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 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 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.

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

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.

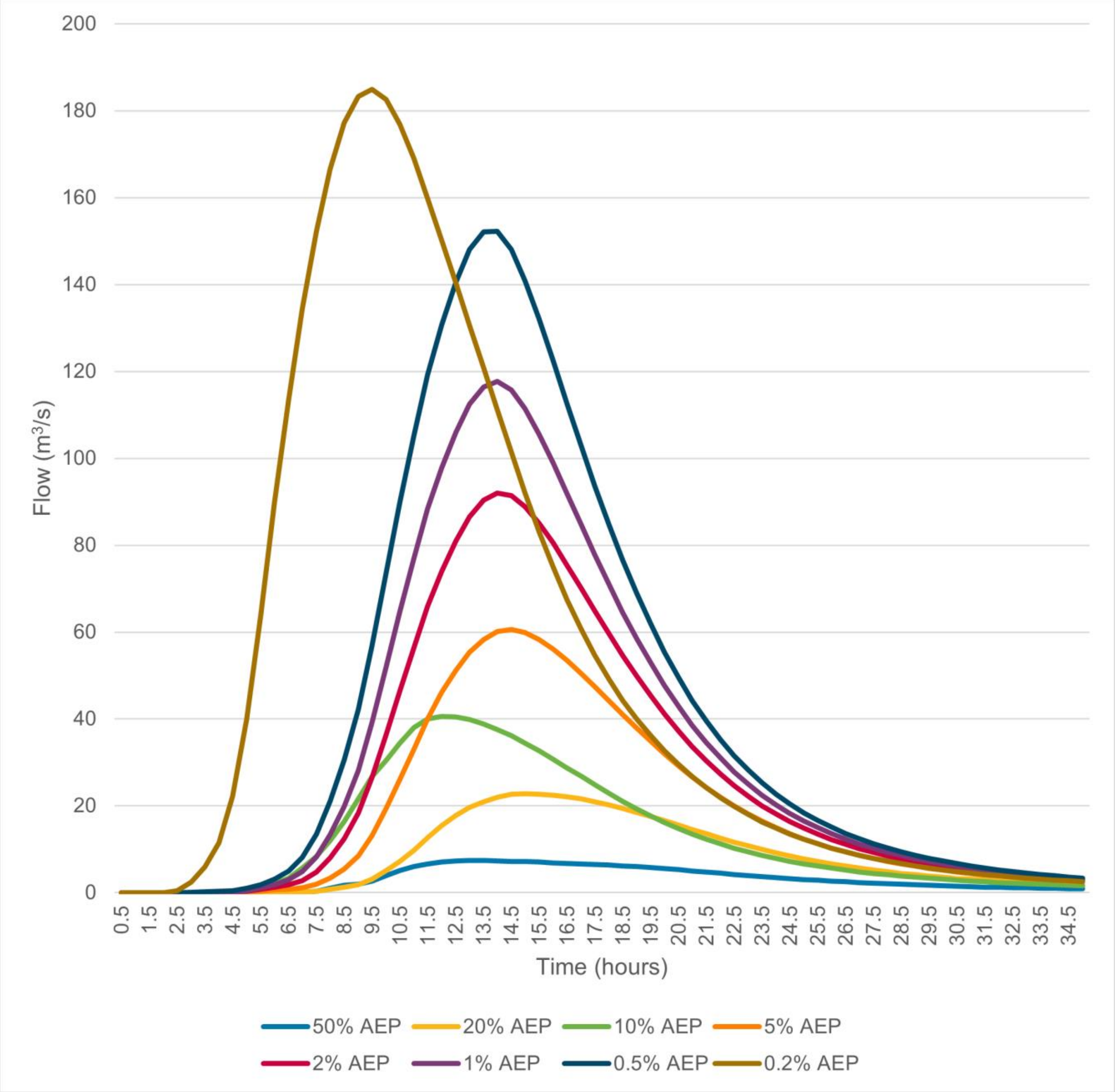

Figure 1 Design hydrographs, Native Hut Creek at Bannockburn-Shelford bridge

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.

