Flood modelling of the Feilding West area

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1 Introduction

Mangaone West Stream drains a catchment of about 50 km^2 between Feilding and Halcombe, and flows into Makino Stream just downstream of the town of Feilding. The catchment is almost entirely in pasture, rolling countryside varying in elevation from farmland, a sloping plain intersected by gullies, varying in elevation from about 50m to 131m (both Mt Biggs and Mt Stewart). In its lower valley, Mangaone Stream is meandering and sluggish at low flows.

The hills immediately west of Feilding provide one boundary of the Mangaone West catchment, with mostly minor gullies providing runoff that flows into the town of Feilding. Feilding itself is bisected by Makino Stream.

The area addressed by this flooding study comprises the minor streams running into Feilding, the town itself west of Makino Stream, and the Mangaone Stream catchment in its entirety.

The soils of the Feilding West area are Perch-Gley Pallic soils, which are "slowly permeable with near-surface waterlogging, … dry in summer and wet in winter[1].

This flooding study was proposed in response to a request from Horizons Regional Council (confirmed by e-mail Jon Bell, 28 June 2017) for numerical modelling to produce flood maps for this area for the 2%, 1% and 0.5% Annual Exceedance Probability (AEP) flood events, aka 50-year, 100-year and 200-year Average Recurrence Interval (ARI). Horizons also requested modelling of a rainfall event from June 2015, although (unlike the adjacent Makowhai / Piakatutu catchment) no calibration data were available from that event.

1.1 Brief observations from a site visit

1.1.1 Feilding town

Low-flow runoff from the hill gullies running into Feilding is captured by the urban network (Figure 1), generally near West St and Lethbridge St, which mark the western edge of the flat part of town. This urban network includes some lengths of open drain running parallel to these two streets (Figure 2**Error! Reference source not found.**), and discharges into Makino Stream.

The railway embankment runs through Feilding including parallel and adjacent to Lethbridge Street. It forms a near-complete barrier to overland flow, except for three culverts.

The part of Feilding included in this study is almost entirely residential (and therefore offering high resistance to overland flow).

[1] landcareresearch.co.nz: Fundamental Soil Layers » Maps of Fundamental Soil Layers

Figure 1 Stream north of Halcombe Road, at Lethbridge Road

Figure 2 Urban drain, West St near South St

1.1.2 The rural catchment

In the gullies draining into Feilding (Figure 3), and in the minor tributaries of Mangaone West Stream (Figure 4), flow paths are generally constrained within gullies and swales. The large tributaries and (particularly) the lower reaches of Mangaone West Stream, are somewhat meandering with some flood plain areas (Figure 5 and Figure 6). Almost all of the Feilding West area is good quality pasture.

As well as minor culverts, there are several road crossings of Mangaone West Stream and its major tributaries. Some of these are bridges, others are culverts.

Figure 3   Gully south of Highfield Road

Figure 4   Minor tributary, Halcombe Road, looking downstream

Figure 5 Tributary of Mangaone West Stream, from Lethbridge Road

Figure 6 Mangaone West Stream, looking downstream from Te Rakehou Road

2 Methodology: model build

2.1 Modelling framework and overland flow grid

The model was built in MIKE 21 "Classic", i.e. the rectangular-grid form of overland flow model, with "Inland flooding" specified. The model domain is a rectangle 13.3 km by 11km, enclosing the Feilding West area, which has an area of about 100 square kilometres. A 5m square grid was chosen to provide the best compromise between model run time and representing the topography in sufficient detail. In particular, this grid size provided continuous representation of roads and of stream channels.

A rectangle circumscribing the area was modelled as a “closed” area, i.e. with its entire perimeter represented as land. This was done partly for convenience and partly to avoid difficulties with boundary conditions affecting the area required to be modelled. The modelled area included Makino Stream where it flows through Feilding, but without its normal flow, so that the stream could take whatever runoff that reaches it flowing through town from the minor gullies. The model therefore does not accommodate design events occurring simultaneously in the Feilding West area and in Makino Stream. Makino Stream outflow from the modelled area was represented as several sinks, with the combined outflow rate set high enough to accommodate peak flood flow, and the boundary of the modelled area far enough downstream to avoid any spurious backwater effects within the Feilding West area.

The model was run with a time step of either 0.75 s or 1s. Instabilities leading to “blow-ups” typically occurred 2-3 times during a run, necessitating a restart using the “hot-start” file and sometimes also requiring a reduction in time step.

Model parameters included flooding and drying depths of 20mm and 10mm respectively. With the overland flow version of MIKE 21, water does not flow at depths less than the drying depth, and fully observes the fluid mechanics equations of motion at depths exceeding the flooding depth, with a gradual transition between those two depths.

The output plots have then been trimmed (“clipped”) to the Feilding West area (including the Mangaone West catchment and half of Feilding), and a shapefile provided to allow the same to be done to any GIS files produced from the MIKE files..

2.2 Culverts, Bridges, and the Feilding urban network.

No data were available for the culverts and bridges within the Feilding West area. It was therefore agreed with Horizons staff that these would be modelled by simply altering the bathymetry to allow runoff to pass without heading up.

This approach was not practicable for Feilding town. The 5m DEM does not fully pick up the open drains, so that none of the network has been modelled. It was agreed with Horizons staff that the network would be credited with carrying up to the 5-year ARI event arriving as runoff from the hill gullies to the west. To do this, the 5-year rainfall was modelled, and flows from the gullies up to the 5-year peak flow were accommodated by sinks placed at suitable locations near West and Lethbridge Streets.

The mixed-use area of Maewa appears to have its own drainage characteristics, including culverts under the railway embankment that might prove ineffective in their present state. Any flooding problems in this area would warrant a more detailed investigation.

2.3 Rainfall hyetographs

Horizons supplied hyetographs for three adjacent rainfall gauge locations: Forest Rd @ Drop Structure, Mangaone @ Milson Lane, and Makino @ Halcombe Rd. The data comprised the rainfall measured during the significant event in June 2015 (Figure 7), as well as design hyetographs for 2% and 1% AEP rainfall events (Figure 8).

