Design Modelling Report

Teesdale Flood Risk Identification Study

Golden Plains Shire

21 April 2023

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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.
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 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 - This Report**
- R04 – Flood Intelligence and Flood Warning Report
- R05 – Flood Damages and Mitigation Assessment 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 use as farmland.

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 km². 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 or 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 and Context

This report follows report R02 – **Joint Validation Modelling Report**. The Joint Validation Modelling Report details the hydrologic and hydraulic model builds and modelling completed for three historic flood events:

- February 1973 – largest recent flood (anecdotally)
- April 2001 – significant event causing overbank flooding of Native Hut Creek within Teesdale
- January 2011 – a very recent, less severe event selected for validation due to the availability of anecdotal community evidence

The Joint Validation Modelling Report and model results produced were used to finalise the design model parameters, which are detailed herein. The models achieved good agreement with community observations of the January 2011 event, which was largely contained within the bed and banks of Native Hut Creek. Observations from the 1973 event were sparse given the time passed since that event however a photograph confirmed widespread flooding in the area of Pantics Road which was reflected in the modelling. The April 2001 event again had few available observations. Two observations from the 2001 event were conflicting, however based on the available evidence the modelling is considered to represent that event well.

This report should be read in conjunction with the Joint Validation Modelling Report. Key model parameters are repeated herein however the full details of the model builds are contained within the previous report.

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2 METHODOLOGY

2.1 Overview

The Teesdale Flood Risk Identification Study has adopted a hydrologic/hydraulic modelling approach with the hydrology modelling completed using RORB software and hydraulic calculations completed within TUFLOW. Hydrologic model parameters were sourced from recent studies in the area and the ARR datahub, and validated against community observations in a joint model validation approach. Joint model validation consisted of producing streamflow hydrographs in RORB, running the TUFLOW model with the hydrographs as inflow boundaries and comparing the results to community observations. After some iteration, a good agreement between the model results and community observations was achieved and those model parameters were adopted for design modelling.

2.2 Hydrologic Model Parameters

The design hydrologic model (RORB) parameters are summarised in Table 1 below. The Joint Validation Modelling Report details the model build and parameter selection in more detail.

Table 1 RORB Model Parameters Summary

Parameter/Input	Value/Description
Kc/Dav Ratio	1.25
Kc – Tawarri area	2.55
Kc – Learmonth Street area	3.11
Kc – Main Native Hut Creek catchment	32.90
m	0.8
Burst Rainfall	Intensity-Frequency-Duration (IFD) information obtained from the Bureau of Meteorology, spatially compiled to produce a Native Hut Creek IFD table applied in conjunction with subarea weighting to account for spatial variation.
Pre-Burst Rainfall	Initial losses adjusted to account for pre-burst rainfall by subtracting the median pre-burst depth from the storm initial loss.
Initial Loss (storm)	17 mm
Continuing Loss	3.2 mm/hr
Reach Types	Type 1 (Natural) where no clear waterway present Type 2 (Excavated, unlined) where a waterway is clearly present
Storages	N/A
I/O Reaches	N/A

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2.3 TUFLOW Model Summary

Table 2 summarises the key model parameters/inputs adopted for the TULFLOW modelling. Further details on the TUFLOW model inputs are described in detail in Section 4 of the Joint Validation Modelling Report.

Table 2 Key TUFLOW Parameters Summary

Parameter	Value
Model Build	2023-03-AA-iSP-w64
Model Precision	Single Precision
Grid Cell Size	3 metres
Sub Grid Sampling	Not adopted
Solution Scheme	HPC – Comparison with Classic to be completed
Inflows	Source-Area boundaries coupled with streamlines
Outflow	Height-Flow Slope of 0.3%
Hydraulic Roughness	Manning's 'n', varies with land use
1-Dimensional elements	Culverts and pipes linked to 2-D domain

3 RESULTS

3.1 Design Hydrology

The RORB model was ran for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% AEP and PMF events. Flows for the design events (excluding PMF) have been extracted from the model at the Bannockburn-Shelford bridge and are presented in Figure 1 below.

Native Hut Creek flows applied to the TUFLOW model were extracted from the RORB model at a print location upstream of Teesdale and at other print locations throughout the study area as required. This enables the model to account for local inflows while avoiding duplicate routing of flows in both the hydrologic and hydraulic models.

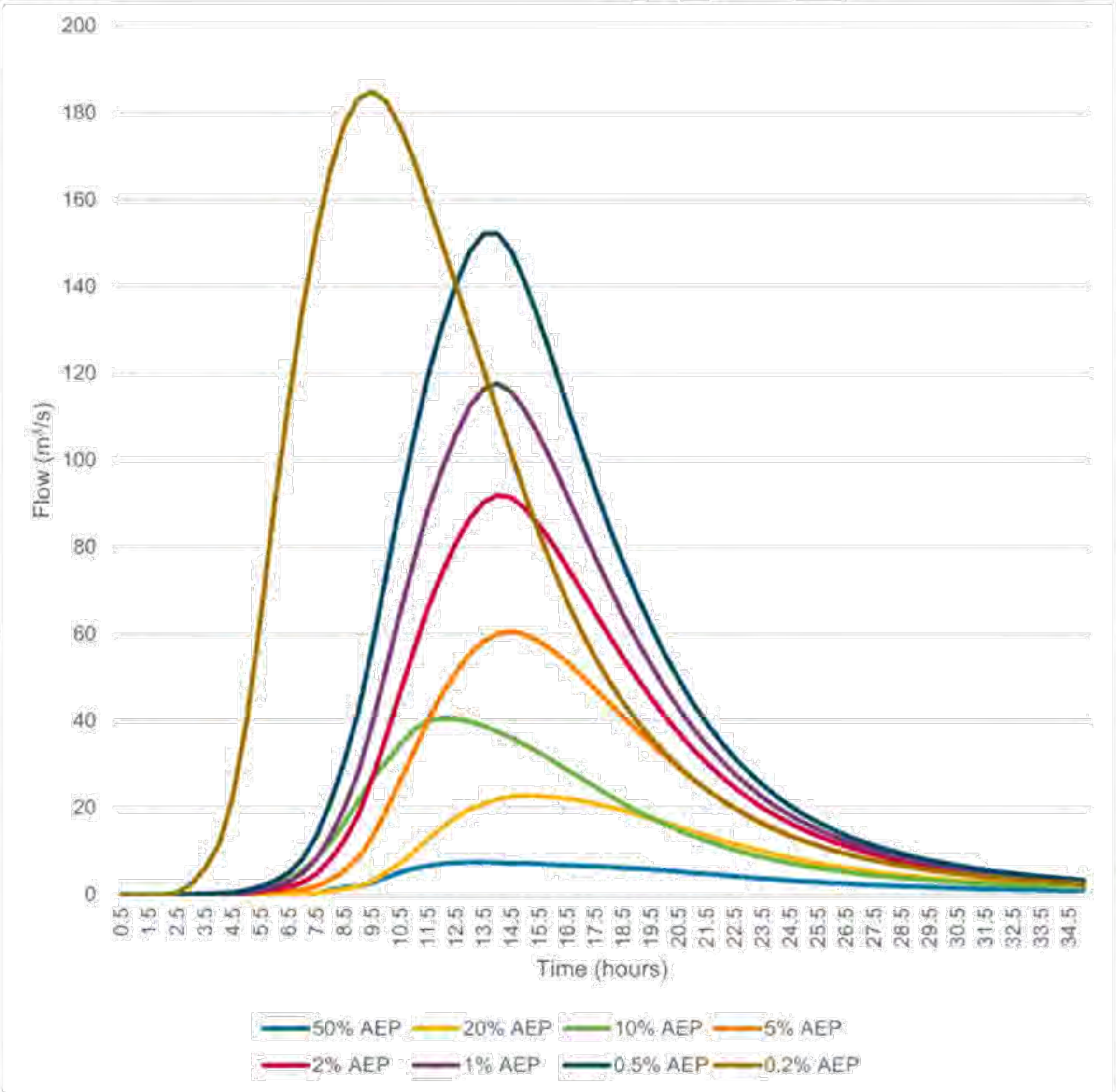

Figure 1 Design hydrographs, Native Hut Creek at Bannockburn-Shelford bridge

Critical Events and Temporal Patterns

As discussed in the Joint Validation Modelling Report, temporal patterns were selected from the "Southern Slopes (Vic) region". Given the size of the catchment and in line with the recommendations of ARR2019, areal temporal patterns were adopted in the first instance. Areal temporal patterns are only available for durations 12 hours and longer. As the 12-hour duration event was shown to be critical for most design event magnitudes, point temporal patterns were also run to ensure that the critical event had been captured. In two cases, the point temporal pattern produced a critical flow for the 9-hour event. In both cases the point temporal pattern was adopted as the design event.

The critical event durations, temporal patterns, source of pattern and peak flow rate at the bridge are shown in Table 3 below.

Table 3 Critical durations, temporal patterns and sources, and peak flows for modelled events

AEP	Duration	Temporal Pattern	Temporal Pattern Source	Peak Flow at Bridge (m^3/s)
50%	9 Hours	4	Point	7.4
20%	12 Hours	4	Areal	22.8
10%	9 Hours	7	Point	40.6
5%	12 Hours	4	Areal	60.6
2%	12 Hours	4	Areal	92.0
1%	12 Hours	4	Areal	117.7
0.5%	12 Hours	4	Areal	152.2
0.2%	12 Hours	5	Areal	184.9

3.2 Climate Change Assessment

The 10% and 1% AEP events were modelled with increases in rainfall intensity associated with climate change. Modelling considered Representative Concentration Pathways (RCP) 4.5 and 8.5 under projections to the years 2050 and 2100 in line with the ARR guidelines with rainfall scaling factors obtained from the ARR datahub. The resultant rainfall depths and resultant peak flows at the Bannockburn-Shelford Road bridge modelled are shown in Table 4 below.

The model results shown in Table 4 indicate that climate change scenarios cause an increase in flow at the Shelford-Bannockburn Road bridge. The 1% AEP flows under an RCP8.5, 2100 scenario are increased 44% and are between present day 0.2% and 0.5% AEP flows. Similarly, the 10% AEP flows for the same climate scenario are increased 59% and are between present day 5% and 2% AEP flows.

The increased rainfall depths were applied to the RORB model and the produced hydrographs which were applied to the TUFLOW model as inflow boundaries. TUFLOW results for the RCP8.5, 2100 1% AEP event are shown in Section 4 below.

As expected, the increased rainfall intensity RCP8.5, 2100 scenario produces an increase in flood levels across the study area. In the township, levels increase in the order of 0.15 to 0.25 metres upstream of the bridge where the floodplain is relatively wide. Downstream of the bridge, increases in flood levels are between 0.4 and 0.5 metres where the floodplain is more confined. Flood level increase mapping is shown in Figure 5 below.

Table 4 Climate change assessment summary

10% AEP	RCP4.5 2050	RCP4.5 2100	RCP8.5 2050	RCP8.5 2100
IFD Rainfall (mm)	54.11	54.11	54.11	54.11
% Increase	5.4%	7.8%	7.3%	18.4%
Projected Rainfall Depth (mm)	57.03	58.33	58.06	64.06
Peak Flow at Bridge	46.79	50.06	49.50	64.66
Increase in Flow (%)	15.19	23.24	21.85	59.17
1% AEP	RCP4.5 2050	RCP4.5 2100	RCP8.5 2050	RCP8.5 2100
IFD Rainfall	85.06	85.06	85.06	85.06
% Increase	5.4%	7.8%	7.3%	18.4%
Projected Rainfall Depth (mm)	89.65	91.69	91.27	100.71
Peak Flow at Bridge	137.39	142.97	141.83	169.21
Increase in Flow (%)	16.75	21.49	20.52	43.79

3.3 Probable Maximum Flood

The Probable Maximum Flood (PMF) rainfall depth was interpolated between depths estimated by the Generalised Short Duration Method (GDSM) and the Generalised Southeast Australia Method (GSAM). The rainfall depths were modelled utilising the 'rare' temporal patterns obtained from the ARR datahub and distributed spatially in line with the 0.2% AEP event. An Initial loss of 0mm and a continuing loss of 1mm/hr was applied. All ten temporal patterns were simulated in the ensemble for the PMF. The maximum flow from the ensemble, (9 hour duration, temporal pattern 9) was selected as the design PMF event.

4 FLOOD MAPPING

The peak modelled flood depth in a 1% AEP event and climate change (2100 under an RCP8.5 scenario) are shown in Figure 3 and Figure 4 below. Detailed mapping of all modelled events is provided in PDF form as an appendix and GIS deliverables (grids and extents) will be provided to Council and CCMA.

Flood hazard mapping has been prepared in line with ARR2019 and the Australian Disaster Resilience Guideline 7-3 *Flood Hazard* (AIDR 2017). The hazard classifications are based on the peak depth, velocity and product of depth and velocity. The classifications are shown in Figure 2 below.