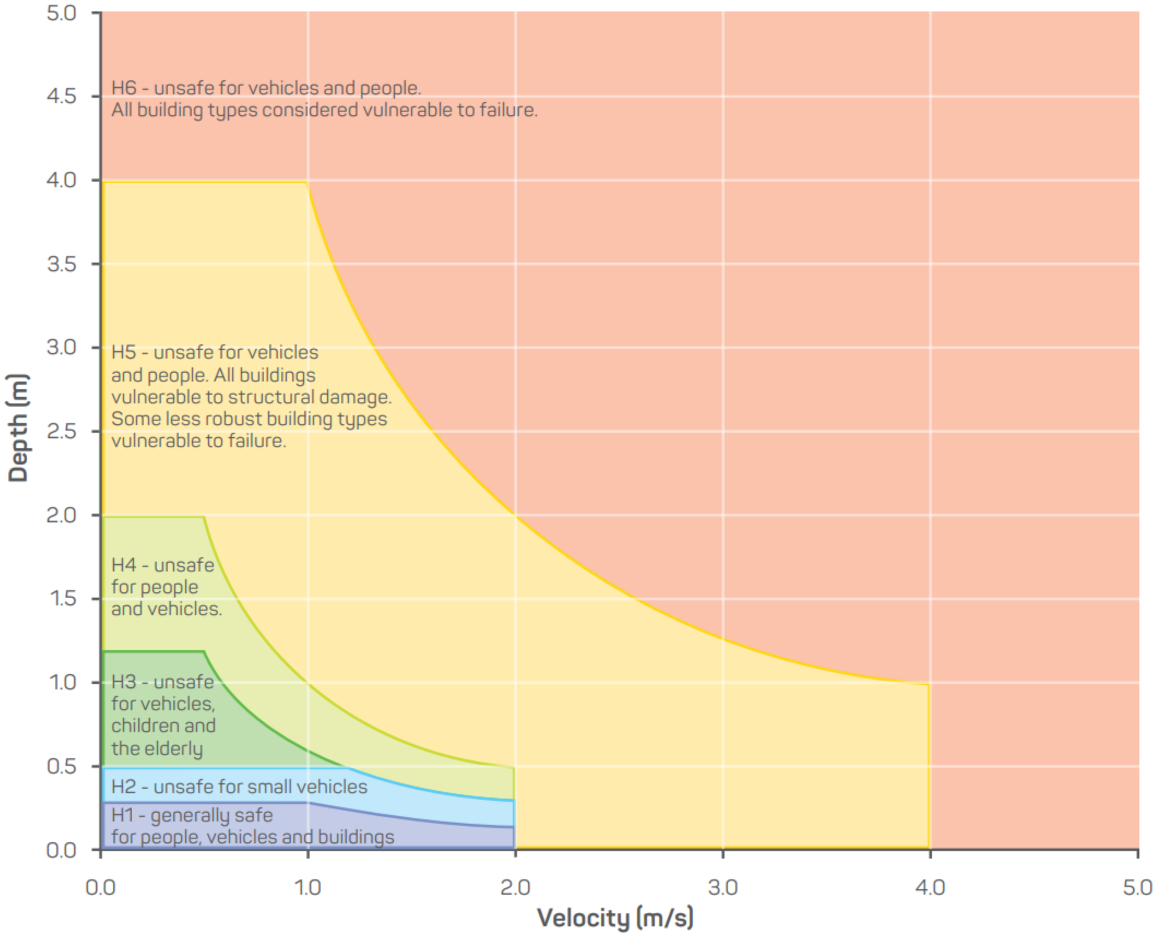

Figure 2 Hazard classifications (AIDR 2017)