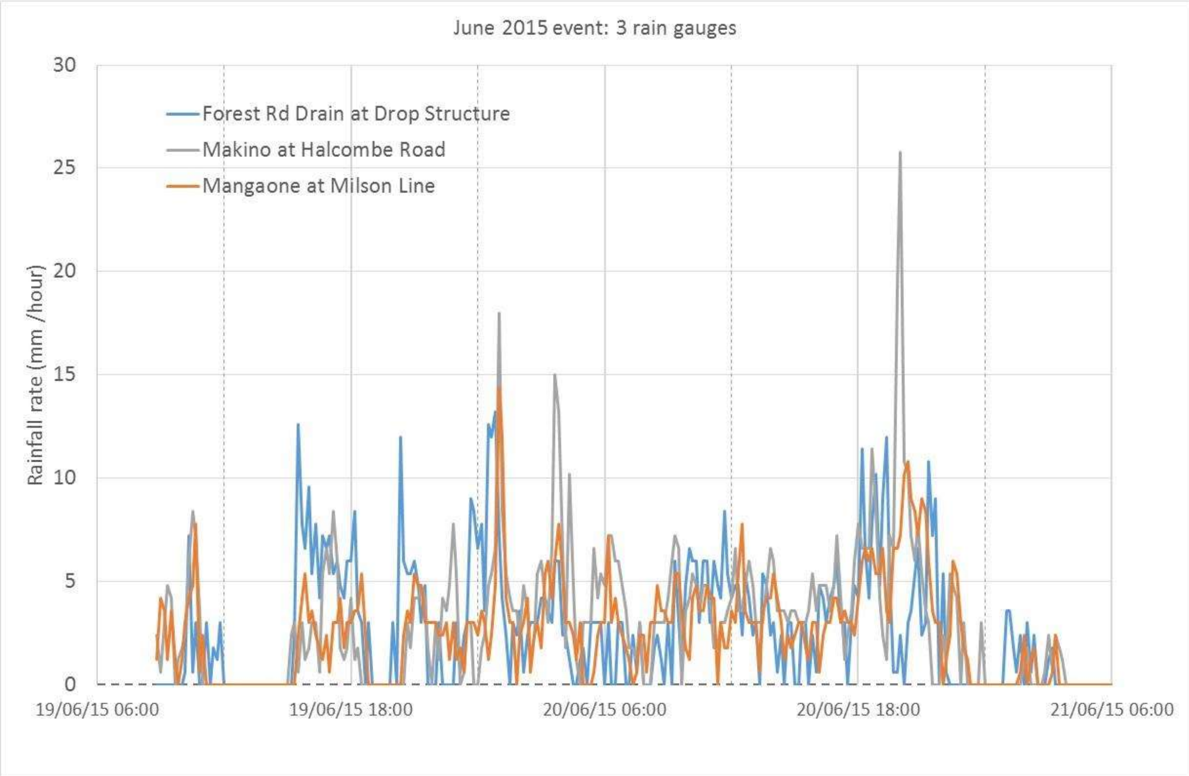

Figure 7 Gauged 2015 hyetographs

The design events are understood to have been obtained from HIRDS version 3, and are in the "Chicago" form, in which rainfall events of different duration but the same AEP are nested within one another. This form of design hyetograph may well be unrepresentative of any single observed event, but have the strong advantage that every sub-catchment, regardless of its response time, experiences the rainfall likely to produce a peak flow with the specified AEP.

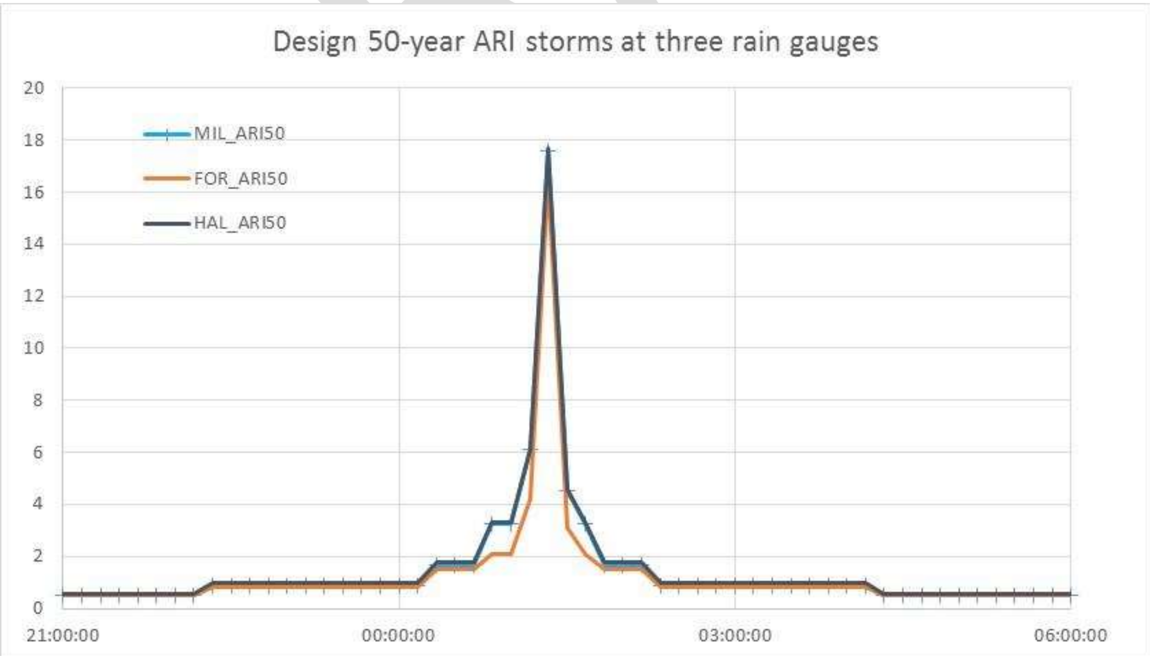

Figure 8 Design 50-year AEP hyetographs for rainfall gauge locations

HIRDS does not provide rainfall depths for the 200-year ARI event, nor for yet more extreme events. It was agreed with Horizons that a 200-year ARI event would be represented by the 100-year ARI design event scaled by 1.14, as has recently been done for the adjacent Makowhai-Piakatutu catchment. This multiplier was adopted in flood studies for Ohakune and later for the Makotuku catchment, and appears reasonably consistent with the difference between the 2% and 1% events.

The Halcombe Road gauge is in the middle of the Feilding West area, and the hyetographs derived from its record have therefore been applied in this modelling. The differences between the design hyetographs at the three rainfall gauge sites are relatively minor (Figure 8). This gives some confidence that the record at the Halcombe Road gauge, and the design hyetographs calculated from that record, are all reasonably representative of the entire Feilding West modelled area.

Halcombe Road hyetographs for the three design rainfall events are shown in Figure 9.