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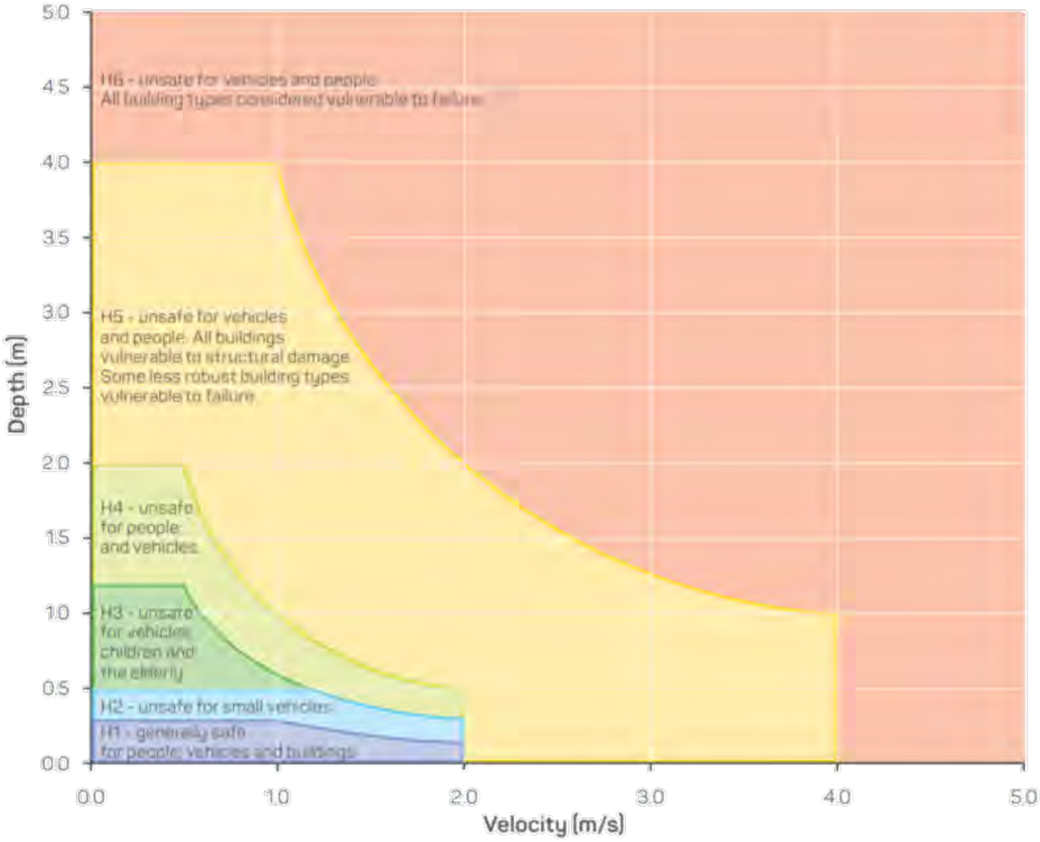

Figure 2 Hazard classifications (AIDR 2017)

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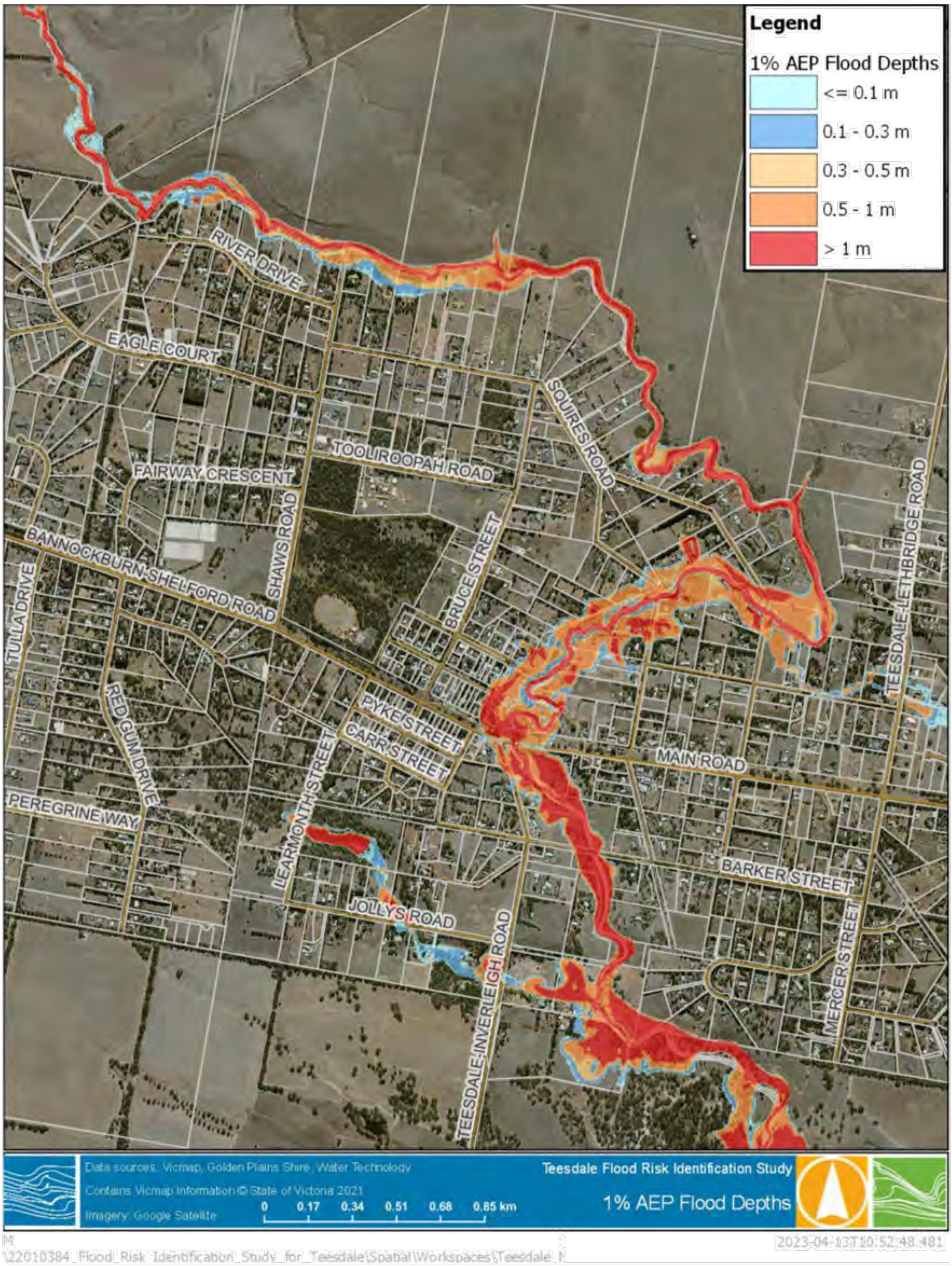

Figure 3 1% AEP Flood Depths in Teesdale (Existing Conditions)

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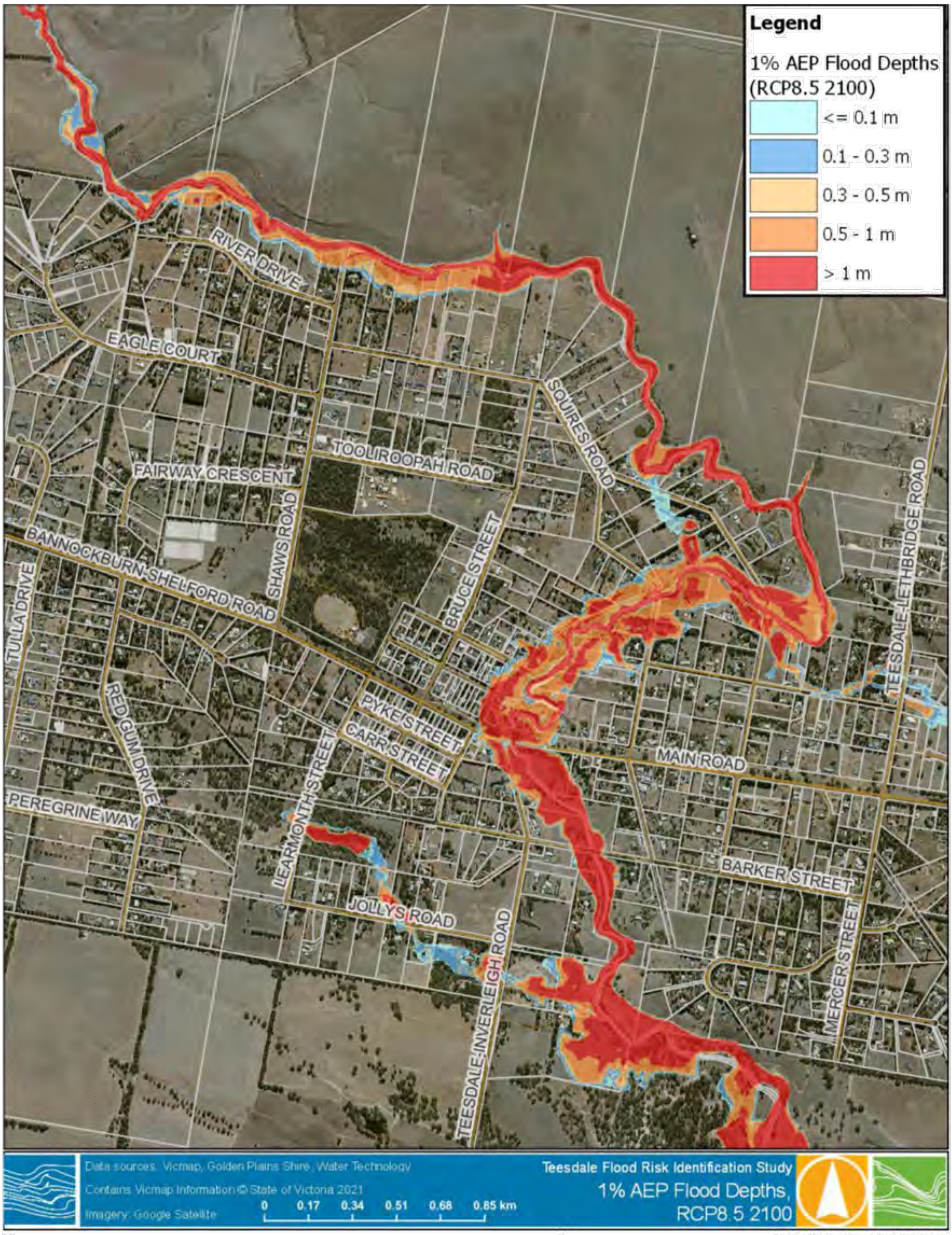

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Figure 4 1% AEP Flood Depths in Teesdale under projected RCP8.5 to 2100

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Figure 5 Flood level increase under RCP8.5 projections to 2100 for the 1% AEP event

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5 SENSITIVITY TESTING

Sensitivity testing of flood models consists of altering an input or parameter and comparing results to the base case, revealing the sensitivity of the model results to that input or parameter. Sensitivity testing of the models have been undertaken for a range of parameters and inputs as described below. Sensitivity testing of the models was completed for the 1% AEP event only.

Afflux mapping of the sensitivity tests compared to the design mapping is shown for each sensitivity test was undertaken in the hydraulic model.

5.1 Losses

Loss parameters were tested in the hydrologic (RORB) model as detailed in Table 5 below.

Table 5 Hydrologic loss sensitivity test scenarios

Losses	Design	Initial Loss Test	Continuing Loss Test
Initial Loss (mm)	17	0	17
Continuing Loss (mm/hr)	3.3	3.3	1

The resultant peak flows at the Bannockburn-Shelford Road bridge are shown in Table 6. Lowering the continuing loss value from 3.2 mm/hr to 1 mm/hr had a significant impact on the modelled peak flow rates due to the critical storm duration of 12 hours resulting in a large proportion of the previously lost rainfall excess now forming runoff.

Table 6 Losses sensitivity testing results

Scenario	Peak Flow at Bridge (m^3/s)	% Increase in Flow
Design	117.7 m^3/s	0
Initial Loss Test	125.7 m^3/s	6.8%
Continuing Loss Test	165.1 m^3/s	40.3%

5.2 Hydraulic Roughness

Sensitivity to adopted roughness within the hydraulic model was tested by both lowering and raising the Mannings 'n' roughness. The roughness values in the model were multiplied by 0.75 and 1.5 for the low and high tests respectively.

Flood levels across the floodplain changed significantly, indicating the hydraulic model is sensitive to the selection of this parameter. The area upstream of the Bannockburn-Shelford Road bridge appears to be the least sensitive area in the model, indicative of the influence the road and bridge has on flood behaviour in that area as well as the width of the flow path. Flood levels upstream of the bridge raised in the order of 0.1 to 0.2 metres in the high roughness scenario, compared to raises of around 0.4 metres downstream of the bridge. The low roughness scenario resulted in lower flood levels of around 0.1 metres upstream and 0.2 metres downstream of the bridge.

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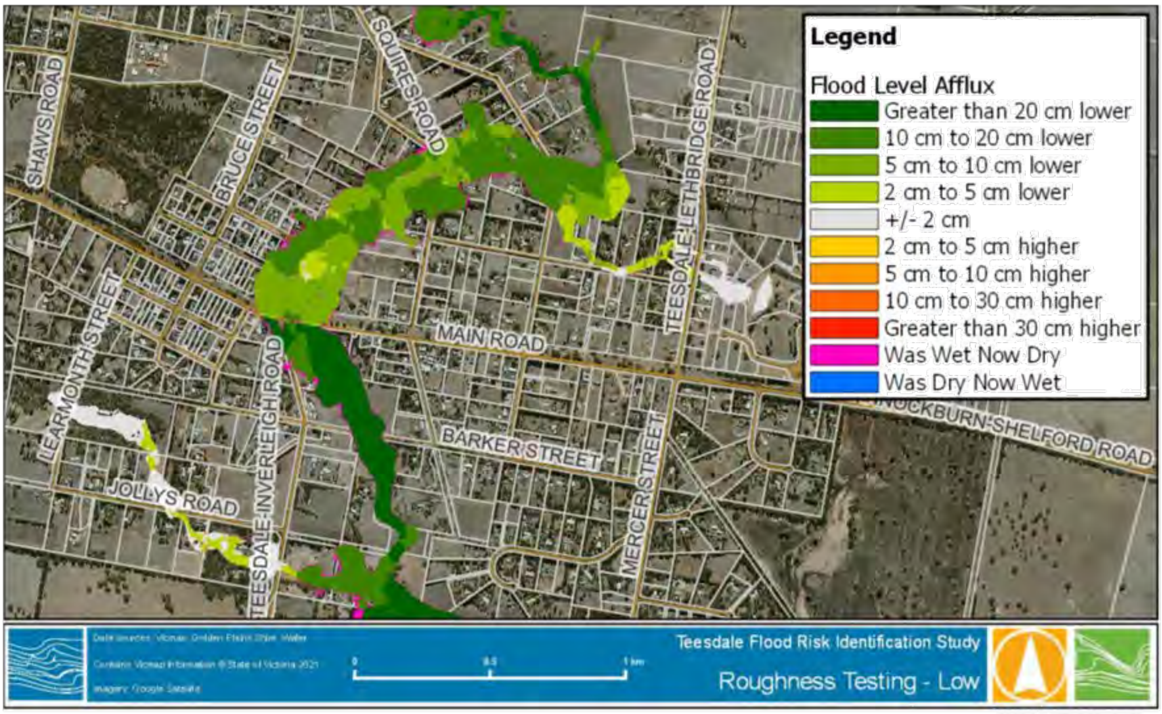

Figure 6 Low roughness sensitivity testing afflux mapping

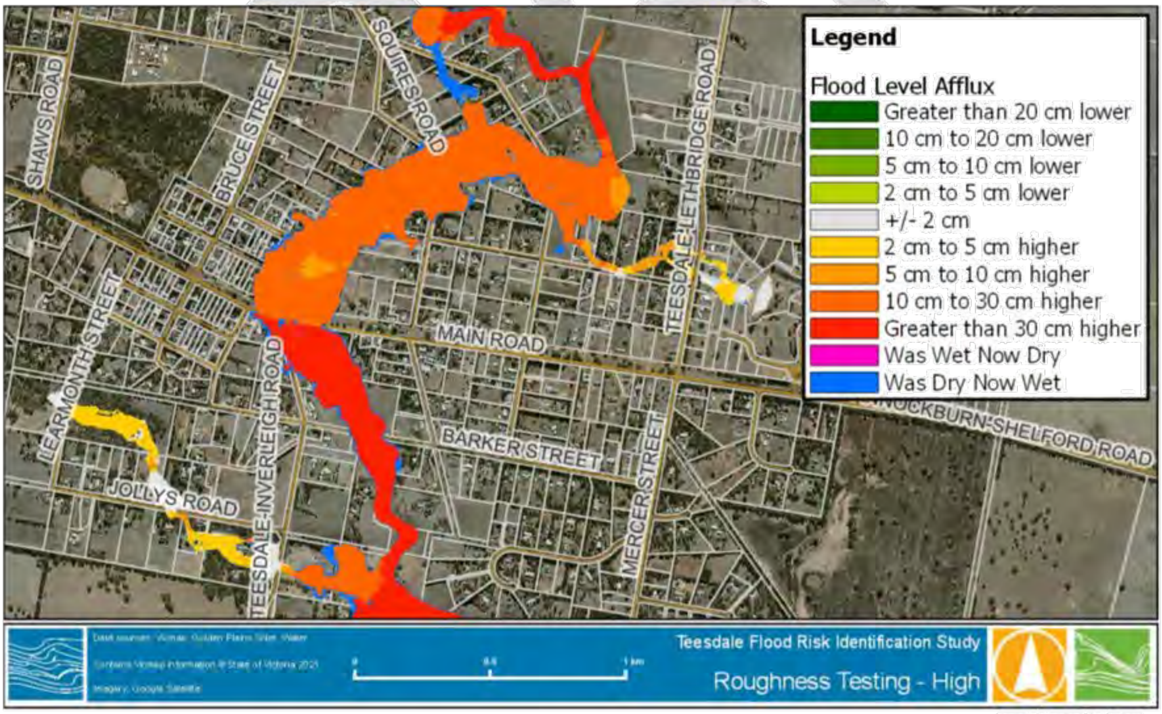

Figure 7 High roughness sensitivity testing afflux mapping

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5.3 Structure Blockage

Blockage factors were applied to the two bridges in town as follows:

- 20% blockage applied to the bridge opening (i.e. underneath the deck); and
- 100% blockage applied to the bridge railing.

