Otago Regional Council

Hydraulic Support for Silver Stream and Gordon Road Floodway Modelling

19 October 2022

BLOXAM BURNETT & OLLIVER

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1. Introduction

1.1 Overview

The Lower Taieri River floodplain comprises mainly farmland, but also includes several townships, the largest being Mosgiel and Outram and the Lower Taieri River floodplain also contains critical infrastructure including Dunedin International Airport (Figure 1). The Lower Taieri River floodplain is exposed to flooding from Taieri River, Silver Stream, Mill Creek, Owhiro Stream, Contour Channel, and runoff from other surrounding hill catchments.

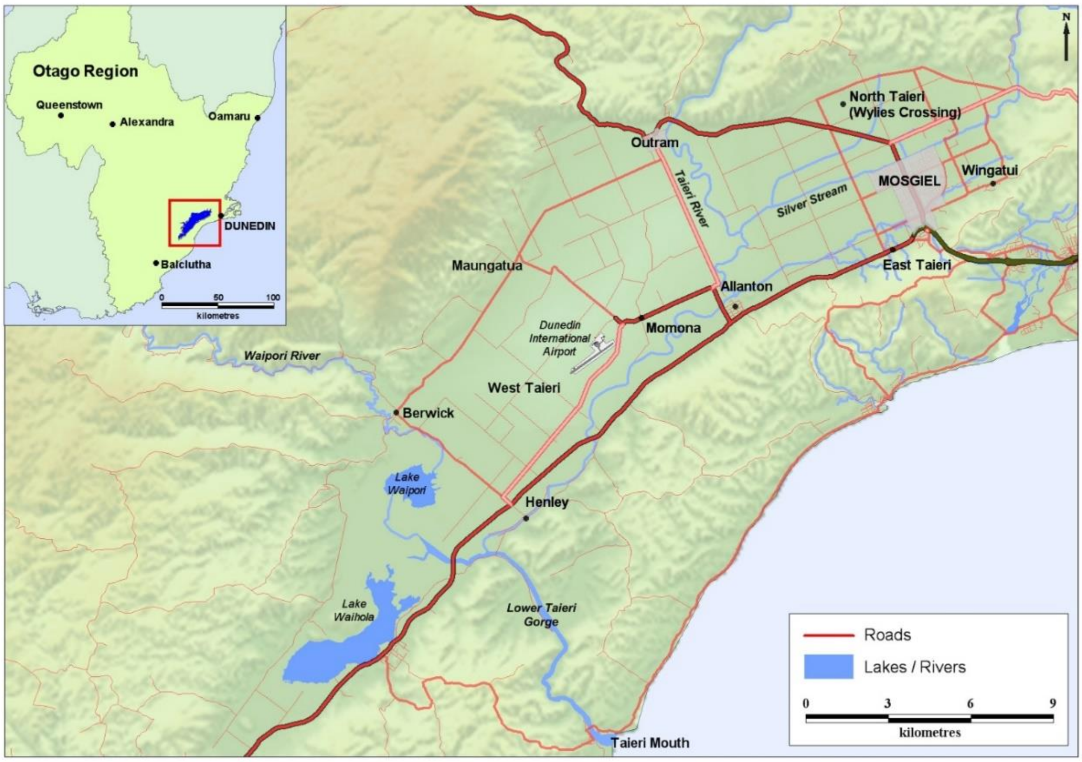

Figure 1. Lower Taieri River floodplain (ORC, 2015).

Otago Regional Council (ORC) initiated the flood-hazard characterization and mapping of the Lower Taieri floodplain in 2006, which was later refined in 2013, 2014 and 2015. The flood hazard map (as presented in Figure 2) was created based on elevation data, historical flood extents, along with flood-extent photos and observations provided by residents, landowners, and ORC field staff during previous flood events.

The North Taieri area is bounded by a range of 300 to 500m high hills to the north, Silver Stream to the south, the East Taieri Upper Pond cut-off bank to the west, and Miners Road to the east. This area is exposed to flooding from Silver Stream, Mill Creek, and small catchments to the north. The Upper Pond cut-off bank is intended to prevent water from the Taieri River from entering this area. ORC has demarked the North Taieri into four hazards areas namely: Area 14A, 14B, 14C, and 14D (Figure 3). Among these four hazard zones, ORC wants to have better understanding of how the North Taieri floodway, also known as Gordon Road floodway (Area 14B), is impacted during flood events.

This report describes the flood hazard assessment carried out to better understand how the North Taieri/Gordon Road floodway is impacted during flood events and details the development of the hydraulic model used to inform the assessment.

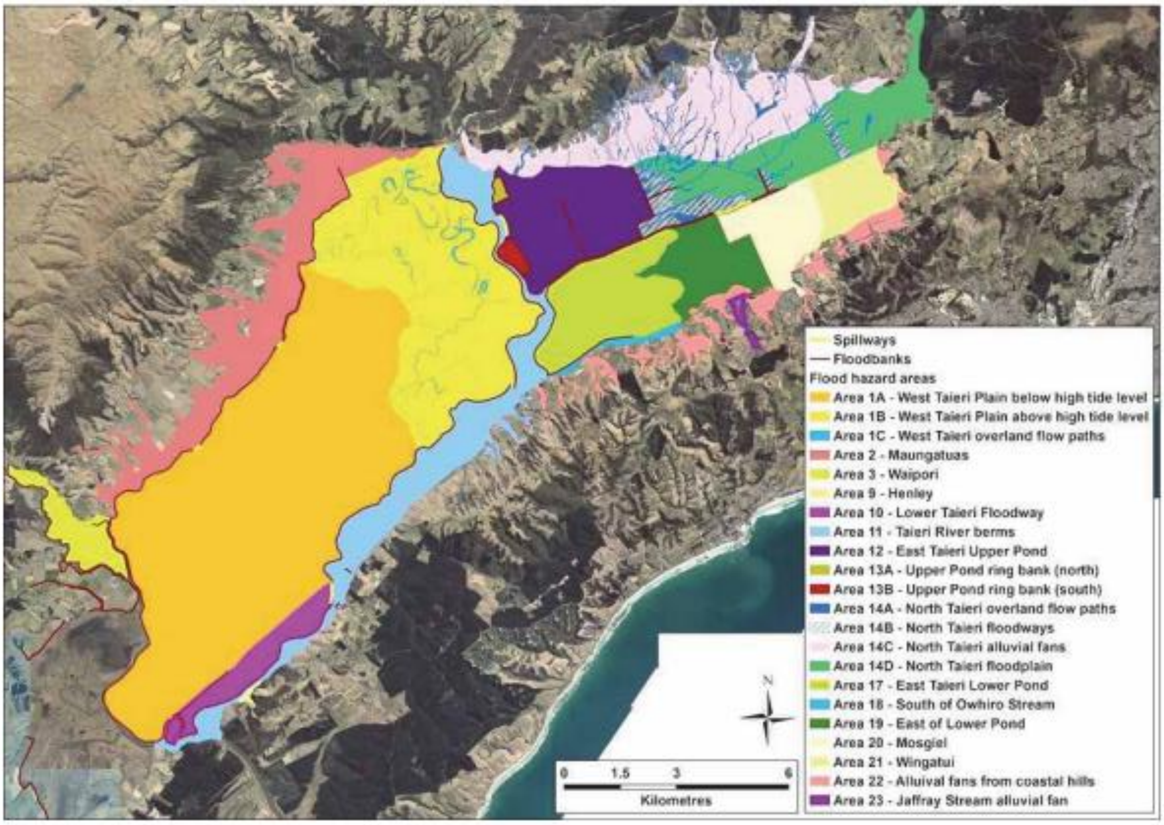

Figure 2. Flood hazard areas of Taieri Floodplain (ORC, 2015).

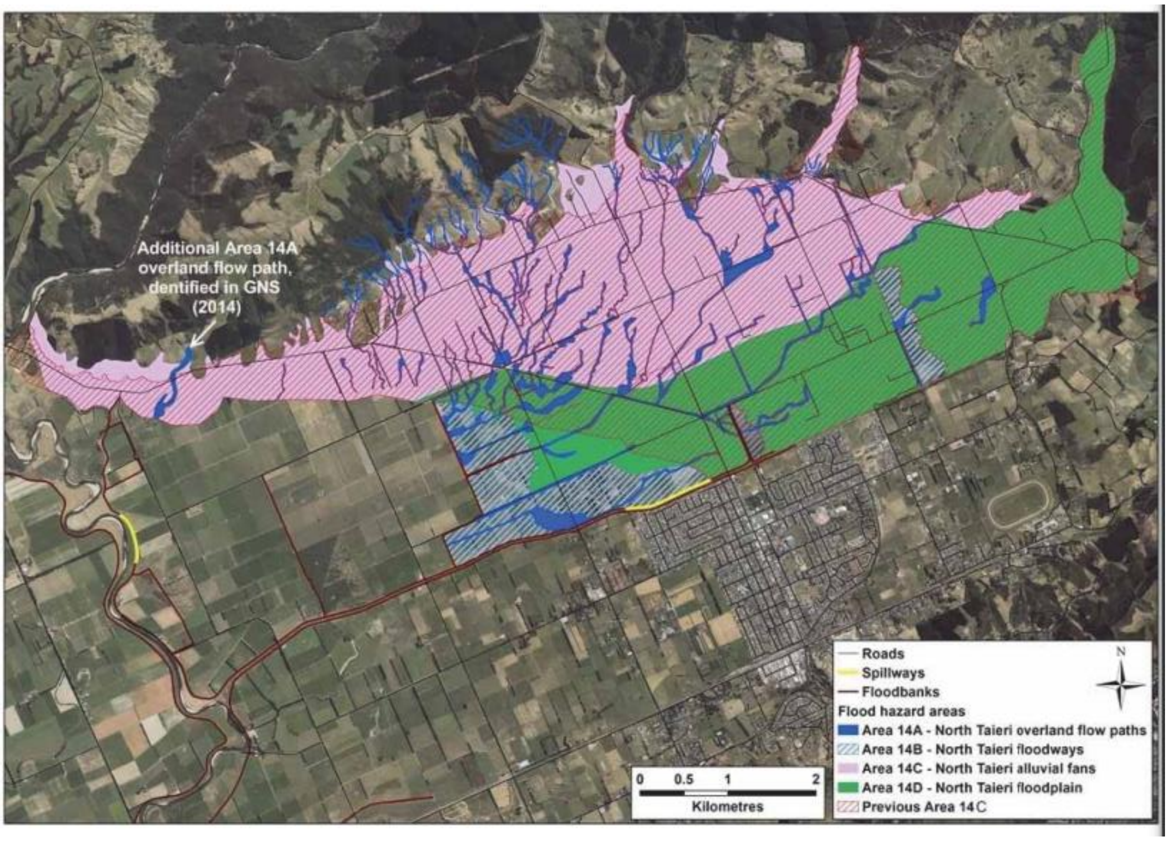

Figure 3. Hazard areas for North Taieri (ORC, 2015).

1.2 Scope

The scope of the investigation was to carry out the flood hazard assessment to determine how North Taieri/Gordon Road floodway, more specifically the area between cut-off banks and State Highway 87, is impacted in flood events using the Taieri hydraulic model previously completed by ORC. The assessment was carried out for July 2017 and 100-yr ARI events.

2. Hydraulic model configuration and hydrological inputs

2.1 Hydraulic model setup

ORC maintains the HEC-RAS (version 5.0.3) 1-Dimensional (1D) / 2-Dimensional (2D) hydraulic model for the Silver Stream, which was created in 2019 to assess the implication of morphological changes of the Silver Stream on the performance of the Gordon Road spillway and recommend possible measures to reduce the impact. The floodplain was modelled as a 2D component, and the Silver Stream was modelled as a 1D component. The 2D flow area elements were connected laterally to the 1D river reach using lateral structures/weirs. 1D and 2D flow area connections in the model primarily represent the existing flood banks which are modelled as broad-crested weirs. For greater accuracy, the station-elevation data for the weir profiles were based on surveyed crest levels, rather than the LiDAR profile. The two bridges over Silver Stream at Gordon Road and Riccarton Road were also modelled using energy equation.

