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HORIZONS REGIONAL COUNCIL

Palmerston North City Flood Mapping

Composite Map Creation

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PROJECT 301015-03179 - PALMERSTON NORTH CITY FLOOD MAPPING

REV	DESCRIPTION	ORIG	REVIEW	WORLEY-PARSONS APPROVAL	DATE	CLIENT APPROVAL	DATE
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1. INTRODUCTION

A number of disparate flood model studies exist across the Palmerston North City Council (PNCC) area. Some of these were carried out for PNCC, whilst the majority were carried out for Horizons Regional Council (HRC).

The aim of this project was to create a seamless, composite layer representing the current 200yr design flood, overlain on the most current high resolution terrain information (LiDAR). The purpose of the composite layer was to provide a single source of flooding information for planning purposes.

The layer was created by sequentially mapping the disparate flood model results to a 2.0m Digital Elevation Model (DEM), derived from the LiDAR datasets.

2. SOURCE DATA

The data sources for the creation of the seamless dataset were provided by Horizons Regional Council (HRC). They consisted of a 2.0m gridded DEM, derived from LiDAR flown in 2005, as well as either raw flood modelling outputs or processed waterRIDE™ surfaces across a number of catchments for the present day 200yr design flood (or equivalent).

The “rapid hazard modelling” that was carried out for Palmerston North City Council (PNCC) included a 100yr ARI design flood and a 100yr design flood incorporating climate change. For the purposes of this project, the 100yr design flood including climate changes was used in lieu of a formal 200yr ARI design flood run, as instructed by HRC.

The source data ranged from traditional, detailed 1D/2D hydraulic model studies, to a coarser, “rapid hazard assessment” modelling approach which involves applying rainfall directly to the hydraulic model grid.

The following table presents the datasets that were used to develop the composite layer:

Catchment	Data Type	Raw Model Output (R) or waterRIDE™ Files Supplied	Resolution	Prepared By	Date Prepared
PNCC Area	LiDAR Based DEM	Raw	2.0m	Horizons Regional Council	2005
Ashurst-1	1D/2D MIKE FLOOD	Raw	4.0m	PNCC	2012
Ashurst-2	MIKE21 "rapid hazard"	Raw	10.0m	DHI	2011
Pohangina	1D/2D MIKE FLOOD	waterRIDE™	12.5m	Hydro Tasmania	2010
Cloverlea	1D/2D MIKE FLOOD	Raw	10.0m	Horizons Regional Council	2008
Oroua-Mangaone	1D/2D MIKE FLOOD	Raw	25.0m	DHI	2007
Upper Mangaone	1D/2D MIKE FLOOD	waterRIDE™	10.0m	DHI	2008
Whakarangaro	1D/2D MIKE FLOOD	Raw	7.5m	Hydro Tasmania	2008
Staces Rd	1D/2D MIKE FLOOD	waterRIDE™	7.5m	Horizons Regional Council	2007
Palmerston North City Overland Flow	MIKE21 "rapid hazard"	Raw	10.0m	DHI	2011
Massey University Overland Flow	MIKE21 "rapid hazard"	Raw	10.0m	DHI	2011
Manawatu River	MIKE11	Raw	-	Horizons Regional Council	-

3. FLOOD MAPPING APPROACH

3.1 Common spatial framework

In order to create a seamless flood surface from disparate model results, a common spatial framework is required. This framework forms the basis onto which the disparate model results, with their own varying spatial framework, are transferred. In this project, the source model frameworks were either 2D grids (of varying cell resolution), 1D cross section based frameworks, or a combination of the two.

Usually, and was the case for this project, the common framework adopted is a Digital Elevation Model (DEM), at a finer scale than the hydraulic modelling. This has the added benefit of improving the resolution of any depth-based outputs such as flood extents and depths.

A 2.0m gridded DEM covering most of the PNCC area was provided by HRC, which was derived from the LiDAR captured in 2005. The extent of the DEM is shown in Figure 1.