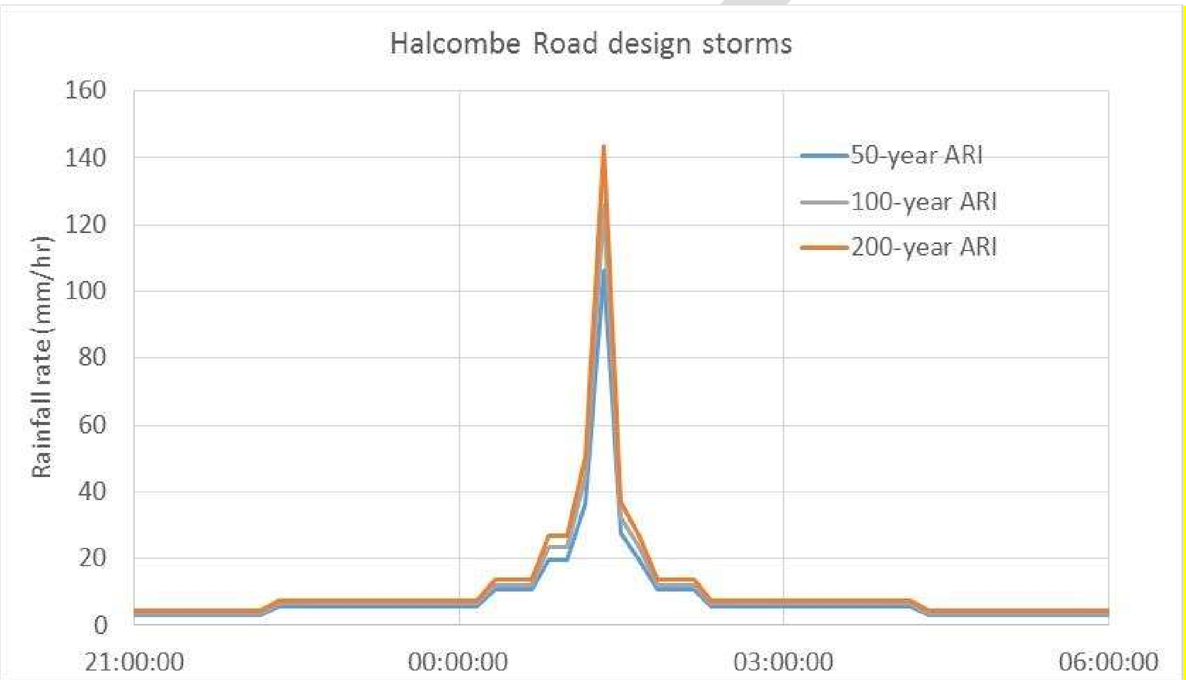

Figure 9 Design hyetographs for the Halcombe Road gauge site; these were adopted for the Feilding West area

2.4 Rainfall to runoff

Infiltration losses were treated simply, as an initial loss depth and a continuing loss rate. The initial loss was manually subtracted from the hyetographs, and for simplicity the continuing loss was specified as evaporation (rather than specified with the infiltration function).

Without any calibration data, the initial and continuing losses had to be simply assumed. The values chosen were an initial loss of 10 mm and a continuing loss rate of 1.6 mm/hour, both of these values being half of those adopted for the adjacent Makowhai catchment, to take account of the less permeable soils within the Feilding West area.

The flooding and drying depths were set to 0.02 m and 0.01 m respectively. With “inland flooding” specified, these two depths define a gradual introduction of hydraulic flow with increasing depth, depths below the drying depth being treated as standing water.

2.4.1 Flow resistance for overland flows

A single Manning M value of 25 (reciprocal of Manning’s n=0.040) was applied to almost all the catchment.

Within the Feilding urban area, different values were applied (Figure 10), including a low flow resistance of M=43 (n=0.023) in the streets and a very high flow resistance M=8 (n=0.125) within residential, commercial and “industrial” lots. The high modelled resistance for the built-up areas represents the effect of obstructed flow paths as well as actual roughness. It has been implemented as a pragmatic alternative to time-consuming detailed specification of individual buildings and other features that divert runoff.

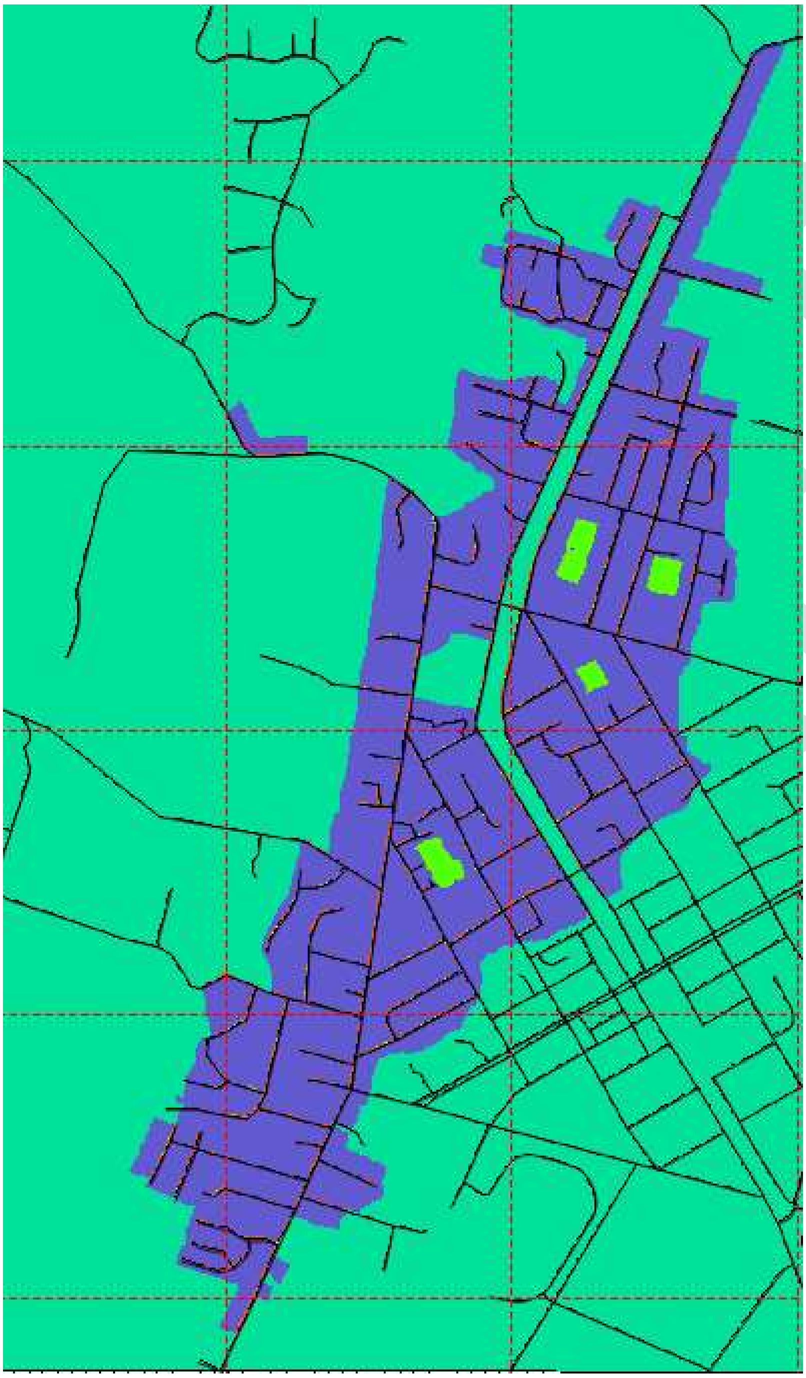

Figure 10 Map of modelled overland flow resistance (Manning’s M = 1/n) in Feilding. M values denoted by: Green: 25; blue: 8 (urban sections); red: 43 (urban streets); lime green: 30 (lawn)

3 The modelled scenarios

The main scenarios were the three design hyetographs of Figure 9, with assigned ARIs of 50 years, 100 years and 200 years. The model was therefore started at the time that the cumulative rainfall of the hyetograph equalled the initial loss plus the drying depth, with rainfall equal to the drying depth delivered within a single time step.

Output data was typically saved every 15 minutes. From inspection, this interval was short enough to capture flood levels very close to peak values.

The model runs were continued until about 5 hours after the hyetograph peak. Checks were made to ensure that peak water levels had been reached earlier throughout the model domain.

The significant rainfall event of June 2015 was also modelled, although unlike the adjacent Makowhai catchment, there were no data from this event for model calibration.

4 Post-processing and file delivery

The MIKE 21 Toolbox (a suite of software tools primarily for post-processing) includes a tool for extracting maximum values for every cell within the domain. This tool has been used to obtain maps of peak water level and of peak velocity.

These maps are presented below, using the colour coding shown in the legends in Figure 11.