The existing 1D/2D model covers the area between Outram-Mosgiel Road (SH 87) on the east and north, Owhiro River on the south and Taieri River on the west (as presented in Figure 4). The existing model has been setup utilizing 2016 LiDAR data (Figure 5), which has an expected vertical accuracy of +/- 30 cm, along with 23 surveyed cross-sections of the Silver Stream (March 2003, November 2011 and October 2017), and flood bank crest level survey data gathered in July 2017. The cross-section spacing for Silver Stream ranges between 50m – 488m. Land use data (Figure 6) from Landcare Research (LCDB v4.1 - Land Cover Database version 4.1, Mainland New Zealand) was used to set Manning’s roughness values for floodplain areas (Table 1). Manning’s roughness values for floodplain areas were set based on recommendations made by Chow (1959), Babister and Barton (2012), and previous modelling exercises.

The model has been calibrated using a June 2015 event and validated for May 2006, May 2010, and July 2017 events as presented in Figure 7. The debris data collected for four different flood events (May 2006, May 2010, June 2015, and July 2017) were used for model calibration and validation. It is to be noted that during the calibration period (June 2015) Silver Stream cross-section surveyed in November 2011 was used, while for the validation period of May 2006, May 2010 and July 2017 Silver Stream cross-section surveyed in March 2003, November 2011 and October 2017 were used, respectively. During the calibration process Manning’s n roughness value of the Silver Stream channel was changed. The Manning’s n of 0.03 was found to be appropriate representation of channel roughness for the Silver Stream. The comparison of modelled water level against the debris mark suggests that the modelled value aligns well with the debris marks.

Table 1. Hydraulic Roughness of the floodplain area.

Surface type	Manning's n
Broadleaved indigenous hardwoods	0.05
Built-up area	0.15
Deciduous hardwoods	0.09
Exotic forest	0.09
Flax land	0.1
Forest-harvested	0.05
Gorse and /or broom	0.2
Gravel or rock	0.02
Herbaceous freshwater vegetation	0.06
High producing grassland	0.05
Indigenous forest	0.09
Lake or pond	0.01
Low producing grassland	0.035
Manuka and/or Kanuka	0.15
Mixed exotic shrubland	0.05
Orchard, vineyard or other perennial crop	0.05
Short-rotation cropland	0.04
Surface mine or dump	0.03
Tall tussock grassland	0.05
Transport infrastructure	0.016
Urban parkland/open space	0.035

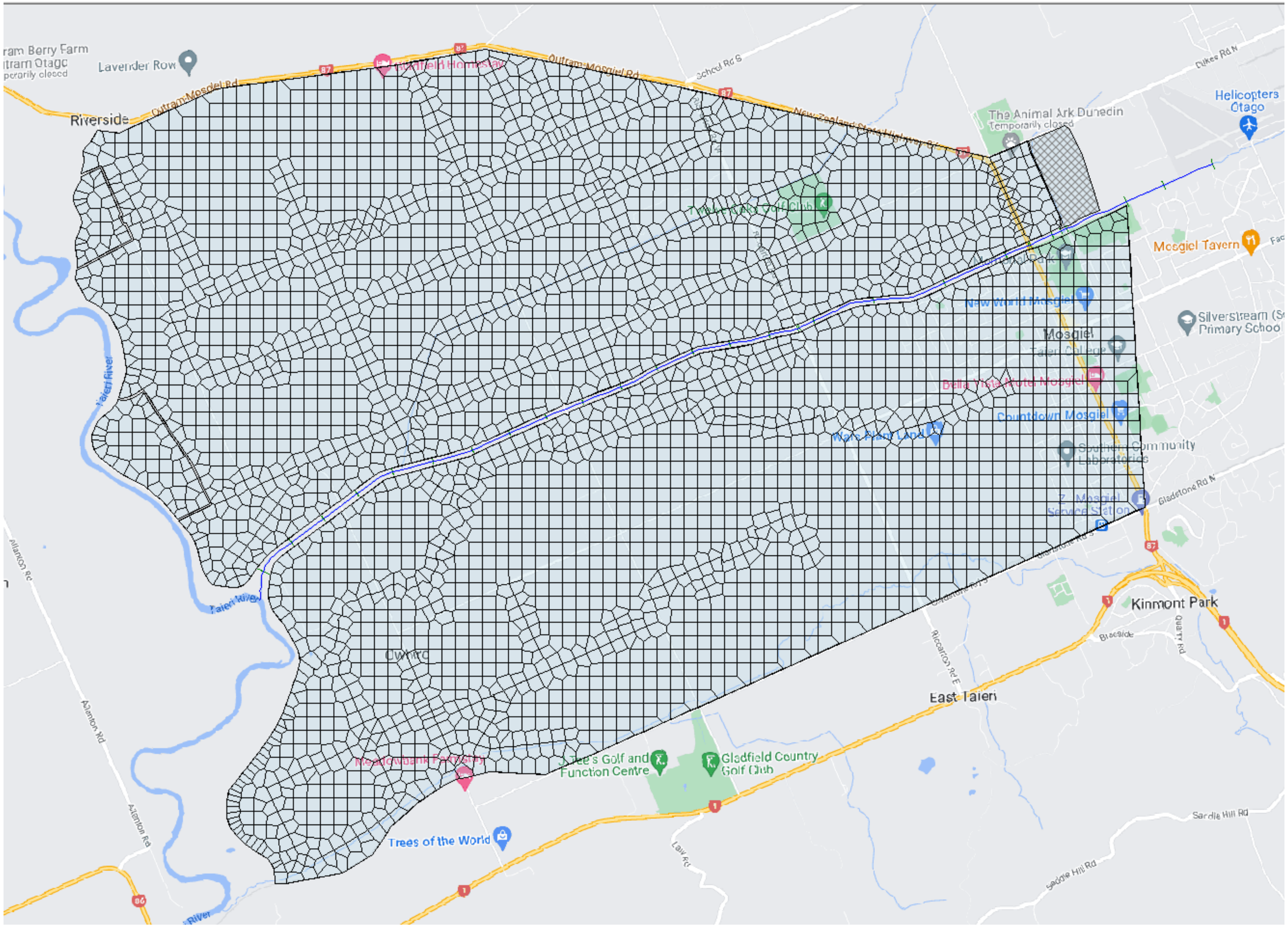

Figure 4. Extent of the 1D/2D hydraulic model of the Silver Stream maintained by ORC.

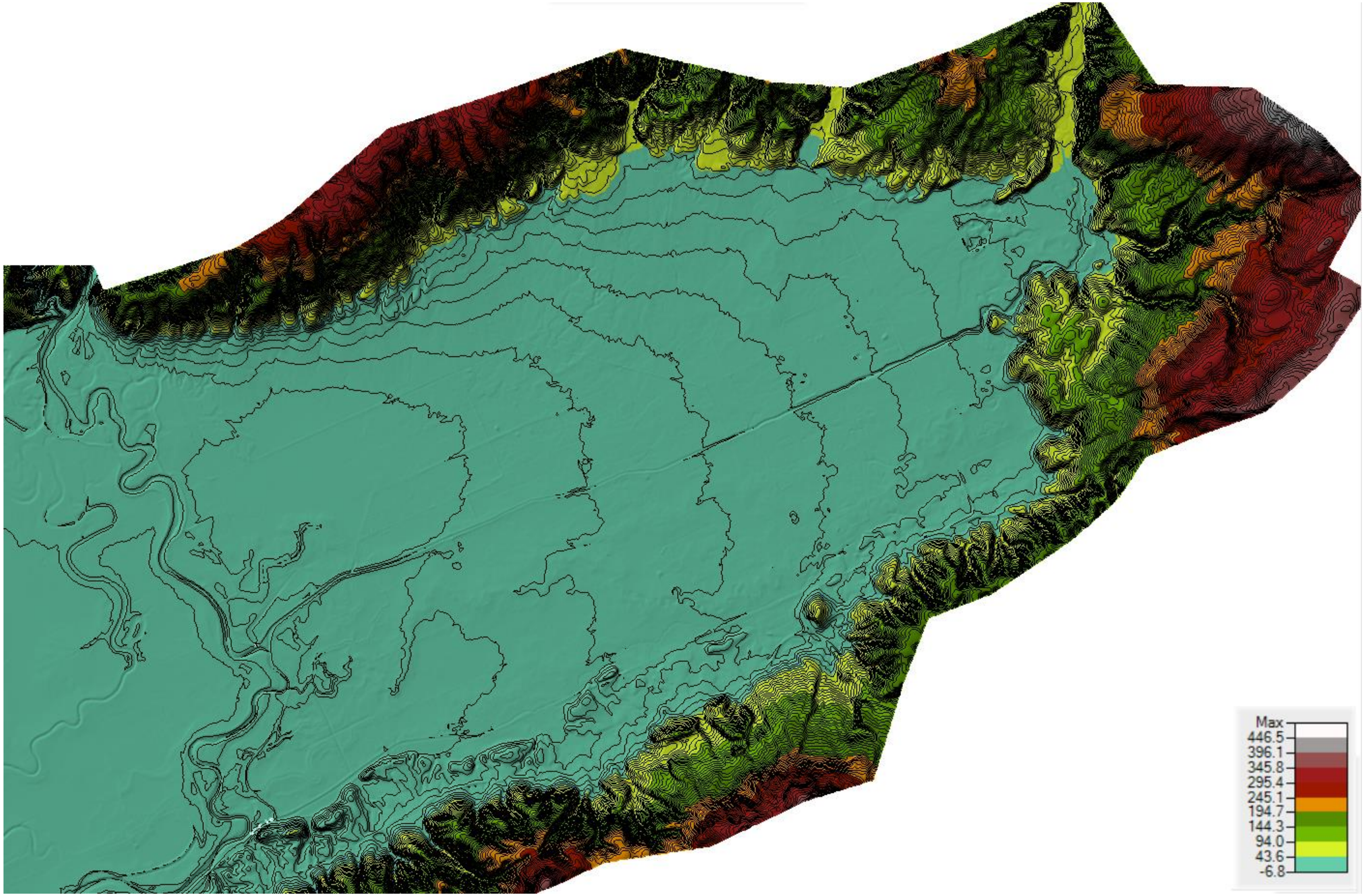

Figure 5. Taieri LiDAR Terrain 2016.