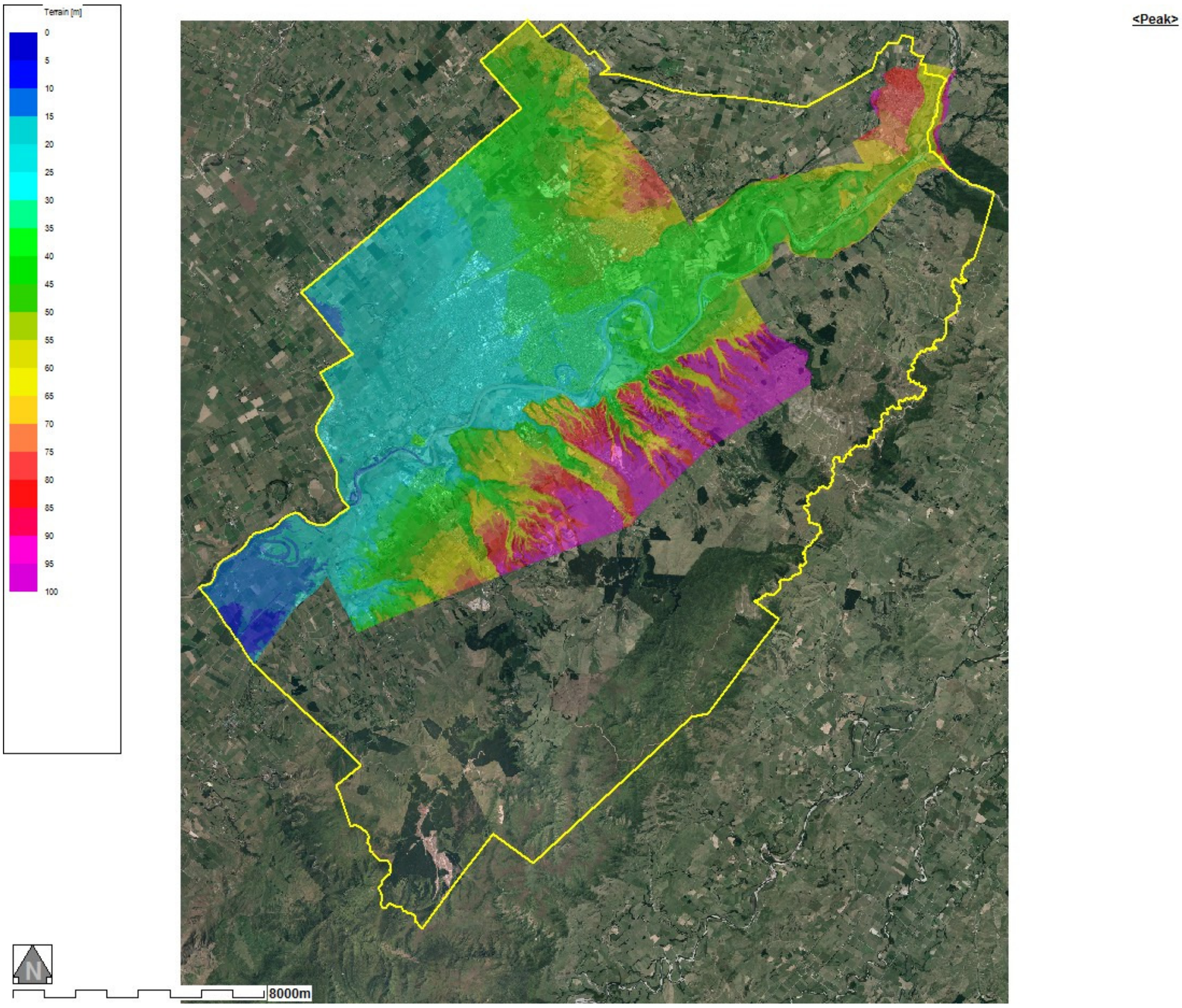

Figure 1 – LiDAR based DEM within PNCC Area.