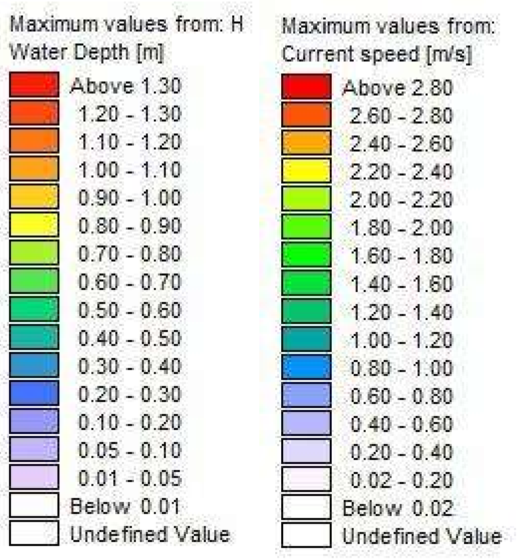

Figure 11 Legends for Figure 12 to Figure 19: color-coding for maximum depth (left) and maximum velocity (right)

4.1 Maps of maximum flood depth

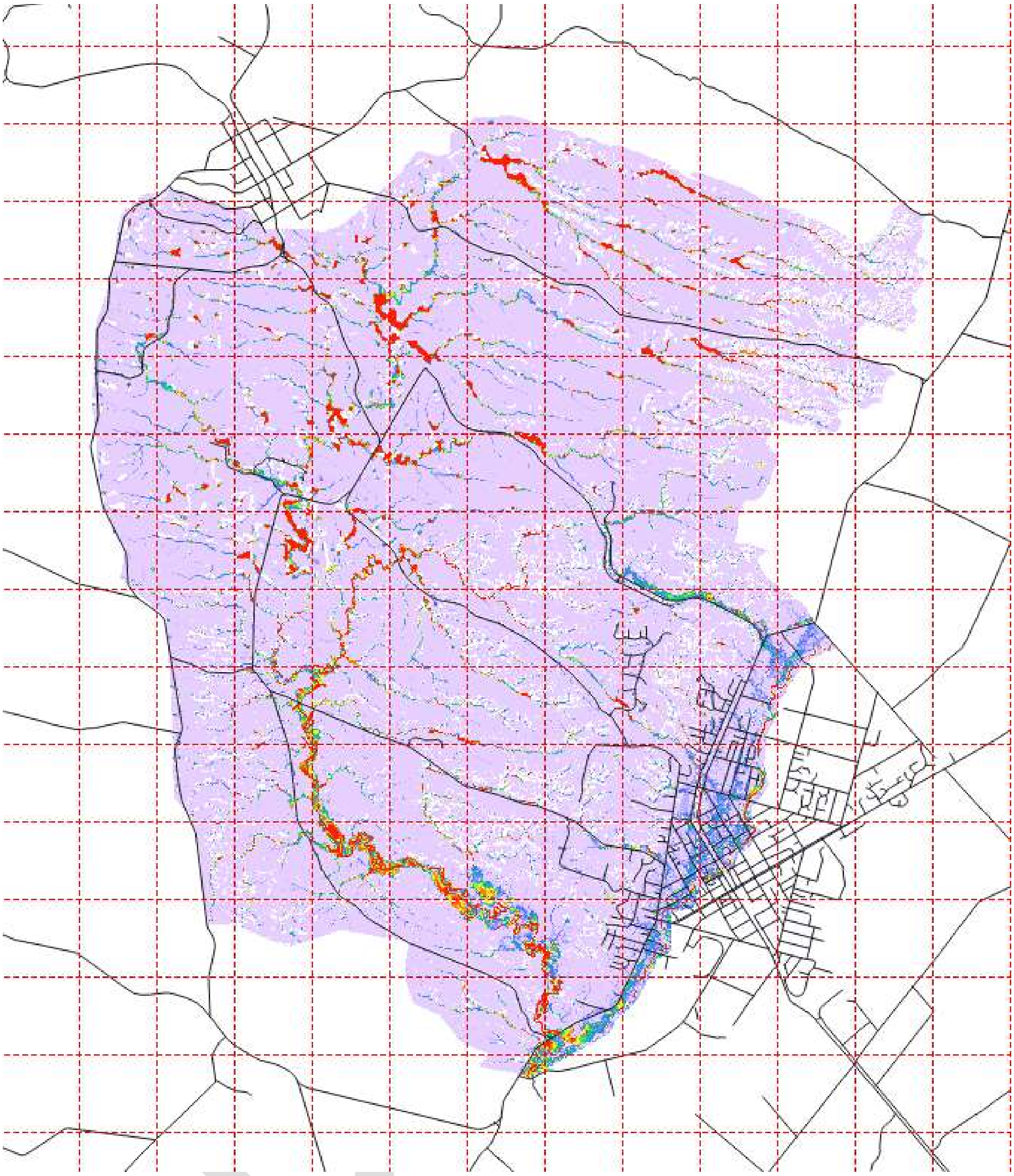

Figure 12 Computed maximum depth, 50-year ARI design event

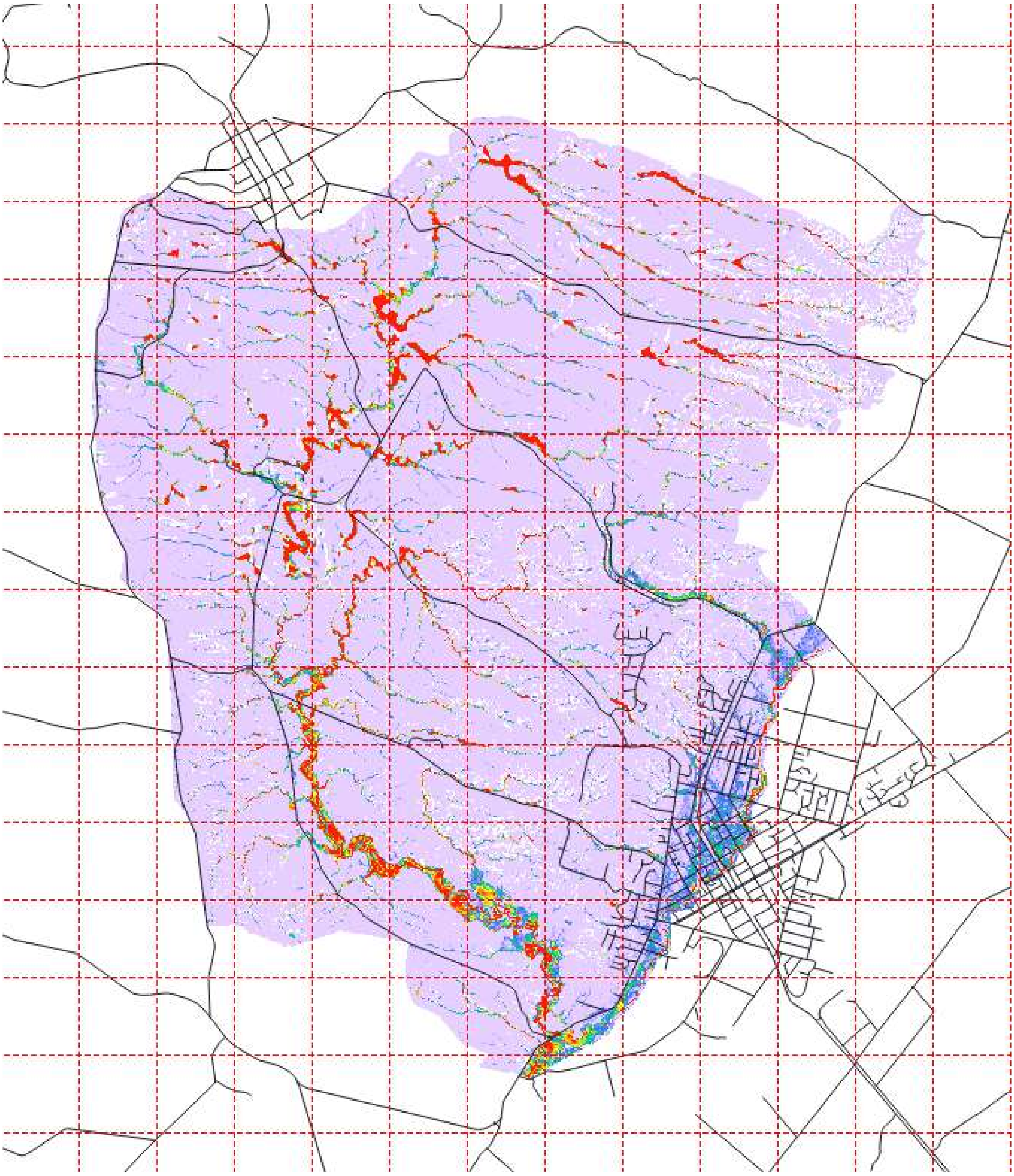

Figure 13 Computed maximum depth, 100-year ARI design event

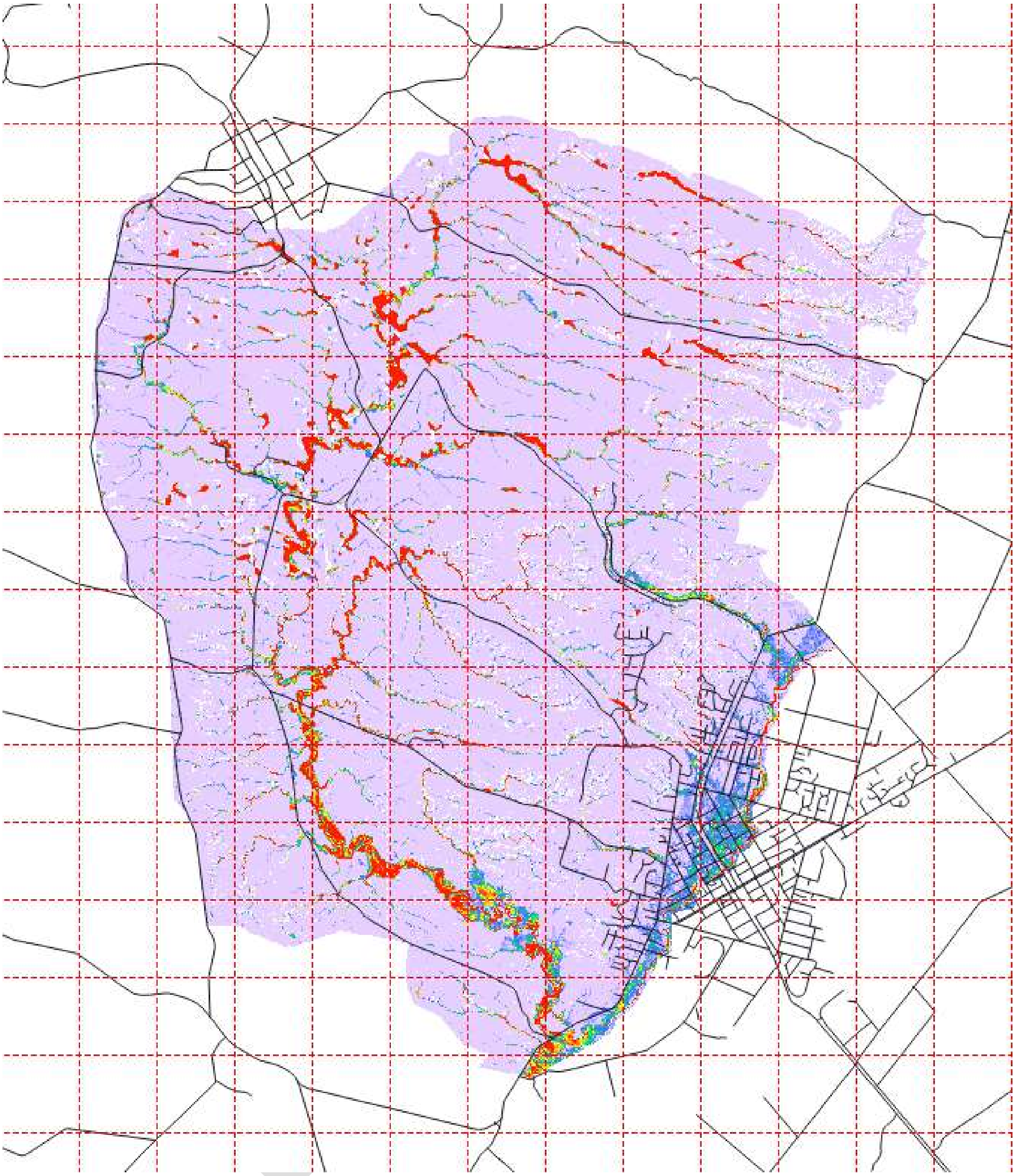

Figure 14 Computed maximum depth, 200-year ARI design event

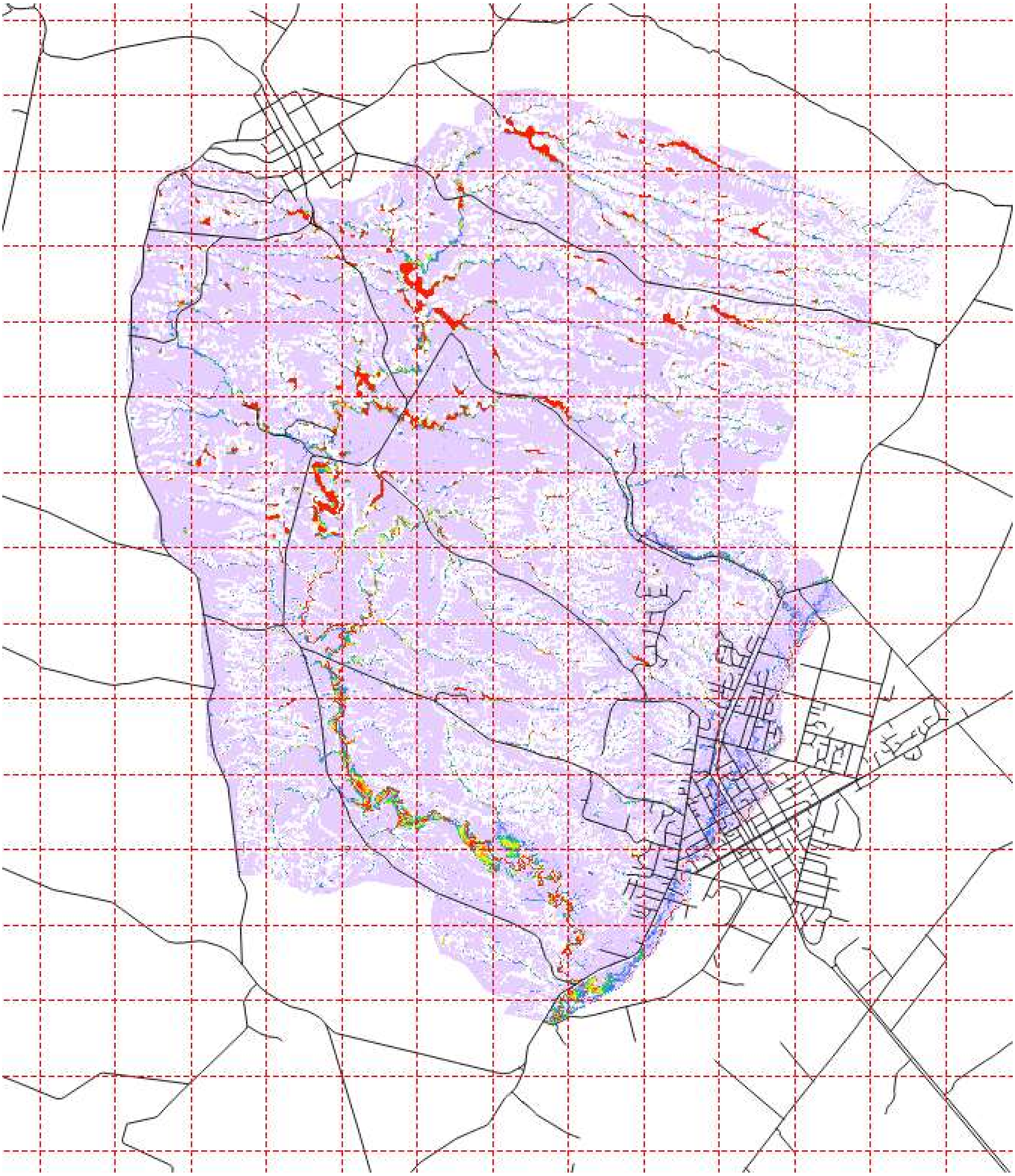

Figure 15 Computed maximum depths, June 2015 event

4.2 Maps of maximum velocity

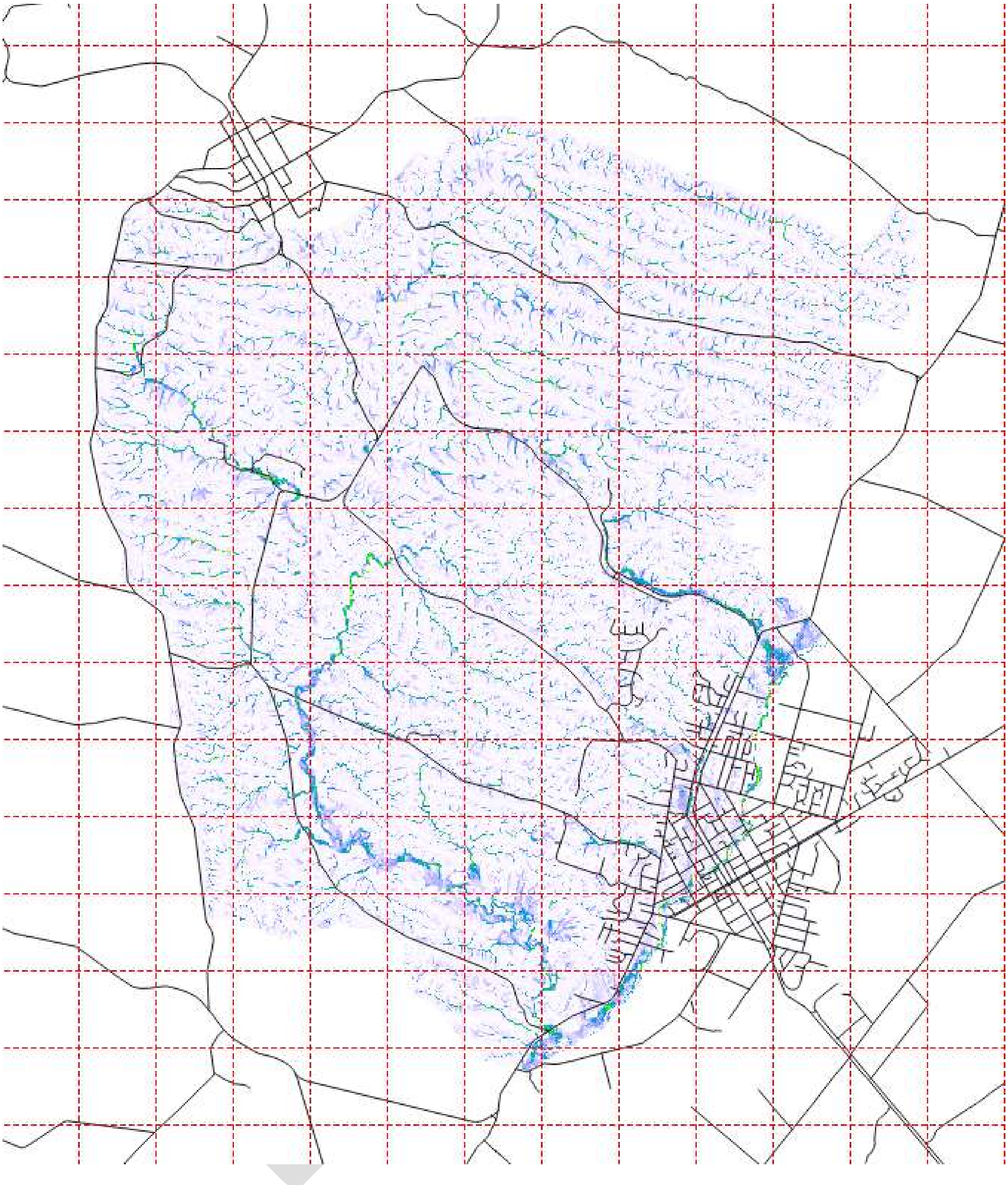

Figure 16 Computed maximum velocity, 50-year ARI design event

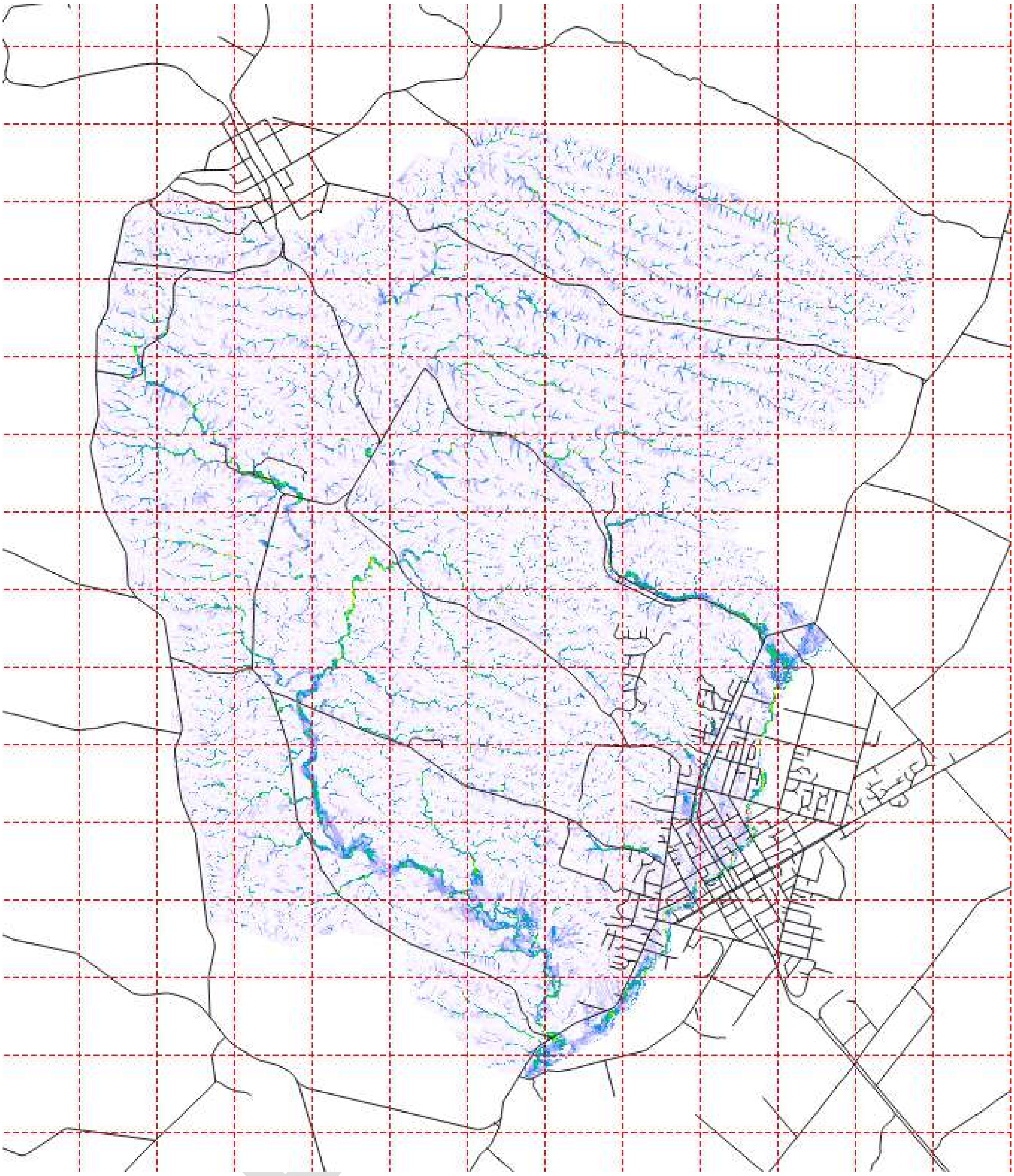

Figure 17 Computed maximum velocity, 100-year ARI design event

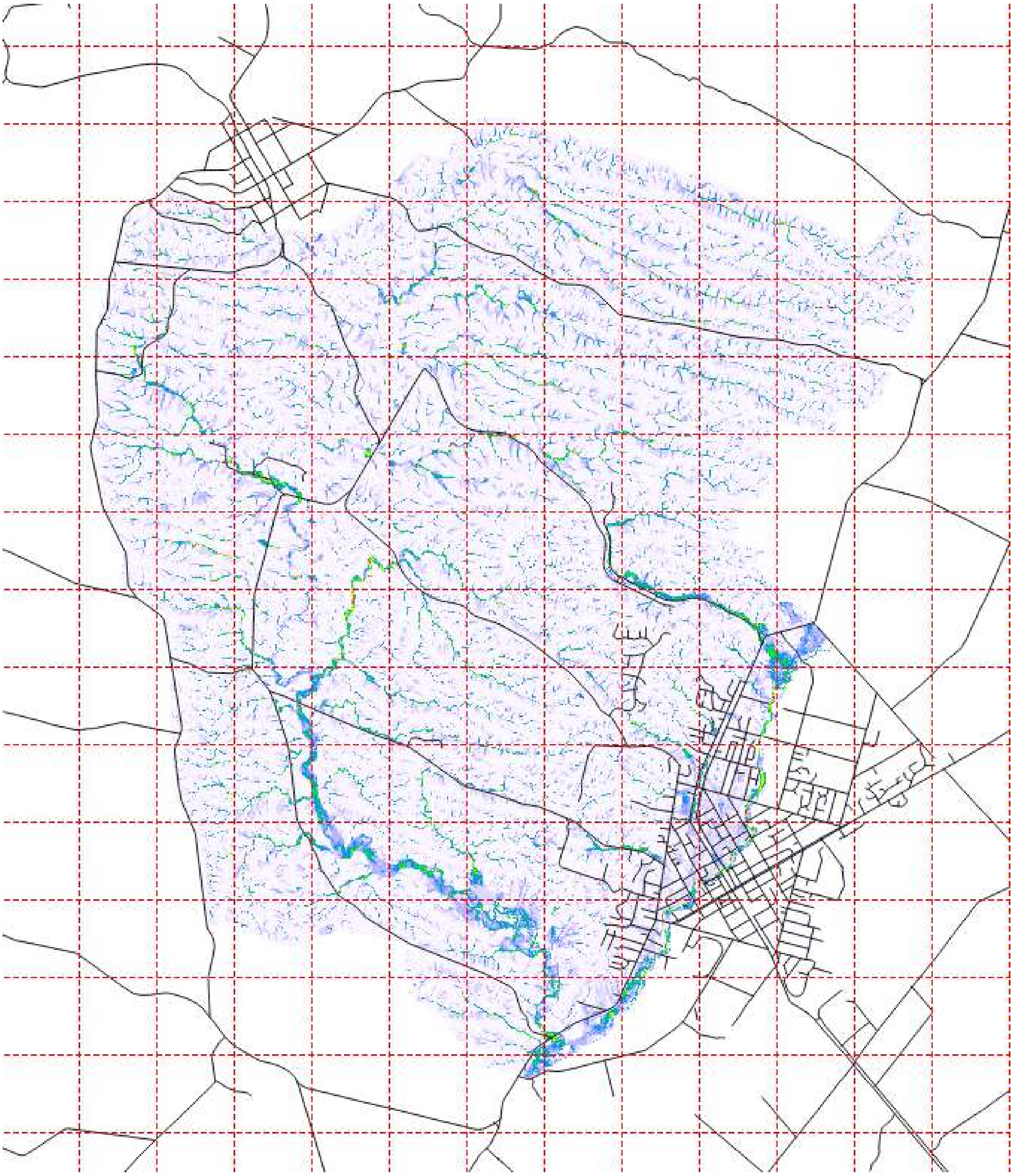

Figure 18 Computed maximum velocity, 200-year ARI design event

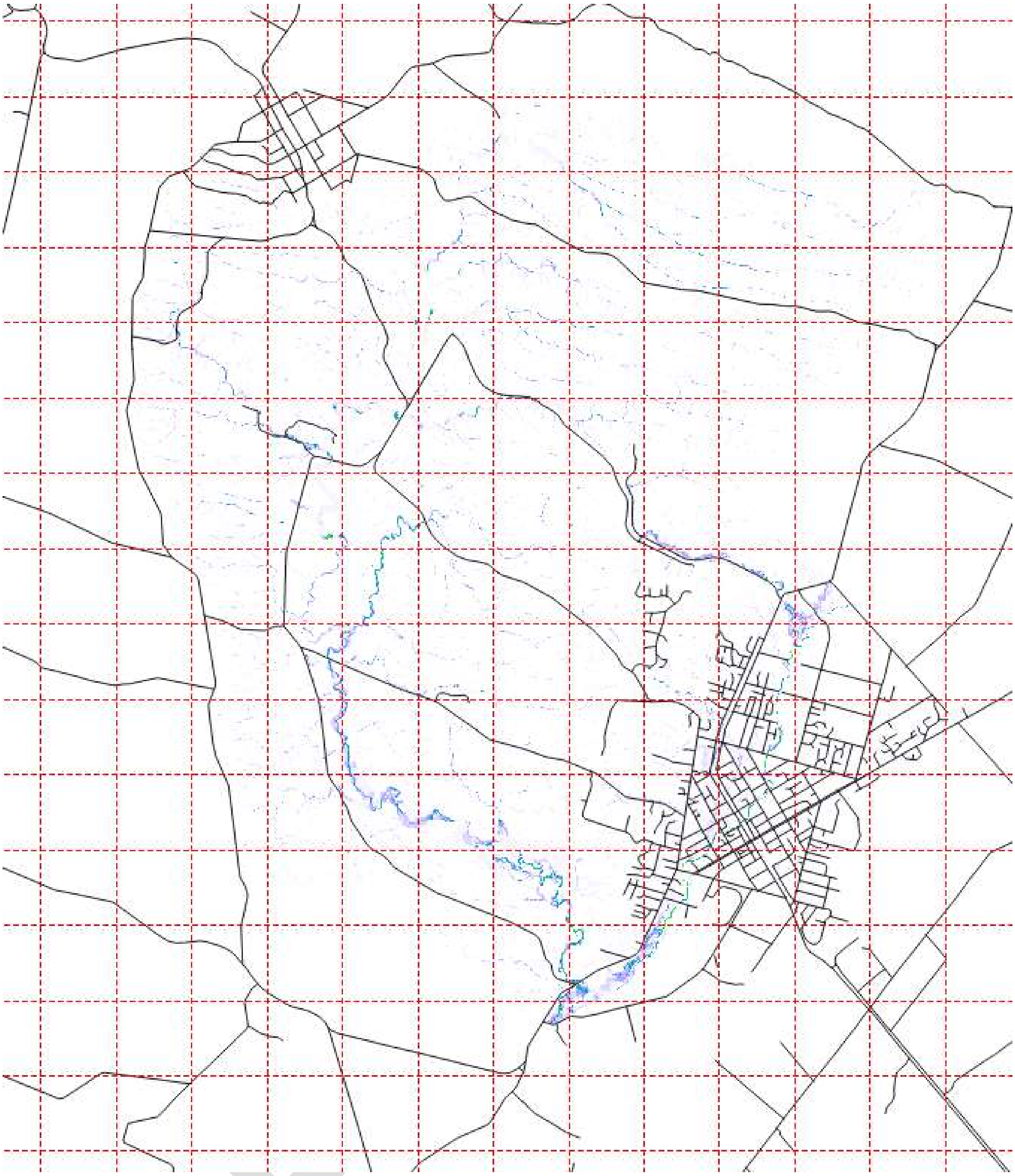

Figure 19 Computed maximum velocities, June 2015 event.

4.3 Files to be supplied with this report