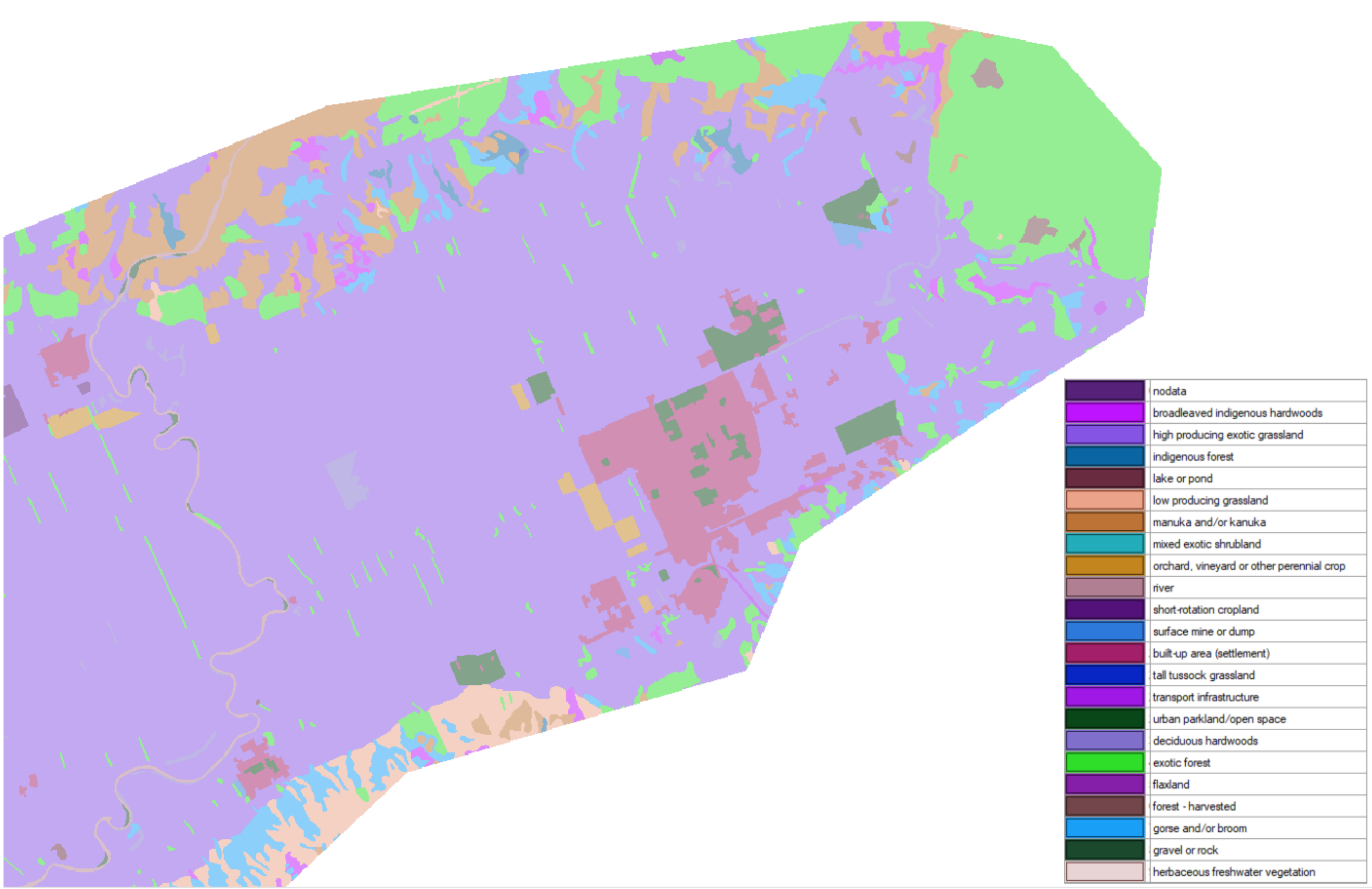

Figure 6. Land use data of Lower Taieri Floodplain.

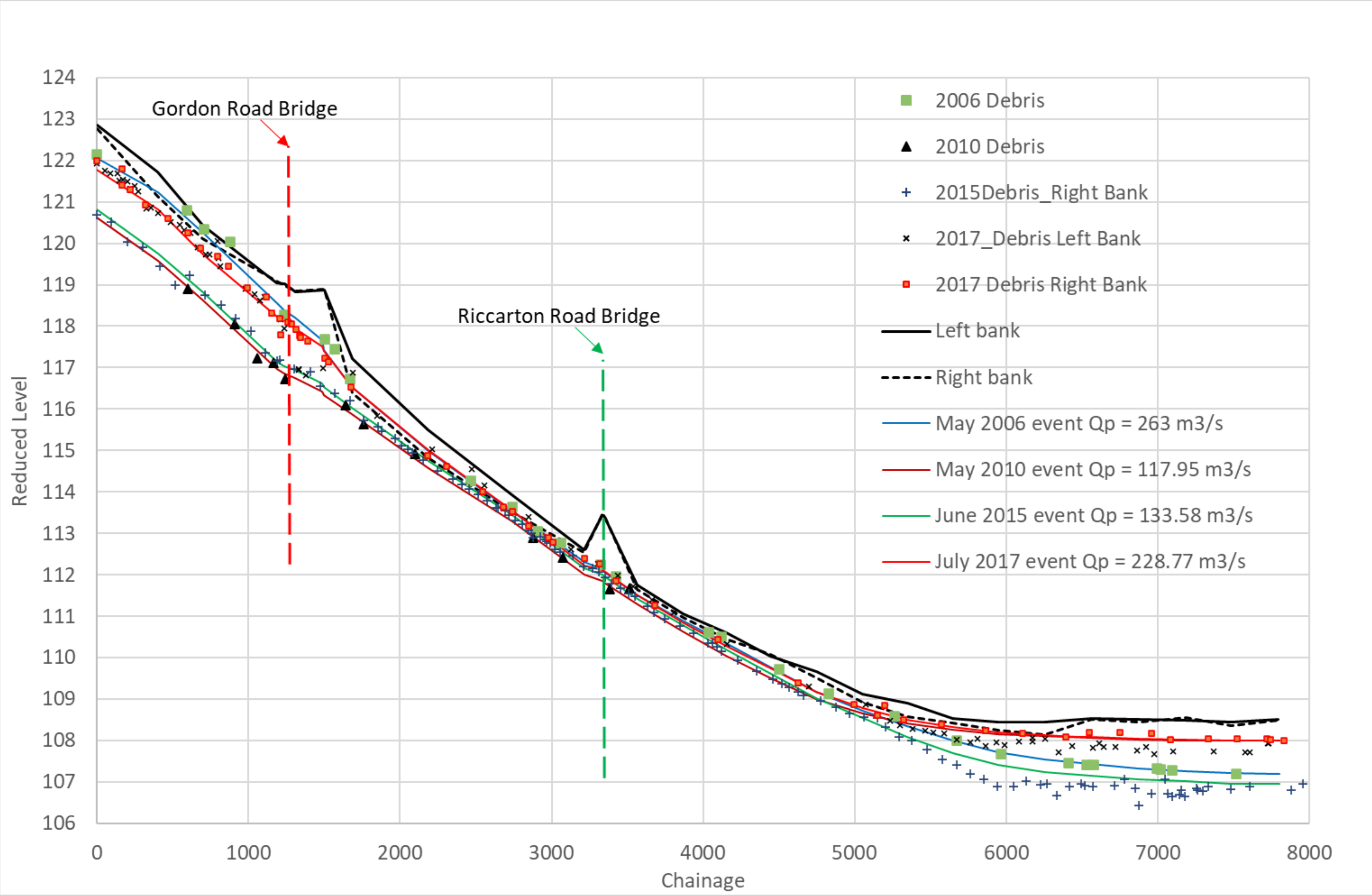

Figure 7. Comparison of observed high water level against modelled water levels for various events.

For the current assessment several modifications were made to the existing ORC model which are outlined below:

a) The 2D area of the existing model was further extended (area under red boundary as indicated in Figure 8) to include the area between Miner Road on the east, Tirohanga Road on the north, Outram-Mosgiel road on the west and Silver stream on the south. The area between Wingatui road and Outram-Mosgiel road on the Lower Pond area was also included. The 2D area was extended to have better understanding of the contribution of Mill creek, area east of Outram-Mosgiel road and catchments to the north to the flooding of North Taieri/Gordon Road floodway.
b) The grid size of the 2D area was refined from 100m x 100m to 50m x 50m for Lower Pond area and 15m x 15m for Upper Pond and North Taieri area. Break line spacing was further refined to 5m x 5m grid spacing for better representation of cut-off banks.
c) The grid sizes along the major roads and high ground were also refined with break lines using 5m x 5m grid spacing to better represent terrain and avoid leakage in the model.
d) Interpolated cross-sections, with spacing of 50m, for Silver Stream, upstream of Mill Creek diversion and Silver Stream confluence, were added to the model.
e) The terrain was also modified to include the bund erected at 50 Dukes Road (Figure 9).
f) The bridges - at Dukes Road and Hazlett Road were also included in the model and modelled as culvert structure. The Mill Creek channel was modelled only using LiDAR data, without cross sections.
g) Eight culverts with flap gates through the cut-off banks and a bridge at Riccarton Road over the Mill Creek were included in the model. The bridge at Riccarton Road was modelled as culvert structure. The details on culverts through the cut-off banks and a bridge at Riccarton Road are provided in Appendix A.
h) The model was transferred from HEC RAS version 5.0.3 to 5.0.7 and the model parameters including manning's roughness were also transferred.
i) Rain on grid was used as an internal boundary to the Upper Pond and North Taieri area to have a better understanding of the contribution of internal runoff to the flooding of the floodplain.

The hydraulic model simulation uses the full momentum equation set with computation interval of 2 seconds.

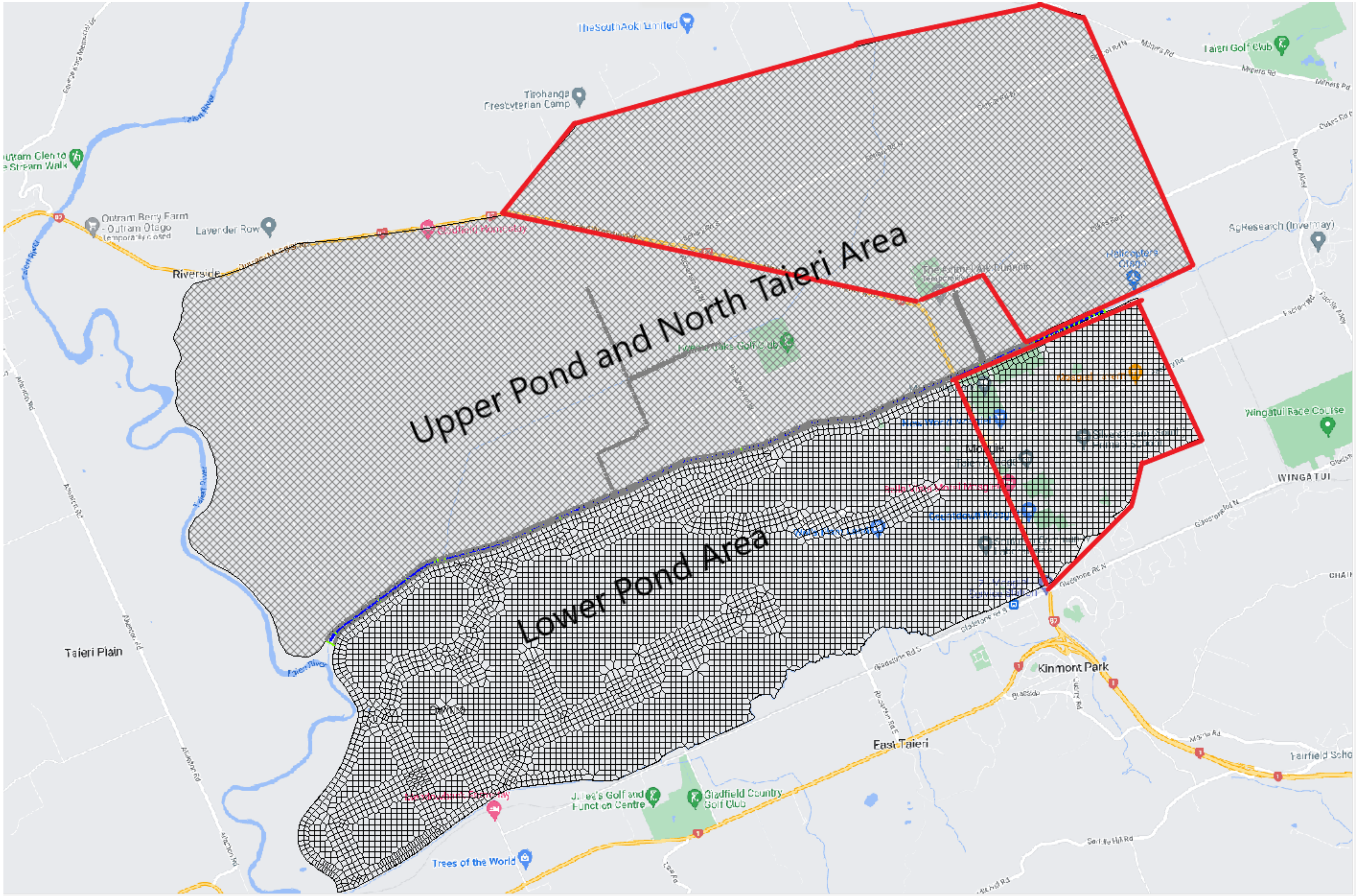

Figure 8. Current Silver Stream hydraulic model extent.

