studies, easements and/or the acquisition of land; resolving internal drainage issues and legislative costs can skew typical cost per linear meter significantly (Wollongong City Council, 2017).

Table 10.1: Typical cost for various flood barriers

Option	Cost (±30%)	Cost source
Temporary inflatable tube (1m high)	$500 per meter	Discussion with manufacturer
Earth Levee (1.5m high)	$1,000 per meter	Two similar projects recently completed in Burnie and NSW; Wollongong City Council, 2017
Concrete wall (1.5m high)	$1,300 per meter	Wollongong City Council. 2017
Glass wall (1m high on 0.5m high foundations)	$3,000 per meter	IBS Technics GMBG (ibs-technics.de)
Self-closing mechanical barrier (1.2m high)	$15,000 per meter	Discussion with manufacturer

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H House flood-proofing overview

Flood-proofing is any measure - structural or non-structural - intended to prevent damage from flooding to a building.

Broadly, structural house flood-proofing techniques usually cover the following three techniques (FEMA, 2012):

- Elevation of the structure floors on fill or foundation elements such as solid perimeter walls, piers, posts, columns, or pilings.
- Dry Floodproofing: Strengthening of existing foundations, floors, and walls to withstand flood forces while making the structure watertight.
- Wet Floodproofing: Making utilities, structural components, and contents flood- and water resistant during periods of flooding within the structure

In **elevation**, the structure is raised so that the lowest floor is at or above the Design Flood Elevation (DFE) to avoid damage from a base flood. Heavy-duty jacks are used to lift the existing structure. Cribbing supports the structure while a new or extended foundation is constructed below. In lieu of constructing new support walls, open foundations such as piers, posts, columns, and piles are often used. Elevating a structure on fill may also be an option in some situations. This option seems unlikely to be viable for the Latrobe CBD.

In **dry floodproofing**, the portion of a structure that is below the DFE (walls and other exterior components) is sealed to make it watertight and substantially impermeable to floodwaters. Such watertight impervious membrane sealant systems can include wall coatings, waterproofing compounds, impermeable sheeting and, supplemental impermeable wall systems, such as cast-in-place concrete. Doors, windows, sewer and water lines, and vents are closed with permanent or removable shields or valves. The expected duration of flooding is critical when deciding which sealant systems to use because seepage can increase over time, rendering the floodproofing ineffective.

Wet floodproofing includes modifying a structure to allow floodwaters to enter it in such a way that damage to the structure and its contents is minimized.

Wet floodproofing is often used when all other mitigation techniques are technically infeasible or are too costly. Wet floodproofing is generally appropriate if a structure has available space where damageable items can be stored temporarily. Utilities and furnaces may need to be relocated or protected along with other non-movable items with flood damage-resistant building materials. Wet floodproofing may also be appropriate for structures with basements and crawlspaces that cannot be protected technically or cost-effectively by other retrofitting measures.

Compared with the more extensive flood protection, such as elevation or levies, wet floodproofing is generally the least expensive. Major disruptions to structure occupancy often result during conditions of flooding.

Besides structural measures, flood-proofing also covers the **preparation of plans to initiate standby or emergency measures** in anticipation of a flood, such as sandbagging, moving furniture and valuables to high floors, blocking openings or safely evacuating the premises.

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I Kings Creek detention basin costs

