
# Flood Damages and Mitigation Assessment

## Teesdale Flood Risk Identification Study

Golden Plains Shire

5 May 2023

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## Project Details

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| **Project Name** | Teesdale Flood Risk Identification Study |
| **Client** | Golden Plains Shire |
| **Client Project Manager** | Daniel Murrihy |
| **Water Technology Project Manager** | Lachlan Inglis |
| **Water Technology Project Director** | Johanna Theilemann |
| **Authors** | Michael Clarke |
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51 Little Fyans Street
Geelong VIC 3220
Telephone (03) 8526 0800
ACN 093 377 283
ABN 60 093 377 283

# CONTENTS



# LIST OF FIGURES



# LIST OF TABLES

# GLOSSARY OF TERMS

| | |
|---|---|
| **Afflux** | Refers to the difference in water level (or depth) between two modelling scenarios, usually measured in metres and a change in extent (e.g. "was wet now dry") |
| **Annual Exceedance Probability (AEP)** | Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded; it would occur quite often and would be relatively small. A 1% AEP flood has a low probability of occurrence or being exceeded; it would be fairly rare but it would be of extreme magnitude. |
| **Australian Height Datum (AHD)** | A common national surface level datum approximately corresponding to mean sea level. Introduced in 1971 to eventually supersede all earlier datums. |
| **Averange Annual Damages (AAD)** | A measure of average flood damages expressed as a dollar cost per year. Takes into account the expected damages of each event along with the event's probability of occurring in any year. |
| **Average Recurrence Interval (ARI)** | Refers to the average time interval between a given flood magnitude occurring or being exceeded. A 10 year ARI flood is expected to be exceeded on average once every 10 years. A 100 year ARI flood is expected to be exceeded on average once every 100 years. The AEP is the ARI expressed as a percentage. |
| **Cadastre, cadastral base** | Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc. |
| **Catchment** | The area 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. |
| **Design flood** | A design flood is a probabilistic or statistical estimate, being generally based on some form of probability analysis of flood or rainfall data. An average recurrence interval or exceedance probability is attributed to the estimate. |
| **Discharge** | The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving. |
| **Flood** | Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from elevated sea levels and/or waves overtopping coastline defences. |
| **Flood frequency analysis** | A statistical analysis of observed flood magnitudes to determine the probability of a given flood magnitude. |

| | |
|---|---|
| **Flood hazard** | Potential risk to life and limb caused by flooding. Flood hazard combines the flood depth and velocity. |
| **Floodplain** | Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land. |
| **Flood storages** | Those parts of the floodplain that are important for the temporary storage, of floodwaters during the passage of a flood. |
| **Geographical information systems (GIS)** | A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data. |
| **Hydraulics** | The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity. |
| **Hydrograph** | A graph that shows how the discharge changes with time at any particular location. |
| **Hydrology** | The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods. |
| **Intensity frequency duration (IFD) analysis** | Statistical analysis of rainfall, describing the rainfall intensity (mm/hr), frequency (probability measured by the AEP), duration (hrs). This analysis is used to generate design rainfall estimates. |
| **LiDAR** | Spot land surface heights collected via aerial light detection and ranging (LiDAR) survey. The spot heights are converted to a gridded digital elevation model dataset for use in modelling and mapping. |
| **Peak flow** | The maximum discharge occurring during a flood event. |
| **Probability** | A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Average Recurrence Interval. |
| **Probable Maximum Flood** | The flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in a particular drainage area. |
| **RORB** | A hydrological modelling tool used in this study to calculate the runoff generated from historic and design rainfall events. |
| **Runoff** | The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess. |
| **Stage** | Equivalent to 'water level'. Both are measured with reference to a specified datum. |

| | |
|---|---|
| **Stage hydrograph** | A graph that shows how the water level changes with time. It must be referenced to a particular location and datum. |
| **Topography** | A surface which defines the ground level of a chosen area. |

# 1 INTRODUCTION

## 1.1 Overview

Water Technology has been commissioned by Golden Plains Shire Council (Council) to undertake the Teesdale Flood Risk Identification Study. The investigation area covers the Native Hut Creek and tributaries in the township of Teesdale. Teesdale is identified as a Priority Flood Risk Area in the Corangamite Regional Floodplain Management Strategy (2018), which identifies both riverine and flash flood risks for the town and states that "*flooding associated with Native Hut Creek has damaged several residential properties*".

Previous flood investigations covering Teesdale include CCMA investigations undertaken in 2008 and 2019. The 2008 study utilised RORB hydrologic modelling and HEC-RAS one-dimensional hydraulic modelling, while the 2019 study utilised HEC-RAS two-dimensional hydraulic modelling. A regional flood study of the Barwon River catchment which covers the study area was also completed in 2016 (GHD, 2016).

The CCMA modelling completed in 2019 indicates that the current flood mapping which is the basis for the current Floodway Overlay (FO) and Land Subject to Inundation Overlay (LSIO) in the Golden Plains Planning Scheme understates the flood hazard in Teesdale. The Flood Risk Identification Study is being carried out to ensure that the planning scheme mapping accurately reflects flood hazard to ensure that growth in Teesdale is managed appropriately into the future. As such, updated flood mapping suitable for inclusion in the Golden Plains Planning Scheme is a key output required from the study.

In addition, the study will produce flood intelligence information for use in emergency management situations, assess the current flood impact/exposure in terms of annual average damages caused by flooding in Teesdale, investigate structural and non-structural mitigation options to reduce damages, investigate and make recommendations for establishing a flood warning system for the town.

This report is one of a series documenting the outcomes of the Teesdale Flood Risk Identification Study. Each reporting stage is shown below:

- R01 - Data Review and Validation
- R02 – Joint Validation Modelling Report
- R03 – Design Hydrology and Hydraulic Modelling Report
- R04 – Flood Intelligence and Flood Warning Report – This Report
- **R05 – Flood Damages and Mitigation Assessment Report – This Report**
- R06 – MFEP Documentation
- R07 – Final Summary Report

## 1.2 Study Area

Teesdale is located approximately 8.5 km north of Inverleigh and is situated on the banks of Native Hut Creek. The Native Hut Creek catchment begins approximately 22.5 km north of Teesdale near the town of Meredith. The creek meanders south across agricultural land, the vast majority of which has been historically cleared of large vegetation in line with its agricultural use.

The catchment within and upstream of the study area is mostly cleared agricultural land, and the main waterway (Native Hut Creek) has several onstream dams of varying size along its alignment. The Native Hut Creek catchment, draining to Teesdale is approximately 110 km$^2$. The entire catchment is located within the Golden Plains municipal area. The study area is focussed on the township of Teesdale and includes the following waterway structures:

- Two large on-stream dams approximately 3km upstream of the township.
  - An indicative assessment of the impact of the upstream dams was completed in R01 – Data Collation and Validation. The assessment found the dams would have minimal impact on peak flow rate or flood levels in a significant storm event.
- Road crossings, formal and informal, at the following roads:
  - Tolson Road/Stones Road
  - Sutherland Street
  - Bannockburn-Shelford Road
  - Barkers Road
- Several off-stream dams throughout the town.

## 1.3 Previous Reporting

This report follows report R04 – Flood Intelligence and Warning. The previous report presented the flood intelligence products developed for Teesdale informed by the modelling and analysis undertaken earlier in the project.

This report presents the results of the flood damages assessment for Teesdale, presenting the estimated average annual cost of flooding for the township. Mitigation options are also considered with the aim to reduce current and future flood risk and damages.

# 2 FLOOD BEHAVIOUR

## 2.1 Overview

Flooding in Teesdale occurs as a result of both local rainfall (i.e. overland/stormwater inundation) and riverine flooding when Native Hut Creek breaks its banks. The Teesdale Flood Risk Identification Study considers the impacts and behaviour of *riverine* flooding only (in accordance with project scope). A separate drainage investigation is also underway which will investigate inundation from local runoff in the town.

Native Hut Creek enters Teesdale at the northwest corner of the town, near the ends of River Drive and Eagle Court. The floodplain in this area is reasonably narrow and contained, although the northern portions of properties along Eagle Drive and Squires Road become inundated in large events of around a 5% to 2% AEP. East of the Squires Road/Bruce Street intersection the floodplain again becomes narrow, with the majority of flow contained within the waterway. Approximately 200m upstream of the Stones Road/Tolson Road bridge flows break out of the waterway corridor in even low magnitude (frequent) events.

The floodplain from the Stones Road/Tolson Road breakout through town is generally wide spread, with deep, high hazard flows observed in the floodplain in events greater (rarer) than a 10% AEP (rarer).

## 2.2 Roads

Inundation of roads presents a risk to pedestrians and vehicles safety, as the safe limits of depth and velocity are often exceeded and extremely difficult to observe or measure during an event. Isolation of community members also creates a need or desire to use inundated roads. Community and emergency services members may therefore inadvertently traverse roads which are extremely unsafe and should not be attempted.

The results of the flood modelling and mapping show a number of roads within Teesdale are overtopped in floods of varying magnitude. Table 2-1 shows the roads impacted by flooding and the lowest magnitude (i.e. most frequent) event at which the road is impacted within Teesdale.