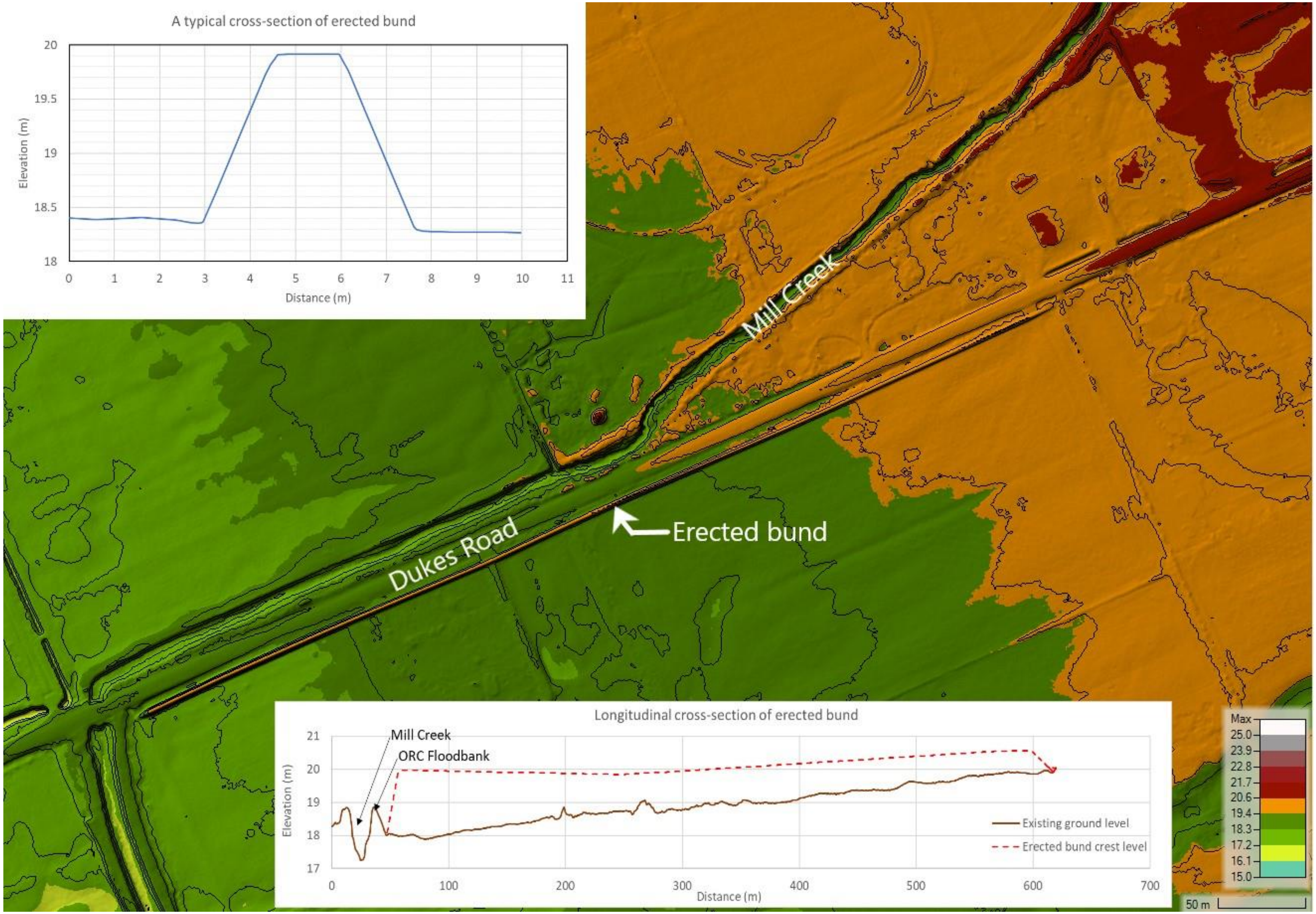

Figure 9. Modified terrain at the Dukes Road and a typical cross-section of erected bund.

2.2 Hydrological Inputs

There were eleven boundary conditions for the model, namely Mill Creek flow at railway line, flows from six catchments to the north and Silver Stream flow as upstream boundaries, effective precipitation as internal boundary at Upper Pond and North Taieri area, Taieri flow level at the Taieri and Silver Stream confluence as downstream boundary, and overflows from Taieri River via Riverside Spillway to Upper Pond. The flow and precipitation boundaries were provided by ORC, while the Taieri flow level at the Taieri and Silver Stream confluence and overflows from Taieri River via Riverside Spillway to Upper Pond were extracted from the Lower Taieri HEC RAS model. It is to be noted that during the large events the flow from Taieri River enters the East Taieri Upper Pond via Riverside Spillway. The culverts across the cut-off banks are provided with flap gates to prevent flow from the Upper Pond to the Gordon Road Floodway. The operation of the flap gates at culverts across the cut-off banks is affected by Taieri overflows to Upper Pond. Further, the modelling of Lower Taieri by ORC also suggests that during the 100-year event the overflows from Taieri River is likely to overtop the cut-off banks. Hence, the overflows from Taieri River was also included in the model.

ORC gauges the Silver Stream at Gordon Road around 235m downstream of the Mill Creek diversion and Silver Stream confluence. The length of records ranges from 9 July 1975 till date. Frequency analysis of available flow data of the Silver Stream was carried out by ORC utilizing the Partial Duration Series (PDS) approach.

Table 2. Silverstream design flows**.**

Return Period (yrs)	Design Flow (m^3/s)
5	120
10	158
20	196
50	251
100	296
200	345

The flow hydrographs for design event were produced by ORC utilizing the design relative hydrograph (Figure 10) derived based on six significant Silver Stream high flow events.

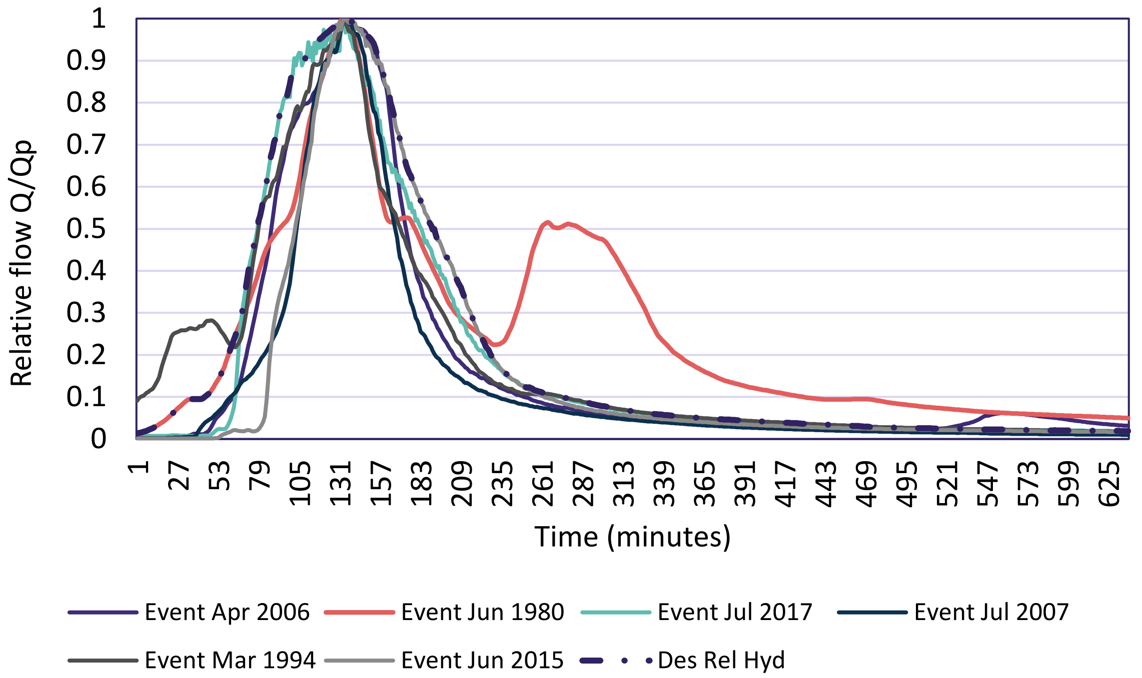

Figure 10. Silver Stream design relative hydrograph (DRH).

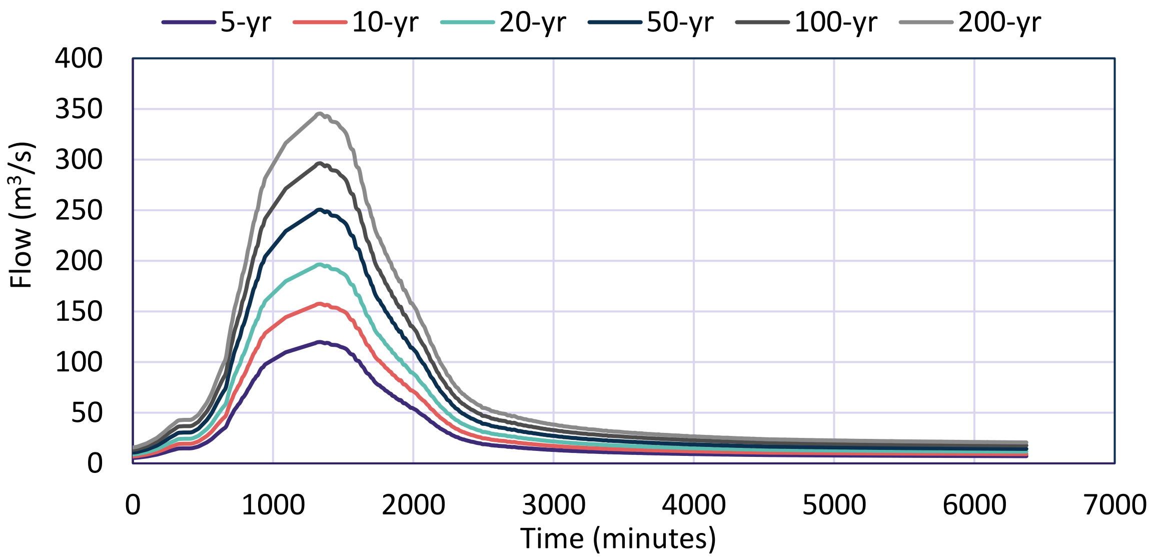

Figure 11. Silver Stream design flow hydrographs for various event.

There are no flow observations for the Mill Creek and catchments to the north (Figure 12) hence, to produce 2017 July event flow and design flows for the Mill Creek catchments upstream of railway line and catchments to the north, a HEC-HMS model was developed by ORC making use of the catchment areas and topographical characteristic, including the initial and constant losses which were estimated for Silver Stream. Design rainfalls were obtained from HIRDS (NIWA High Intensity Rainfall Design System), and these design rainfalls were applied to the developed HEC-HMS model to estimate the design flows (Figure 13) for different return periods.