ITEM	DESCRIPTION OF WORKS	QTY	UNIT	RATE	AMOUNT	TOTAL
1	**PRELIMINARIES**					**$11,700.00**
1.1	*Site establishment, de-establishment, set out, compaction and testing, site offices, amenities and all items and works required but not specifically mentioned elsewhere.*	*1*	*item*	*$5,000.0*	*$5,000.00*	
1.2	*Access road*	*1*	*item*	*$2,000.0*	*$2,000.00*	
1.3	*Locate and protect all existing services*	*1*	*item*	*$1,000.0*	*$1,000.00*	
1.4	*Prepare and maintain a Project Plan to include Traffic Management Plan, OH&S, risk, environmental management and construction program.*	*1*	*item*	*$1,000.0*	*$1,000.00*	
1.5	*As Constructed Drawings*	*1*	*item*	*$1,000.0*	*$1,000.00*	
1.6	*Traffic Management including the supply, erection and maintenance of traffic control devices and the liaison/direction of residents & businesses*	*1*	*item*	*$500.00*	*$500.00*	
1.7	*Remove debris/rubbish from the creek channel inc. disposal*	*8*	*hrs*	*$150.00*	*$1,200.00*	
2	**EARTHWORKS**					**$43,000.00**
2.1	*Site clearing*	*50,000*	*m2*	*$0.5*	*$25,000.00*	
2.2	*Excavation inc. disposal of excavated material*	*600*	*m3*	*$10.00*	*$6,000.00*	
2.3	*Level and grade pond edges to 1:4 fall*	*2,000*	*m2*	*$3.5*	*$7,000.00*	
2.6	*Rip-rap in the detention pond and downstream overflow structure (tentative cost)*	*1*	*item*	*$5,000.0*	*$5,000.00*	
3	**CONCRETE WEIR**					**$153,000.00**
3.1	*Precast concrete wall panels with a smooth off-form finish (up to 3m high); adopted as "costs of retaining wall per sqm" from Rawlinsons (2016)*	*325*	*m2*	*$440.00*	*$143,000.00*	
4.2	Coffer Dam and miscellaneous items	1	item	$10,000.00	*$10,000.00*	
4	**OUTFLOW STRUCTURE**					**$3,000.0**
4.1	*Procure and install twin 1.2m diamater pipes, including headwall to suit culvert*	*1*	*item*	*$3,000.00*	*$3,000.00*	

ITEM	DESCRIPTION OF WORKS	QTY	UNIT	RATE	AMOUNT	TOTAL
5	**SITE RESTORATION**					**$2,000.0**
5.01	*Seeding or sodding*	*2,000*	*m2*	*$0.50*	*$1,000.00*	
5.02	*Planting/transplanitng (tentative)*	*1*	*items*	*$1,000.00*	*$1,000.00*	
	SUB TOTAL					**$210,700.00**
7	**CONTINGENCY SUM (Approx. 10%)**					**$21,070.00**
8	**PLANNING AND DESIGN (10% of total)**					**$23,177.00**
	TOTAL LUMP SUM (ex. GST)				**$254,947.00**	

J Cost estimate for four options

J.1 Option A

Item	Units	Cost per unit	Cost
Permanent flood barrier behind houses at 20-42, Gilbert Street	350	$1,300	$455,000
Contingency at Concept (30% of above)			$136,500
Planning and design (10% of the above)			$59,150
Estimated total cost			$650,650

J.2 Option B

Item	Units	Cost per unit	Cost
Permanent flood barrier behind houses at 20-42, Gilbert Street	350m	$1,300	$455,000
Permanent flood barrier opposite 1-5, Gilbert Street	140m	$1,300	$182,000
Permanent flood barrier along River Road and Last Street	400m	$1,300	$520,000
Address breakout areas in Kings Creek	1	$25,000	$25,000
Address potential backflow in Sewerage Pump Station and contingency for other drainage issues	1	$25,000	$25,000
Flood-proofing of houses at 46-70 and 45-87, Gilbert Street	23	$20,000	$460,000
Contingency at Concept (30% of above)			$500,100
Planning and design (10% of the above)			$216,710
Estimated total cost			***$2,383,810***

J.3 Option C

Item	Units	Cost per unit	Cost
350 m flood barrier behind houses at 20-42 Gilbert Street	350m	$1,300	$455,000
150 m long flood barrier downstream the Mersey River Bridge, along Gilbert Street.	140m	$1,300	$182,000
200m long flood barrier along Kobie Lane.	200m	$1,000	$200,000
Victor Street Bridge replacement	1	$350,000	$350,000
Flood barriers along left and right Kings Creek banks	700m	$1,000	$700,000
Modification of Sheean Walk to be able to cater for flow diversion from Kings Creek.	700m	$1,000	$700,000
Address potential backflow in Sewerage Pump Station and contingency for other drainage issues	1	$25,000	$25,000
Kings Creek embankment stabilisation from Sheehan Walk to Gilbert Street based on completed works at Kings Park	250m	$2,000	500,000
Contingency at Concept (30% of above)			$933,600
Planning and design (10% of the above)			$44,560
Estimated total cost			**$4,450,160**