3.2 Mapping Technique

The following mapping process was carried out on each of the model results provided (details of each component are provided in the subsequent sub-sections of this report :

1. Convert to waterRIDE™ format, if required
2. Stretch water surface
3. Convert gridded models into a TIN framework
4. Manage overlapping areas (clipping or 'peak of peaks' mapping)
5. Map to the finer scale DEM

3.2.1 Convert to waterRIDE™ format

Where the model results were provided in a raw format, they were converted into a waterRIDE™ surface using waterRIDE™ FLOOD Manager. The waterRIDE™ surface reflects the model results "as modelled", with the exception of the rapid hazard modelling of Palmerston North City, Massey University, and Ashurst. For these models, only those cells that had a minimum depth of 0.1m or greater at the peak of the flood were retained, in accordance with the recommendations of DHI in their flood modelling report (*Rapid Flood Hazard Mapping For Palmerston North City Council, DHI, March 2001*). Further processing of the overland flow modelling was carried out and is discussed in section 4.

3.2.2 Stretch water surfaces

Generally, gridded flood models only contain valid water surface information for cells that are 'wet'. The boundary between a wet cell and a dry cell is, effectively, a "glass wall". Whilst this does not affect flood extents on the model framework, when mapping to a finer framework, the "glass walls" can result in an undefined intersection between the water surface and the terrain. Consequently, all gridded models (with the exception of the rapid hazard models) were hydraulically stretched by 1 cell *prior* to mapping to the finer scale DEM. Assuming consistency between the terrain frameworks, this ensures an intersection between the terrain and the water surface, thereby defining the flood extent. This is illustrated in Figure 2, where stretching the water surface (blue) of a 10m model forces intersection with the terrain (grey-brown).

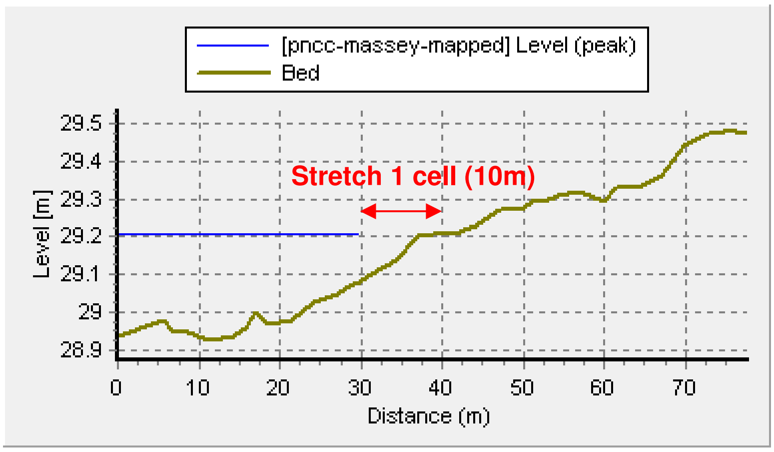

Figure 2 -Illustration of stretching to the flood extent.

The nature of rapid hazard modelling often results in an "unrealistic" over-stretching of flood surfaces when stretched prior to mapping to a finer scale DEM. Iterative stretching *after* mapping was found to yield better results, with a stretching of 3 cells on the DEM framework providing a good compromise between over and under stretching.

3.2.3 Convert gridded models to a TIN framework

In gridded models, the water surface across any cell is considered flat, and is discontinuous across cell boundaries. In reality, the water surface is continuous, with a gradient across cells. By TINning a grid, a continuous surface is created through linear interpolation between cell centres. Such an approach yields smoother mapping, especially in areas of shallow flow where an alternating pattern of "wet then dry" cells can occur. This is illustrated in Figure 3 where the top chart shows a profile along an area of shallow flow using the gridded surface (water surface in blue and ground in grey-brown), and the lower chart shows the same profile from a TIN surface.