The results show very minor impacts localised to the immediate area of the bridges. Both bridges show a slight raising of flood levels on the upstream side of the bridge. The Bannockburn-Shelford Road bridge also shows minor afflux with increases of up to 0.04 metres on the downstream western side of the bridge adjacent to the kindergarten. This is a result of the blockage causing additional overtopping of the road on that side. The kindergarten buildings remain out of the flood extent.

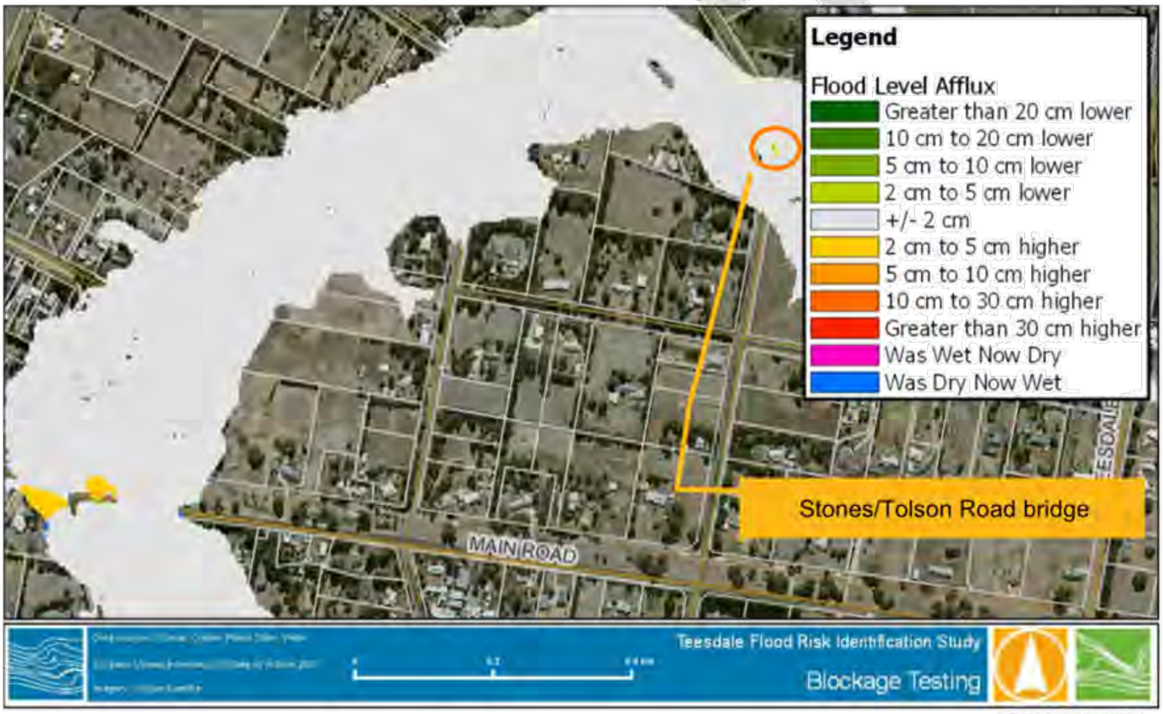

Figure 8 Blockage sensitivity testing afflux mapping

5.4 Boundary Conditions

The model has a single outflow boundary, which adopted a slope of 0.3% based on the slope of Native Hut Creek at the boundary location. Changing the downstream boundary slope to 5% lowers flood levels in the vicinity of the boundary. Flood levels in Teesdale are unaffected by the change, confirming the boundary was set a sufficient distance from the township. Flood levels at the boundary were lowered by 1.3 metres, quickly tapering to less than 10cm ~150 metres upstream of the boundary, and less than 1cm approximately 600 metres upstream of the boundary.

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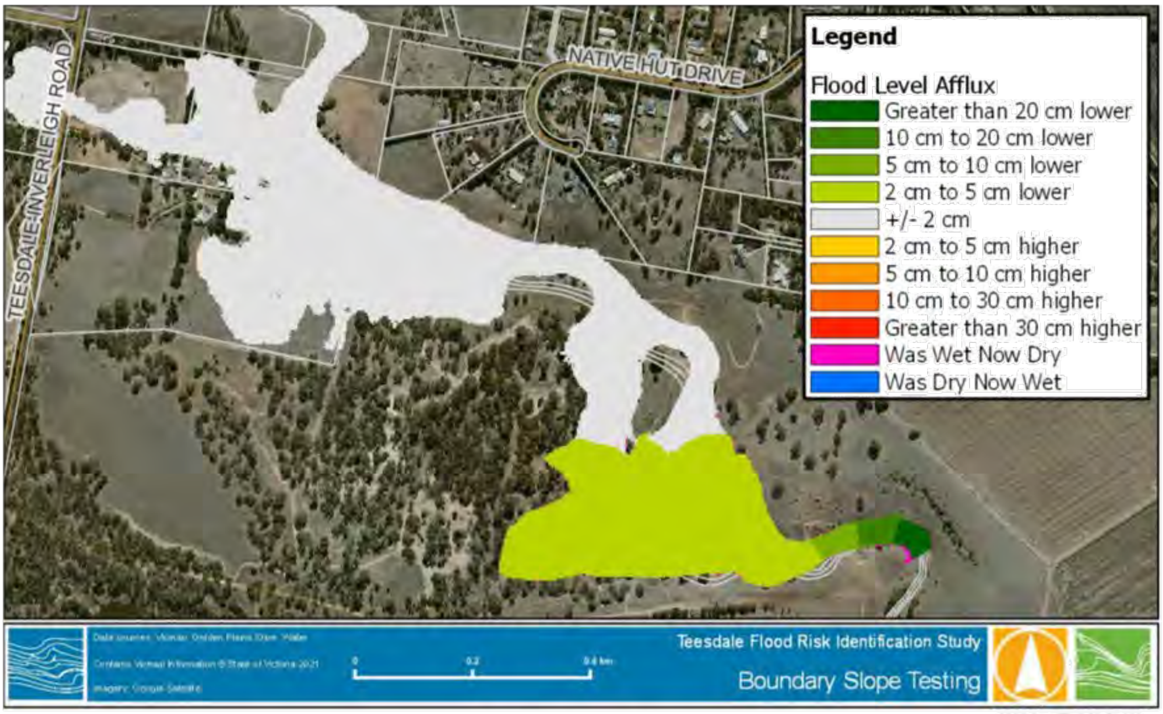

Figure 9 Boundary slope sensitivity testing afflux mapping

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6 SUMMARY

Design modelling and sensitivity testing of the hydrologic and hydraulic models built as part of the Teesdale Flood Risk Identification Study has been completed and detailed in this report. Design flood mapping is provided as a separate appendix to this report.

The models have been simulated for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% and PMF events. The 10% and 1% were simulated with projected climate change increased rainfall intensity under RCP4.5 and RCP8.5 for the years 2050 and 2100.

Flood mapping has been produced in line with industry standards and the current Australian Rainfall and Runoff guidelines. The mapping is fit for the purposes of informing land use planning in Teesdale. The mapping will be used to assess average annual flood damages for the township and the models utilised to assess potential structural mitigation options. Flood intelligence products will be developed to inform emergency management planning and response.

Sensitivity testing shows the models are particularly sensitive to continuing loss in the hydrology and hydraulic roughness in the hydraulic model. For the 1% AEP event, structure blockage and boundary conditions were shown to be uninfluential on results in the township.

The flood mapping produced will inform draft planning scheme amendment mapping to update the planning scheme in line with the new intelligence.

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APPENDIX A
FLOOD MAP PDFS

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Flood Intelligence and Warning

Teesdale Flood Risk Identification Study

Golden Plains Shire

5 May 2023

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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.
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.

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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
- 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 R03 – Design Modelling Report. R03 detailed the design event modelling for the range of modelled events (50% AEP to PMF). The previous report also detailed climate change modelling under a range of scenarios in addition to model sensitivity testing.

This report discusses the Flood Intelligence products developed as part of the study. It also provides an assessment of the Total Flood Warning System components currently in place for Teesdale, with recommendations for further improvement to the flood warning system.

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2 BACKGROUND: TOTAL FLOOD WARNING SYSTEM

The Total Flood Warning System (TFWS) is intended to encompass all of the elements required to produce an appropriate timely response to flooding. The elements of the core TFWS are shown in Figure 2-1 below.

Figure 2-1 Total Flood Warning System elements[1]

The information produced by a flood investigation generally relates to the "monitoring and prediction" and "interpretation" elements. Flood mapping, damages and intelligence produced by the study will be valuable in interpreting incoming data. Some of the elements of the study (for example the "Flood/No Flood" tool produced in the Municipal Flood Emergency Plan) can aid with prediction.

Message construction, communication, and protective behaviour are outside the scope of a flood investigation however would generally be completed from within an Incident Control Centre (if one has been set up) and the applicable Incident Management Team controlling the incident. Formal flood warning messages in Victoria fall within the remit of the Bureau of Meteorology and fall within two classes: Flood Watches and Flood Warnings.

Flood Watches are general warnings covering a large area and are not specific to particular waterways or townships. They can be delivered well before flooding is expected to arise and are often based on forecast rainfalls.

Flood Warnings, on the other hand, are specific to a location and will predict how high the water will peak at that location. Flood Warnings are often related to Flood Class Levels (see Section 8 below).

Review of the available information should take place after any event, or any other discovery of new flood information as appropriate. Historic events should be added to the available information, particularly the MFEP, as they occur.

Monitoring, in the context of flooding, generally refers to monitoring rainfall and stream levels but may include other aspects such as storage levels and catchment conditions to name a few. Locations to monitor will depend on the available data sources and the catchment of interest.

The following sections will discuss the current and ideal monitoring capability for Native Hut Creek; a draft rating curve of Native Hut Creek at Teesdale to assist in future data collection and prediction where possible; flood behaviour and impacts at the modelled AEPs; flood travel times; and flood classification levels for Teesdale.

3 RATING CURVE DEVELOPMENT

A rating curve has been extracted from the TUFLOW hydraulic model at the Bannockburn-Shelford Road bridge. This location represents the most appropriate location for a gauge on Native Hut Creek due to the confined nature of the waterway corridor at this location, with flow contained in most events. In events larger than around a 2% AEP event, flows will overtop the road. Gauge boards on the upstream side of the road placed at the low point where overtopping commences along with a location further from the bridge would ensure gauge readings could be undertaken during large events, however the model indicates readings at this location may be slightly higher than those taken upstream of the bridge opening. Manual gauge readings may therefore overestimate the flow in Native Hut Creek at high flow rates.

The rating curve has been developed utilising a least squares polynomial fit across the model results for flow and height at the upstream side of the bridge. Model results for the 10%, 5%, and 0.5% AEP events informed the curve. A clear inflexion point can be seen just above 30 m^3/s, where the floodplain upstream of the bridge is engaged and small increases in water level correspond to significant increases in flow.

The curve is shown in Figure 3-1 and Figure 3-2 below. Also plotted are the flows and heights extracted from the model for all modelled events except the PMF. An example rating table, in the same format as that currently used by the Department of Energy, Environment and Climate Action, is provided in Appendix A. The example table is based on a gauge zero of 99.037 mAHD, which was taken from the TUFLOW model. Should the gauge site be developed, a gauge zero will be required and the stage heights can be linked using mAHD as a datum.