4.3.1 Output files

The MIKE 21 files listed below include the entire modelled area. Some parts of this area outside the Feilding West area are poorly modelled and should be excluded. A shapefile, *domain.shp*, is therefore provided to be used for clipping rasters and shapefiles generated from the M21 maps.

MIKE 21 raw output files (time series of maps of depth and velocity components)

feildingw50yr171007concat.dfs2
feildingw100yr171006concat.dfs2
feildingw200yr171009concat.dfs2
FeildingWHalc2015171010.dfs2 and 10 continuation files

MIKE 21 maps of maximum depth and velocity

FeildingW50yr171007MAX.dfs2
FeildingW100yr171009MAX.dfs2
FeildingW200yr171009MAX.dfs2
FeildingW2015171011MAX.dfs2

Image files of maximum depth and velocity

50yrDepClipped.png
50yrVelClipped.png
100yrDepClipped.png
100yrVelClipped.png
200yrDepClipped.png
200yrVelClippedA.png
2015DepClipped.png
2015VelClipped.png

4.3.2 Model files

FeildingWestResist170906a.dfs2	Flow resistance map, M=1/Manning's n
FeildingWestTopo_wCulvGaps171007.dfs2	"Bathymetry" map, as edited to accommodate flow through culverts
FeildingW50yr171006.m21	Control file, 50-year ARI design event
FeildingW50yr171007.m21	Control file, 100-year ARI design event
FeildingW50yr171009.m21	Control file, 200-year ARI design event
FeildingWHalc2015171010.m21	Control file, June 2015 event
FeildingW50yr171006.dfs0	Rainfall file, 50-year ARI design event
FeildingW100yr171007.dfs0	Rainfall file, 100-year ARI design event
FeildingW200yr171009.dfs0	Rainfall file, 200-year ARI design event
FeildingWJune2015.dfs0	Rainfall file, June 2015 calibration event

All model runs ended abnormally due to "blow-up", and had to be restarted with a modified .m21 file using the Hotstart file generated by the original run. These files are not included with this report but can be supplied on request.

5 Conclusions

An overland flow model of the Feilding West area has been assembled, using a Digital Elevation Model with a 5m grid derived from LiDAR. However, there have been no data for calibration of this model.