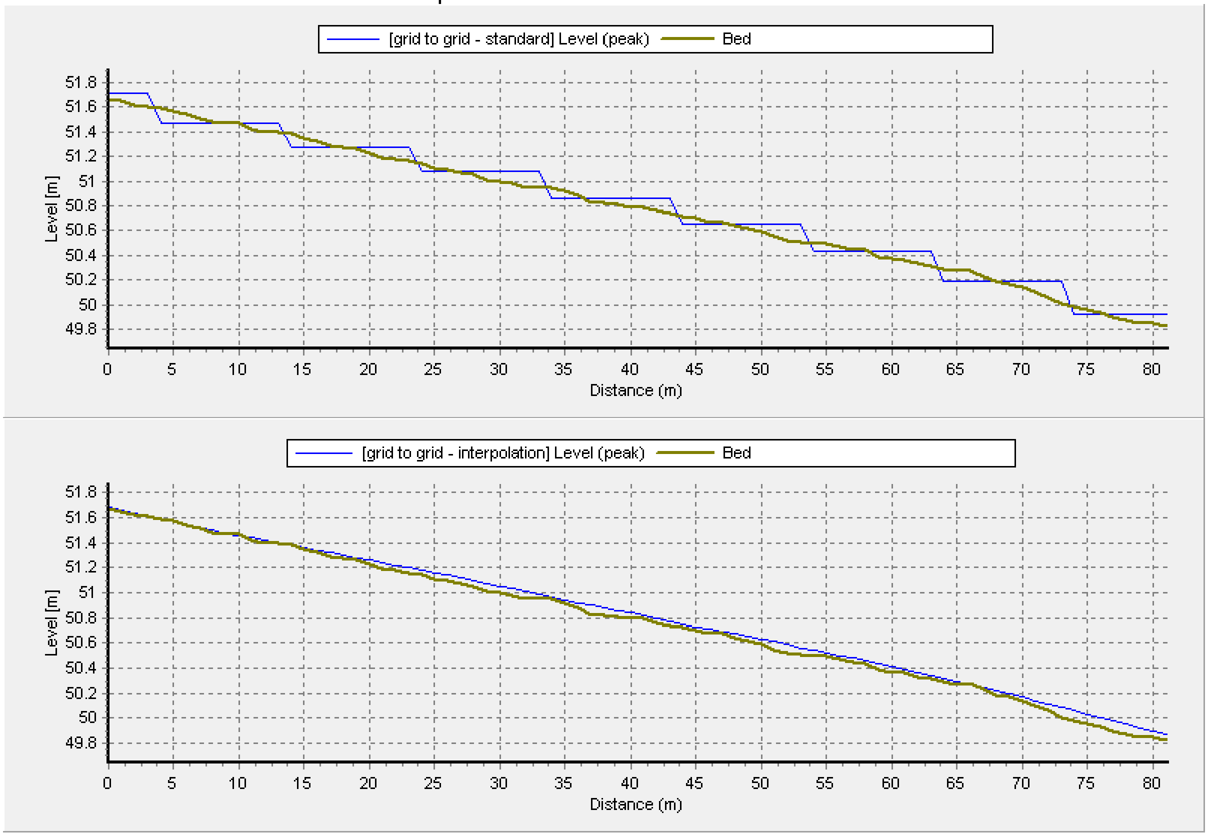

Figure 3 – TINning of gridded water surfaces to produce a continuous surface.

3.2.4 Managing overlapping areas

In some areas, the results of multiple models overlapped. In most cases, where a clear distinction in model coverage was evident (or instruction provided by HRC) this was addressed by mapping higher quality modeling on top of lower quality modelling. However, in cases where there was not a clear distinction between modelled areas and model quality, a "peak of peaks" approach was used whereby the maximum water level across all overlapping model results was retained at each cell.

The approaches used in overlapping between the various model results are indicated in

Figure 4 and Figure 5.