J.4 Option D

Item	Units	Cost per unit	Cost
350 m flood barrier behind houses at 20-42 Gilbert Street	350m	$1,300	$455,000
600 m long flood barrier downstream the Mersey River Bridge, along Gilbert Street.	600m	$1,300	$780,000
200m long flood barrier along Kobie Lane.	200m	$1,000	$200,000
Victor Street Bridge modification	1	$350,000	$350,000
Flood barriers along left and right Kings Creek banks	700m	$1,000	$700,000
Provisional item for Spillways/Fuse plugs (cost on top of levee length)	1	$100,000	$100,000
Address potential backflow in Sewerage Pump Station and contingency for other drainage issues	1	$25,000	$25,000
Kings Creek embankment stabilisation from Sheehan Walk to Gilbert Street based on completed works at Kings Park	250m	$2,000	500,000
Contingency at Concept (30% of above)			933,000
Planning and design (10% of the above)			$404,300
Estimated total cost			**$4,447,300**

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K Flood mitigation options

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Mersey River Flood Mitigation Options Assessment

Short-listed mitigation options - Option A

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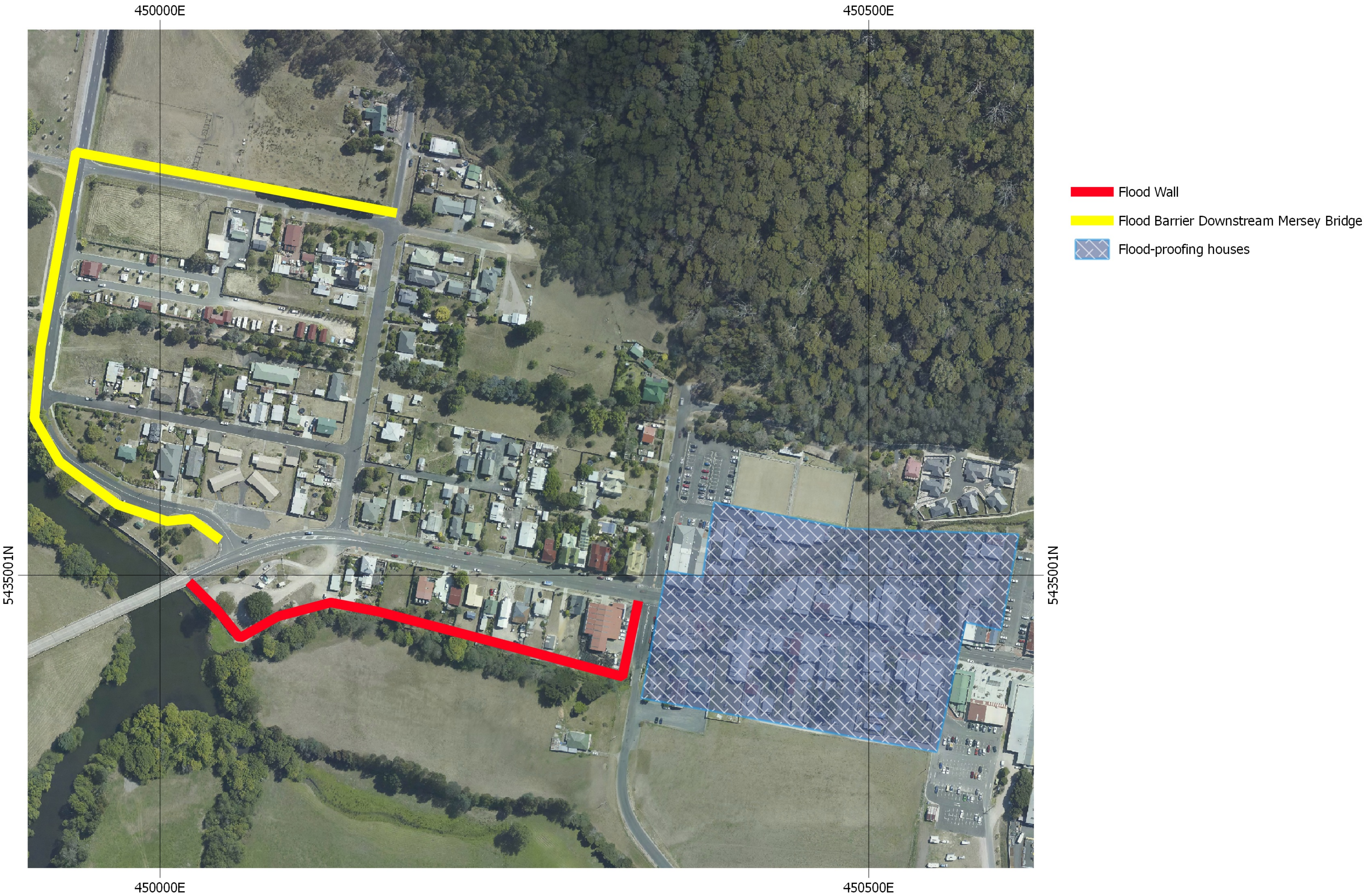