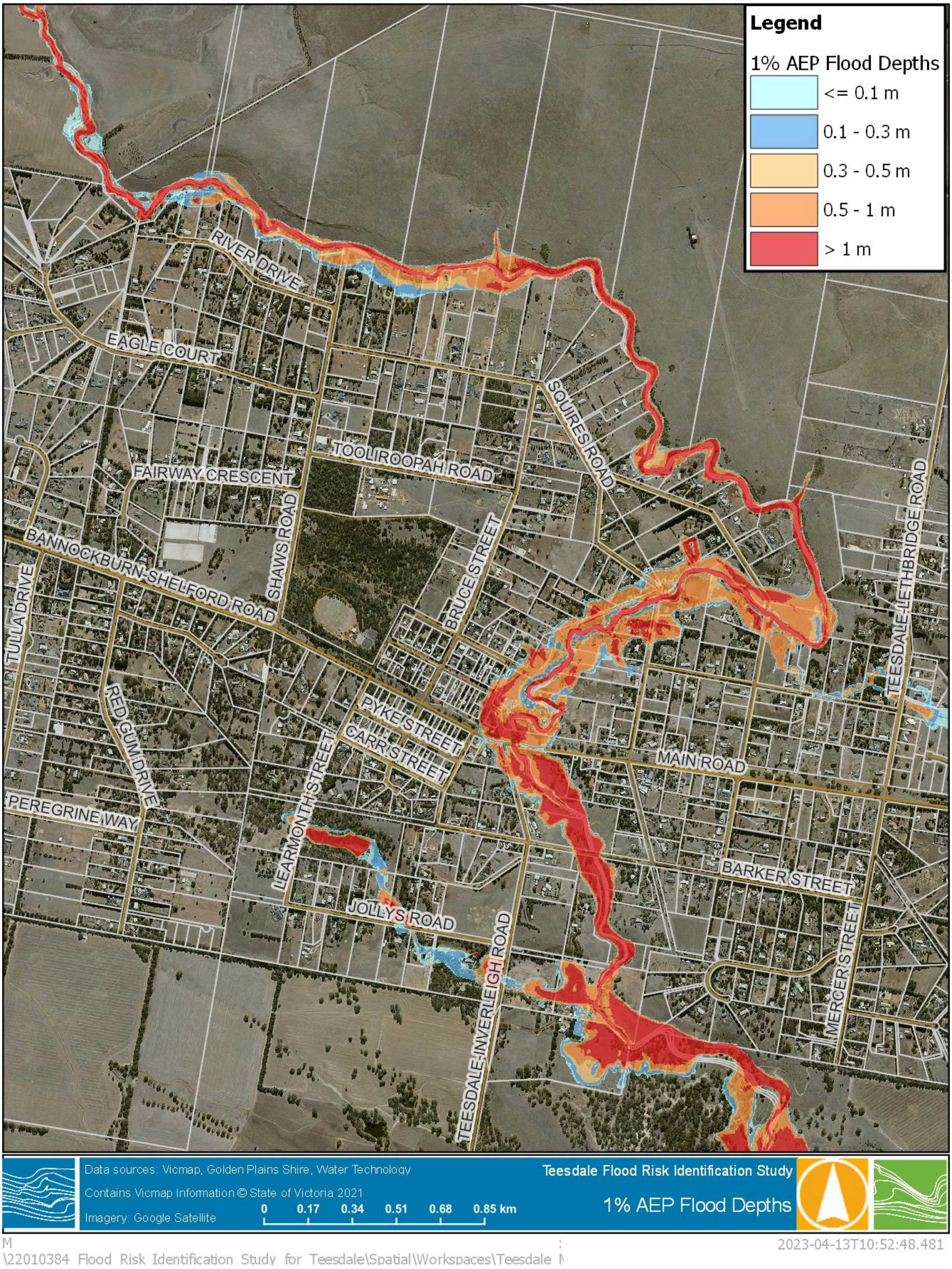

Figure 3 1% AEP Flood Depths in Teesdale (Existing Conditions)