**Table 2-1 Roads Overtopped within Teesdale**

| Road | Design Event Overtopped |
|---|---|
| Barker Street | 50% AEP |
| Stones Road/Tolson Road | 50% AEP |
| Russell Street | 50% AEP |
| Learmonth Street | 50% AEP |
| Pantics Road/Squires Road | 20% AEP |
| Mercer Terrace | 10% AEP |
| Sutherland Street | 10% AEP |
| Teesdale-Inverleigh Road | 5% AEP |
| Bannockburn-Shelford Road | 2% AEP |
| Jollys Road | 2% AEP |
| Teesdale-Lethbridge Road | 0.5% AEP |
| Bruce Street | PMF |

Road inundation mapping for the 1% AEP event is shown in Figure 2-1 below. Mapping for all events has been supplied to Council and Corangamite CMA with the project deliverables and has been included in a draft update to the Golden Plains Municipal Flood Emergency Plan.

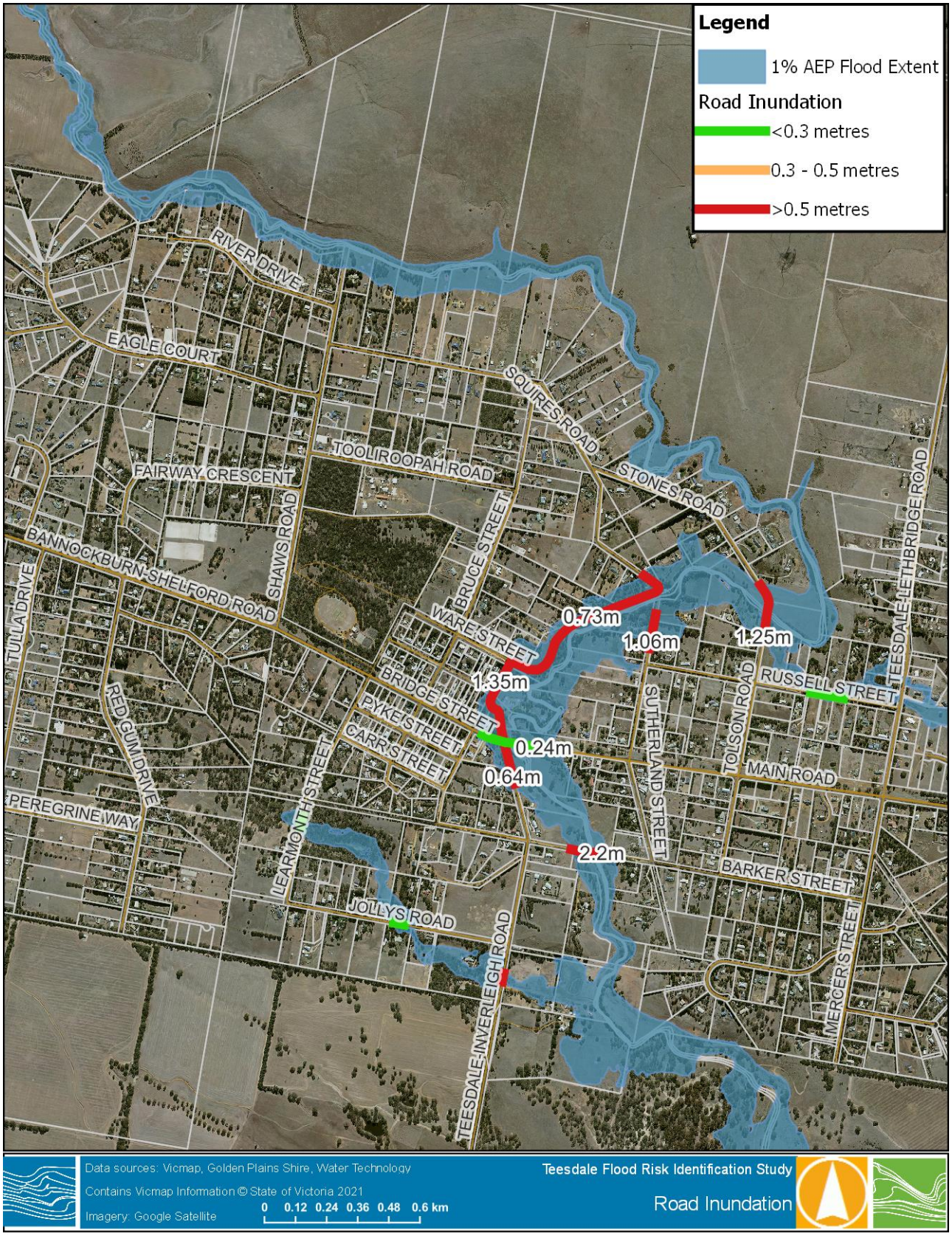


**Figure 2-1 1% AEP Road Inundation and Depths**

## 2.3 Properties

Properties bordering Native Hut Creek are generally large lots. The majority of lots bordering the creek prior to the Stones Road/Tolson Road breakout are long lots with the dwellings positioned away from the creek. Throughout town the lot shapes and orientations have more variety however most lots are large enough to have some flood free land in even very rare events.

Historical development of the town has largely avoided the placement of dwellings within the floodplain. In the 0.2% (1 in 500) AEP event, only two dwellings in town are flooded above floor. One dwelling, located at 87 Pantics Road, is inundated above floor in a 10% AEP event or larger. Another dwelling located at 844 Teesdale Inverleigh Road is inundated above floor in a 2% AEP event or larger. This is likely a combination of low historical development pressure in the town combined with some large flood events in the past.

Table 2-2 summarises property inundation in Teesdale under various modelled design events. It should be noted that Table 2-2 does not include above floor flooding of sheds, agricultural structures etc. in the above floor flooding figures. A number of these structures are within the flood extent and may be subject to above floor inundation as these buildings often have their floor level at or close to ground level.

In accordance with the above section 2.2, a number of properties which are not necessarily directly impacted by flooding (at the dwelling) are liable to be isolated during large events in Native Hut Creek. The majority of properties liable to be isolated are on Pantics Road.

**Table 2-2 Summary of properties flooded in Teesdale**

| Design Event (AEP) | Dwellings Flooded Above Floor | Properties Impacted by Floodwater |
|---|---|---|
| 50% | 0 | 63 |
| 20% | 0 | 73 |
| 10% | 1 | 90 |
| 5% | 1 | 93 |
| 2% | 2 | 102 |
| 1% | 2 | 108 |
| 0.5% | 2 | 111 |
| 0.2% | 2 | 112 |

The two dwellings impacted by above floor flooding are shown in Figure 2-2 below.