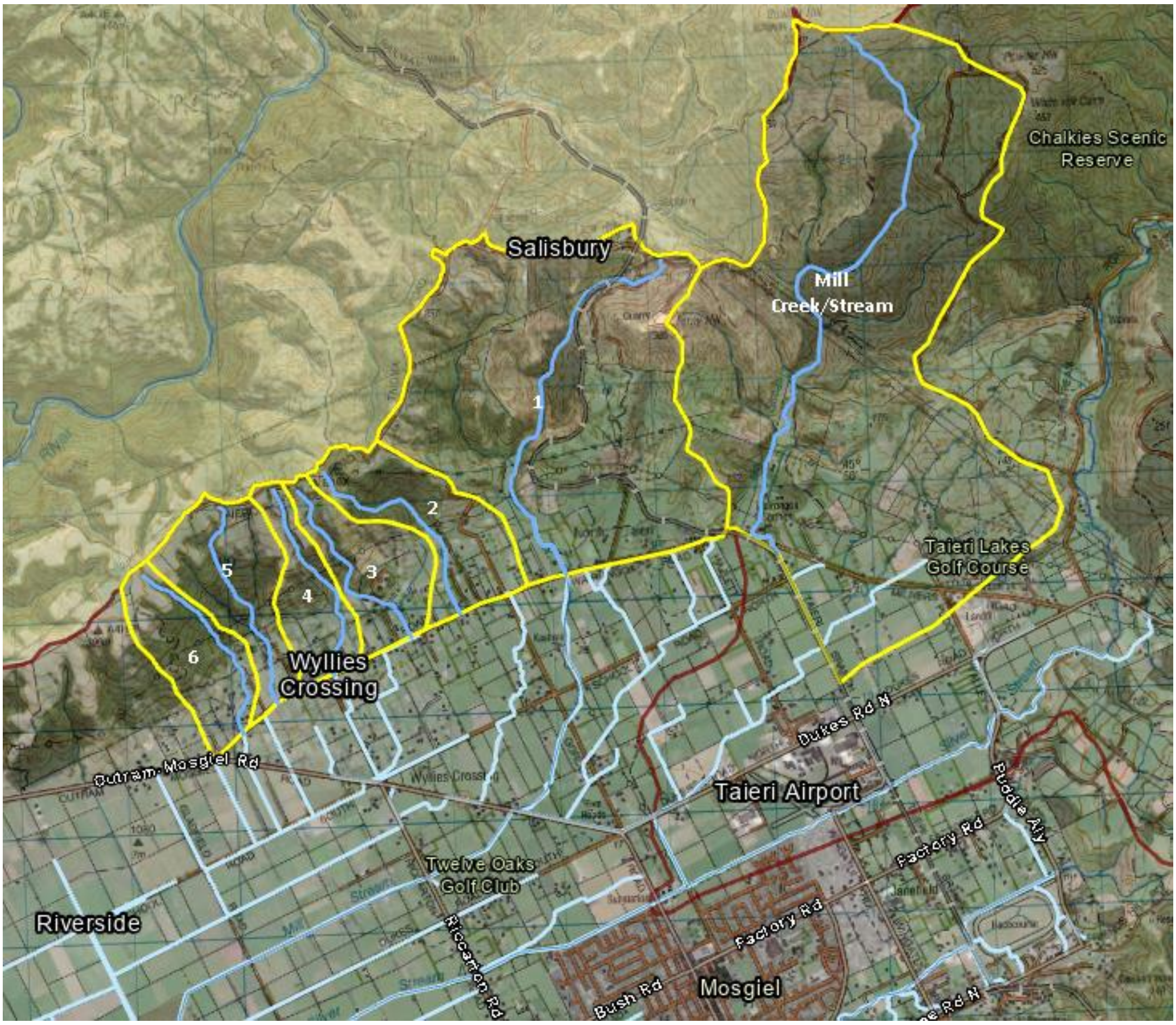

Figure 12. Mill Creek catchment and six catchments to the north.

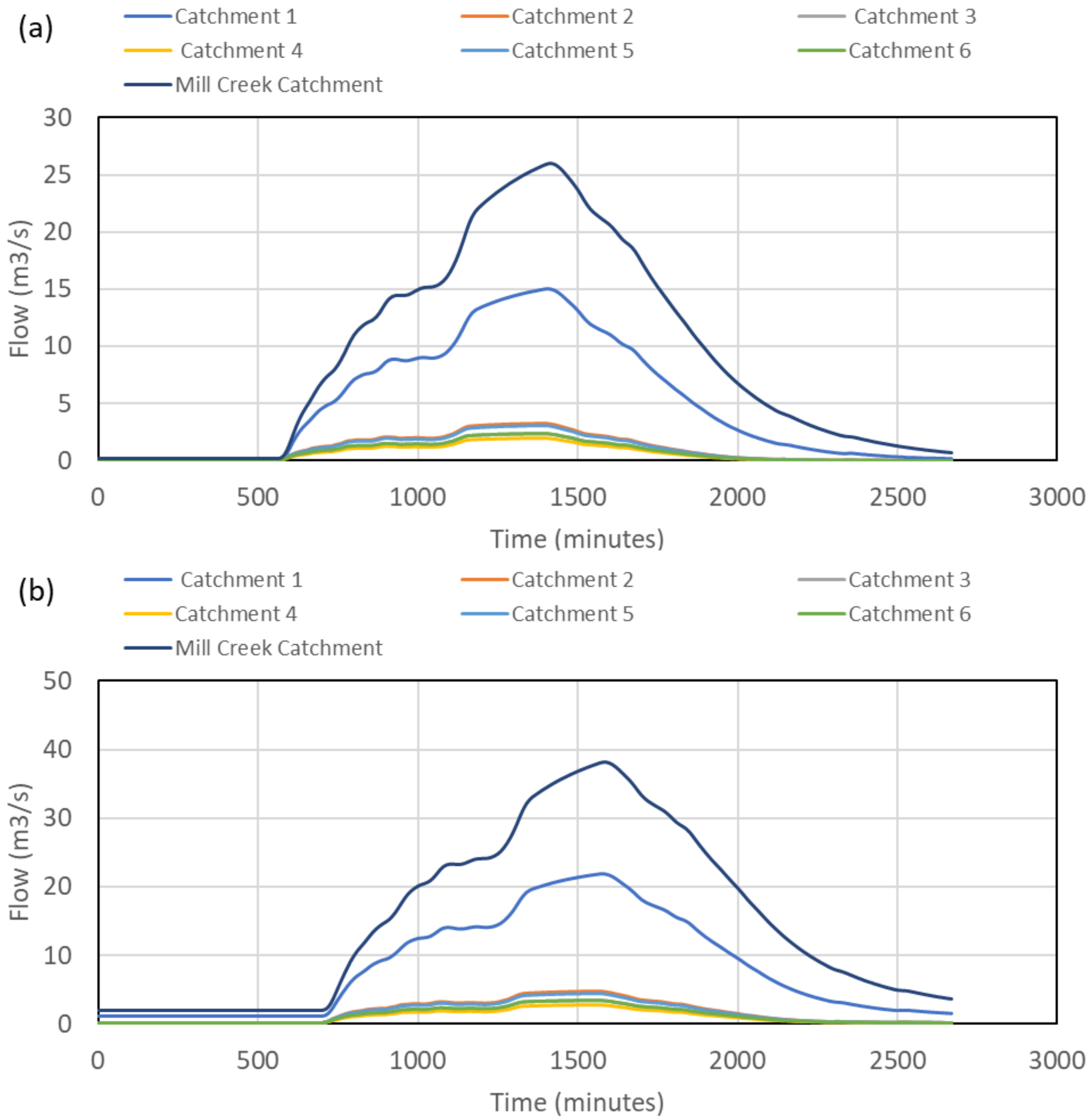

Figure 13. Mill Creek at the railway line and catchments to the north flow hydrographs for (a) July 2017 event and (b) 100-yr ARI event

It is to be noted that the flow boundary for Silver Stream was applied approximately 1200m upstream of the confluence of Mill Creek diversion and Silver Stream. ORC measures flow downstream of the confluence of Mill Creek diversion and Silver Stream which is the combined flow of Silver Stream and Mill Creek diversion (Figure 14). Since Mill Creek is not gauged the flow contribution from Mill Creek diversion is not known. For modelling purposes, the July 2017 observed flow and 100-yr ARI design flow were modified using trial and error approach. The modified hydrographs were applied at the upstream boundary such that the combined flow from Silver Stream upstream of confluence and Mill Creek diversion aligns with the observed and design flows downstream of the confluence.

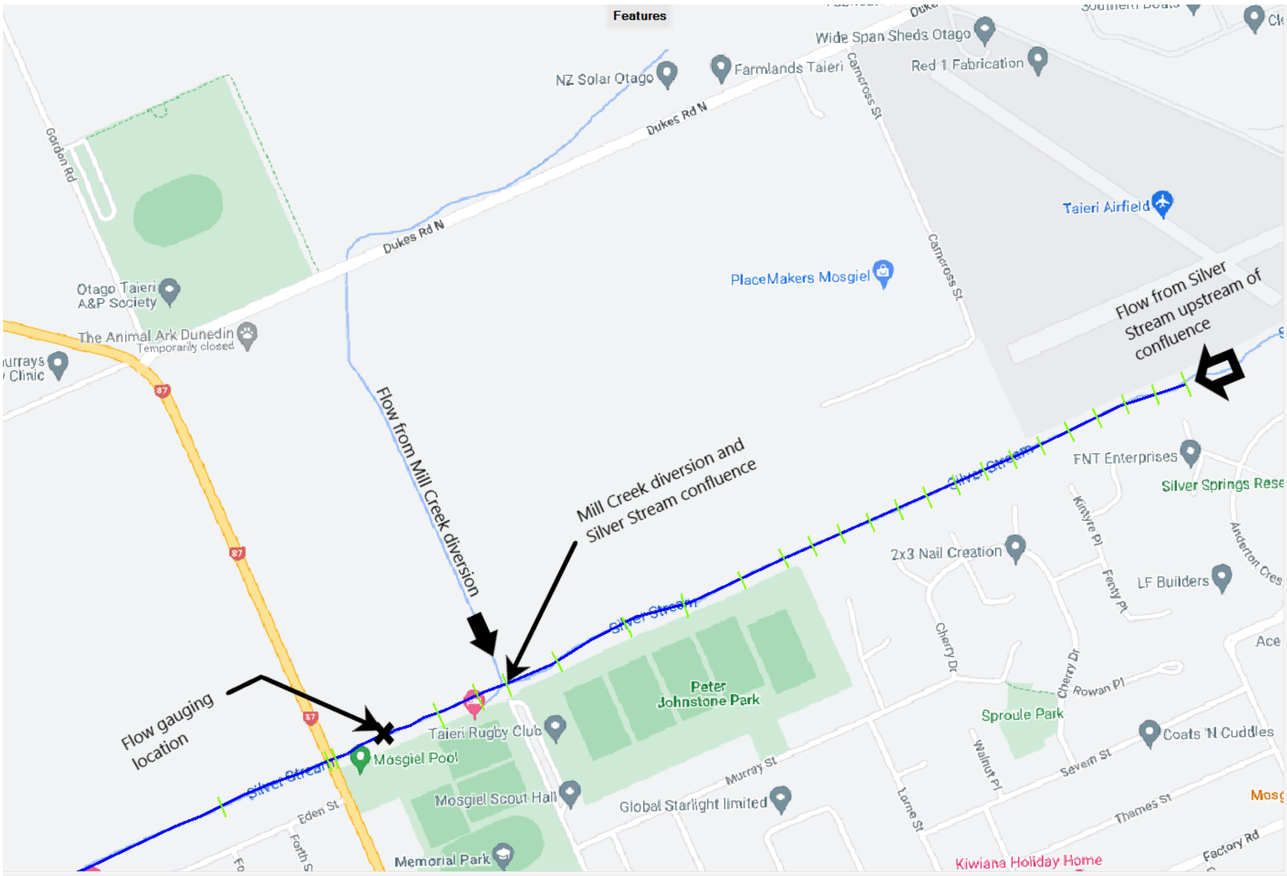

Figure 14. Location of gauging station and upstream flow boundary of Silver Stream.