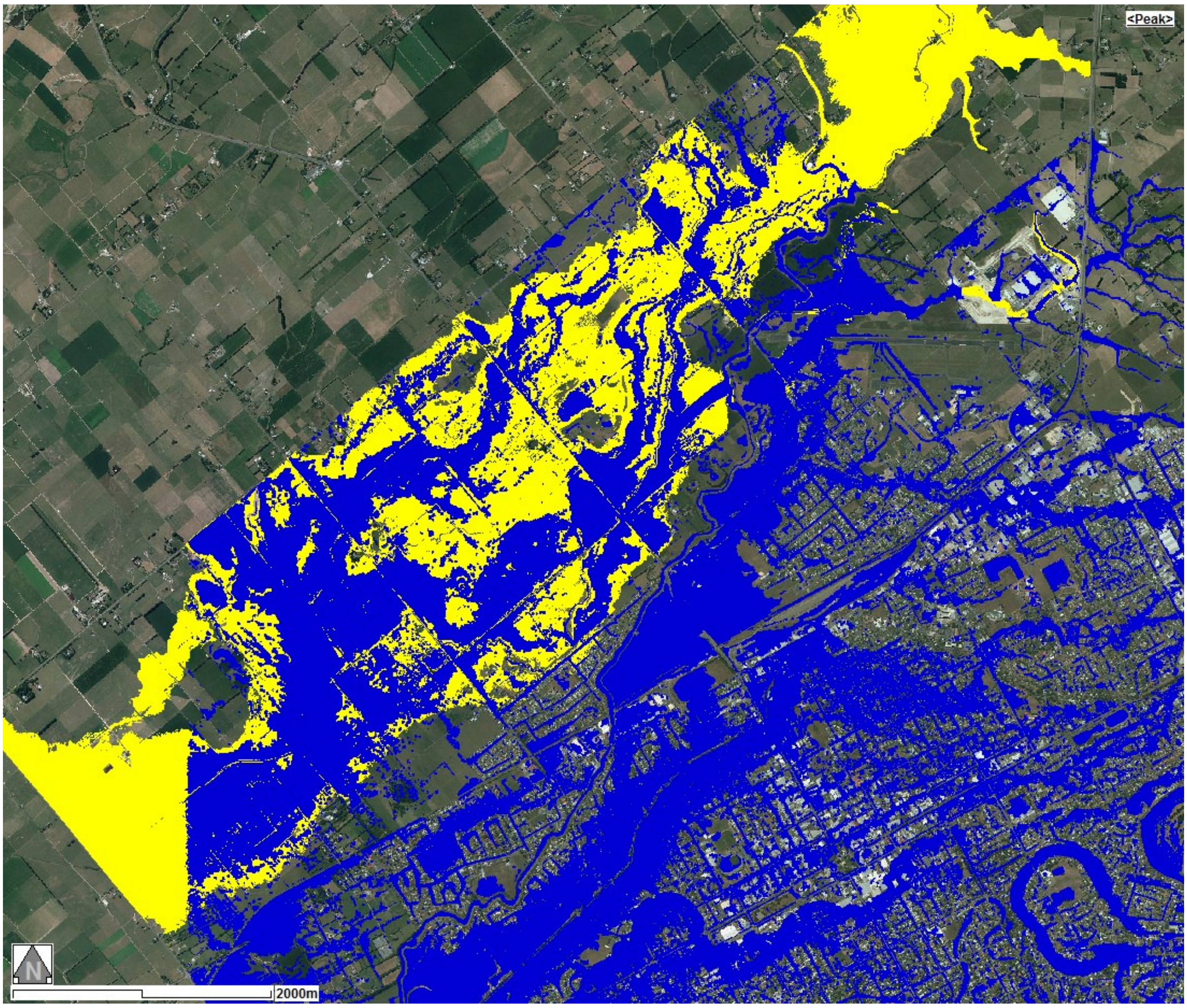

Figure 4 – Oroua-Mangaone-Cloverlea-Upper Mangaone "peak of peaks" (yellow) replaces PNCC Rapid Hazard Mapping (blue) in overlapping areas.