The entire rural catchment is presented by a single flow resistance value, Manning's n of 0.04, but the urban areas of Feilding have been given a high resistance (n=.125) for developed properties (representing obstructions to direct flow as well as true resistance) and a low resistance for the roads.

With these features, the model should provide a good broad-brush representation of flooding in response to design events. With the road culverts included, model output should provide a good indication of where culvert drainage is adequate and where it might be improved by additional culverts or larger ones.

However, the model's 5m grid, and the approach taken to flow resistance, do not make it particularly suitable for detailed analysis of local drainage. Furthermore, the model does not include the Feilding drainage network in the two towns. Culverts on farm land have not been included at all. In contrast, the ground levels have been altered so that road culverts and bridges, for which no data were available, have been treated as operating perfectly. The flood modelling results may therefore be conservative in some places and optimistic in others.

Three design events have been modelled, with ARIs of 50, 100 and 200 years. The design hyetographs for these events at the Halcombe Road rain gauge (in the middle of the modelled area) are quite similar to those from two other reasonably close gauges (at Milson Land and Forest Road), lending some confidence to the application of the Halcombe Rd hyetograph to the entire area.

The peak flooding depths from these simulations show flooded valley floors in various parts of the area. Modelled flooding within the town of Feilding is minor; bearing in mind that overflows from Makino Stream have not been included.

Modelled flooding from the June 2015 event is minor. This might be exp[ected, as that event was lengthy but with relatively light rain (Figure 7). With road culverts modelled as conveying all incoming flow without heading up,

The present model does not include Makino Stream flows and so modelled flooding in Feilding town does not account for major rainfall events occurring together in the Feilding West area and the Makino Stream catchment.