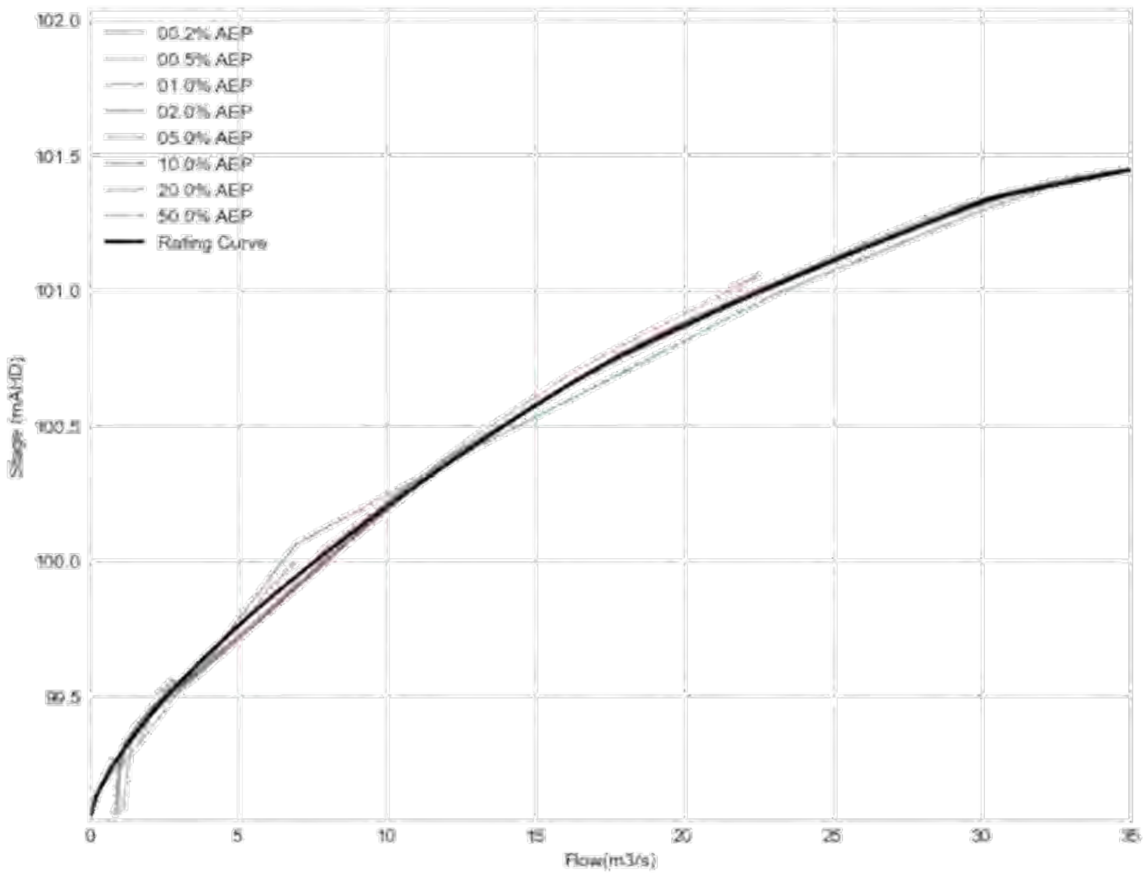

Figure 3-1 Native Hut Creek at Bannockburn-Shelford Road bridge, low flows

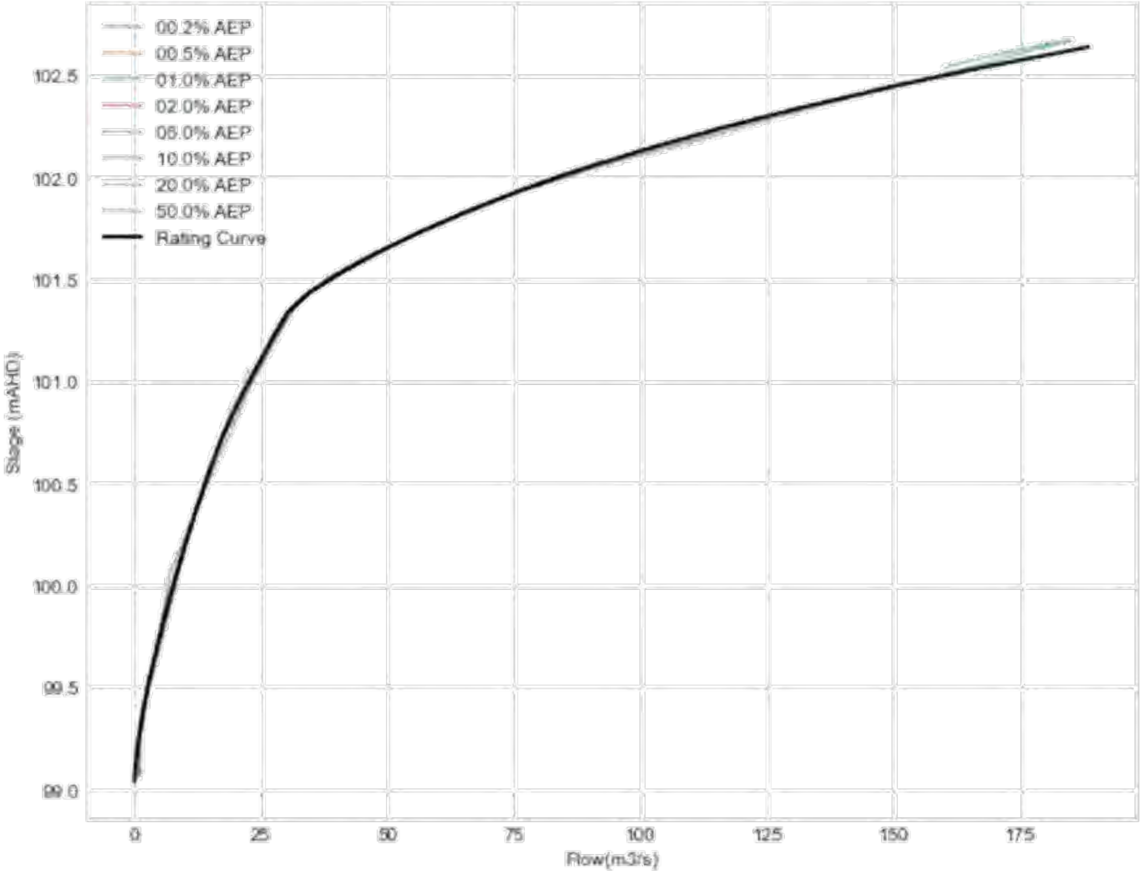

Figure 3-2 Native Hut Creek at Bannockburn-Shelford Road bridge, high flows

4 FLOOD BEHAVIOUR AND IMPACTS

4.1 Overview

When Native Hut Creek flows, water first breaks the banks at 4 Stones Road, flowing towards the west and over Stones Road before re-joining the creek upstream of Squires Road/Sutherland Street. Model results indicate this occurs at relatively low flow rates in the creek of around 10m^3/s (~50% AEP). Barker Street overtops shortly after, with the minor culvert's capacity overcome in minor events. At higher flowrates of around 40m^3/s (10% AEP), flows break out near the Stones Road/Tolsons Road bridge on the south side of the creek, flowing through residential properties and over Sutherland Street, re-joining the waterway approximately 200m north of the Bannockburn-Shelford Road bridge.

The elevated Bannockburn-Shelford Road overtops at around 90m^3/s (~2% AEP), with overtopping commencing at a low point on the road 90 metres east of the bridge. As flows increase, another low point approximately 90 metres to the west begins to overtop. The depression on the west side of Teesdale-Inverleigh Road fills and the road is overtopped. The floodplain downstream of the bridge narrows towards Barker Street and remains relatively confined until the confluence with the Learmonth Street tributary, downstream of which numerous breakouts occur as the creek flows away from Teesdale.

4.2 Flood Impacts Summary

Table 4-1 provides a summary of key flood behaviour and impacts with a summary of roads inundated. Behaviours and impacts are shown in the likely order of inundation, i.e. from more frequent, lower magnitude events to less frequent larger flood events.

Note the table below refers to Stones Road, however it should be noted that this is also Tolsons Road. The inundation of Stones Road joins Tolsons Road at approximately 10% AEP and there are no properties or otherwise between the two inundation points, thus they have been combined.

Table 4-1 Flood Impacts Summary

Flood Event	Characteristics – Flood Behaviour	Roadways Inundated
50% AEP ~600 ML/d ~7.4 m^3/s 99.99 m AHD at Bannockburn-Shelford Road bridge	Breakout occurs upstream of Stones Road, flowing along the north side of Native Hut Creek and filling local depressions. The breakout rejoins Native Hut Creek at Pantics Road.	▪ Learmonth St (<0.1m) ▪ Stones Road (<0.3m) ▪ Barker Street (<0.3m) ▪ Russel St (<0.1m)
20% AEP ~1,950 ML/d ~23 m^3/s 101.05 m AHD at Bannockburn-Shelford Road bridge	Breakout upstream of Stones Road becomes more significant with deep flows on the north side of Native Hut Creek. Breakout from dam at 95 Tolson Road flows over paddocks south of Native Hut Creek, rejoining before Sutherland Street. Stones Road and Barker Street flooded to hazardous depths. Minor breakouts on west side of Native Hut Creek, north and south of Bannockburn-Shelford Road. Significant breakouts around and downstream of Barker Street and around Native Hut Drive.	▪ Learmonth St (<0.1m) ▪ Stones Road (>0.5m) ▪ Pantics Road (<0.1m) ▪ Barker Street (>0.5m) ▪ Russel St (~0.1m)

Flood Event	Characteristics – Flood Behaviour	Roadways Inundated
10% AEP ~3,400 ML/d ~40.5 m^3/s 101.53 m AHD at Bannockburn-Shelford Road bridge	Floodplain fully engaged with breakout flows on both sides of Native Hut Creek throughout the town. Turtle Bend inundated with isolated islands. **Teesdale Kindergarten driveway and carpark inundated.** Access via community hall possible. **87 Pantics Road inundated above floor.**	▪ Learmonth St (<0.1m) ▪ Stones Road (>0.5m) ▪ Mercer Tce (~0.5m) ▪ Pantics Road (<0.3m) ▪ Barker Street (>1m) ▪ Sutherland Street (~0.3m) ▪ Russel St (<0.3m)
5% AEP ~5,200 ML/d ~60.5 m^3/s 101.78 m AHD at Bannockburn-Shelford Road bridge	Generally as above with deeper, faster flowing water. Hazardous depths across floodplain. **Teesdale Kindergarten driveway and carpark inundated to hazardous depths. Access via community hall possible.**	▪ Learmonth St (<0.1m) ▪ Stones Road (~1m) ▪ Pantics Road (>0.3m) ▪ Mercer Tce (~0.9m) ▪ Barker Street (>1.0m) ▪ Sutherland Street (~0.5m) ▪ Teesdale-Inverleigh Road (<0.3m) ▪ Russel St (<0.3m)
2% AEP ~7,950 ML/d ~92 m^3/s 102.08 m AHD at Bannockburn-Shelford Road bridge	Generally as above with deeper, faster flowing water. Hazardous depths across floodplain. Bannockburn-Shelford Road overtopped. **844 Teesdale-Inverleigh Road inundated above floor.**	▪ Learmonth St (~0.1m) ▪ Bannockburn-Shelford Road (<0.1m) ▪ Jollys Road (<0.1m) ▪ Stones Road (>1m) ▪ Pantics Road (>0.5m, ~750m length) ▪ Mercer Tce (>1m) ▪ Barker Street (>1.0m) ▪ Sutherland Street (~0.8m) ▪ Teesdale-Inverleigh Road (~0.4m) ▪ Russel St (<0.3m)
1% AEP ~10,150 ML/d ~118 m^3/s 102.25 m AHD at Bannockburn-Shelford Road bridge	Generally as above with deeper, faster flowing water. Hazardous depths across floodplain.	▪ Learmonth St (~0.1m) ▪ Bannockburn-Shelford Road (<0.3m) ▪ Jollys Road (<0.1m) ▪ Stones Road (>1m) ▪ Pantics Road (>0.5m, ~750m length) ▪ Mercer Tce (>1m) ▪ Barker Street (>1.0m) ▪ Sutherland Street (>1m) ▪ Teesdale-Inverleigh Road (~0.6m) ▪ Russel St (<0.3m)

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Flood Event	Characteristics – Flood Behaviour	Roadways Inundated
0.5% AEP ~13,100 ML/d ~ 52 m³/s 102.48 m AHD at Bannockburn-Shelford Road bridge	Bannockburn-Shelford Road overtopped to depths greater than 0.3 metres. Generally as above with deeper, faster flowing water. Hazardous depths across floodplain.	▪ Learmonth St (~0.1m) ▪ Bannockburn-Shelford Road (>0.3m) ▪ Jollys Road (<0.1m) ▪ Stones Road (>1m) ▪ Pantics Road (>0.5m, ~750m length) ▪ Mercer Tce (>1m) ▪ Barker Street (>1.0m) ▪ Sutherland Street (>1m) ▪ Teesdale-Inverleigh Road (~0.9m) ▪ Russel St (<0.3m) ▪ Teesdale-Lethbridge Road (<0.1m)
0.2% AEP ~16,000 ML/d ~185 m³/s 102.67 m AHD at Bannockburn-Shelford Road bridge	Generally as above with deeper, faster flowing water. Hazardous depths across floodplain.	▪ Learmonth St (~0.1m) ▪ Bannockburn-Shelford Road (<0.5m) ▪ Jollys Road (<0.1m) ▪ Stones Road (>1m) ▪ Pantics Road (>0.5m, ~750m length) ▪ Mercer Tce (>1m) ▪ Barker Street (>1.0m) ▪ Sutherland Street (>1m) ▪ Teesdale-Inverleigh Road (>1m) ▪ Teesdale-Lethbridge Road (<0.1m)

5 FLOOD PEAK TRAVEL TIME

With no active or historic gauges on Native Hut Creek, flood peak travel times have been extracted from the RORB model built for the study. The model is sensitive to selection of the K_c routing parameter with respect to flood timing. Flood timing is also expected to be influenced by antecedent catchment conditions. Given no gauge monitoring is possible, flood peak timing at Teesdale has been estimated from the start of significant rainfall.

The modelled hydrographs for the 10% AEP and 1% AEP rainfall events are shown in Figure 5-1 and Figure 5-2. The below graphs show all modelled events for the AEP between 3 hours and 72 hours in duration for all ten temporal patterns. A total of 100 hydrographs were produced for each AEP. Also shown on the graphs is the critical peak flow, selected in accordance with the recommendations of ARR.

The graphs show the significant range in peak flows and timing produced by rainfall depths of a certain AEP when that rain falls over different durations and patterns within the duration. This illustrates the difficulty in accurately predicting flood peaks and timing from rainfall alone.

The graphs show that flood peaks can manifest around 7 hours from the start of intense rainfall, with the majority of events peaking between 7 hours and ~30 hours from the start of the rainfall burst. Some events peak beyond 30 hours from the start of rainfall however these become rarer and may contain "embedded bursts" where rainfall intensity within the burst increases for a period of time.