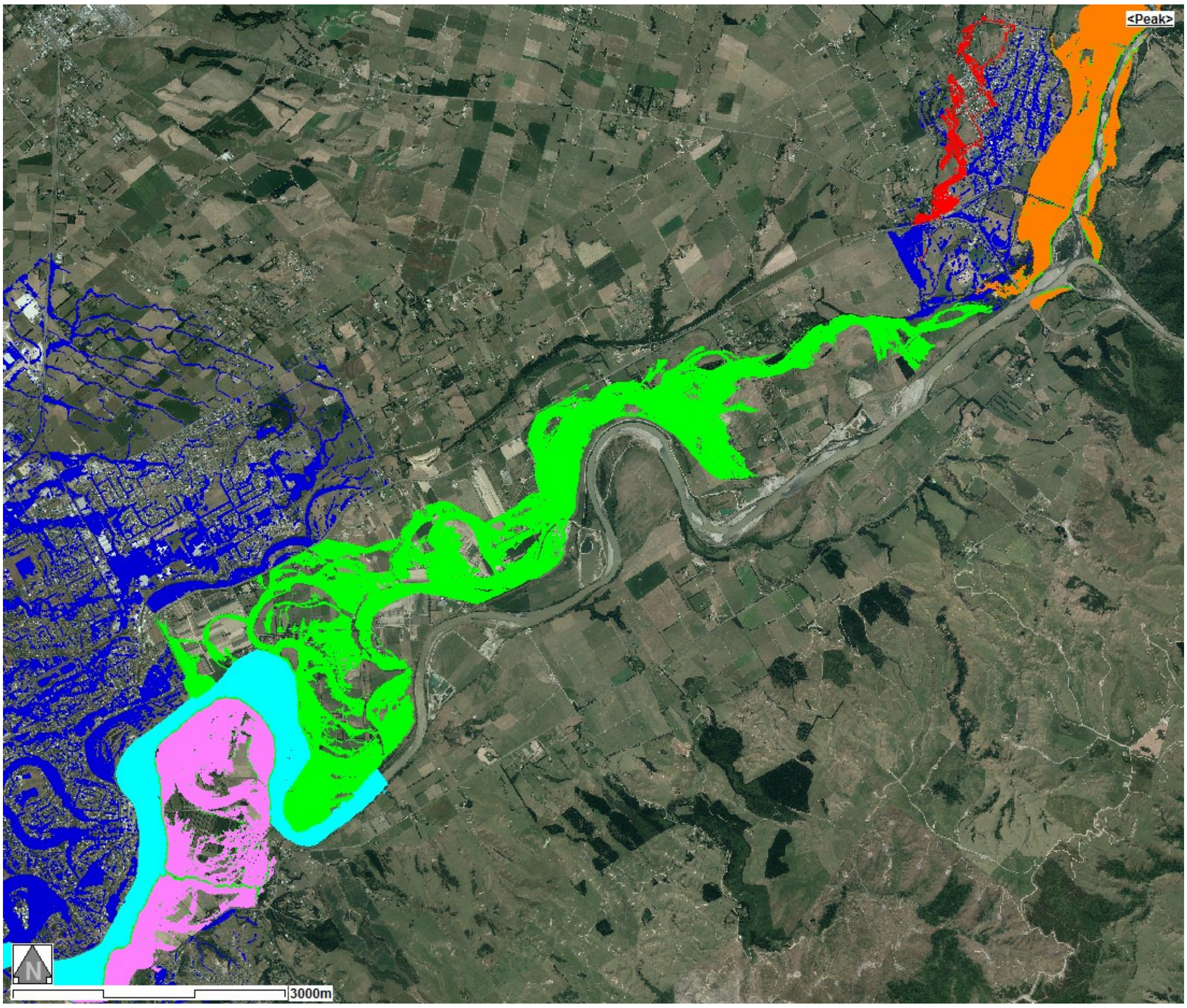

Figure 5 – Staces Rd (pink), Whakarangaro (Green), Manawatu River (Light Blue), Ashurst-1 (Red), Pohangina (Orange) and PNCC Rapid Hazard Mapping (Blue)

3.2.5 Indicative flooded areas

A GIS layer depicting “indicative flooded areas” was provided by HRC. This layer represents areas that have been identified as having been flooded within the past 50 years from an historical photography analysis carried out by HRC. It was digitised using 1:50,000 scale topographic mapping. The polygons in this layer *outside* of the modelled areas were aligned against the more accurate LiDAR DEM, whilst maintaining a similar overall shape to the original polygons. WorleyParsons did not carry out a review the sensibility of these polygons, as does not warrant their validity.