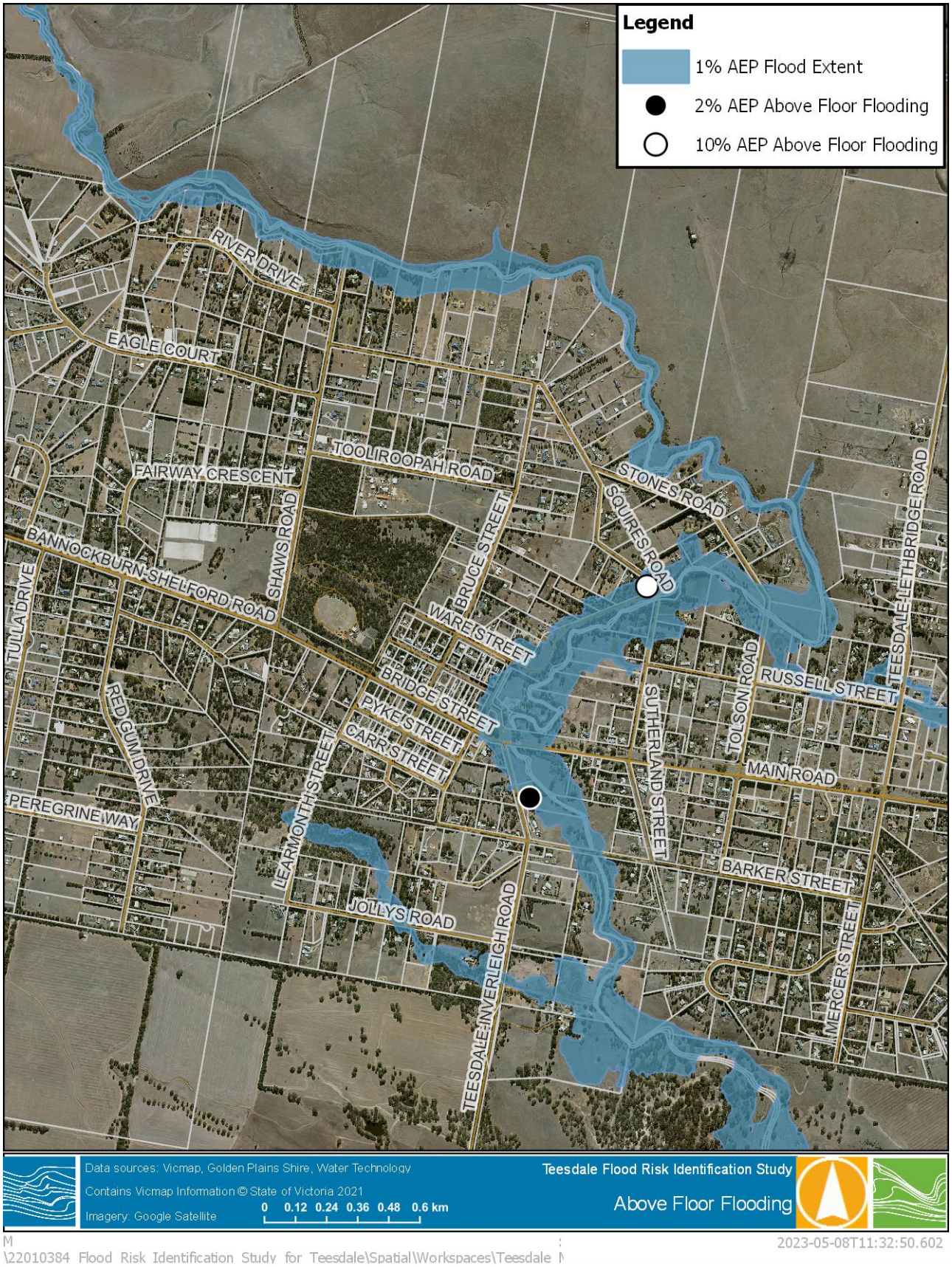


**Figure 2-2 Dwellings impacted by above floor flooding**

# 3 DAMAGES ASSESSMENT

A flood damage assessment was undertaken for the study area under existing conditions. The flood damage assessment determined the monetary flood damage for the range of modelled design events (i.e. 20%, 10%, 5%, 2% 1%, 0.5%, 0.2% AEP and PMF floods).

Model results for all mapped flood events were processed to calculate the number and the locations of properties and roads affected. These included properties inundated above floor, properties inundated below floor, properties which were not impacted but the grounds of the property were, and the lengths of flood affected roads. It should be noted that only sealed roads were assessed due to the availability of associated costs for flood damages.

Flood damages were calculated and summed for each property and road utilising the damage curves in Table 3-1 below.

**Table 3-1 Damage Curves Utilised in Assessment**

| Damage Category | Damage vs Depth Curve |
|---|---|
| Residential | Stage damage curves based on NSW Office of Environment and Heritage 2007 methodology[1] (factored up to 2022 CPI) |
| Commercial | Stage damage curves based on ANUFLOOD 1992 methodology (increased by 60% as per RAM 2000 methodology[2], and factored up to 2022 CPI) |
| External Below Floor | Damage curve from NSW DPIE 1992 methodology (factored up to 2022 CPI) |

A summary of the flood damage assessment is shown below in Figure 3-1. The assessment reveals an AAD for Teesdale of **$113,366 per year**. The AAD value for Teesdale is quite low given the small population of the town and the central presence of Native Hut Creek. This is reflective of the fact that few dwellings have been placed within the floodplain.

**EXISTING CONDITIONS**

| ARI (years)<br>AEP | PMF<br>0.00001 | 500yr<br>0.002 | 200yr<br>0.005 | 100yr<br>0.01 | 50yr<br>0.02 | 20yr<br>0.05 | 10yr<br>0.1 | 5yr<br>0.2 | 2yr<br>0.5 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| Residential Buildings Flooded Above Floor | 16 | 2 | 2 | 2 | 2 | 1 | 1 | 0 | 0 |
| Commercial Buildings Flooded Above Floor | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Properties Flooded Below Floor | 164 | 119 | 119 | 114 | 109 | 101 | 98 | 76 | 64 |
| **Total Properties Flooded** | **182** | **121** | **121** | **116** | **111** | **102** | **99** | **76** | **64** |
| Direct Potential External Damage Cost | $1,582,730 | $643,420 | $583,954 | $521,971 | $470,489 | $402,605 | $319,425 | $179,678 | $87,892 |
| | | | | | | | | $0 | $0 |
| Direct Potential Residential Damage Cost | $2,173,478 | $197,000 | $185,013 | $170,988 | $160,202 | $81,321 | $73,152 | $0 | $0 |
| Direct Potential Commercial Damage Cost | $418,468 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| **Total Direct Potential Damage Cost** | **$4,174,676** | **$840,420** | **$768,967** | **$692,959** | **$630,691** | **$483,926** | **$392,577** | **$179,678** | **$87,892** |
| **Total Actual Damage Cost** *(0.8*Potential)* | **$3,339,741** | **$672,336** | **$615,174** | **$554,367** | **$504,553** | **$387,141** | **$314,062** | **$143,742** | **$70,314** |
| **Infrastructure Damage Cost** | **$198,267** | **$102,406** | **$96,149** | **$83,456** | **$71,859** | **$53,936** | **$46,225** | **$15,463** | **$11,352** |
| Indirect Clean Up Cost | | | | | | | | | |
| Indirect Residential Relocation Cost | | | | | | | | | |
| Indirect Emergency Response Cost | | | | | | | | | |
| **Total Indirect Cost** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** |
| **Total Cost** | **$3,538,008** | **$774,742** | **$711,323** | **$637,823** | **$576,412** | **$441,077** | **$360,287** | **$159,206** | **$81,665** |

| | |
|---|---|
| **Average Annual Damage (AAD)** | $113,366 |

**Figure 3-1 Existing Conditions Average Annual Damages (AAD)**

[1] NSW Office of Environment and Heritage (2007) Floodplain Risk Management Guidelines: Residential Flood Damages
[2] Rapid appraisal method (RAM) for floodplain management, Victorian Department of Natural Resources and Environment, 2000

# 4 STRUCTURAL MITIGATION ASSESSMENT

## 4.1 Overview

Three potential structural mitigation options were tested in the hydraulic model for all design events. The three options considered were as follows:

- Raising of Pantics Road to above the 1% AEP flood level with 300mm freeboard;
- Additional culverts under Bannockburn-Shelford Road adjacent to the bridge; and
- Clearing Native Hut Creek of vegetation and large wood.

The results of the modelling were then processed to determine the AAD for each mitigation option to enable a comparison with the existing conditions. High level cost estimates for each option were developed and utilised to prepare a cost-benefit assessment. For each cost-benefit analysis, a 30-year project timeline was adopted with a discount rate of 6%.

The three options, their respective model results and cost benefit analyses are described in detail below. Cost estimates for the works have been based on Water Technology's experience of works on waterways and developments with supplementation from Rawlinsons Construction Cost Guide 2023 and Rawlinsons Australian Construction Handbook 2021 where required. Estimates from the 2021 edition have been increased by 20% due to the significant rises in construction costs (labour and materials) since then. A 30% contingency has been included in the total cost estimates for each option to account for administration, project management and unforeseen contingencies.

Each option has had its cost/benefit assessed in terms of the net present value of the option over a 30 year timeframe. The net present value of each option was assessed according to the below equation.

$$NPV = \sum \frac{R - M}{(1 + i)^n} - C$$

Where:

$R$ = Reduction in AAD ($)

$M$ = Annual Maintenance Cost ($)

$i$ = Discount/Interest Date

$C$ = Capital Cost ($)

$n$ = Year (from 1 to 30)

## 4.2 Option 1: Raising of Pantics Road

This option, shown in Figure 4-1, involves raising Pantics Road to approximately 300mm above the 1% AEP flood level. This, combined with the upgrade of culverts under the road to include backflow prevention valves, aims to protect properties on the west side of the road along with the road itself.