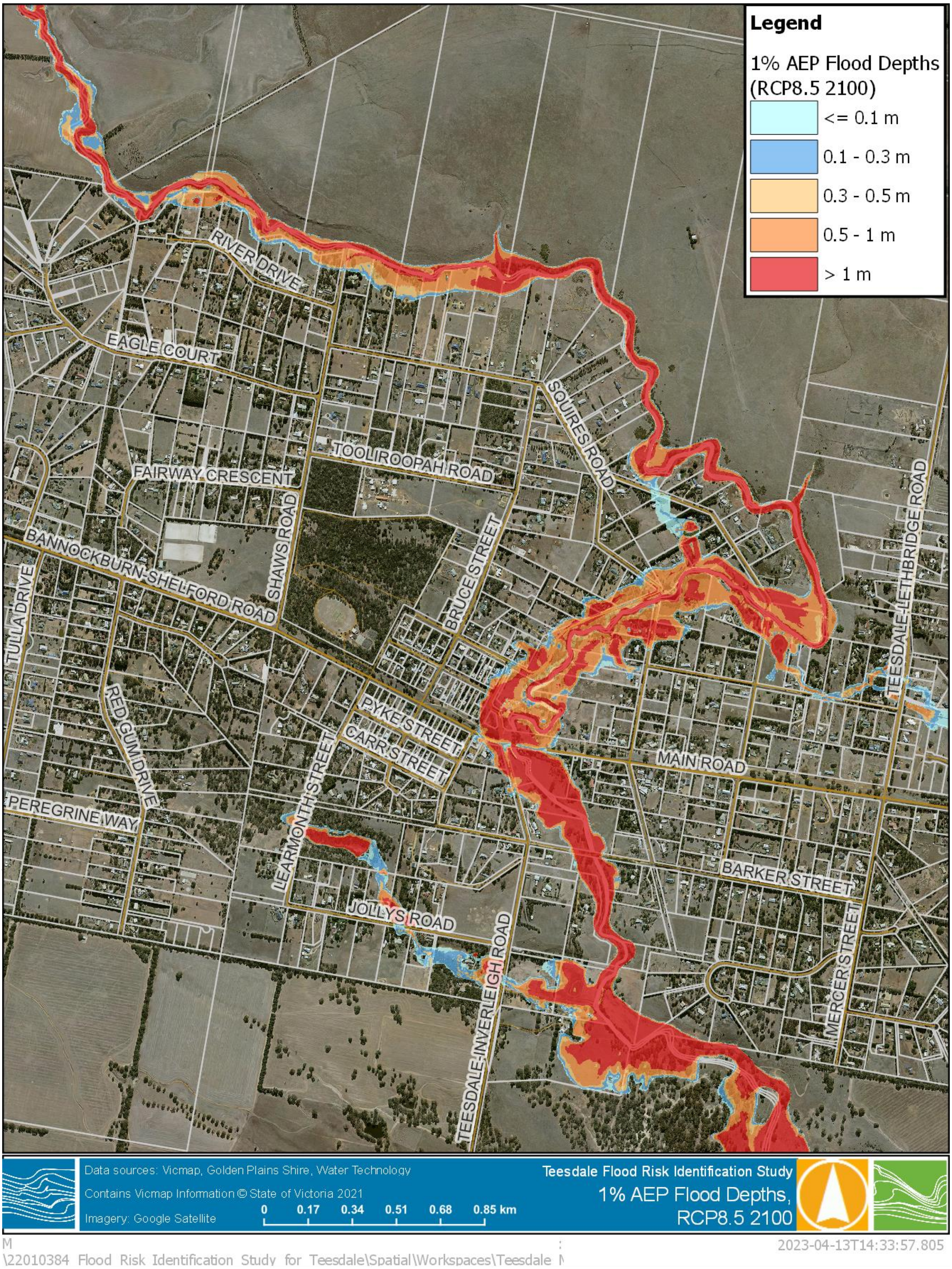

Figure 4 1% AEP Flood Depths in Teesdale under projected RCP8.5 to 2100

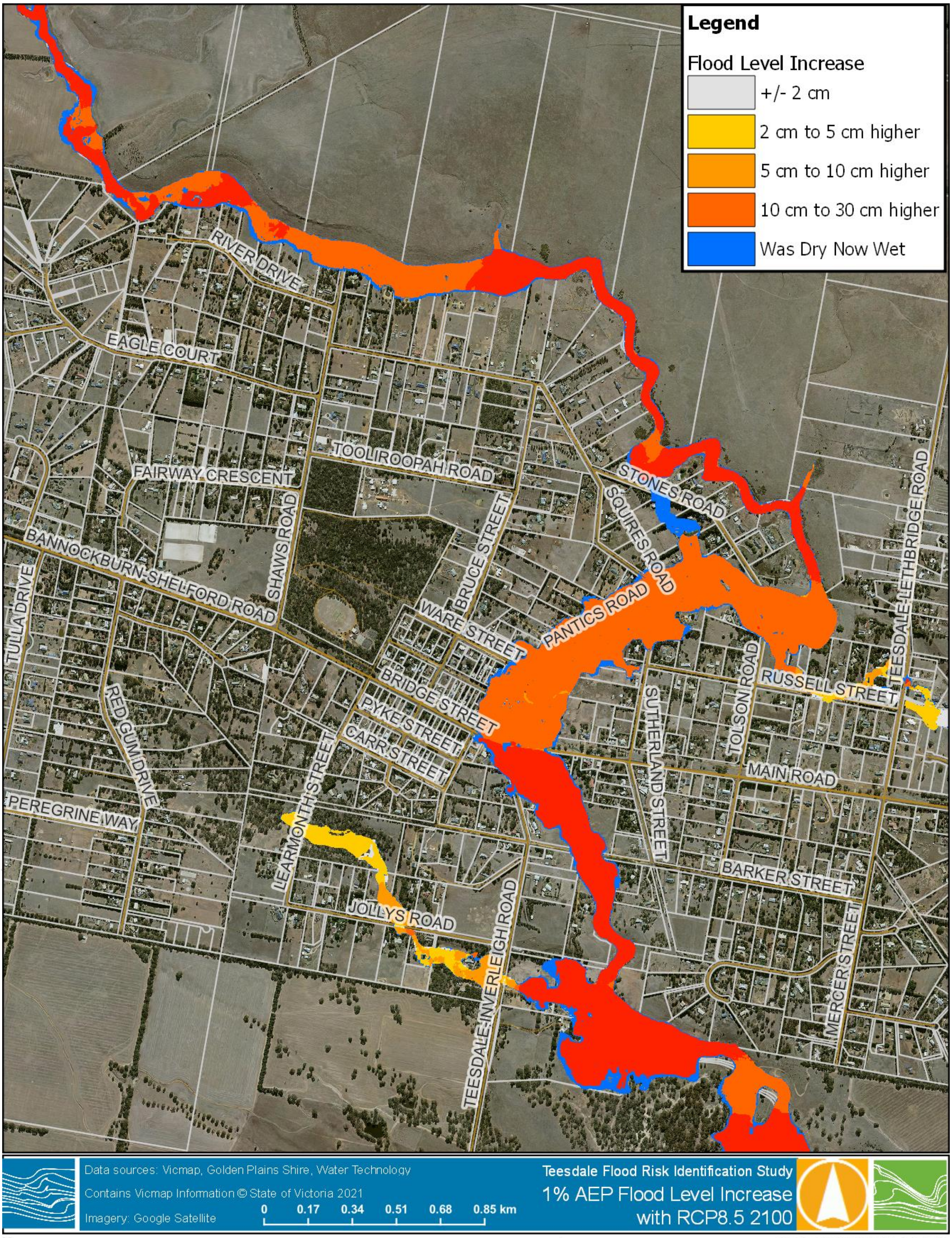

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Figure 5 Flood level increase under RCP8.5 projections to 2100 for the 1% AEP event

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.