3.2.6 Relative accuracy

The quality of the composite surface in any given area is a function of the quality of the underlying modelling, and the quality of the DEM being mapped to. In this case, the DEM coverage was consistent, being the 2.0m LiDAR derived DEM. Consequently, the rating system presented in the following table was developed and is reflected in the GIS "quality polygons" provided with the project deliverables.

Quality Label	Description
A	Fine scale 2D detailed flood modelling (<5m grid size)
B	Medium scale 2D detailed flood modelling (5 - 15m grid size)
C	Coarse scale 2D detailed flood modelling (>15m grid size), or detailed 1D modelling
D	Rapid Flood Hazard Assessment/"Direct Rainfall" Approach or Coarse 1D Modelling
E	"Indicative Flooded Areas" – no flood modelling carried out. Known to flood.

↓ **Decreasing Quality**

Table 1 – Relative Accuracy of Source Model Data

3.2.7 Mapping to finer scale DEM

The following table provides a summary of the processing applied to each surface.

Area	Stretching	TIN before Mapping	Comments
Ashurst-1	1 cell before mapping	Yes	-
Ashurst-2	3 cells after mapping	No	Overlain by other model results, where overlapping
Pohangina	1 cell before mapping	Yes	-
Cloverlea	1 cell before mapping	Yes	Peak of peaks mapping with Oroua-Mangaone and Upper Mangaone
Oroua-Managaone	1 cell before mapping	Yes	Peak of peaks mapping with Cloverlea and Upper Mangaone
Upper Mangaone	1 cell before mapping	Yes	Peak of peaks mapping with Oroua-Mangaone and Cloverlea
Whakarangaro	1 cell before mapping	Yes	Overlaid with Staces Rd results
Staces Rd	1 cell before mapping	Yes	-
Palmerston North City Overland Flow	3 cells after mapping	No	Overlain by other model results, where overlapping
Massey University Overland Flow	3 cells after mapping	No	Overlain by other model results, where overlapping
Manawatu River	N/A	Yes	-

4. PALMERSTON NORTH CITY "RAPID HAZARD MAPPING" PONDING AREAS ADJUSTMENT

4.1 Background

The "Rapid Hazard Mapping" of Palmerston North City and Massey University incorporated a static tailwater boundary condition in the Manawatu River, corresponding to the peak of the 200yr design flood. In reality, the Manawatu River levels would vary with the progression of the Manawatu River floodwave through the system. Consequently, an elementary assessment of the *dynamic* river conditions was made to determine the potential for any additional floodwaters to escape the CBD via culverts through the stopbanks.

Specifically, an assessment was made between the water levels in the ponding areas behind culverts 1 to 6 (as shown on Figure 6) and the dynamic river levels (note that the location of culvert 6 was assumed, as no information was available in DHI's report). The ponding areas were considered to be the flat water surface areas connected to each culvert. Culvert dimensions were extracted from DHI's report (*Rapid Flood Hazard Mapping For Palmerston North City Council, DHI, March 2001*).

Figure 6 – Culvert locations used in "Rapid Flood Hazard" Assessment carried out by DHI.

HRC carried out an assessment between the timing of the peak (at Palmerston North) of the 5 largest floods of the Manawatu River, and the timing of cessation of rainfall in the CBD. Rainfall at the Mangaone gauge (on the western side of the city) was found to generally cease 8hrs prior to the peak of the Manawatu River. Consequently, this time difference was used in the dynamic analysis of water levels inside the stopbanks and in the river.

4.2 Approximate Dynamic Analysis

A comparison between water levels inside the stopbanks and in the Manawatu River was carried out at each of the culverts. The results are shown on Figure 7 to Figure 12, where the blue line represents the water level inside the stopbank, the green line the tailwater water level used in the rapid flood hazard modelling, and the red line the levels in the Manawatu River from HRC's 1D modelling "adjusted" for the 8 hour time difference.