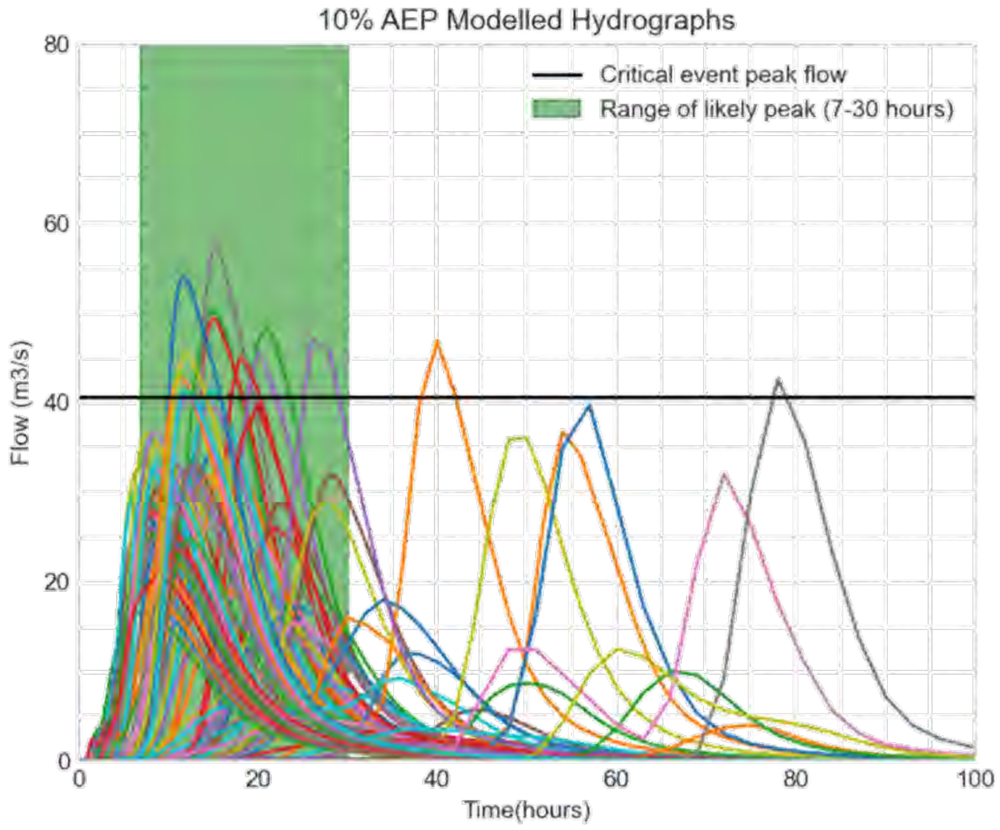

Figure 5-1 10% AEP hydrographs from all 100 modelled rainfall events

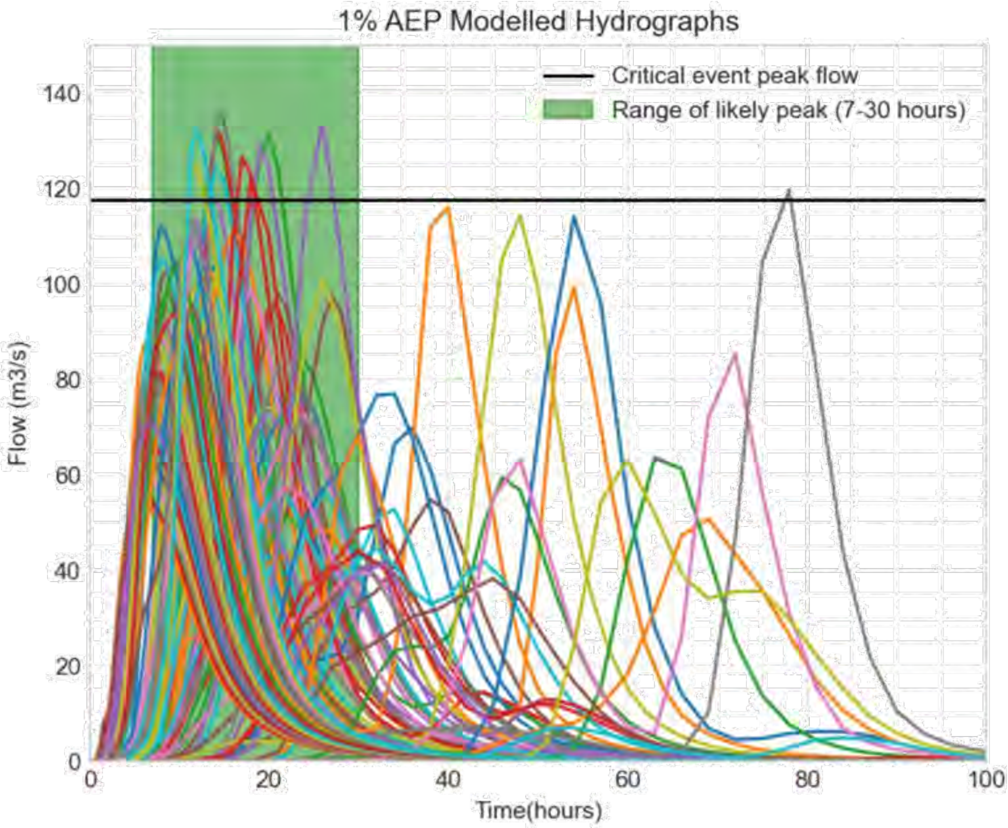

Figure 5-2 1% AEP hydrographs from all 100 modelled rainfall events

Similar graphs for the remaining AEPs modelled were used to develop Table 5-1 below of expected rises and peak times in the Native Hut Creek at Teesdale from the start of rainfall.

Table 5-1 Flood peak timing for Teesdale

Location From	Location To	Typical Travel Time	Comments	Duration
Teesdale (Native Hut Creek)				
Start of rainfall (catchment)	Teesdale	2 - 5 hours	Begin to rise from normal levels	Generally <24 hours
Start of rainfall (catchment)	Teesdale	7 - 30 hours	To peak – may be longer dependent on rainfall temporal pattern	

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6 FLOOD/NO FLOOD TOOL

In the absence of a warning system, an estimate of the magnitude of flooding in Native Hut Creek at Teesdale may be obtained by monitoring the depth of rainfall in a given event, taken from the start of the event.

The Flood/No Flood tool in Figure 6-1 below provides a graphical representation of the Intensity-Frequency-Duration relationships for various AEP events as presented in R03 – Design Modelling.

To use the table, plot the total rainfall depth obtained against elapsed time since the start of the event. Exclude very light rain or drizzle when determining the event start point. Plotting of rainfall data should occur periodically as the event progresses. The likelihood and potential severity of flooding can be estimated by checking the rainfall and adopting the nearest curve AEP event as being likely.

It may be appropriate to step up or down a level depending on catchment antecedent conditions, for example if the rainfall for a 12 hour duration indicates a 5% AEP event will occur, but the catchment is dry with most farm dams empty, it may be appropriate to "step down" to a 10% AEP event or even lower. Similarly a very wet catchment will produce a greater response and may justify a "step up" in estimated AEP for response purposes.

The tool can provide a quick estimate as to whether there will be a flood and how severe that flood may be, however it must be stressed that the tool cannot provide accurate flood predictions and should not be relied upon entirely. Should life or property be in danger a cautious approach should be taken.

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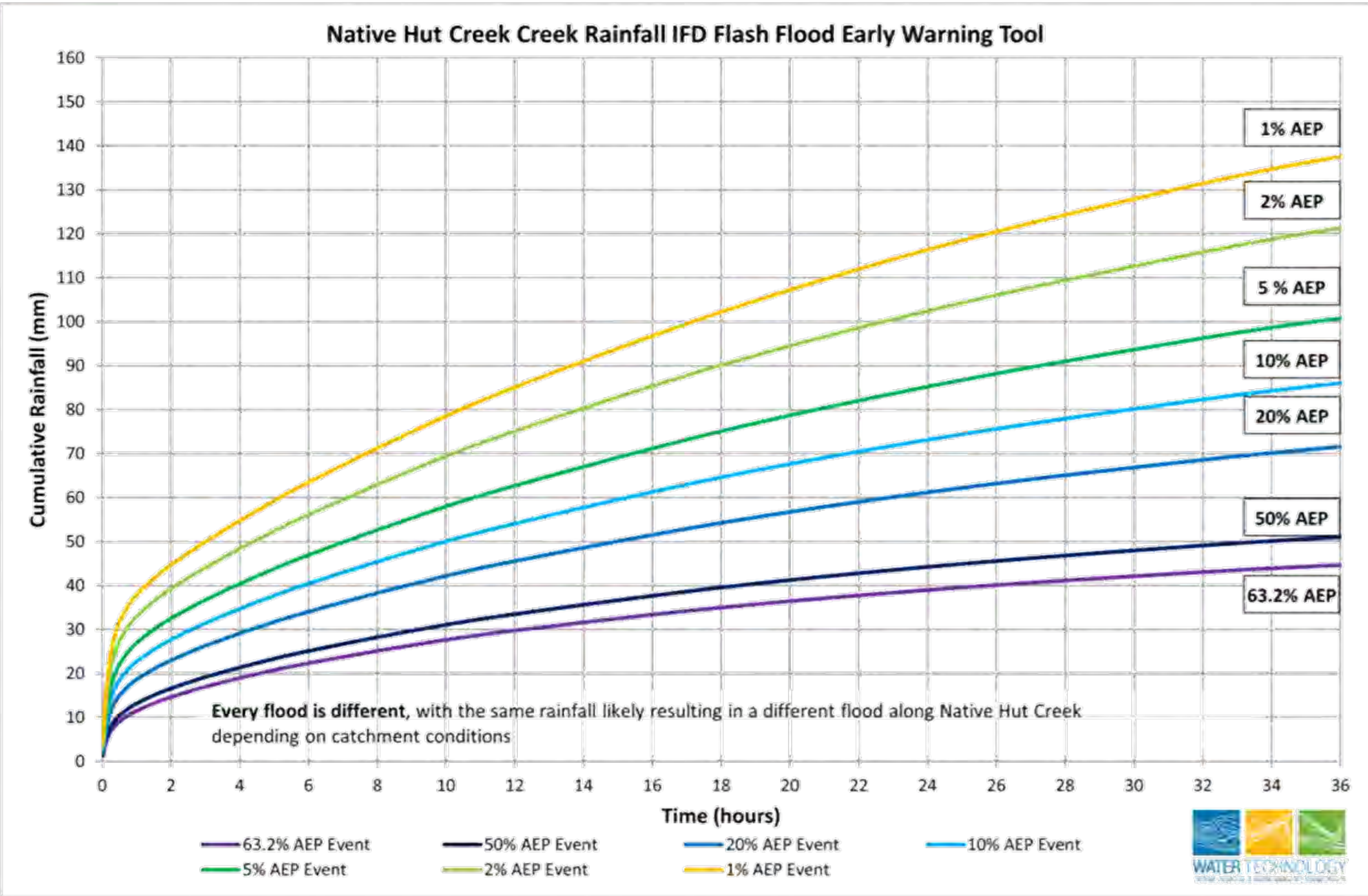

Figure 6-1 Teesdale Flood/No Flood Tool

7 FLOOD CLASSIFICATION LEVELS

While no gauge exists at Teesdale, recommended Flood Classification Levels (FCLs) have been developed utilising the theoretical gauging site and rating curve developed for the Bannockburn-Shelford Road bridge and the Bureau of Meteorology's definitions of FCLs. The bureau defines FCLs as per the below[1]:

Minor flooding

If the water level reaches the minor flood level, it causes inconvenience. Low-lying areas next to water courses are inundated. Minor roads may be closed and low-level bridges submerged. In urban areas flooding may affect some backyards and buildings below floor level as well as bicycle and pedestrian paths. In rural areas removal of livestock and equipment may be required.

Moderate flooding

If the water level reaches the moderate flood level, the area of inundation is larger. Main traffic routes may be affected. Some buildings may be affected above floor level. Evacuation may be required. In rural areas removal of livestock is necessary.

Major flooding

If the water level reaches the major flood level large areas are inundated. Many buildings may be affected above floor level. Properties and towns are likely to be isolated and major rail and traffic routes closed. Evacuation may be required. Utility services may be affected.

The results of the modelling have been assessed against the above criteria and flood class levels have been set for the proposed gauge location at the Bannockburn-Shelford Road bridge. The proposed flood class levels are detailed in Table 7-1 below.

Table 7-1 Proposed Flood Class Levels for Teesdale

Flood Class	Level at Bridge	Description
Minor	101.05 mAHD	The 20% AEP event matches the above minor flooding definition quite well, as Stones Road requires closure and low-lying areas next to Native Hut Creek are inundated.
Moderate	101.53 m AHD	The 10% AEP event floods Pantics Road to potentially hazardous levels and may require evacuation of vulnerable residents on that road. The area of inundation is significant. No buildings are flooded above floor level in this event.
Major	102.25 mAHD	The 1% AEP flood level is likely to require closure of the Bannockburn-Shelford Road bridge, potentially isolating parts of the town. Detours are likely to require careful management. Flooding of this magnitude is likely to be accompanied by flooding in neighbouring catchments.

[1] http://www.bom.gov.au/australia/flood/knowledge-centre/about-warning-service.shtml

8 MONITORING CAPABILITY FOR NATIVE HUT CREEK

8.1 Existing Capability

Currently, there is no formal flood warning system in place for the Native Hut Creek catchment. Additionally, there are no streamflow or rainfall gauges within the catchment. Due to this, official flood warning capability for the catchment and township is limited to the issue of a Flood Watch for the Barwon, Leigh and Moorabool Rivers area. Note a flood watch is not necessarily guaranteed to be issued prior to flooding.

The closest rain gauges that record sub-daily rainfalls and report to the Bureau of Meteorology's website are detailed in Table 8-1 below, with the distance measured from the Bannockburn-Shelford Road bridge.

Table 8-1 Nearby hourly rain gauges (Bureau of Meteorology)

Site Number	Name	Distance from Teesdale
87168	She Oaks AWS	15.2 km North-East
89104	Mt Mercer	25.6 km North
90167	Winchelsea	24.4 km South

8.2 Ideal (Potential) Capability

Flood data monitoring for Native Hut Creek would benefit from the placement of a rain gauge and stream gauge within the catchment. Rainfall in the north of the catchment is expected to be captured quite well by the Sheoaks gauge, however Teesdale itself lies between a number of gauges which may not reflect rainfall in the immediate vicinity of the township.

A sub-daily rain gauge within Teesdale would therefore improve the monitoring capability for the township and lower areas of the catchment. A Teesdale rain gauge would provide the additional benefit of allowing for monitoring of flash flooding conditions within the township, which is known to have caused issues recently, based on feedback received during community consultation sessions for this project.

In addition to a rain gauge within the township, a stream gauge on Native Hut Creek immediately upstream of the Bannockburn-Shelford Road bridge would greatly improve monitoring and data gathering for the township. Outputs from this Flood Risk Identification Study have been linked, where possible, to a gauge height at this proposed location. A stream gauge here would also gather stream height data in future flood events, allowing more detailed catchment analysis and calibration of models to improve confidence in the flood intelligence products.

Stream gauging in the catchment upstream is not expected to provide significant benefit to Teesdale. This is due to the following factors:

- The catchment shape and size already produce fast response times. Upper or mid catchment gauging may not provide sufficient lead time in an event to enable suitable response actions to be implemented.
- There is a significant tributary which enters Native Hut Creek immediately upstream of the Stones Road/Tolsons Road bridge. Any mid/upper catchment gauging would not be able to take account of this tributary and could therefore underestimate peak flows at Teesdale should the tributary influence flooding in a particular event.