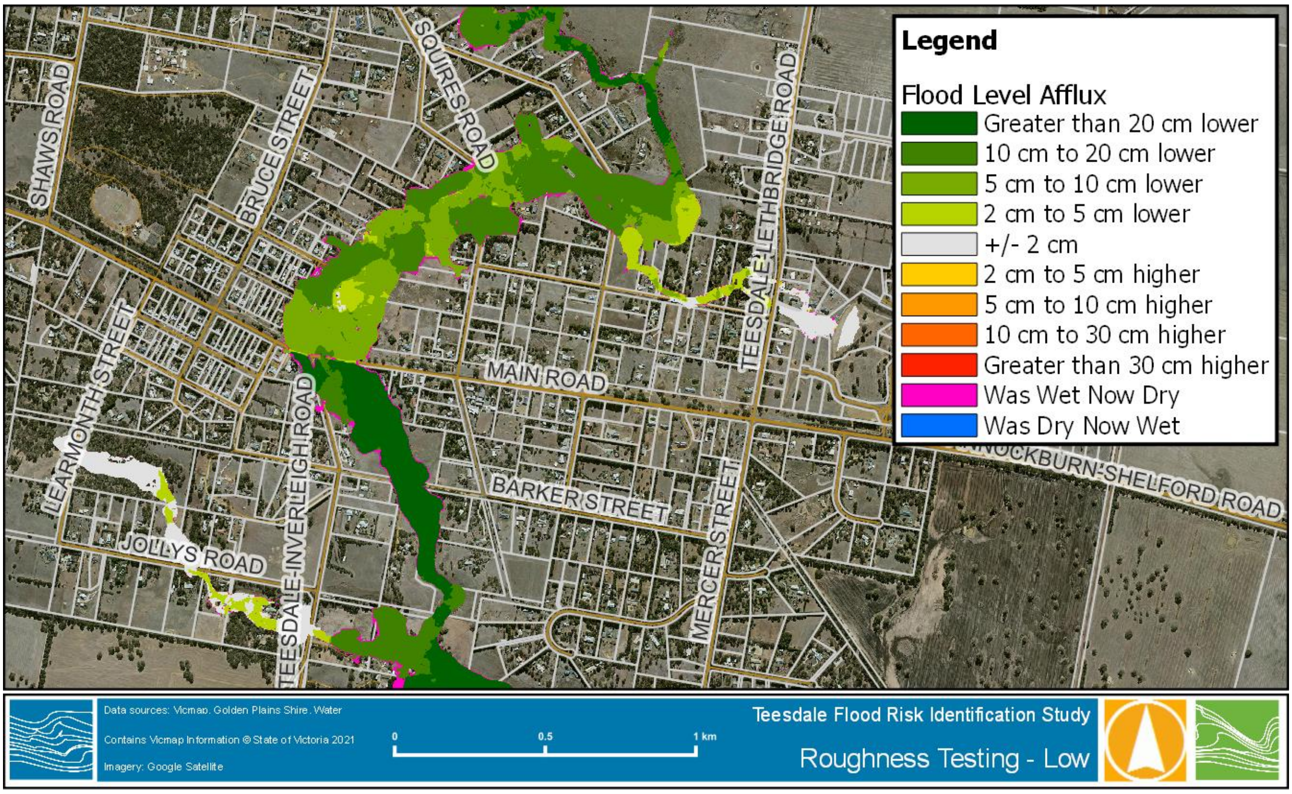

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Figure 6 Low roughness sensitivity testing afflux mapping