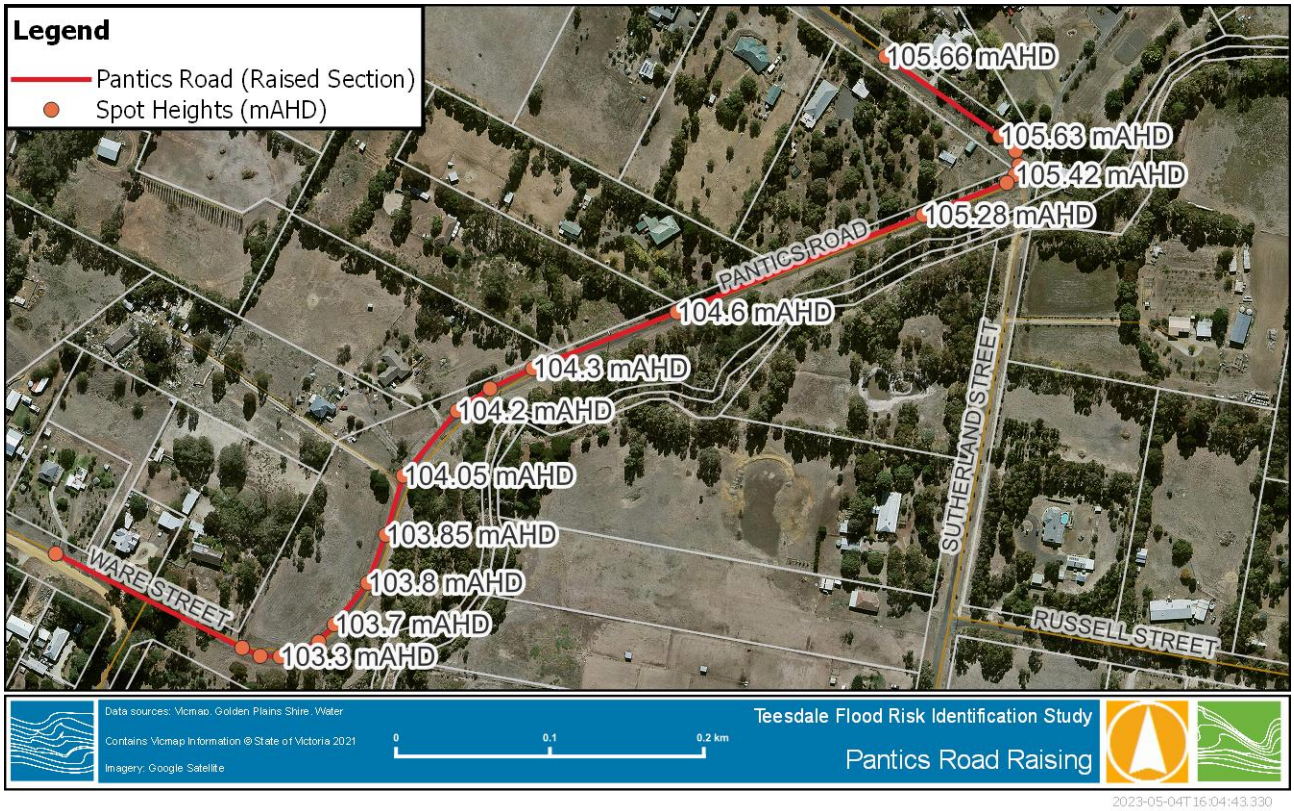


**Figure 4-1 Mitigation Option 1: Raising of Pantics Road**

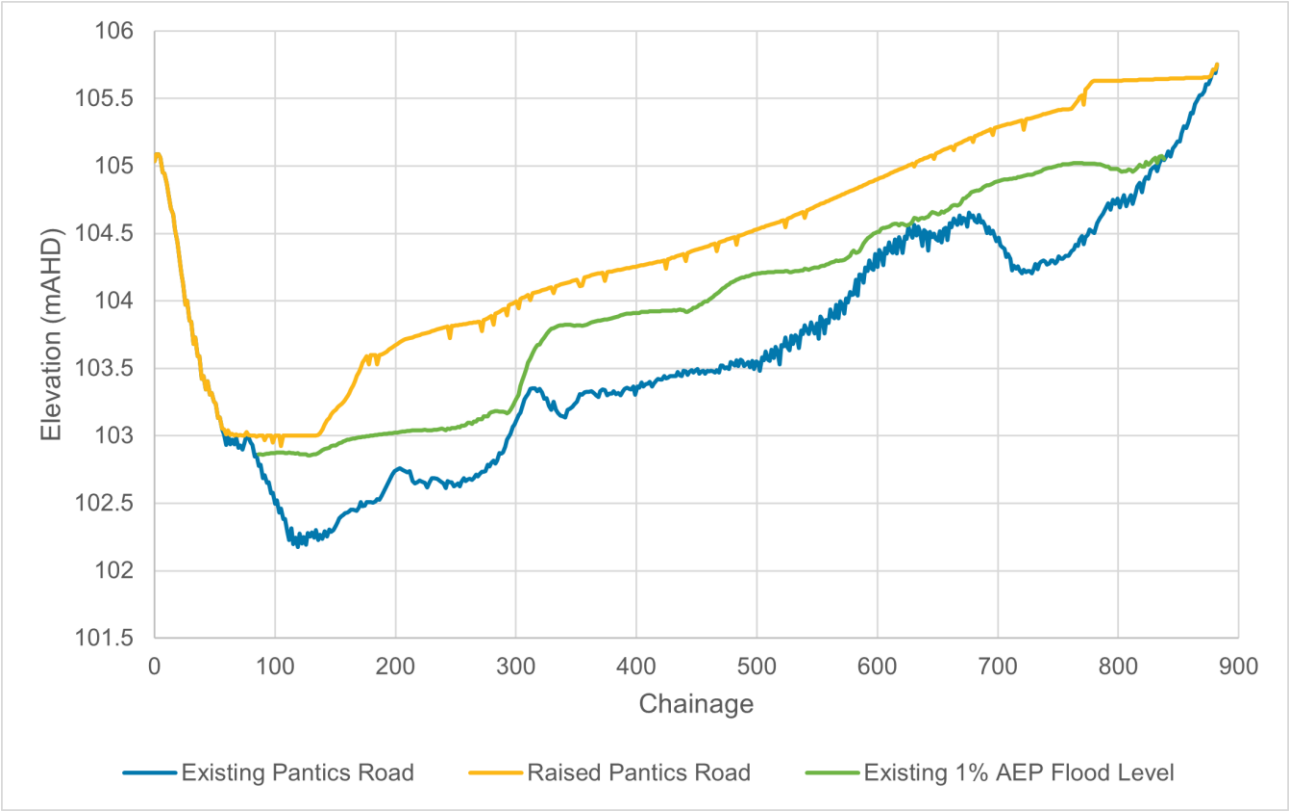


**Figure 4-2 Existing and Proposed Pantics Road Long Section**

### 4.2.1 Option 1 Flood Impact

The levee/road prevents inundation of the Pantics Road and properties on its western side in modelled events up to a 0.5% AEP event. The 0.2% AEP event overtops the conceptual levee, however depths are not as high in this scenario as the existing conditions. A flood level difference map for the 1% AEP event are presented in Figure 4-3 below, comparing the mitigation option to the existing conditions.

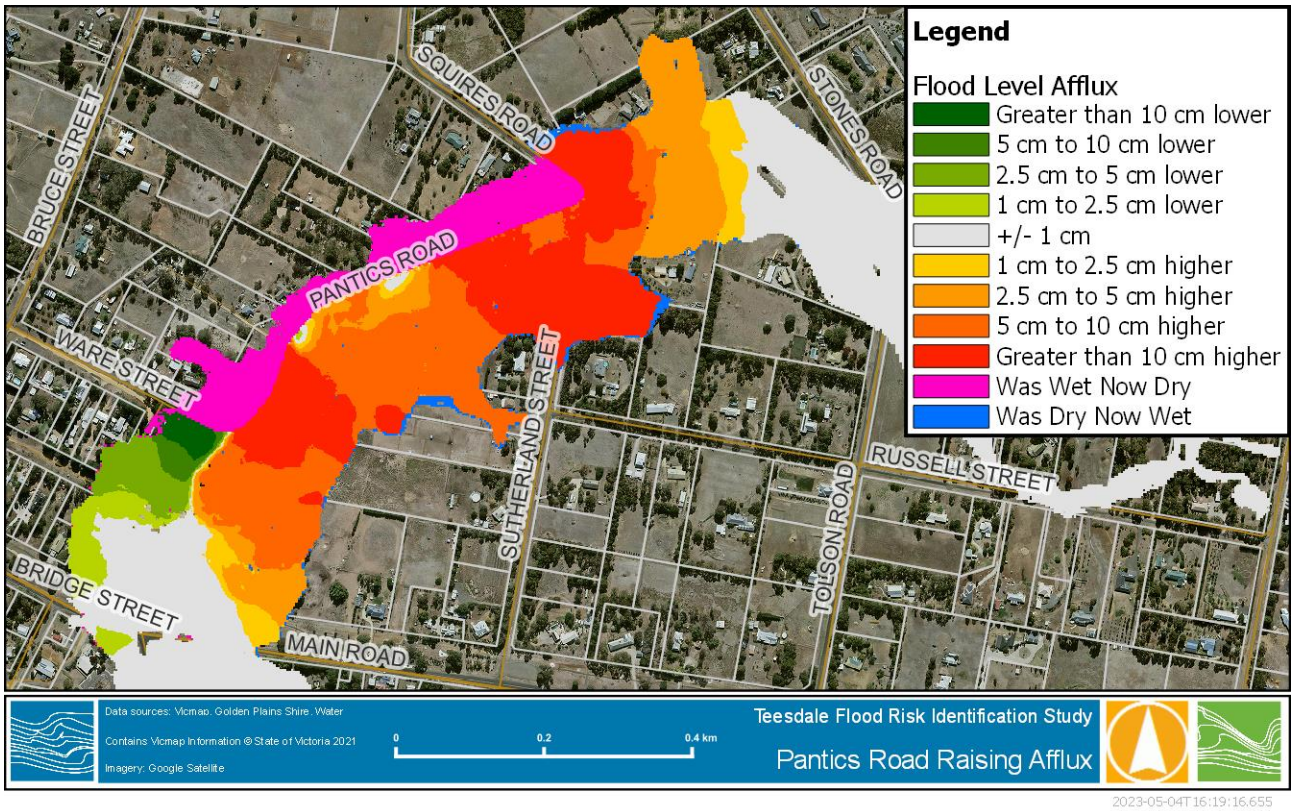


**Figure 4-3 1% AEP Flood Level Afflux – Raising of Pantics Road**

The levee has the following impact in events where it doesn't overtop (i.e. events lower in magnitude than the 0.5% AEP):

- Pantics Road is flood free, providing an access/egress route to many properties
- Properties west of Pantics Road are flood free, including 87 Pantics Road which has a building flooded over floor in a 10% AEP event
- Flood levels and extents to the east and north of Pantics Road are increased by varying amounts, with the worst increases being around Sutherland Street (~0.16m) and Squires Road (up to 0.25m)
    - The dwelling at 169 Squires Road becomes inundated above floor in a 0.2% AEP event – a change from the existing conditions where this dwelling was not inundated in any events other than the PMF

As can be seen from the mapping, the levee results in significant raising of flood levels in adjacent areas. This combined with the impact at 169 Squires Road means the proposal is unlikely to gain support from the community or approval authorities given more properties are negatively impacted than benefiting from the proposal. In general, flood mitigation proposals must demonstrate no negative impacts to gain support and funding from government.