Mersey River Flood Mitigation Options Assessment

Short-listed mitigation options - Option B

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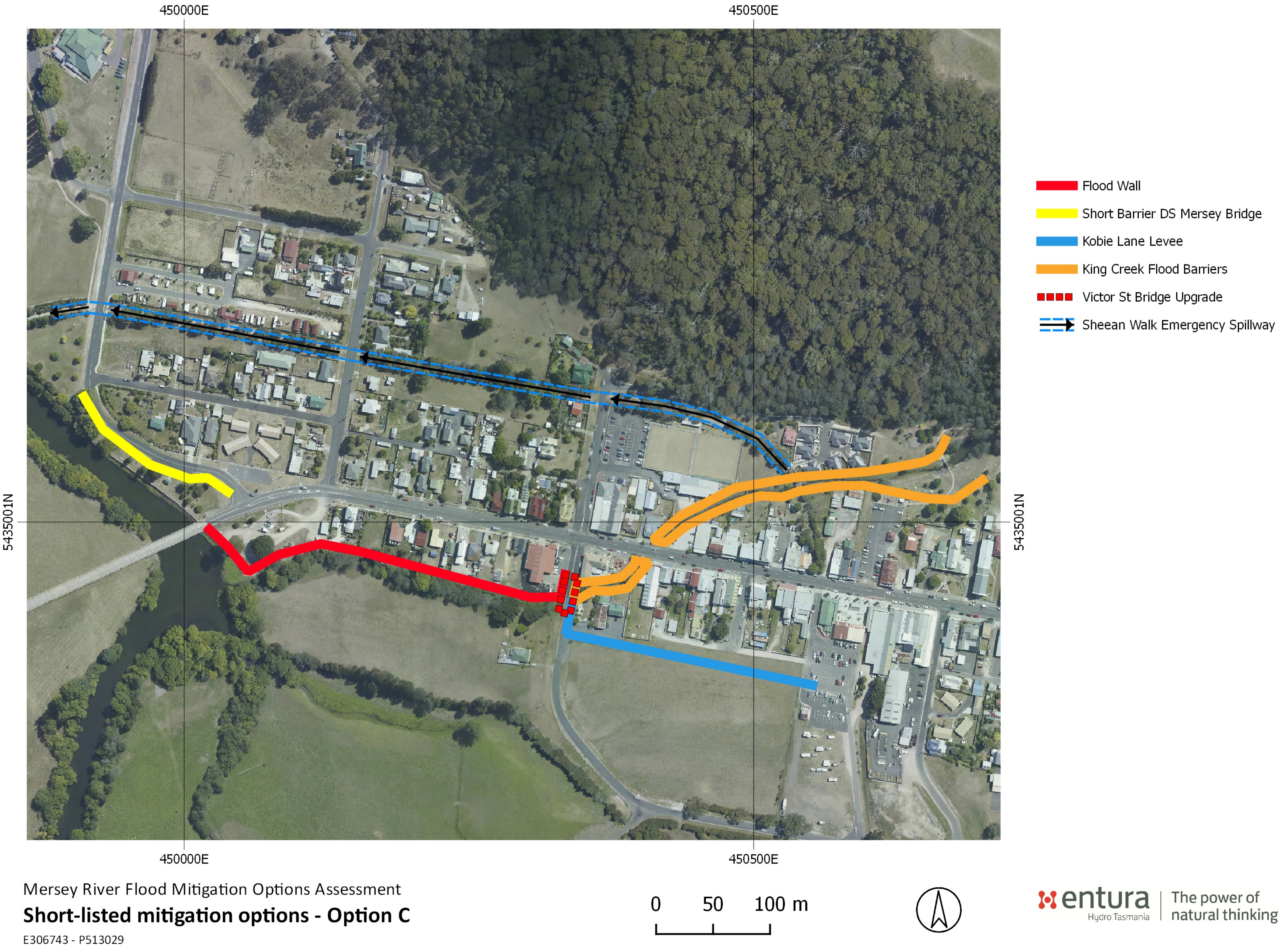