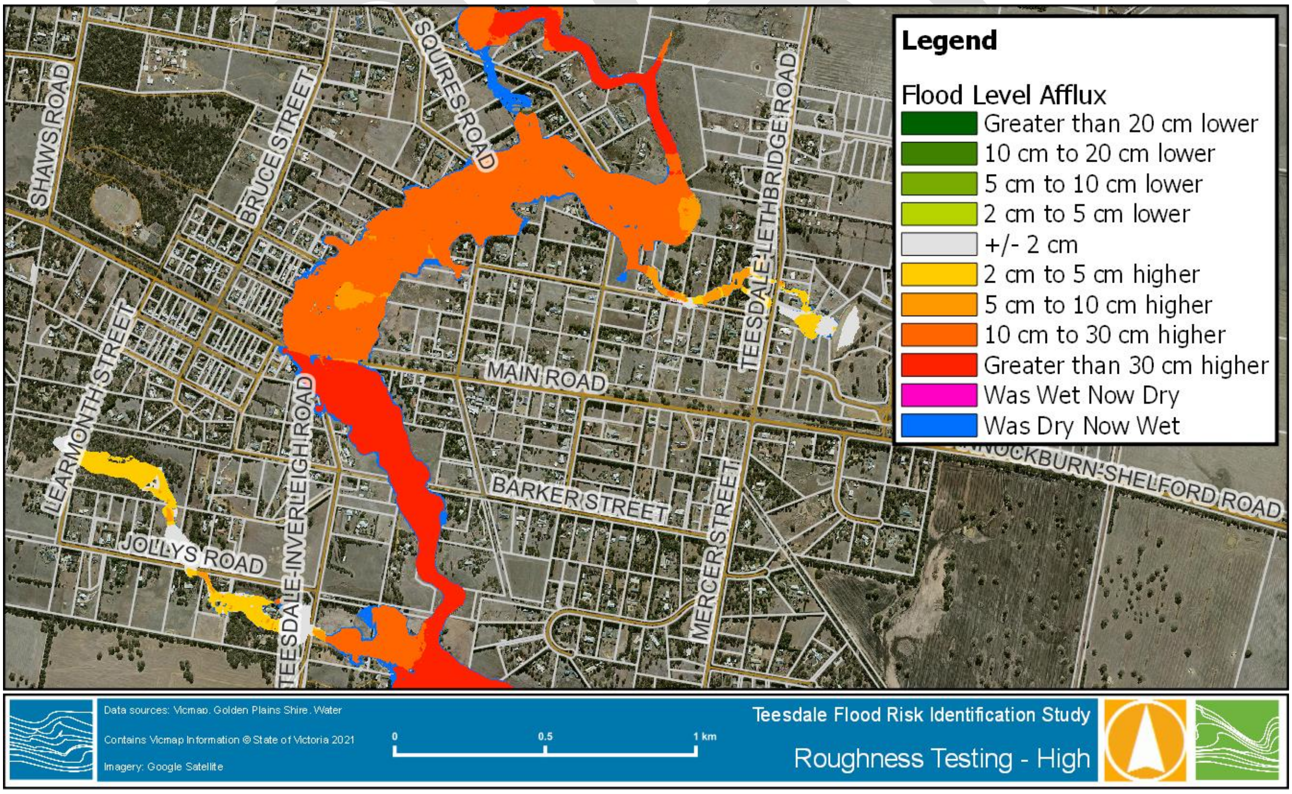

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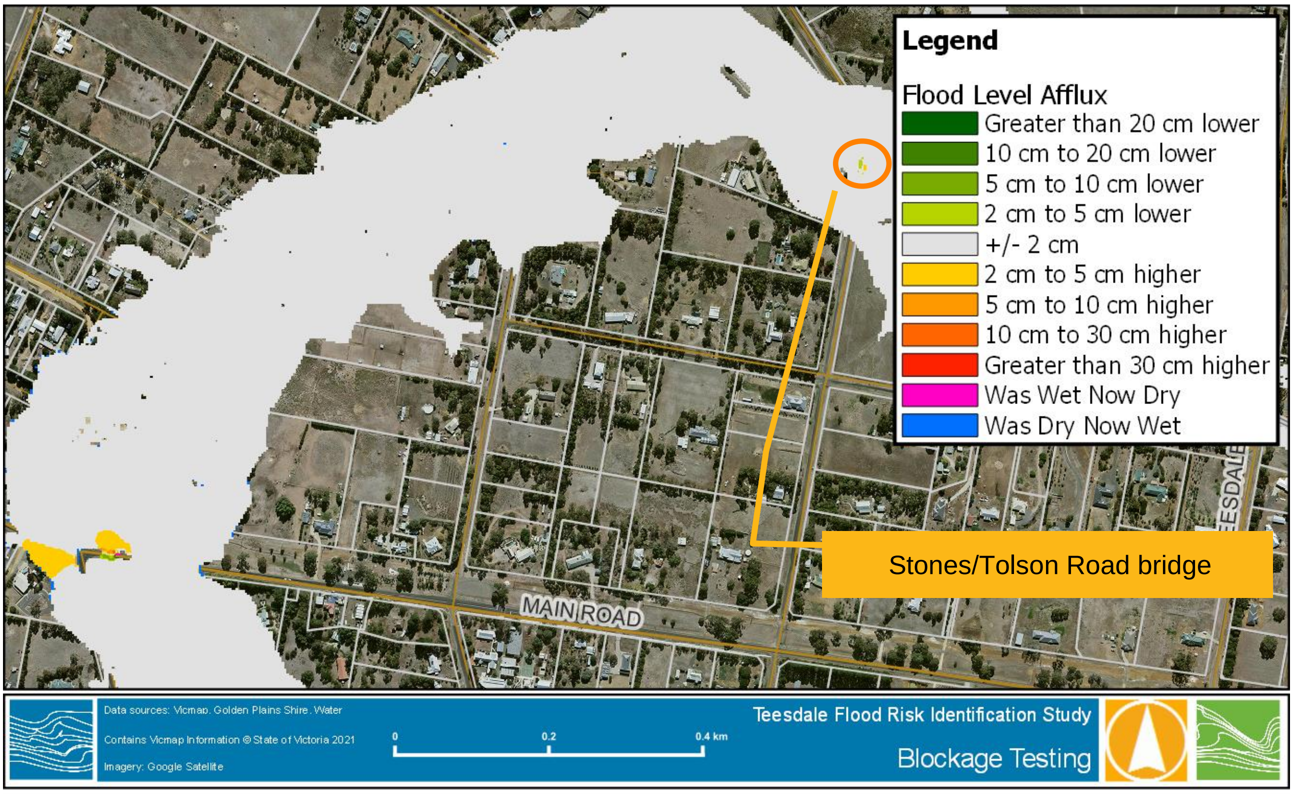
Figure 7 High roughness sensitivity testing afflux mapping

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.