### 4.2.2 Option 1 Cost/Benefit Assessment

Costs associated with levee construction are generally driven by the required levee dimensions, primarily height and width which in turn drive the total materials, machinery and labour required to construct the levee. In the case of the proposed Pantics Road raising, the levee is intended to also function as a road, resulting in a surfaced, wide top levee. Culverts will also be required to allow local drainage, although culvert sizing has not been undertaken.

On average, the levee requires raising of ground levels by 0.784 metres to reach the heights shown in Figure 4-1. The levee/road is a total of 882 metres long. Lane widths have been assumed to be 3 metres thus to total assumed width is 6 metres. Slopes of verges have been assumed at 1V:5H to allow mowing. The total volume of fill required is therefore estimated to be 6,900 $m^3$.

An estimated cost has been prepared based on the quantities shown in Table 4-1 below. The total preliminary cost estimate for the works is $905,556. No ongoing maintenance has been included as it is assumed that such work would form part of council's ongoing capital works regime and should be similar to the existing allocation, however this assumption should be confirmed as part of detailed cost estimation should the option be further progressed.

**Table 4-1 Option 1 Cost Estimate**

| Item | Quantity | Units | $/Unit | Subtotal ($) |
|---|---|---|---|---|
| Removal of existing road surface | 5,280 | m2 | $3.80 | $20,064.00 |
| Fill – compacted material suitable for levee and roadbase | 6,900 | m3 | $40.00 | $276,000.00 |
| Crushed rock/metal base course including grading, rolling and consolidating to receive paving 150 mm thick | 5,280 | m2 | $12.95 | $68,376.00 |
| Prime and two coats sprayed bitumen seal | 5,280 | m2 | $11.20 | $59,136.00 |
| Hot Bituminous Concrete 25 mm thick | 5,280 | m2 | $22.30 | $117,744.00 |
| Supply and install 450 RCP with anti backflow valves | 48 | m | $258.00 | $12,384.00 |
| Driveway crossovers | 10 | each | $5,000.00 | $50,000.00 |
| Design and Labour | | | | $120,740.80 |
| Contingency | | | | $181,111.20 |
| **Total** | | | | **$905,556.00** |

The model results were processed to assess the new AAD for Teesdale under the mitigated scenario. The resultant AAD was $100,819 per year, providing an annual reduction of $12,547. The reduction in AAD is a result of seven properties now having flood immunity for events up to and including a 0.5% AEP flood.

The resultant net present value for option 1 was -$732,848.66, meaning the project will cost more than it will save, on average, over a 30-year period.

### 4.2.3 Option 1 Discussion and Recommendation

While the conceptual levee does provide a significant benefit to properties on the west side of Pantics Road, adverse flood impacts caused by the levee cannot be ignored and are very difficult to justify. The savings afforded by this option are offset somewhat by additional flooding on properties on the flood side of the levee.

One factor that has not been considered in this assessment is the impact that the raised road may have on local runoff. While the cost estimate has included culverts with backflow valves, a detailed assessment of the upstream catchments and required capacity of those culverts has not been undertaken. It may be that the option worsens inundation from local runoff in such a way that the riverine benefits are lost completely.

The option has a significant cost associated with it and does not reduce flood damages sufficiently to offset this cost, leaving the project over half a million dollars in deficit after the 30 year test period. Further analysis indicates that with the saving of $12,547 in AAD, the total project cost would need to be reduced to $172,707.34 to achieve an even cost/benefit ratio, i.e. NPV = 0.

The financial analysis here does not account for isolation of properties during floods. In existing conditions, Pantics Road floods to depths beyond the limits of safety for most vehicles. Raising the road increases its flood immunity and therefore increases safety for residents of the road.

Further analysis and testing of various flood immunity levels for the road may provide a more favourable option, although it is noted that any reduction in road flood immunity is likely to reduce the savings in AAD. It is unlikely that any road height will produce a favourable benefit/cost ratio. Due to this further investigation of raising Pantics Road is not recommended. Future development in the area should consider the construction of a new road that does not traverse the floodplain, ensuring (rear) access to the properties along Pantics Road.

## 4.3 Option 2: Additional culverts under Bannockburn-Shelford Road

The Bannockburn-Shelford Road bridge lacks sufficient capacity to pass 2% AEP flows without overtopping the road. The existing bridge is approximately 18m wide with the soffit approximately 3.5 above the invert of the waterway. In a 1% AEP event there is a 0.6m drop in water level (head) across the road, indicating a large amount of energy is being lost as water passes over the road. Given the significant head drop across the road, adding additional flow capacity may prevent overtopping of the road in a 1% AEP event. This option was pursued iteratively, with the final run including 20 box culverts of dimension 2.1 x 0.9 metres on the east side of the bridge.

The final iteration of 20 x 2.1m x 0.9m culverts was arrived at after previous attempts to alleviate flooding of the road in a 1% AEP were unsuccessful. Previous runs had included 10 x 2.1m x 0.6m culverts and 20 x 2.1m x 0.6m culverts. The project team decided to have a final attempt at mitigating flooding with 20 culverts, despite the significant capital cost associated with such works.

In addition to the culverts themselves, this option requires excavation on the upstream side of the new culvert crossing to allow water to reach the proposed culverts at the nominated invert.

### 4.3.1 Option 2 Flood Impact

Modelling results indicate that the addition of 37.8m$^2$ of flow area was not enough to alleviate inundation of the road in a 1% AEP event. The option did have some benefit to the area upstream of the road with minimal impacts downstream. Flood levels were reduced by 0.33m immediately upstream of the culvert, tapering quickly to less than 0.15m. At a distance of around 250m from the culverts, the impact is negligible.

Downstream of the culverts, increased flood levels are localised to within 40m of the culvert outlet and are generally less than 0.1m. It is noted, however, that this occurs on private land and a shed does exist in the flow path. Negotiations with the impacted landholder would have to occur prior to further consideration of this option.

The resultant change to flood levels in a 1% AEP event is shown in Figure 4-4 below.