In summary, a rain gauge at Teesdale and a stream gauge at the Bannockburn-Shelford Road bridge would improve flood monitoring and data gathering capabilities in Teesdale significantly. The rain gauge would play a direct role in warning of impending floods while the stream gauge would provide invaluable data to benchmark other monitoring information against.

In heavy rainfall events where Native Hut Creek rises quickly, a stream gauge may only provide warning time sufficient to enact response actions other than evacuation. A more cost effective option may therefore be to install a gauge without telemetry, or to have the site ready for deployment of a Portable Automatic Logging System (PALS) to monitor levels in Native Hut Creek during expected flow events. One potential issue with the PALS option is the demand for PALS units during events for which heavy rainfall is forecast. PALS ownership and deployment arrangements should therefore be confirmed prior to pursuing this option.

9 SUMMARY

Preferred monitoring capability and infrastructure to support a Total Flood Warning System for Teesdale has been discussed, with a sub-daily rain gauge and stream gauge suggested. Both the rain gauge and stream gauge are proposed within Teesdale itself and would improve the monitoring and data gathering capability for flood conditions in the town. A rating curve has been developed for Native Hut Creek at the Bannockburn-Shelford Road bridge, which can act as a starting rating table should the site be adopted until gauging can occur.

A number of flood intelligence products have been developed to improve flood response capability for the town, including a flood impact summary table, flood peak timing estimates and the development of a quick "flood/no flood" tool designed to estimate the magnitude of flooding based on observed rainfall.

Flood Class Levels have been recommended based off the Bureau of Meteorology's definitions and flood mapping completed for Teesdale. The Flood Class Levels utilise the proposed stream gauge site as their basis.

Much of the flood intelligence information contained in this report will be included in a draft revision of the Golden Plains Municipal Flood Emergency Plan (MFEP) for SES and Council approval.

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APPENDIX A RATING TABLE

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Table A-1 Rating Table for Native Hut Creek at Bannockburn-Shelford Road bridge in ML/d

mLGH	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	0.00	0.89	2.43	4.36	6.62	9.14	11.9	14.9	18.0	21.4
0.1	24.9	28.6	32.5	36.4	40.6	44.8	49.2	53.7	58.4	63.1
0.2	68.0	72.9	78.0	83.2	88.5	93.9	99.4	105	111	116
0.3	122	128	134	134	140	153	159	166	172	179
0.4	185	192	199	206	213	220	227	234	241	249
0.5	256	263	271	279	286	294	302	310	317	325
0.6	333	341	350	358	366	374	374	383	391	408
0.7	417	425	434	443	452	460	469	478	478	487
0.8	506	515	524	533	543	552	561	571	580	590
0.9	599	609	619	629	638	648	658	668	678	688
1	698	708	719	729	739	749	760	770	781	791
1.1	802	812	823	833	844	855	866	876	887	898
1.2	909	920	931	942	953	964	976	987	998	1010
1.3	1020	1030	1040	1060	1070	1080	1090	1100	1110	1120
1.4	1140	1150	1160	1170	1180	1200	1210	1220	1230	1240
1.5	1260	1270	1280	1290	1300	1320	1330	1340	1350	1370
1.6	1380	1390	1400	1420	1430	1440	1450	1470	1480	1500
1.7	1520	1530	1550	1560	1580	1600	1610	1630	1650	1660
1.8	1680	1700	1710	1730	1750	1770	1780	1800	1820	1840
1.9	1850	1870	1890	1910	1920	1940	1960	1980	2000	2010
2	2030	2050	2070	2090	2110	2130	2140	2160	2180	2200
2.1	2220	2240	2260	2280	2300	2320	2340	2360	2380	2390
2.2	2410	2430	2450	2470	2490	2510	2530	2560	2580	2600
2.3	2620	2620	2660	2660	2700	2700	2800	2800	2900	2900
2.4	3010	3010	3110	3110	3220	3220	3330	3330	3450	3450
2.5	3560	3620	3680	3740	3810	3870	3930	4000	4060	4130
2.6	4190	4260	4330	4400	4470	4540	4610	4690	4760	4830
2.7	4910	4980	5060	5140	5220	5300	5380	5460	5540	5630
2.8	5710	5710	5880	5880	6060	6060	6240	6240	6420	6420
2.9	6610	6610	6800	6800	7000	7000	7200	7200	7400	7400
3	7610	7720	7830	7940	8050	8160	8270	8380	8500	8610
3.1	8730	8850	8960	9090	9210	9330	9450	9580	9710	9830
3.2	9960	10100	10200	10400	10500	10600	10800	10900	11000	11200
3.3	11300	11300	11600	11600	11900	11900	12200	12200	12500	12500
3.4	12800	12800	13100	13100	13500	13500	13800	13800	14100	14100
3.5	14500	14600	14800	15000	15200	15400	15500	15700	15900	16100
3.6	16300	16500	16700	16800	17000	17200	17400	17600	17800	18000

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Flood Damages and Mitigation Assessment

Teesdale Flood Risk Identification Study

Golden Plains Shire

5 May 2023

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GOLDEN PLAINS SHIRE

Cover Image: Golden Plains Planning Scheme LSIO and FO mapping, sourced from https://mapshare.vic.gov.au/vicplan/ on 11/08/2023

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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.

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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.

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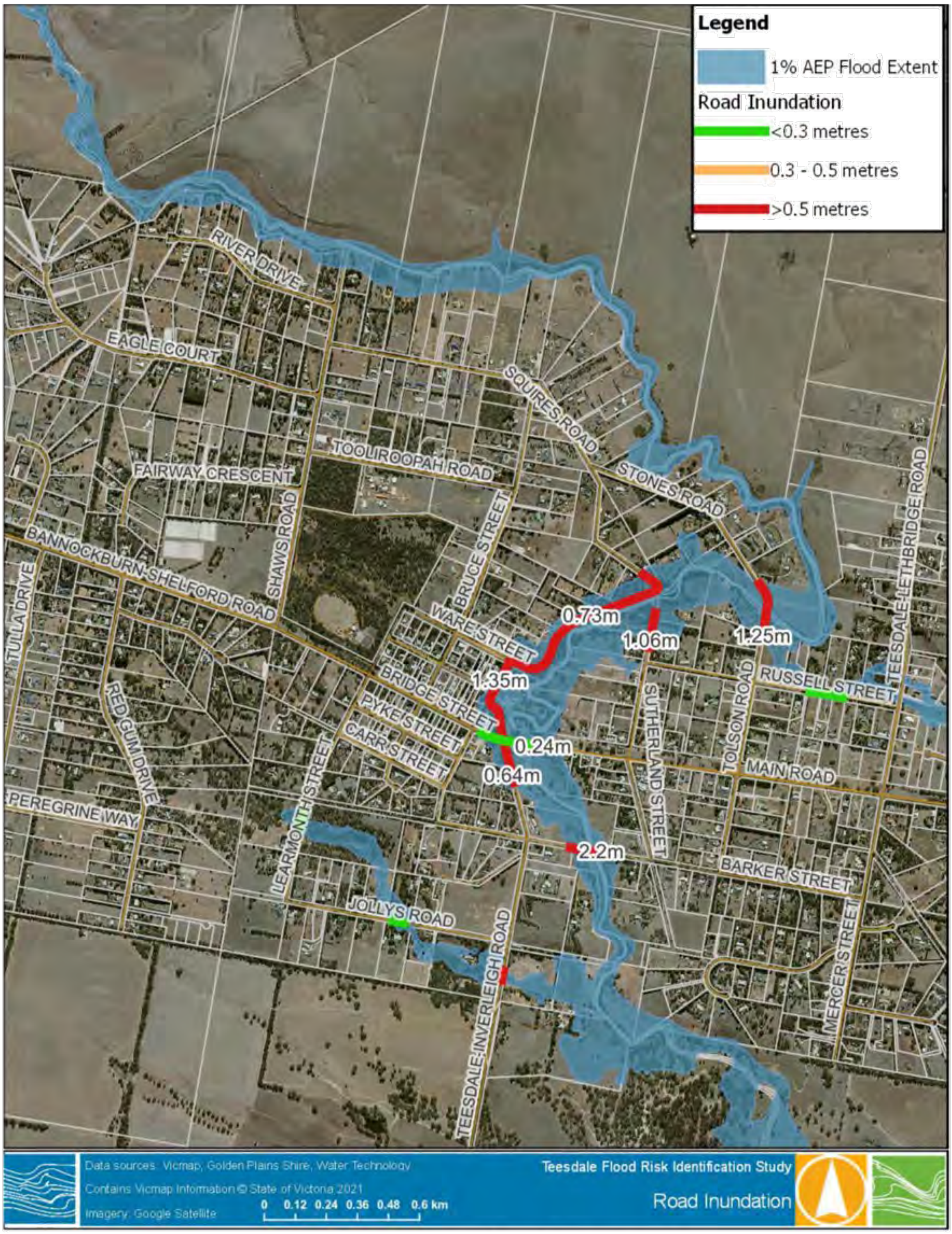

Figure 2-1 1% AEP Road Inundation and Depths

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.

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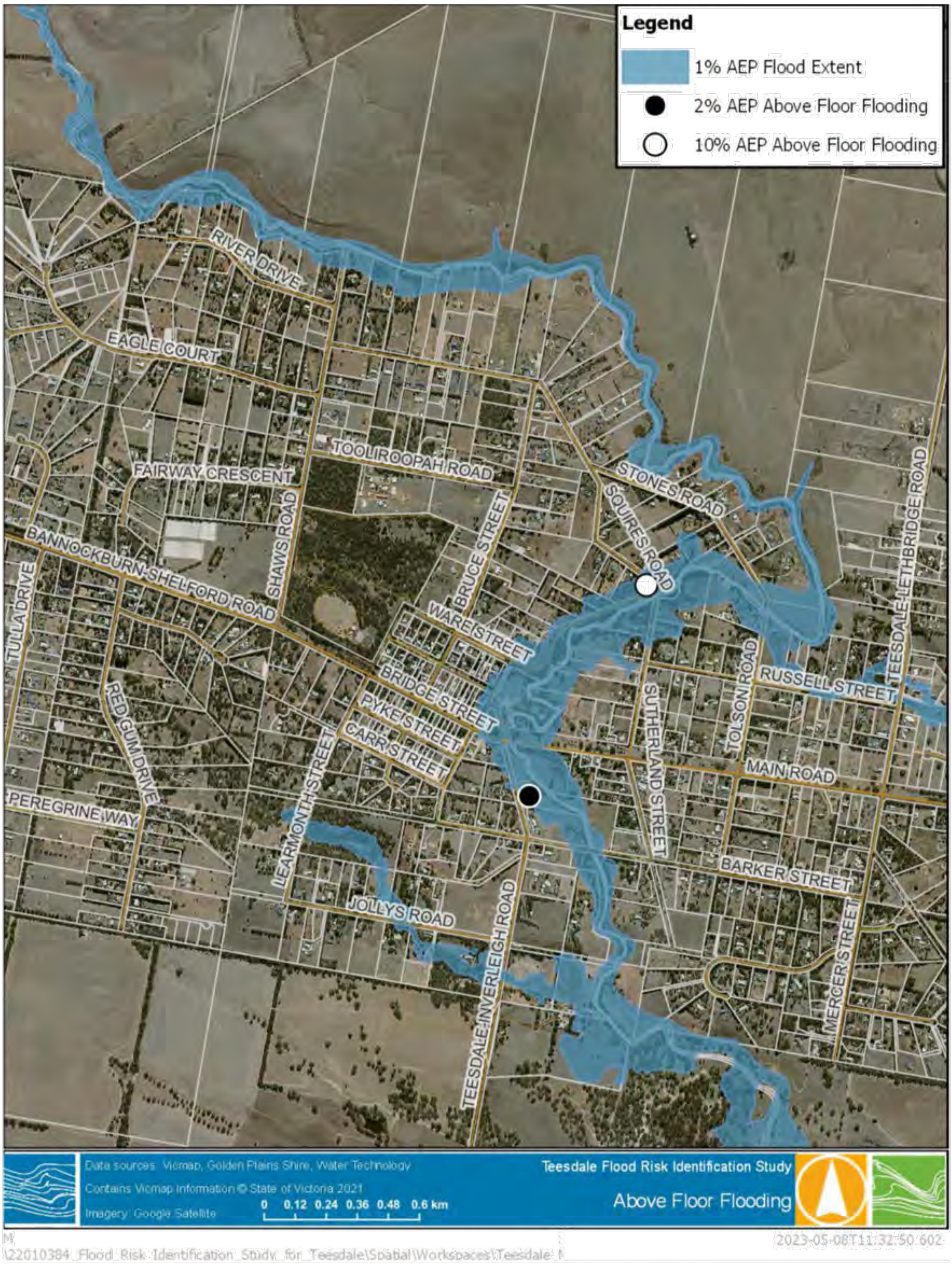

Figure 2-2 Dwellings impacted by above floor flooding

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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) / AEP	PMF 0.00001	500yr 0.002	200yr 0.005	100yr 0.01	50yr 0.02	20yr 0.05	10yr 0.1	5yr 0.2	2yr 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.

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

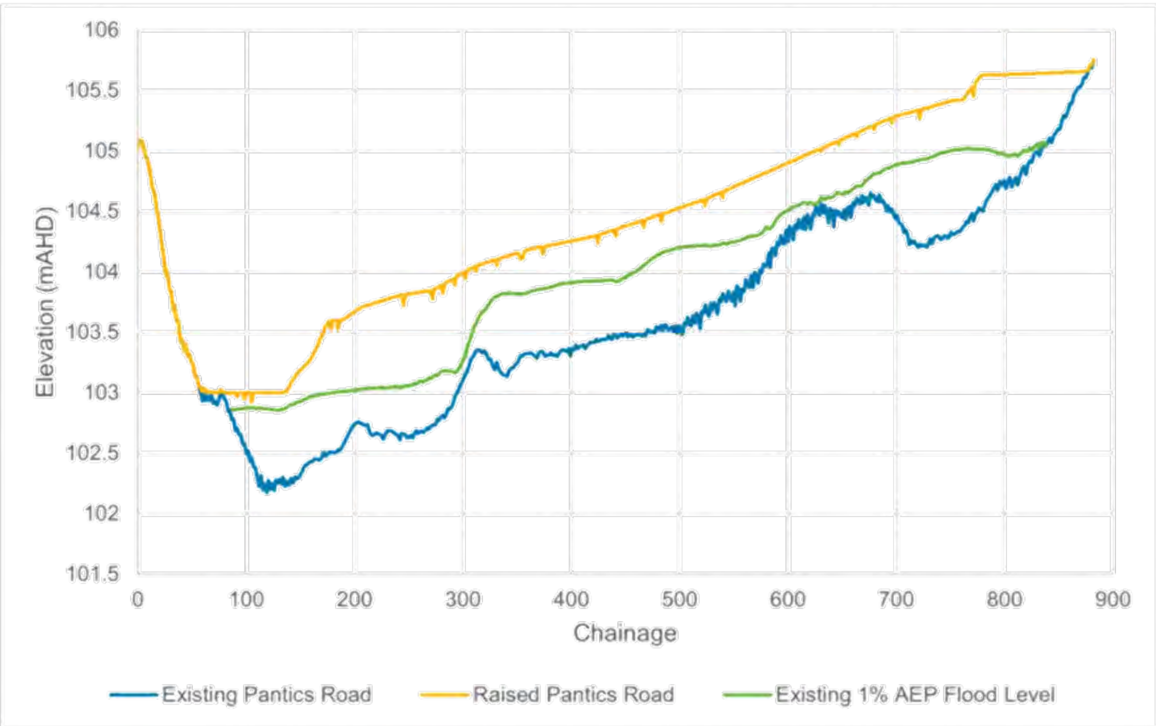

Figure 4-2 Existing and Proposed Pantics Road Long Section

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.