Stones/Tolson Road bridge

Data sources: Vicmap, Golden Plains Shire, Water
Contains Vicmap Information © State of Victoria 2021
Imagery: Google Satellite

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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.

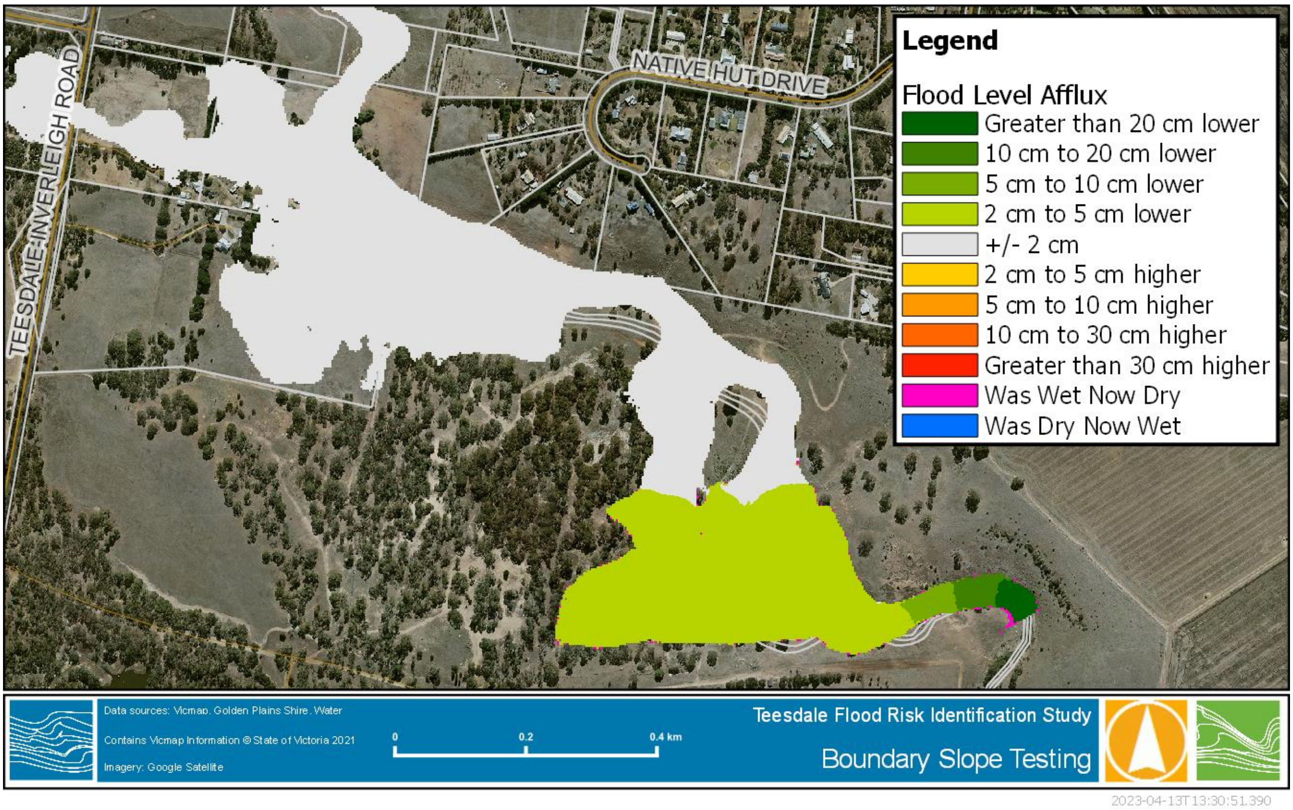

Figure 9 Boundary slope sensitivity testing afflux mapping

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.

APPENDIX A
FLOOD MAP PDFS

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