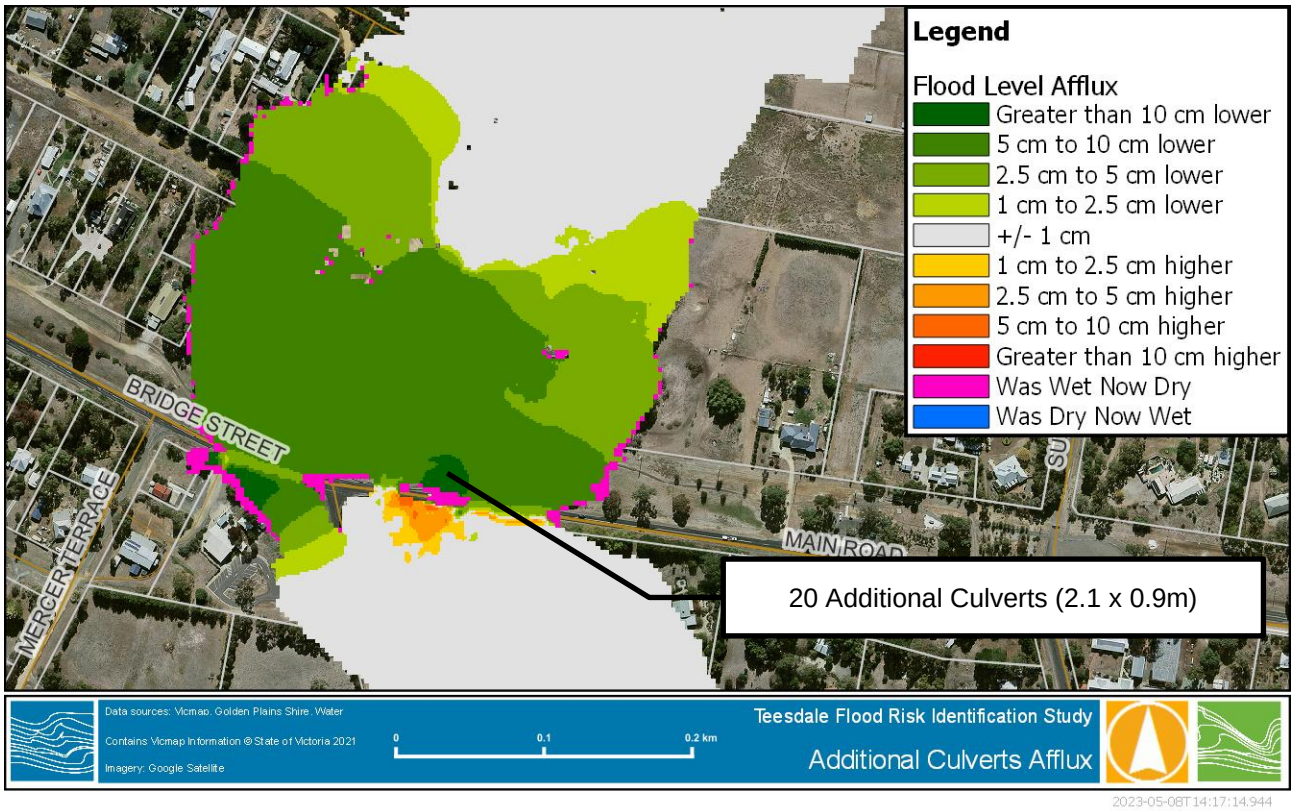


**Figure 4-4 1% AEP Flood Level Afflux – Additional Culverts**

### 4.3.2 Option 2 Cost/Benefit Assessment

The assessed reduction in AAD associated with Option 2 is $538 per year. This reduction is a result of the modest reductions in flood depths upstream of the crossing. Given no significant change to road inundation was achieved the minor change in AAD is not surprising.

The capital cost of implementing the option is shown in Table 4-2 below, with a total estimated cost of $478,712.50. No ongoing estimated costs have been assumed; however it is noted that at some point in time the culverts will require replacement which will be a significant renewal cost.

**Table 4-2 Option 2 Cost Estimate**

| Item | Quantity | Units | $/Unit | Subtotal ($) |
|---|---|---|---|---|
| Remove road surface | 450 | m2 | $3.80 | $1,710.00 |
| Excavate road and approaches for culverts | 1000 | m3 | $20.70 | $20,700.00 |
| Supply and install 2.1 x 0.9 RCBC | 270 | metres | $1,080.00 | $291,600.00 |
| Supply and install headwall suitable for above | 2 | units | $40,000.00 | $80,000.00 |
| Supply and install road barriers at headwalls | 100 | m | $395.00 | $39,500.00 |

| Item | Quantity | Units | $/Unit | Subtotal ($) |
|---|---|---|---|---|
| Backfill and resurface road | 450 | m2 | $46.45 | $20,902.50 |
| Design and Labour | | | | $90,882.50 |
| Contingency | | | | $136,323.75 |
| **Total** | | | | **$681,618.75** |

Given the insignificant reduction in AAD achieved, it is not surprising that the option results in a significant financial deficit. The resultant net present value for option 2 was -$674,213.27, meaning the project will cost more than it will save, on average, over a 30-year period.

### 4.3.3 Option 2 Discussion and Recommendation

While some additional benefit may be realised by adding more culverts, increasing their size and/or lowering their invert levels, the cost/benefit ratio is unlikely to reach a level where the proposal becomes viable economically. Furthermore, by increasing the flow conveyance to the point where overtopping of the Bannockburn-Shelford Road is prevented, impacts downstream in the form of increased flood levels and potentially newly impacted properties become more and more likely.

Based on the cost/benefit ratio above, this option is not financially viable. In addition to the significant estimated cost for the works, the area of works is within an area of cultural heritage sensitivity and appears to require excavation in previously undisturbed areas. A Cultural Heritage Management Plan (CHMP) is likely to be required. The cost of developing and endorsing a CHMP has not been included in the above estimates. The cost/benefit ratio is therefore likely to be even worse than that stated.

Water Technology recommends that this option is not pursued or investigated further.

## 4.4 Option 3: Waterway Vegetation Clearing

There is a common perception in flood affected communities that waterway vegetation contributes to flooding by resisting flow of water. While this was not raised in the community consultation sessions held for the study, discussions with the Corangamite CMA suggested a mitigation analysis of waterway clearing may be warranted.

Clearing of the waterway was tested by lowering its roughness in the hydraulic model, representing smoother post clearing conditions. The model topography was not altered, i.e. a constructed channel was not considered. The modelling assumes the clearing will be maintained in perpetuity, i.e. that the works will be repeated as necessary to maintain the low roughness but not so regularly as to keep the waterway completely bare of vegetation and weeds.

The modelling adopted a manning's roughness value of 0.045 within the waterway. Design modelling had adopted to the value of 0.07 adopted for design and validation modelling. The value of 0.045 corresponds to a waterway with winding banks, some pools, shoals, weeds and stones. The waterway throughout the model extent had its roughness lowered, being approximately 11 linear kilometres of waterway.

### 4.4.1 Option 3 Flood Impact

As seen in the sensitivity analysis undertaken and detailed in R03 Design Modelling Report, the hydraulic model is highly sensitive to selection of the roughness parameters. It is therefore unsurprising that lowering the roughness of the waterway has a significant impact on flood levels through Teesdale. Flood levels were lowered by around 0.2 to 0.3 metres in confined areas of the waterway. The works had less impact in areas of engaged floodplain where a greater proportion of flow is outside the waterway corridor. Flood levels in the area between the Stones/Tolson Road breakout and the Bannockburn-Shelford Road bridge were lowered by less than 0.1 metres. Downstream of the bridge, flood levels were lowered between 0.1 and 0.25 metres generally.

The increased waterway conveyance benefits the two dwellings liable to above floor inundation. 87 Pantics Road is no longer inundated above floor in a 10% AEP event (although it is in a 5% AEP event) while 844 Teesdale Inverleigh Road is now inundated above floor in the 1% AEP event but not the 2% AEP event.

The 1% AEP flood level afflux results are shown in Figure 4-5 below.

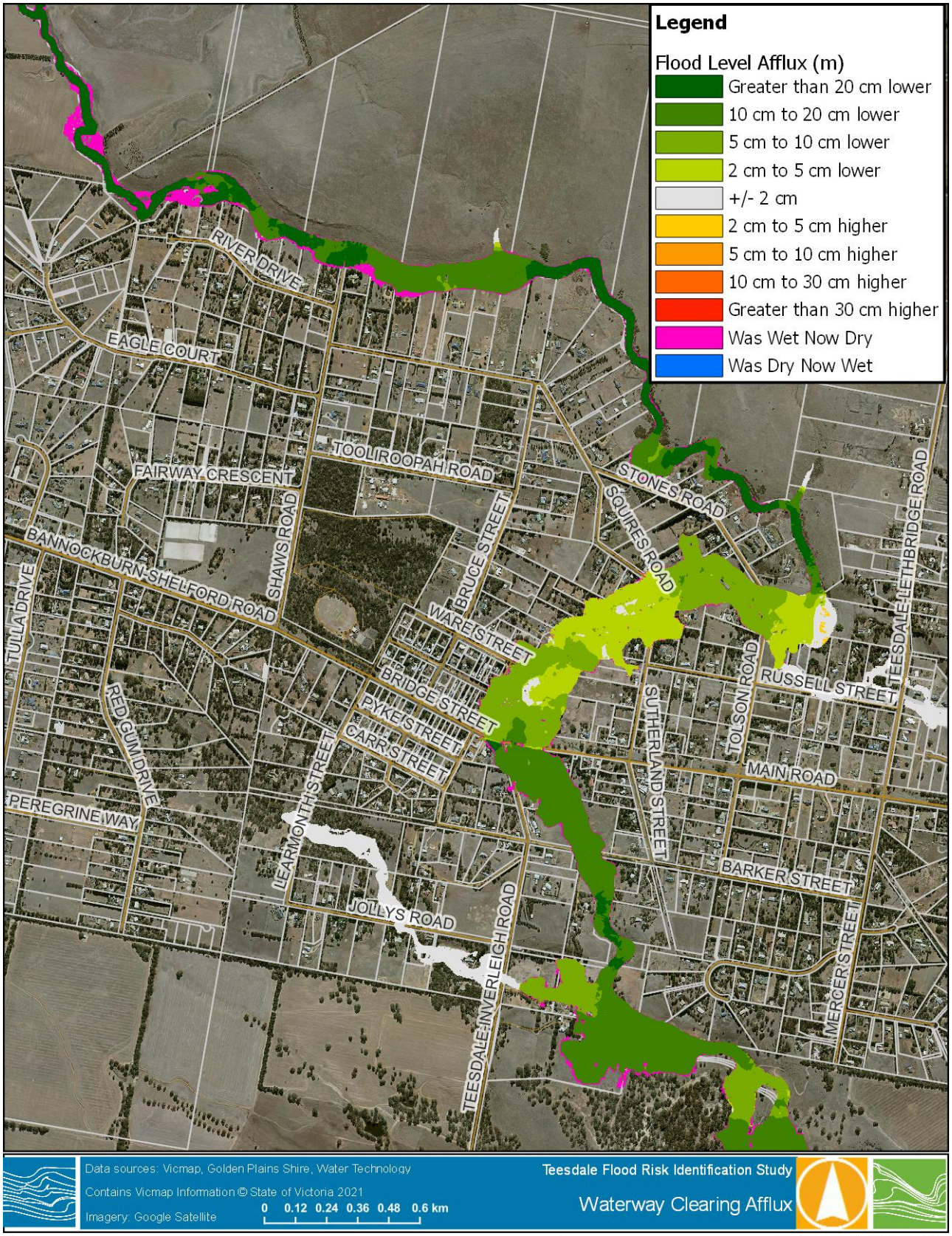


**Figure 4-5 1% AEP Flood Level Afflux – Clearing of Native Hut Creek**

### 4.4.2 Option 3 Cost/Benefit Assessment

Many assumptions are required to estimate the cost of Option 3. Waterway works, based on clearing works completed by contractors working closely with Water Technology recently, are estimated to cost around $35,000 per kilometre of waterway to be cleared. To clear the entire 11km of modelled waterway would cost around $385,000 based on this estimate.