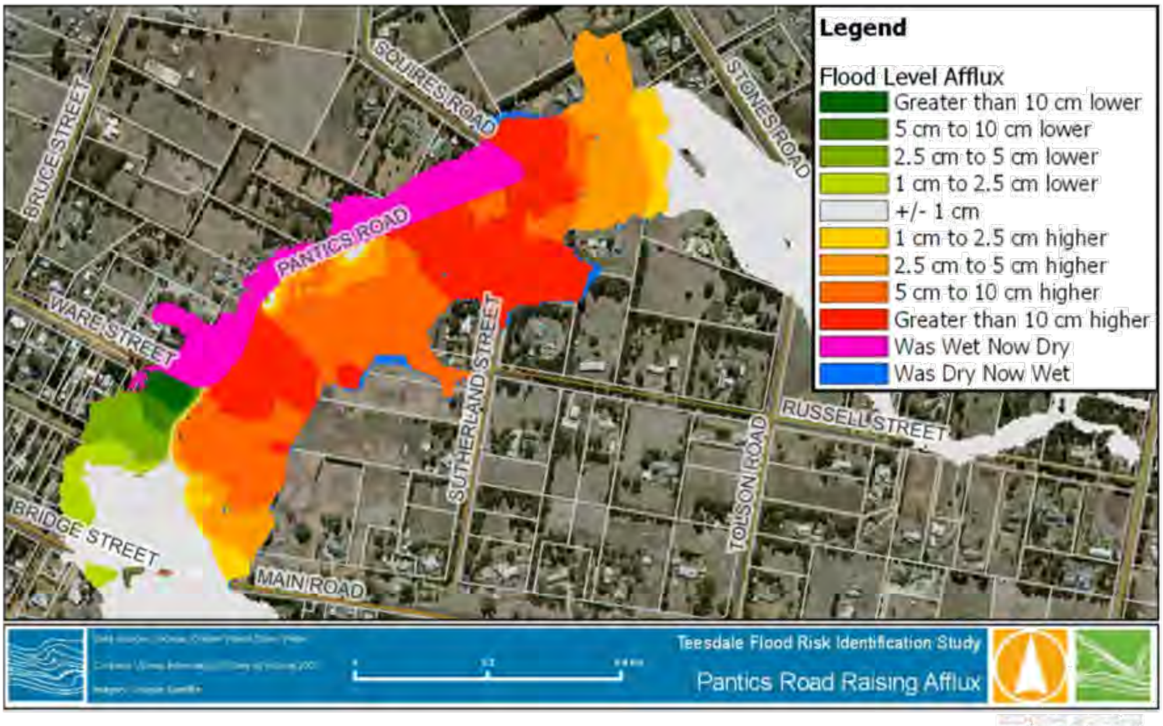

Figure 4-3 1% AEP Flood Level Afflux – Raising of Pantics Road

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.

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

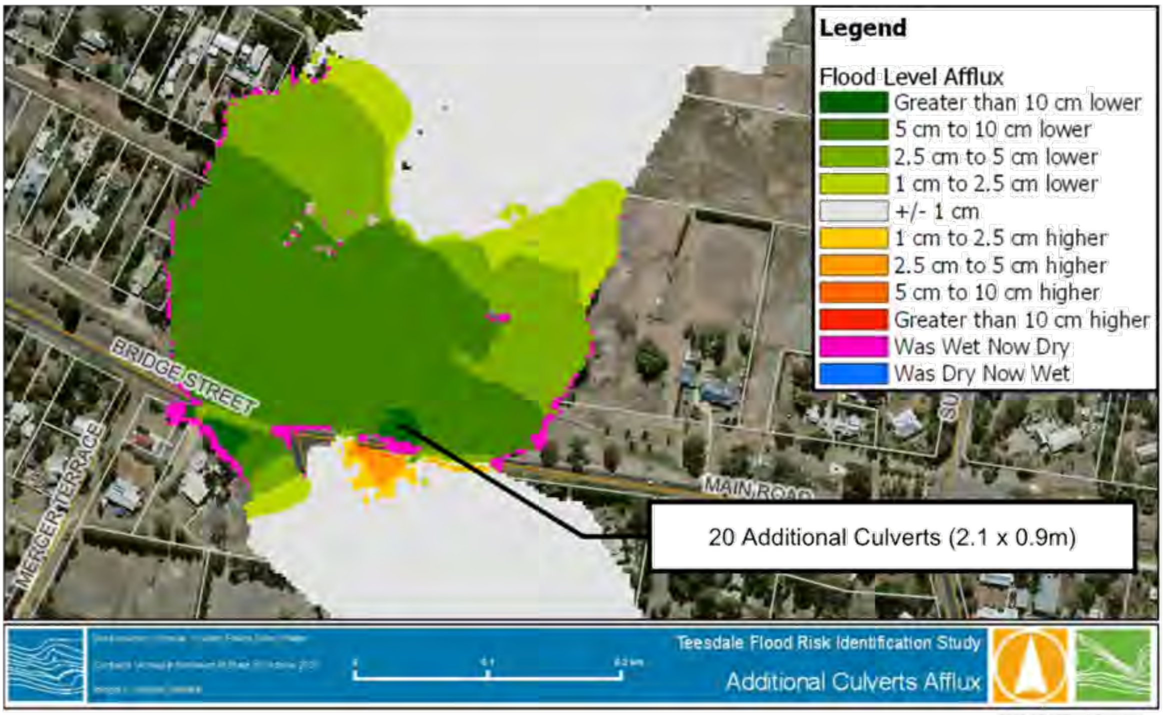

Figure 4-4 1% AEP Flood Level Afflux – Additional Culverts

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.

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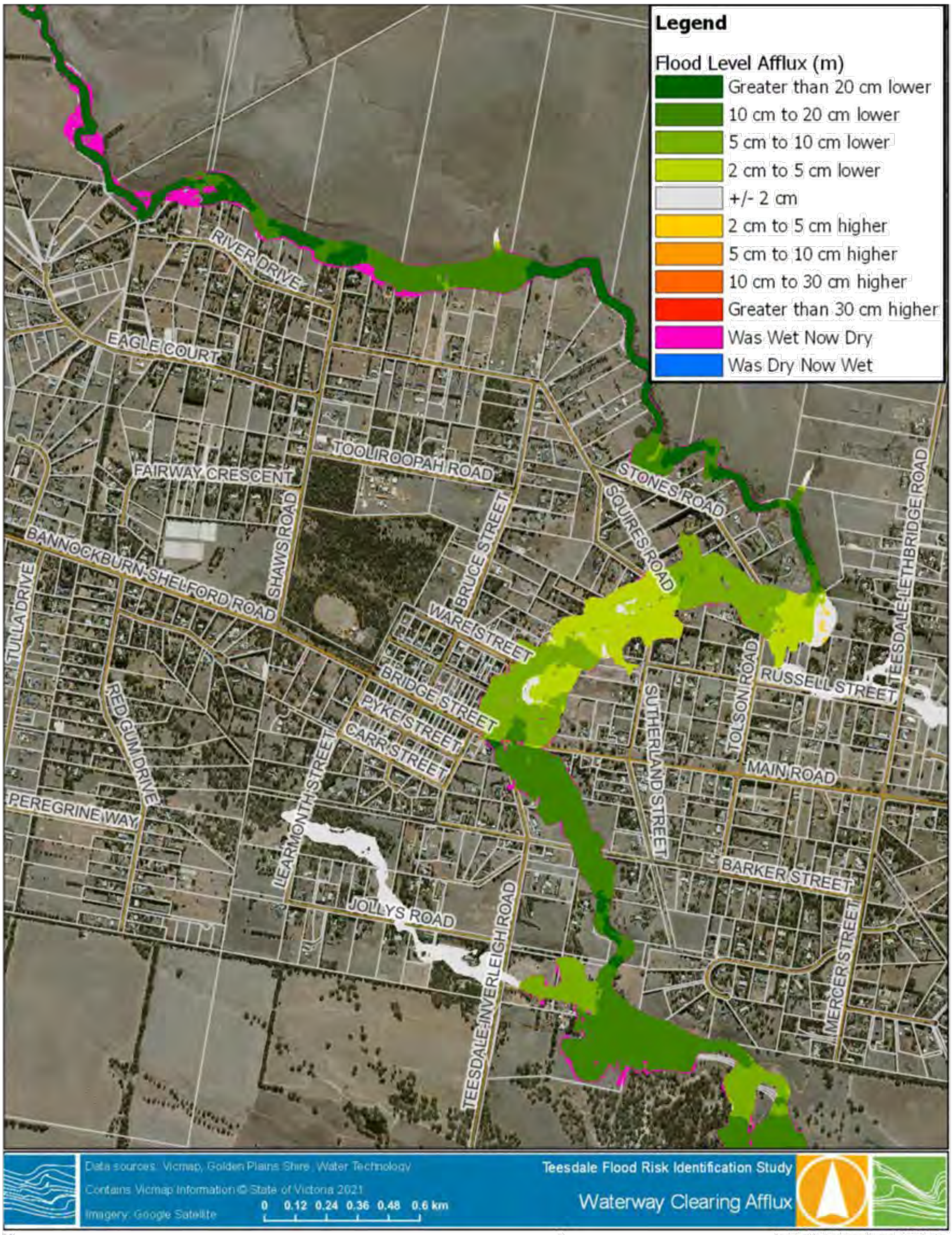

Figure 4-5 1% AEP Flood Level Afflux – Clearing of Native Hut Creek

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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.

M:\22010384_Flood_Risk_Identification_Study_for_Teesdale\Spatial\Workspaces\Teesdale_N 2023-05-02T17:29:23.226

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

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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.

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Telephone (07) 5676 7602

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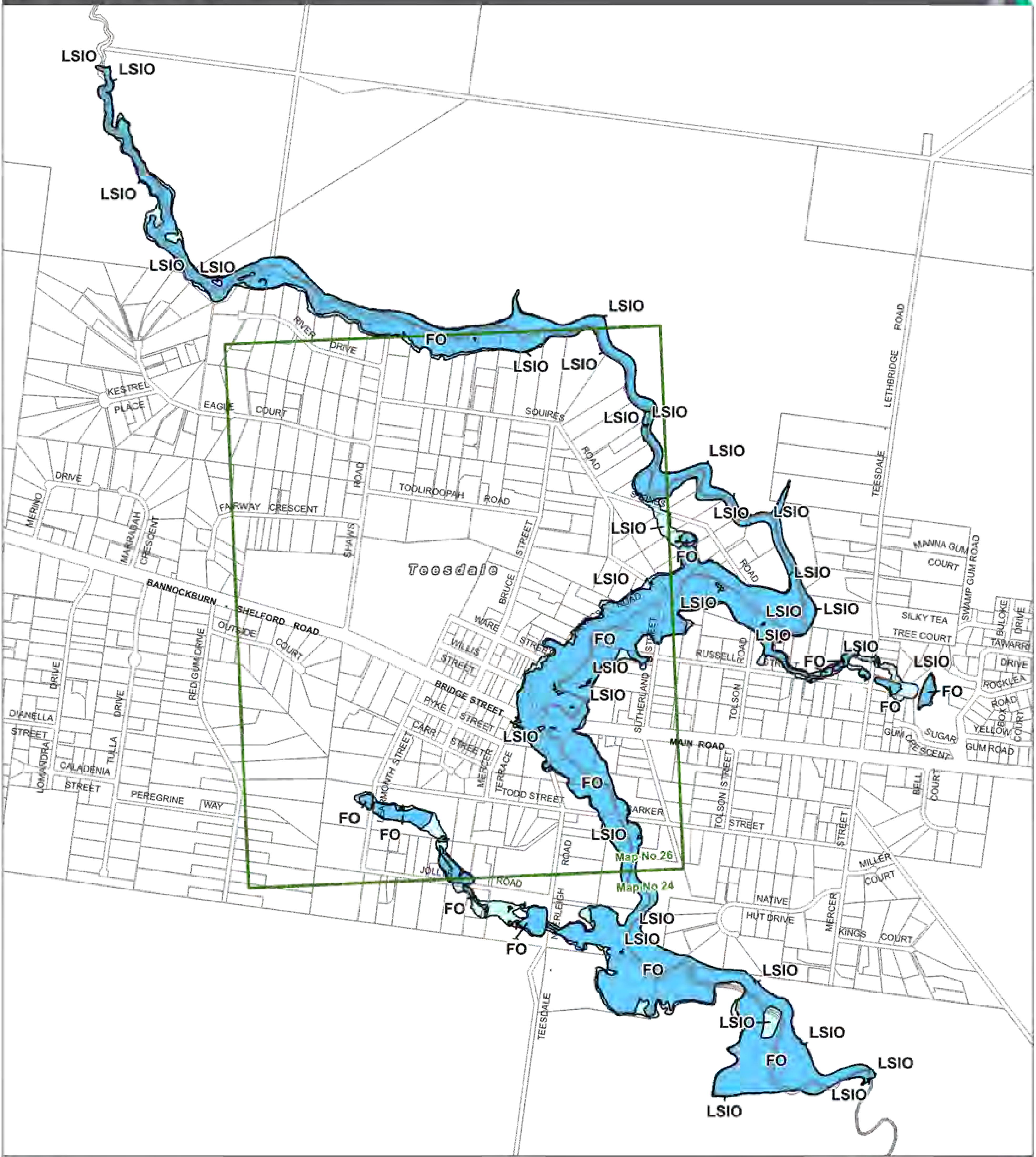
GOLDEN PLAINS PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C104gpla



LEGEND

FO - Floodway Overlay

LSIO - Land Subject to Inundation Overlay

Local Government Area

Part of Planning Scheme Maps 24LSIO-FO & 26LSIO-FO

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Planning Group
Print Date: 23/06/2023
Amendment Version: 1