The peak flow for the 100-yr ARI for Silver Stream at Gordon Road has been estimated as 296m^3/s by ORC based on frequency analysis. However, hydraulic analysis carried out to get the combined flow from the Mill Creek diversion and Silver Stream, upstream of the confluence of Mill Creek diversion and Silver Stream, suggests that the 100-yr ARI peak flow downstream of the Mill Creek diversion and Silver Stream confluence will not reach 296m^3/s because of flow overtopping on the right bank of Silver Stream, upstream of the Mill Creek diversion and Silver Stream confluence. Our analysis suggests that the peak flow for 100-yr ARI flow downstream of the Mill Creek diversion and Silver Stream confluence will be closer to 286m^3/s. Otago Catchment Board (1974) also outlines that the Wingatui Road to Gordon Road bridge reach of Silver Stream was designed to carry flow of 283.17 m^3/s.

3. Hydraulic model results

The original Silver Stream hydraulic model was setup, calibrated, and validated using HEC RAS version 5.0.3. This model was further refined, extended, and transferred to HEC RAS version 5.0.7. The model was re-evaluated against the observed high-water marks for July 2017 event. The results are presented in Figure 15 and Figure 16. The comparison of modelled water level against the debris mark suggests that the modelled value aligns well with the debris marks. In general, the modelled water levels in the floodplain are within the range of +/-250mm (Figure 16), however along the downstream cut-off bank the modelled water levels are more than 500mm higher than the observed data. During the July 2017 event there was overtopping of the cut-off bank at several locations hence the surveyed debris line may not represent the actual water level in the cut-off bank during peak of the event (i.e., during the overtopping of cut-off bank).

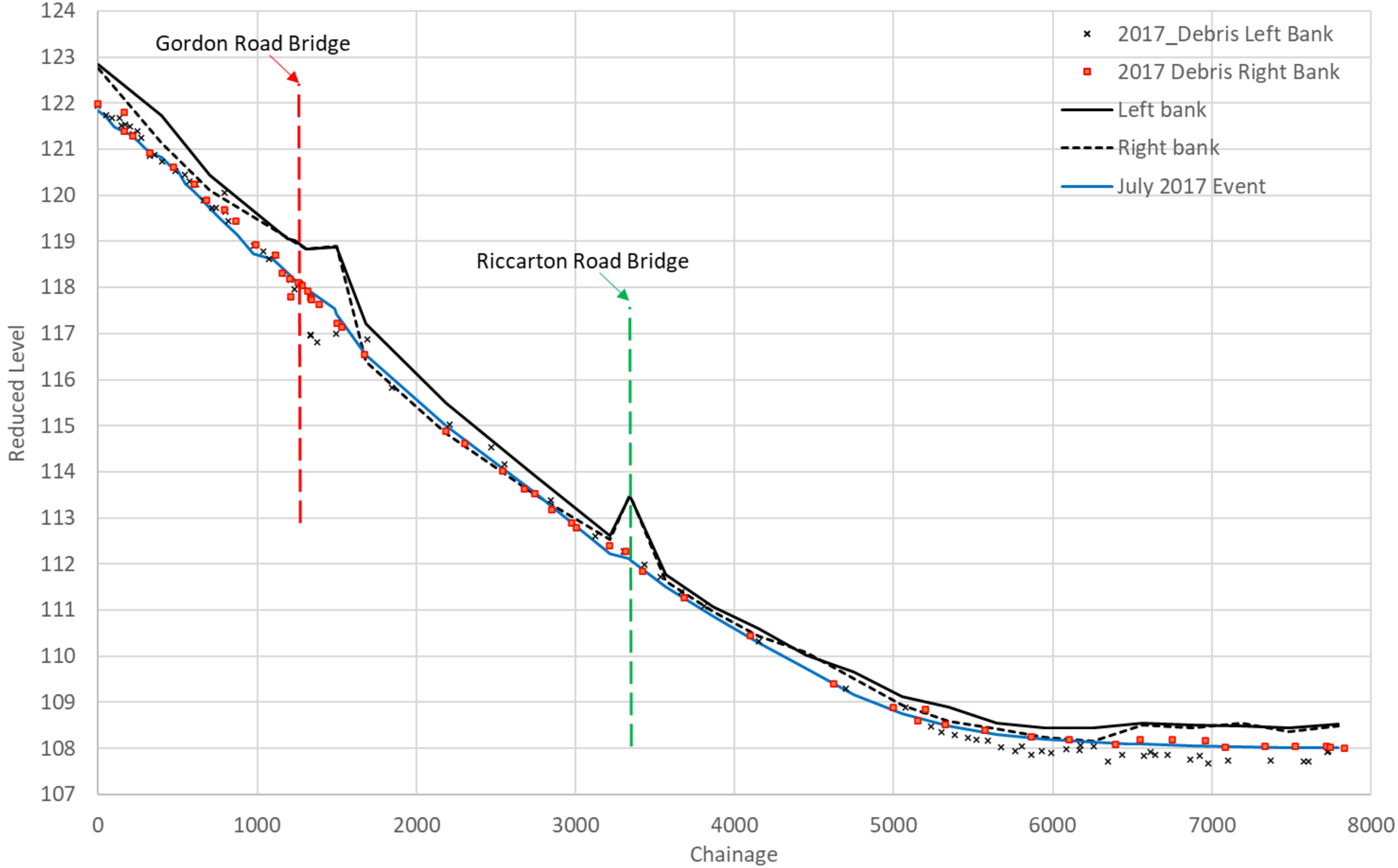

Figure 15. Modelled Silver Stream water level compared against observed high water marks for the July 2017 event.

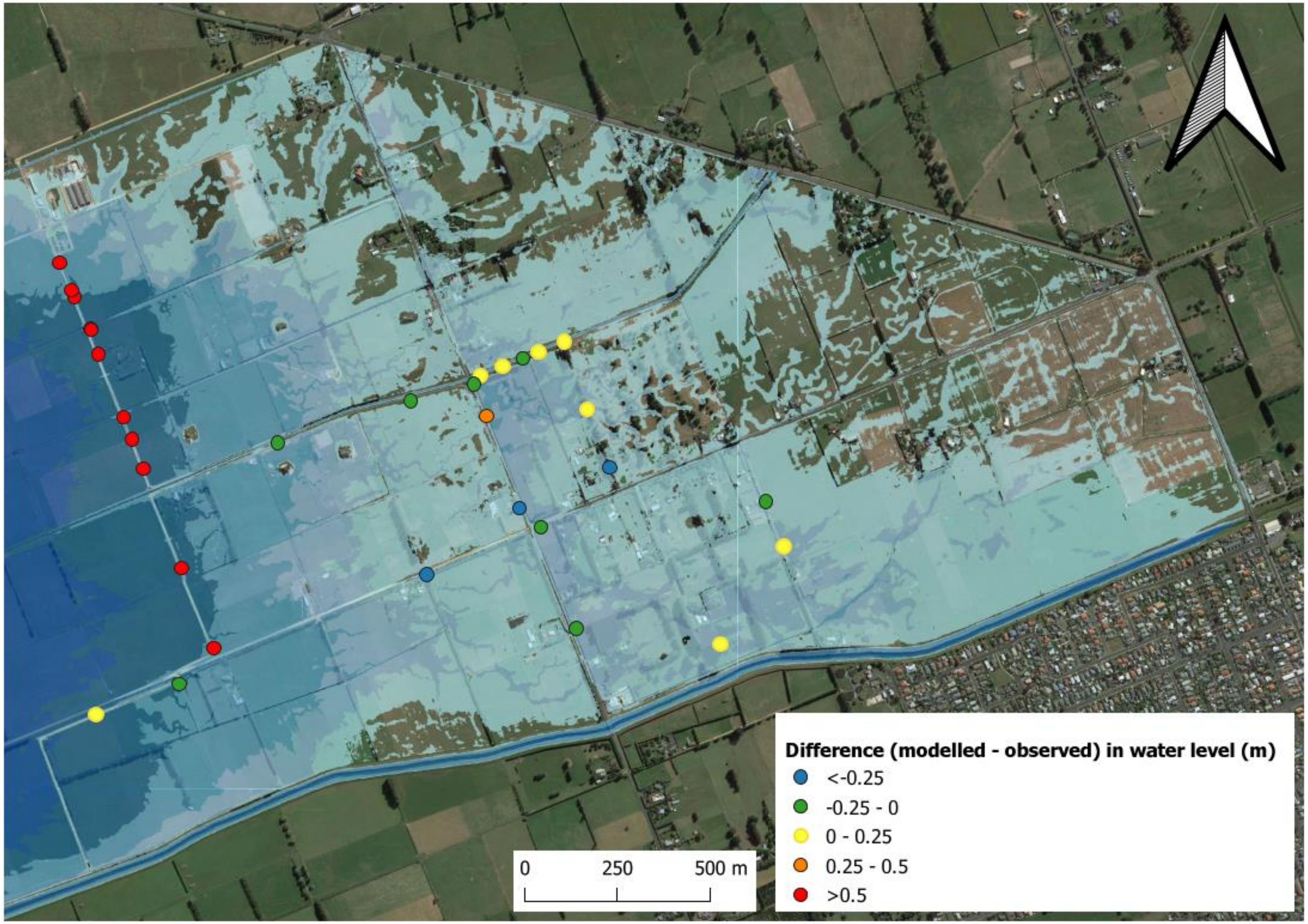

Figure 16. Difference in modelled versus observed debris lines, as an indication of floodplain water level for the July 2017 event.

The modelling result confirms that the overtopping of the true right bank of Silverstream below the Gordon Road bridge (also known as Gordon Road Spillway) is the largest contributor to flooding of North Taieri/Gordon Road floodway. More specifically, the area between the Mill Creek, cut-off bank, and Silver Stream will be flooded primarily due to operation of the Gordon Road Spillway when flow in Silver Stream exceeds 115 m^3/s (Figure 17). Flood water from Mill Creek and runoff from area upstream of Outram-Mosgiel road are the secondary contributors to flooding of the area. The area to the north between Mill Creek, cut-off bank, and Outram-Mosgiel Road is flooded due to runoff from Mill Creek and the area upstream of Outram-Mosgiel Road and internal runoff. For both events (i.e., July 2017 and 100-yr ARI) Dukes Road (between the cut-off bank, and 800m upstream of Riccarton Road), Dukes Road junction, and Riccarton Road are expected to overtop. For July 2017 event the depth of flood water is expected to range between less than 0.5m to almost 3m, while for 100-yr ARI event the flood depth is expected to range between less than 0.5m to more than 3m. For both events the velocity is expected to range between 0.5 to 1 m/s in the floodplain. Higher velocities (greater than 1m/s) are expected in the overtopped portion of Dukes Road and Riccarton Road.