The modelling involved clearing a 20 wide buffer along the waterway for 11km, resulting in a total of 22 hectares of vegetation "cleared" in the model. A detailed site assessment would be required to determine how much of the land to be cleared is native vegetation. Also required would be a tree assessment to determine how many large trees are to be cleared and any threatened fauna that may be living in the area.

In order to produce an estimate of costs, it has been assumed that 50% of the land to be cleared contains native vegetation and requires offsetting. An estimated 50 large trees have also been assumed. While pricing for native vegetation offsets is not standardised and can be difficult to budget for without quotes, the Melbourne Strategic Assessment (Environmental Mitigation Levee) Act 2020 provides a levy with standard pricing in lieu of developers in those areas purchasing offsets directly. Taking costs from the current MSA Levee[3] pricing as a guide, the estimates in Table 4-3 below were produced.

Table 4-3 does not address potential fencing replacement requirements, as these are impossible to predict without detailed planning. Any costs associated with fencing or other unforeseen issues are intended to be captured in the contingency.

**Table 4-3 Option 3 Cost Estimate**

| Item | Quantity | Units | $/Unit | Subtotal ($) |
|---|---|---|---|---|
| Clear Waterway | 11 | km | $35,000.00 | $385,000.00 |
| Native Vegetation Offsets | 11 | ha | $166,874.00 | $1,835,614.00 |
| Large Trees | 50 | No. | $23,195.00 | $1,159,750.00 |
| Contingency | | | | $1,014,109.20 |
| **Total** | | | | **$4,394,473.20** |

In addition to the above capital costs, maintenance is estimated to cost approximately $3,500 per km per year being 10% of the capital clearing cost. Total maintenance therefore equals $38,500 per year.

The cleared scenario produces a resultant AAD of $96,003 per year, corresponding to a reduction of $17,363 per year. Given the reduction in AAD is less than the estimated maintenance, it can already be seen that the project will not achieve net savings.

The resultant net present value for option 3 was -$4,685,420.44, meaning the project will cost more than it will save, on average, over a 30-year period. Removing the ongoing maintenance cost reduces the NPV to -$4,155,474.44 which is still a significant deficit.

### 4.4.3 Option 3 Discussion and Recommendation

Modelling limitations

While the cost/benefit analysis above has attempted to quantify the significant costs associated with clearing of Native Hut Creek, there is no guarantee that the proposal could be approved. There are a number of significant approval hurdles associated with Option 3. These include, but aren't necessarily limited to:

[3] Melbourne Strategic Assessment (Environmental Mitigation Levy) Act 2020, current pricing accessed on 9/5/2023 from https://www.msa.vic.gov.au/regulatory-requirements/habitat-compensation

- Granting of a Planning Permit
- Cultural Heritage Management Plan endorsement
- Achievability of native vegetation offset requirements
- Potential triggering of other environmental legislation such as the Flora and Fauna Guarantee Act 1988, Environmental Protection and Biodiversity Conservation Act 1999 or others.

All of the above have costs associated with their application, investigation, assessment etc. that have not been directly accounted for in the above cost estimate, noting however that the 30% contingency is a significant figure and may account for some or all of these costs.

Even if all of the above challenges were surmountable, the option is financially irrational in addition to being ecologically damaging. Clearing waterways of vegetation degrades and destroys habitat and increases the risk of erosion. Waterway erosion creates the need for significant investment to protect assets threatened by the shifting banks. Eroded material is transported as sediment and deposited downstream, smothering downstream habitats and further degrading the habitat quality of the system.

Further analysis indicates that with the saving of $17,363 in AAD, the total project cost would need to be reduced to $238,998.76 to achieve an even cost/benefit ratio, i.e. NPV = 0, with no ongoing maintenance costs. This is an unachievable budget to undertake the works and approvals required.

Water Technology recommends that this option is not pursued or investigated further.

## 4.5 Cost-Benefit Summary

Table 4-4 summarises the three mitigation methods assessed from financial performance. For each option the benefit/cost ratio has been calculated as the sum of AAD reductions in present value terms minus the capital and maintenance cost in present value terms. A benefit/cost ratio of 1 equates to a net present value of $0. Ideally cost benefit ratio should be greater than 1, however it should be acknowledged that achieving high CBR for flood mitigation works is highly unlikely and should not be the only factor considered. Community safety, resilience and vulnerability must also be taken into account.

**Table 4-4 Cost-Benefit Summary**

| | Option 1 | Option 2 | Option 3 |
|---|---|---|---|
| Capital Cost ($) | $730,345.20 | $478,712.50 | $4,394,473.20 |
| Maintenance Cost ($/year) | $0.00 | $0.00 | $38,500.00 |
| Reduction in AAD ($/year) | $12,547.00 | $538.00 | $17,363.00 |
| Net Present Value ($, total) | -$557,637.86 | -$471,307.02 | -$4,155,474.44 |
| Benefit/Cost Ratio | 0.236 | 0.015 | 0.054 |

Table 4-4 clearly demonstrates that none of the mitigation methods investigated achieve favourable financial outcomes. None of the options are recommended for further investigation.

# 5 NON-STRUCTURAL MITIGATION

## 5.1 Planning Controls

Mitigation of potential future flood impacts can be achieved by updating the local planning scheme to reflect the flood intelligence produced by the Teesdale Flood Risk Identification Study (this study). Updating the planning scheme mapping allows development applications within the floodplain to be assessed in line with current national, state, regional and local policies. The ultimate effect of this will be to ensure inappropriate development within the floodplain does not occur, reducing the number of future buildings and occupants exposed to flood risk. As seen by the damages assessment above, there are few dwellings within the Native Hut Creek floodplain. By implementing planning controls this can be maintained and flood average annual damages for Teesdale can remain low, avoiding significant natural disaster impacts in the future.

Draft planning scheme mapping has been developed in line with the project brief and as discussed in a project meeting on the 4th April 2023. The mapping has not considered the use of the Urban Floodway Zone given the lack of urbanisation in Teesdale, in addition to the highly restrictive nature of that zoning.

The draft flood related overlays have been developed based on the 1% AEP behaviour for the year 2100, as projected under Representative Concentration Pathway RCP8.5. Flood modelling of the scenario was undertaken in line with Australian Rainfall and Runoff 2019 and is detailed in R04 – Design Modelling Report. The Land Subject to Inundation Overlay (LSIO) has adopted the projected flood extent while the Floodway Overlay (FO) has been applied to those areas where any of the following are exceeded:

- Flood depths ≥ 0.3 metres, and/or
- Flood velocities ≥ 2.0 m/s, and/or
- Product of depth and velocity ≥ 0.3 $m^2/s$

The above FO threshold aligns with the “H2” hazard classification threshold as detailed in the Australian Disaster Resilience Guideline 7-3 *Flood Hazard* (AIDR 2017). It is also the Corangamite Catchment Management Authority’s threshold of choice for delineating the high hazard portion of the floodplain.

The resultant draft planning scheme mapping is shown in Figure 5-1 below.


**Figure 5-1 Draft Planning Scheme Mapping**

## 5.2 Discussion – Adoption of Increased Rainfall Intensity

### 5.2.1 Policy Context

As discussed above, the draft planning mapping has been developed based on modelling which accounted for projected increased rainfall intensity to 2100 under RCP8.5. Clause 13.01 of the Victorian Planning Provisions is specific when dealing with sea level rise. The clause includes the strategy to plan for sea level rise of not less than 0.8 metres by 2100 and allow for the combined effects of tides, storm surges, coastal processes and local conditions such as topography and geology when assessing risks and coastal impacts associated with climate change. The Planning Provisions are not so specific when dealing with riverine flood risk, with Clause 13.03-1S including a strategy to identify the 1% AEP floodplain in planning schemes.

Notwithstanding the above, Clause 13.01 of the Provisions deals with climate change and includes the strategies to *respond to the risks associated with climate change in planning and management decision making processes* and to *identify at risk areas using the best available data and climate change science*. Thus the Provisions have established the following:

- The 1% AEP flood is the Design Flood Event against which planning decisions should be made and should be identified in the planning scheme;
- Areas at risk from climate change should be identified using the best available science; and
- A planning horizon to the year 2100 is appropriate in the context of coastal inundation.