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Metres

VICTORIA State Government
Department of Transport and Planning

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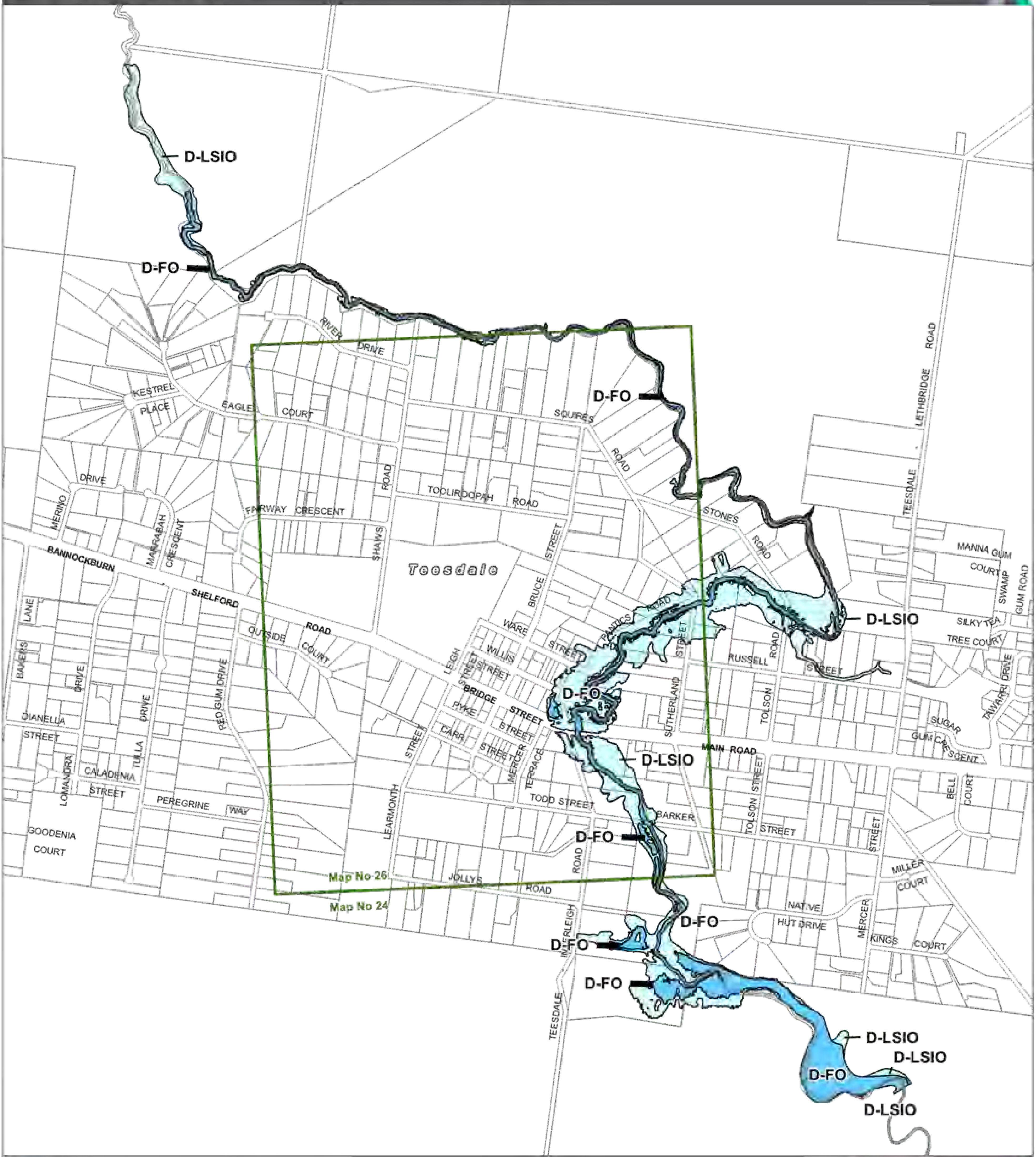
GOLDEN PLAINS PLANNING SCHEME - LOCAL PROVISION
AMENDMENT C104gpla



LEGEND

- D-FO - Area to be deleted from a Floodway Overlay
- D-LSIO - Area to be deleted from a Land Subject to Inundation Overlay
- Local Government Area

Part of Planning Scheme Maps 24LSIO-FO & 26LSIO-FO

Planning Group
Print Date: 23/06/2023
Amendment Version: 1

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Metres

VICTORIA State Government
Department of Transport and Planning

001

Planning and Environment Act 1987

GOLDEN PLAINS PLANNING SCHEME

AMENDMENT C104gpla

INSTRUCTION SHEET

The planning authority for this amendment is the Golden Plains Shire Council.

The Golden Plains Planning Scheme is amended as follows:

Planning Scheme Maps

The Planning Scheme Maps are amended by a total of two attached maps.

Overlay Maps

1. Delete Planning Scheme Map Nos.24LSIO-FO and 26LSIO-FO in the manner shown on the two attached maps marked "Golden Plains Planning Scheme, Amendment C104gpla".

2. Insert Planning Scheme Map Nos. 24LSIO-FO and 26LSIO-FO in the manner shown on the two attached maps marked "Golden Plains Planning Scheme, Amendment C104gpla".

End of document

Planning and Environment Act 1987

GOLDEN PLAINS PLANNING SCHEME

AMENDMENT C104GPLA

EXPLANATORY REPORT

Overview

This Amendment modifies the Land Subject to Inundation Overlay and Floodway Overlay Mapping in Teesdale as identified in the Teesdale Flood Risk Identification Study (Water Technology Pty Ltd, 2023).

Where you may inspect this amendment

The amendment can be inspected free of charge at the Golden Plains Shire website at https://www.goldenplains.vic.gov.au/resident/planning/strategic-planning-projects

And/or

The amendment is available for public inspection, free of charge, during office hours at the following places:

Bannockburn Customer Service Centre	The Well Smythesdale
2 Pope Street	19 Heales Street
Bannockburn VIC 3331	Smythesdale VIC 3351

The amendment can also be inspected free of charge at the Department of Transport and Planning website at http://www.planning.vic.gov.au/public-inspection or by contacting the office on 1800 789 386 to arrange a time to view the amendment documentation.

Submissions

Any person may make a submission to the planning authority about the amendment. Submissions about the amendment must be received by [insert submissions due date].

A submission must be sent to:

Attention: Daniel Murrihy

Golden Plains Shire

PO Box 111

BANNOCKBURN VIC 3331

Panel hearing dates

In accordance with clause 4(2) of Ministerial Direction No.15 the following panel hearing dates have been set for this amendment:

- directions hearing: [insert directions hearing date]
- panel hearing: [insert panel hearing date]

OFFICIAL

Details of the amendment

Who is the planning authority?

This amendment has been prepared by the Golden Plains Shire Council which is the planning authority for this amendment.

The amendment has been made at the request of the Golden Plains Shire Council and the Corangamite Catchment Management Authority.

Land affected by the amendment

The amendment applies to land in Teesdale that is affected by floodwater during a 1% Annual Exceedance Probability flood event with projected increases in rainfall intensity to 2100 under Representative Concentration Pathway RCP8.5, as identified in the Teesdale Flood Risk Identification Study (Water Technology Pty Ltd, 2023). The amendment applies to a large area of land, as indicated on the map below.

The attached Planning Scheme Amendment maps provide further details on the land affected by this amendment.

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A mapping reference table is attached at Attachment 1 to this Explanatory Report.

What the amendment does

The amendment implements the findings of the Teesdale Flood Risk Investigation Study, May 2023.

The amendment

- Amends maps 24LSIO-FO and 26LSIO-FO.

Strategic assessment of the amendment

Why is the amendment required?

The amendment is required to implement the findings of the Teesdale Flood Risk Investigation Study (Water Technology Pty Ltd, 2023). This study provides up to date and more accurate information on flooding in Teesdale than is currently included in the Golden Plains Planning Scheme; therefore the relevant Planning Scheme maps are being updated with the most accurate information available.

How does the amendment implement the objectives of planning in Victoria?

Section 4 of the Planning & Environment Act 1987 sets out the objectives for planning in Victoria, including the following:

- To provide for the fair, orderly, economic and sustainable use, and development of land;
- To secure a pleasant, efficient and safe working, living and recreational environment for all Victorians and visitors to Victoria;
- To balance the present and future interests of all Victorians.

Section 6 of the Planning and Environment Act 1987 identifies what planning schemes can provide for, including (among other things) the ability to:

- Regulate or prohibit any use or development in hazardous areas or in areas which are likely to become hazardous areas.

The Amendment responds to these objectives and responsibilities by identifying flood related hazards within Teesdale, and ensuring that the Planning Scheme accurately identifies the location of these hazards thus ensuring all people are provided with a safe environment, assets are appropriately designed and located, and future development does not compromise natural systems.

The Amendment will assist landowners in understanding potential hazards and guiding development on their land and will assist Council and the Corangamite Catchment Management Authority in making more informed and effective decisions on development of land affected by flooding.

How does the amendment address any environmental, social and economic effects?
Environmental

The Amendment should have a positive effect on the environment. Flooding has environmental benefits as flood-prone areas may provide valuable habitats for plants and animals and serve as natural water storage areas. Areas of environmental significance, such as swamps, billabongs and wetlands have an important role to play in supporting biodiversity, recycling nutrients and maintaining water quality. By accurately identifying flood-prone areas, these areas can be protected from inappropriate development that may pose a threat to water quality and flora and fauna communities. The identification of flood-prone areas will ensure that development is compatible with local environmental conditions including flood hazards and drainage conditions.

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Social

The Amendment seeks to protect new development from the effects of flooding and minimise the effect of development on flood processes.

Economic

The Amendment is expected to have positive economic and social benefits for the municipality. Flooding carries significant costs for the community, individual landowners and the state. Flood damage can disrupt communities and in extreme cases, cause extensive and costly damage to public and private assets, cause agricultural losses, personal hardship and loss of life. By careful planning of new development and earthworks having regard to environmental risks, future financial and community impacts of flooding can be reduced.

Does the amendment address relevant bushfire risk?

The amendment meets bushfire policy in Clause 13.02 of the Planning Scheme because there is no additional bushfire risk that will be caused as a result of the proposed amendment.

Does the amendment comply with the requirements of any Minister's Direction applicable to the amendment?

The amendment complies with Minister Direction No. 11 (Strategic Assessment of Amendments) under section 12 of the Planning and Environment Act 1987. The amendment is consistent with this direction which ensures a comprehensive strategic evaluation of a planning scheme amendment and the outcomes it produces.

How does the amendment support or implement the Planning Policy Framework and any adopted State policy?

The amendment implements and is supported by the State Planning Policy Framework through the following provisions:

- Clause 11 Settlement - identifies that planning for settlements, must have regard to health and safety. The Amendment supports this principle by documenting the extent of flooding and the degree of risk from its impacts by using the Floodway Overlay for areas that are at risk of faster flood flows and depths and the Land Subject to Inundation Overlay for overflow areas. Clause 11 also identifies the need to plan for Climate change adaptation and mitigation. The Amendment supports this principle by identifying land that is likely to be within the 1% AEP flood extent under climate change projections to 2100.
- Clause 13.01-1S Natural hazards and climate change – identifies the need for adaptation response strategies for existing settlements in risk areas to accommodate change over time. The amendment assists in implementing this by providing more accurate information to guide subdivision and development in responding to risks associated with flooding now and into the future.
- Clause 13.03-1S Floodplain management – identifies that planning is to assist the protection of:
  - Life, property and community infrastructure from flood hazard, including coastal inundation, riverine and overland flows.
  - The natural flood carrying capacity of rivers, streams and floodways.

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- The flood storage function of floodplains and waterways.
- Floodplain areas of environmental significance or of importance to river, wetland or coastal health.

The amendment supports these objectives by accurately identifying the floodplains of Teesdale and ensuring that planning controls that seek to protect the environmental functions of the floodplain are accurately applied.

How does the amendment support or implement the Municipal Planning Strategy?

This amendment seeks to implement the MPS Clause 02.03-3

Floodplain management

The catchments of the various rivers and streams within Golden Plains Shire include areas of flood prone land where flooding has historically caused substantial damage to the natural and built environment. The town of Inverleigh is most affected by flooding due to the confluence of the Leigh and Barwon Rivers. The Woady Yaloak River is another key floodplain affecting the north of the Shire. Natural flooding, long term productivity of flood prone land, river and wetland health are all closely linked. Inappropriate development on the floodplain can lead to the deterioration of environmental values and reduced agricultural production.

The impact of floods is increasing due to land use and vegetation changes. In particular, urban expansion, raised earthworks and the clearing of land for rural and urban development have all contributed to the increase in the instances of flooding.

Council seeks to mitigate flood risk by:

- Discouraging the intensification of land use and development in floodplains.
- Ensuring the future use and development of land prone to flooding minimises the consequences of inundation on life and property.
- Protecting floodways for their role in conveying floodwater.

Does the amendment make proper use of the Victoria Planning Provisions?

The amendment makes changes to existing Planning Scheme maps, and minor policy neutral changes to existing ordinance, as such it is considered that the amendment utilises the most effective controls available from the Victoria Planning Provisions in the form of the gazetted Golden Plains Planning Scheme.

How does the amendment address the views of any relevant agency?

The Amendment has been prepared in consultation with the Corangamite Catchment Management Authority (CCMA). The extent of the overlays and the configuration of the mapping included in this Amendment have been prepared in consultation with the CCMA. Other agencies will be consulted via the exhibition process of this amendment.

Does the amendment address relevant requirements of the *Transport Integration Act 2010*?

The Amendment will not impact upon the transport system objectives and decision making principles as set out in the Transport Integration Act 2010.

Resource and administrative costs

What impact will the new planning provisions have on the resource and administrative costs of the responsible authority?

The amendment will improve the application and administration of the Golden Plains Planning Scheme, through providing certainty for Council, CCMA and land owners. It is considered that the amendment will have a minor impact on the resource and administrative costs of the Responsible Authority due to the additional land area covered by the Land Subject to Inundation Overlay and the Floodway Overlay. It is further considered that these increased demands will be offset by the improved performance of the planning scheme and the potential for reduced demands on Council's emergency management response and flood recovery resources.

ATTACHMENT 1 - Mapping reference table

Location	Land /Area Affected	Mapping Reference	Address	Proposed changes		
				Zone	Overlay	Deletion
Teesdale	Land in Teesdale affected by the 1% Annual Exceedance Probability flood extent as identified in the Teesdale Flood Risk Identification Study (Water Technology Pty Ltd, 2023).	Golden Plains C104gpla 002lsio-foMaps24_26 Exhibition			LSIO FO	D-LSIO D-FO

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