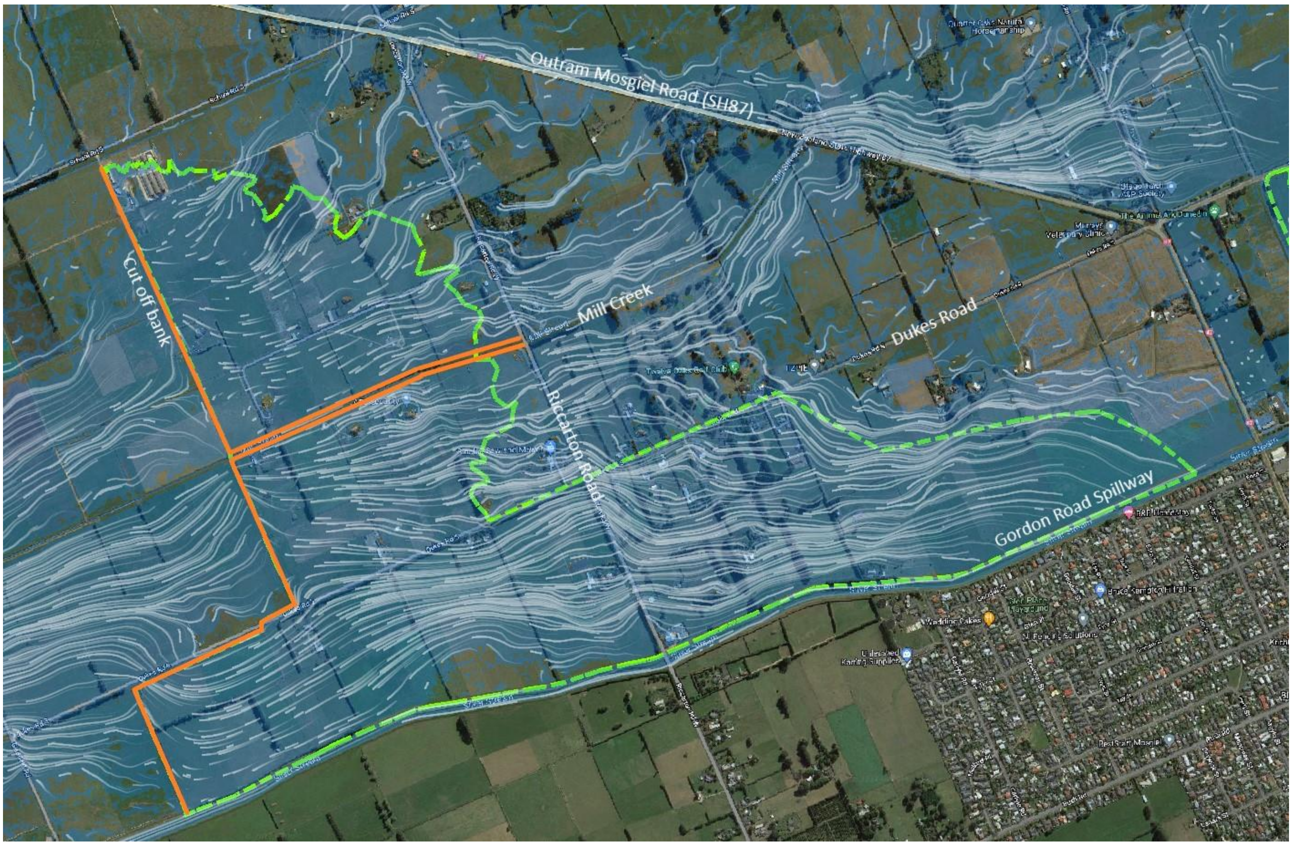

Figure 17. Flood water inundation and particle tracing in North Taieri/Gordon Road floodway.

The depth, velocity, and velocity x depth distribution map for the North Taieri/Gordon Road floodway, more specifically the area between the cut-off banks, and State Highway 87 for July 2017 event and 100-yr ARI events are presented in Figures 18-20, and Figures 21-23 respectively.

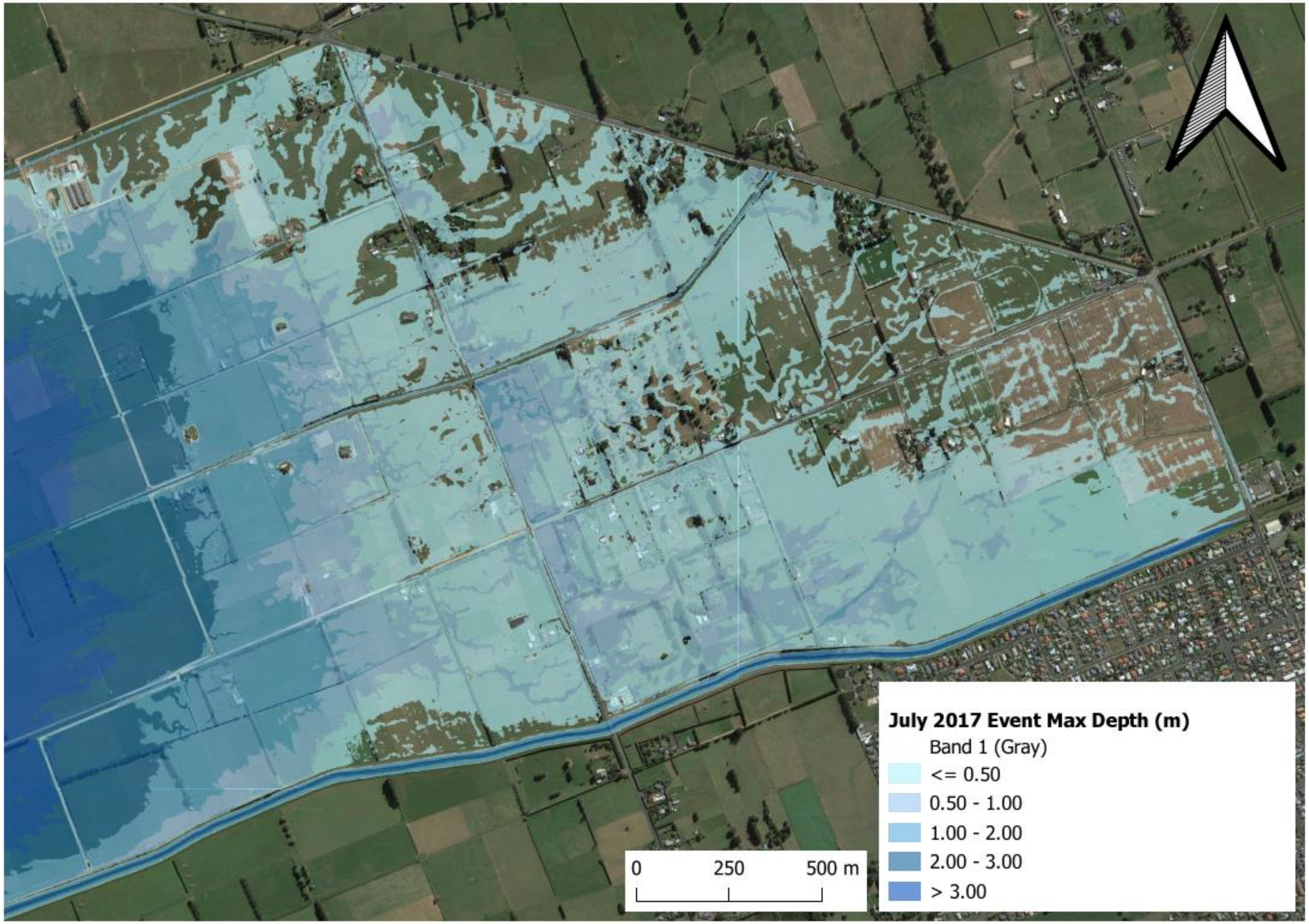

Figure 18. Modelled maximum flood depth distribution map for the July 2017 event.

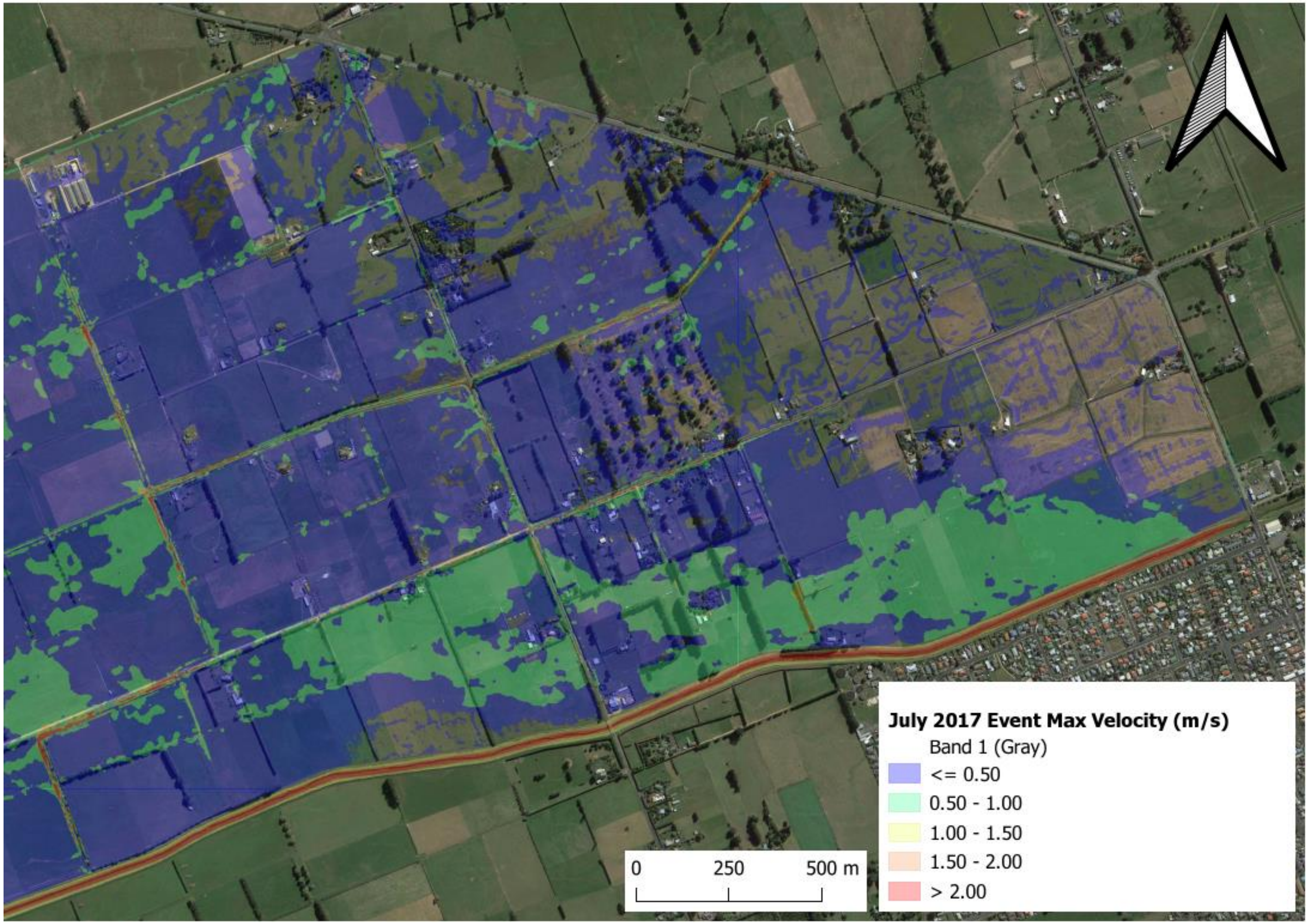

Figure 19. Modelled maximum flood velocity distribution map for the July 2017 event.