It follows that a planning horizon to the year 2100 should therefore be appropriate for riverine inundation. Areas projected to be subject to riverine inundation in 2100, as identified using the best available science, should be identified. The Planning Scheme is the most appropriate means by which to identify these areas, as has recently been done using Schedules to the Land Subject to Inundation Overlay to identify coastal areas subject to inundation in a 1% AEP storm surge event with 0.8 metres of sea level rise[4].

### 5.2.2 Effect of Increased Rainfall Intensity

To understand the implications of adopting this scenario for the planning mapping, a comparison of draft planning scheme mapping has been undertaken for the increased intensity scenario compared to the present day 1% AEP event.

By delineating the flood related planning scheme overlays based on the projected scenarios, a cautious approach is adopted. The actual impact of this approach, however, is minimal. Table 5-1 shows the number of properties impacted by flood related overlays in the present day 1% compared to the climate change scenario. The figures in Table 5-1 exclude public reserves such as Turtle Bend and the waterway parcels.

**Table 5-1 Properties impacted by flood related overlays, present day vs 2100 RCP8.5**

| | Present Day 1% AEP | 2100 1% AEP under RCP8.5 |
|---|---|---|
| **Total Parcels Affected** | 136 | 139 |
| **Parcels Intersecting LSIO** | 136 | 136 |
| **Parcels Intersecting FO** | 125 | 130 |

The most significant difference in the mapping is an additional breakout which occurs in the increased rainfall scenario but not in the present day scenario. The breakout crosses Stones Road and flows through two parcels not impacted by flooding in the present day scenario and can be seen in Figure 5-2 below.

[4] Greater Geelong Planning Scheme Amendment C394ggee

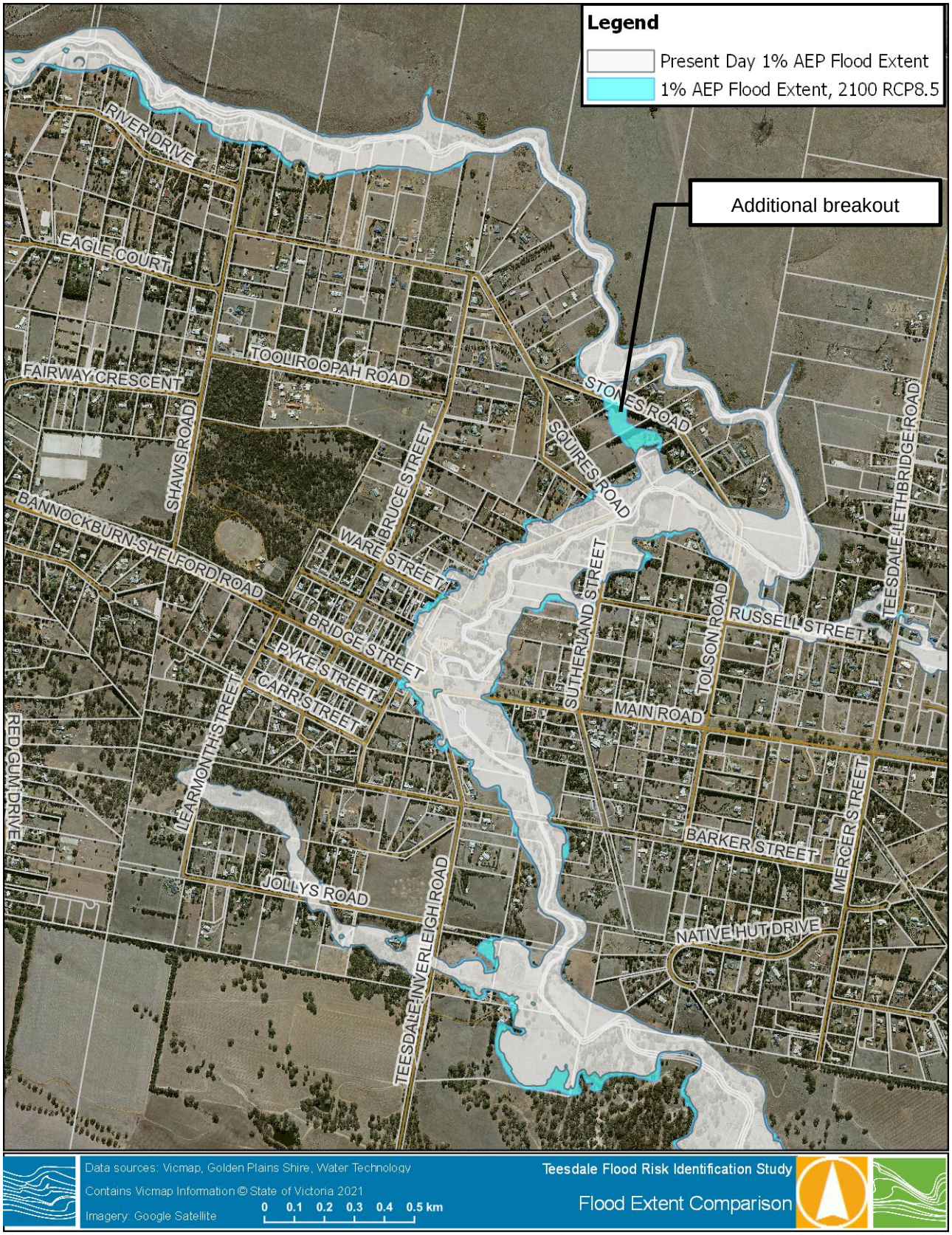


**Figure 5-2 Comparison of the 1% AEP flood extents under present day and 2100, RCP8.5 conditions**

Inclusion of the 2100 mapping in the Planning Scheme does not imply that results from the 2100 RCP8.5 modelling will be used to inform all responses to development within the Teesdale floodplain. Inclusion of the mapping instead triggers a permit application referral and gives the Corangamite CMA the opportunity to *respond to the risks associated with climate change in planning and management decision making processes* as required by the Scheme. If the Scheme mapping were not based on the 2100 RCP8.5 1% AEP extent, that opportunity may be missed.

# 6 SUMMARY

Flood damages, in the form of Average Annual Damages (AAD), have been assessed for the township of Teesdale based on flood modelling of Native Hut Creek undertaken as part of the Teesdale Flood Risk Identification Study. The average annual cost in Teesdale as a result of flooding from Native Hut Creek equates to $113,366 per year. In the 1% AEP flood event, two dwellings are inundated above floor and 114 properties are impacted by floodwaters.

Three structural mitigation options were tested to reduce flood impacts and associated damage costs within the town. The options were:

- Raising Pantics Road to form a levee,
- Placement of additional culverts under Bannockburn-Shelford Road bridge, and
- Clearing the waterway.

Each option was tested in the hydraulic model, with the model results processed and an updated AAD calculated for the mitigation option. Cost estimates of each option were assessed against the option's reduction in AAD from the existing case to inform net present value analysis.

Based on the above assessment methodology, none of the options tested were shown to be financially viable. In addition to not being financially viable, clearing of Native Hut Creek was identified as having numerous legal approvals that are highly unlikely to be obtained regardless of investment. Raising of Pantics Road was found to have potential issues with local stormwater however this was not investigated as the financial viability does not invite further investigation. It is important to consider that future infrustructure upgrades to road and drainage may present an opportunity for improved drainage and flood resilience within the township. While this may not meaningfully reduce damages in measurable financial terms it may support improved resilience and safe access in minor events.

Non-structural mitigation in the form of town planning controls have also been presented. The Planning Scheme mapping has been based on model results with increased rainfall intensity under projected RCP8.5 to the year 2100. A comparison of the resultant maps to those that would have resulted from the "present day" modelling results was presented, with the increased rainfall scenario impacting three additional properties in total. The mapping has delineated the floodway overlay based on the Corangamite Catchment Management Authority's preferred delineation criteria.

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS


## Melbourne

15 Business Park Drive
Notting Hill VIC 3168
Telephone (03) 8526 0800

## Sydney

Suite 3, Level 1, 20 Wentworth Street
Parramatta NSW 2150
Telephone (02) 9354 0300

## Brisbane

Level 5, 43 Peel Street
South Brisbane QLD 4101
Telephone (07) 3105 1460

## Adelaide

1/198 Greenhill Road
Eastwood SA 5063
Telephone (08) 8378 8000

## Perth

Ground Floor, 430 Roberts Road
Subiaco WA 6008
Telephone (08) 6555 0105

## New Zealand

7/3 Empire Street
Cambridge New Zealand 3434
Telephone +64 27 777 0989

## Wangaratta

First Floor, 40 Rowan Street
Wangaratta VIC 3677
Telephone (03) 5721 2650

## Geelong

51 Little Fyans Street
Geelong VIC 3220
Telephone (03) 8526 0800

## Wimmera

597 Joel South Road
Stawell VIC 3380
Telephone 0438 510 240

## Gold Coast

Suite 37, Level 4, 194 Varsity Parade
Varsity Lakes QLD 4227
Telephone (07) 5676 7602

**watertech.com.au**