Mersey River Flood Mitigation Options Assessment

Short-listed mitigation options - Option C

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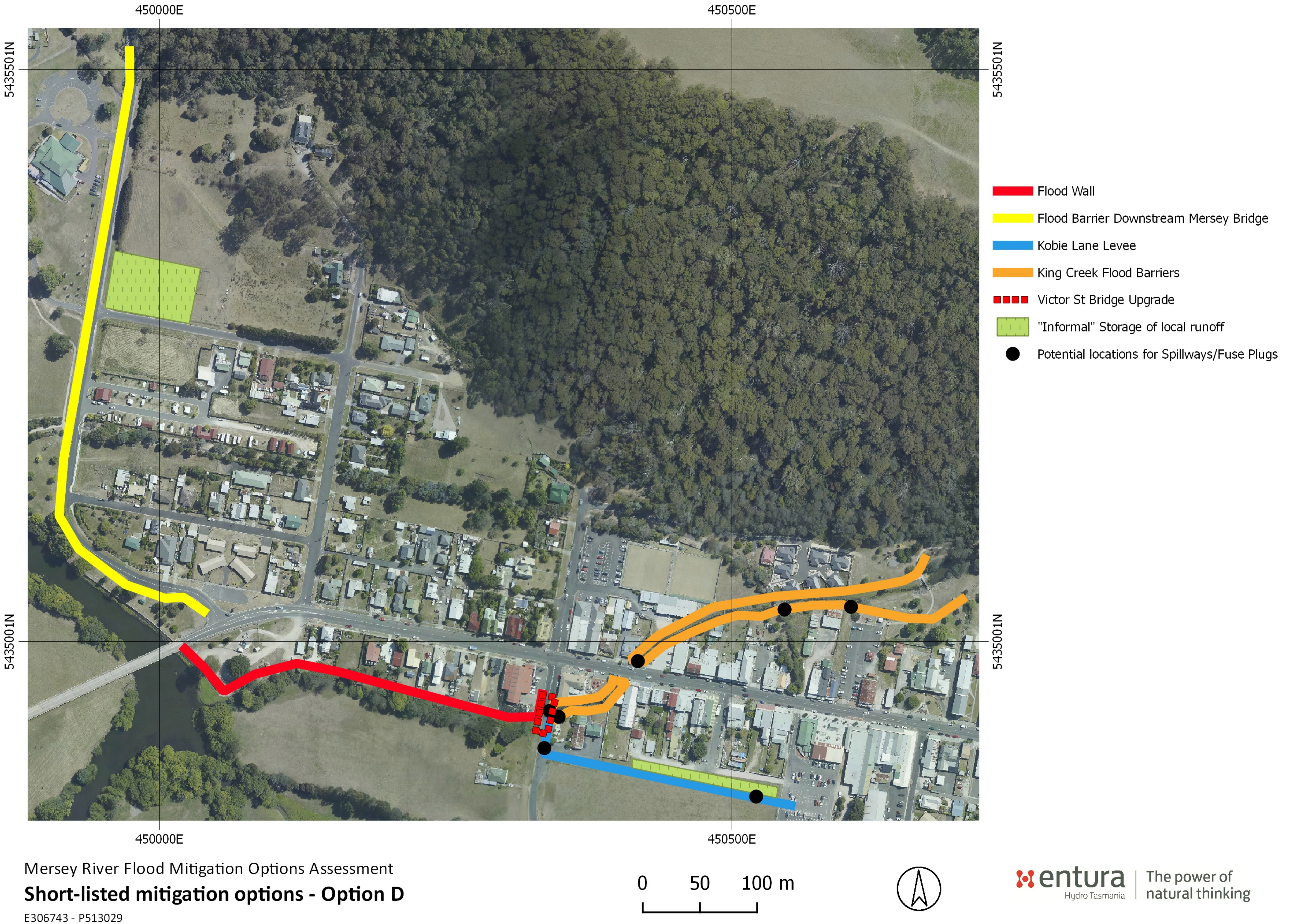

Mersey River Flood Mitigation Options Assessment

Short-listed mitigation options - Option D

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