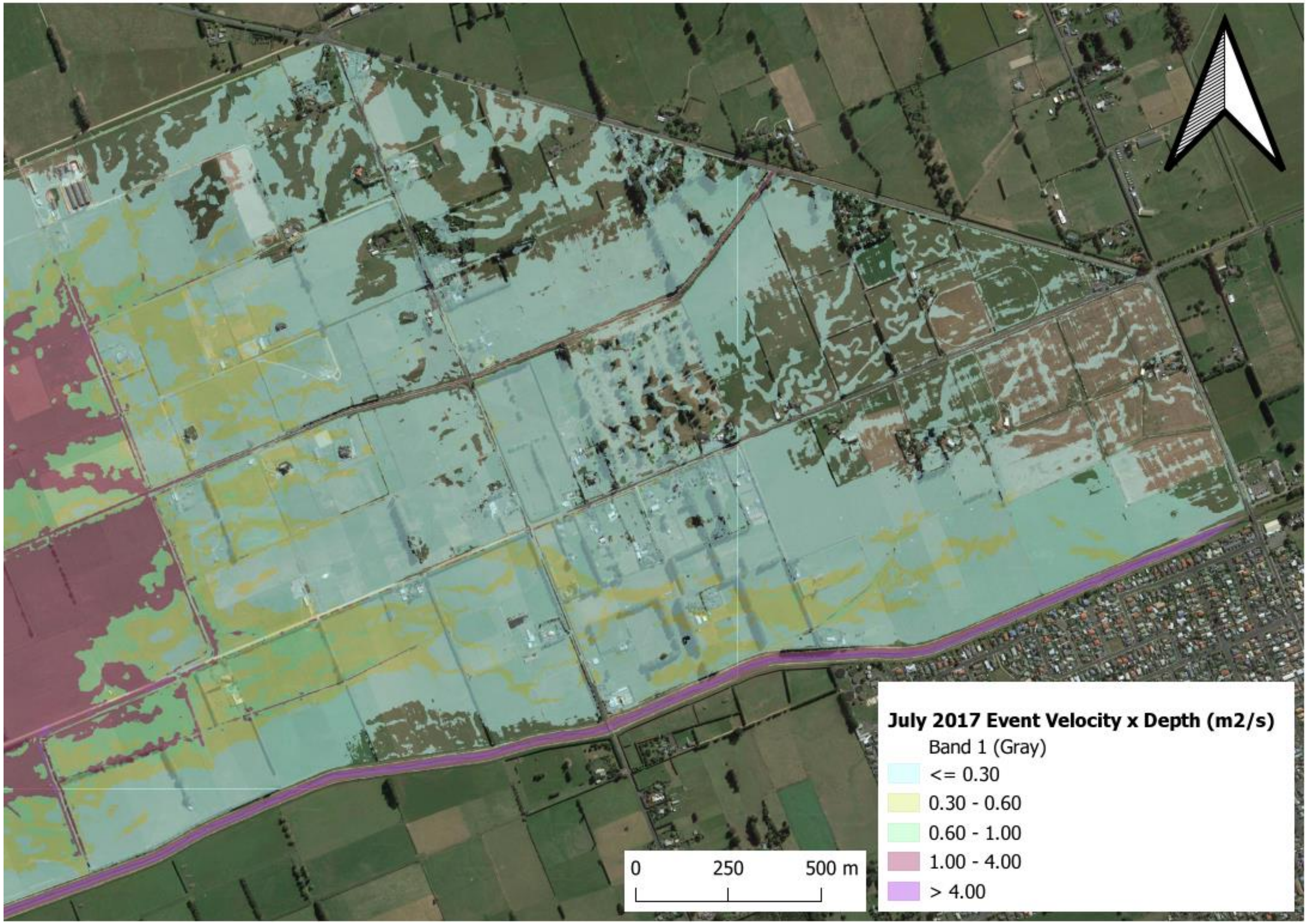

Figure 20. Modelled maximum flood velocity x depth distribution map for the July 2017 event.

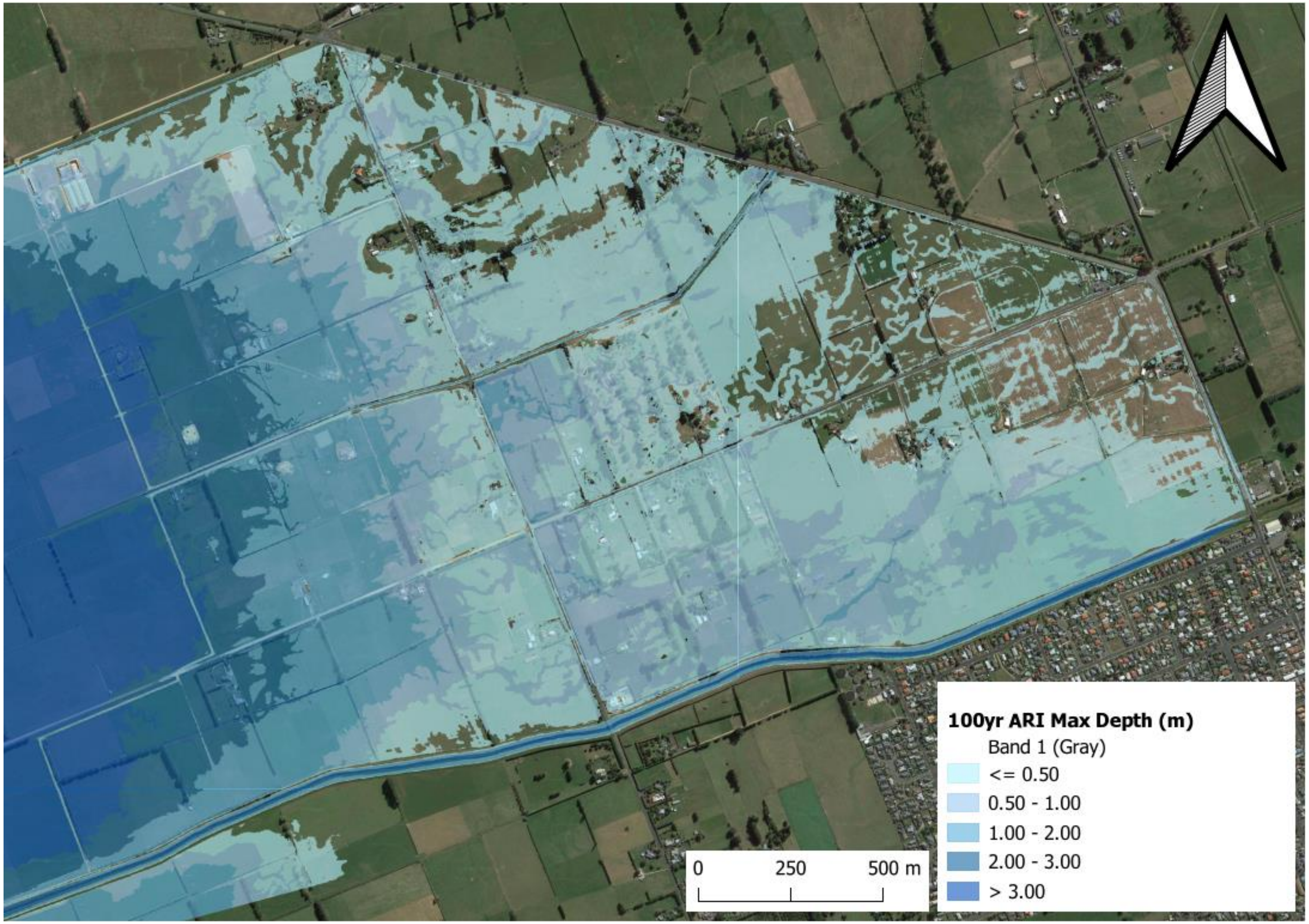

Figure 21. Modelled maximum flood depth distribution map for the 100-yr ARI event.

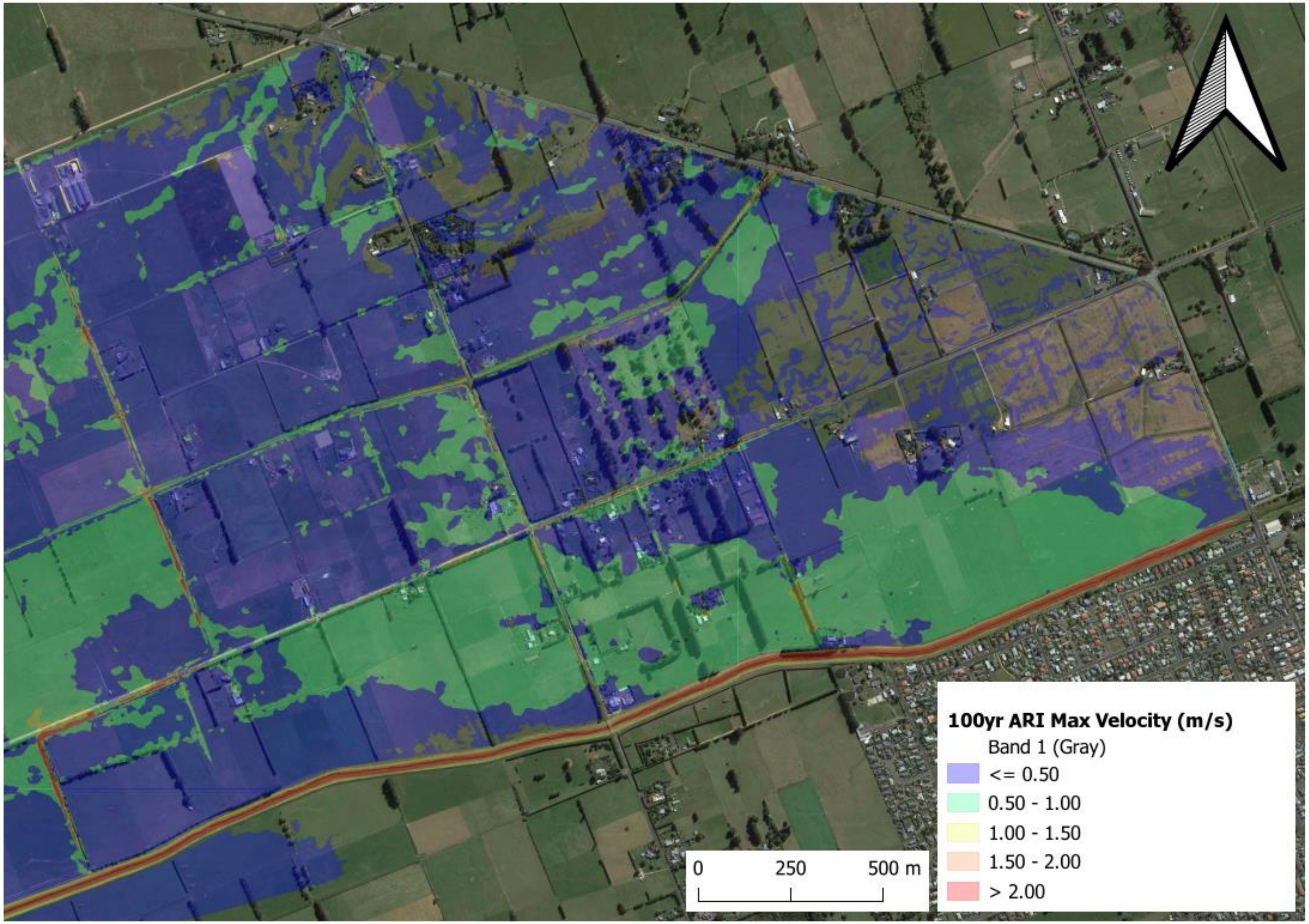

Figure 22. Modelled maximum flood velocity distribution map for the 100-yr ARI event.

Figure 23. Modelled maximum flood velocity x depth distribution map for the 100-yr ARI event.

4. Conclusion

The hydraulic modelling was carried out to assess the flood hazard and determine how North Taieri/Gordon Road floodway is impacted during the July 2017 flood event and the 100-yr ARI event. The modelling results confirm that the overtopping of the true right bank of Silverstream below the Gordon Road bridge (also known as Gordon Road Spillway) is the primary contributor to flooding of North Taieri/Gordon Road floodway area. For July 2017 event the depth of flood water is expected to range between less than 0.5m to almost 3m, while for 100-yr ARI event the flood depth is expected to range between less than 0.5m to more than 3m. For both events the velocity is expected to range between 0.5 to 1 m/s in the floodplain.

5. Reference

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Appendix A

Appendix Figure 1. Map showing the location of culverts across the cut-off banks and a bridge at Riccarton Road

Appendix Table 1. Details of culverts across the cut-off banks and a bridge at Riccarton Road

	Length (m)	Dimension (m)	Materials	Remarks
Culvert 1	21.70	1.2 m diameter	Concrete	With flap gate
Culvert 2	11.40	2 m (W) x 1m (H)	Concrete	With flap gate
Culvert 3	12.19	1.2 m diameter	Concrete	With flap gate
Culvert 4	16.30	0.6 m diameter	Concrete	With flap gate
Culvert 5	10.70	2 m (W) x 1 m (H)	Concrete	With flap gate
Culvert 6	12.00	2 m (W) x 1 m (H)	Concrete	With flap gate
Culvert 7	15.50	0.6 m diameter	Concrete	With flap gate
Culvert 8	16.50	1.2 m diameter	Concrete	With flap gate
Bridge	9.00	7 m (W) x 2.5 m (H)	Concrete	