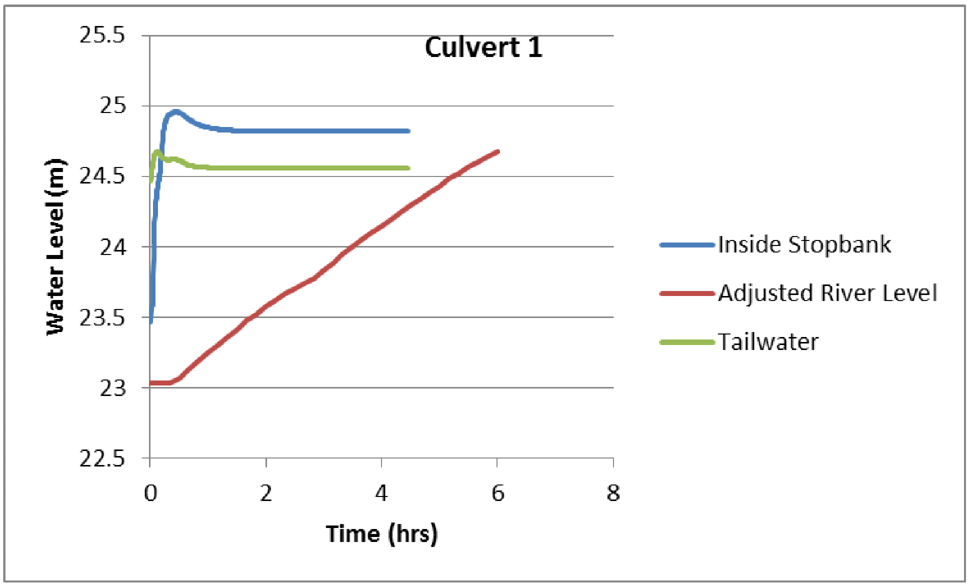

Figure 7 – Water Level vs time – Culvert 1

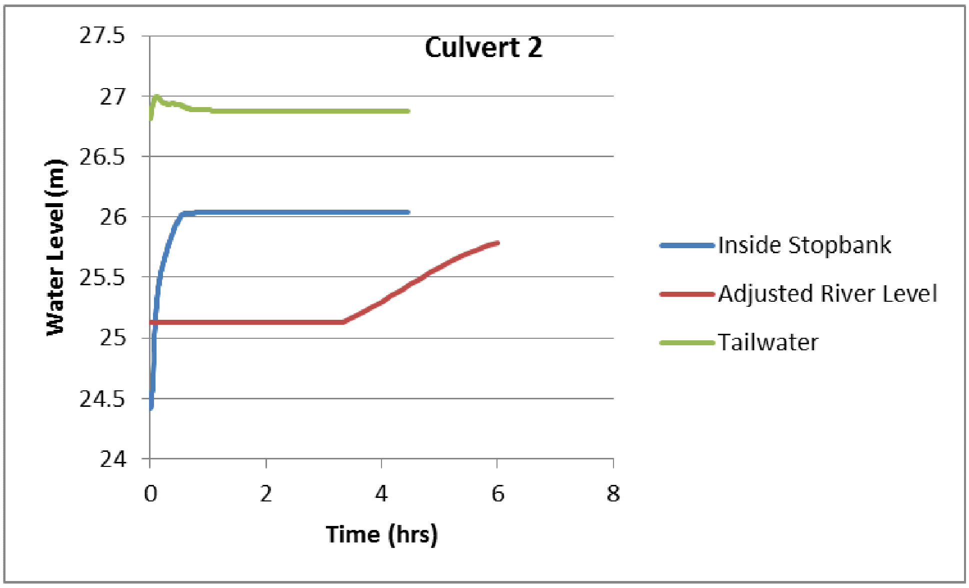

Figure 8 – Water Level vs time – Culvert 2

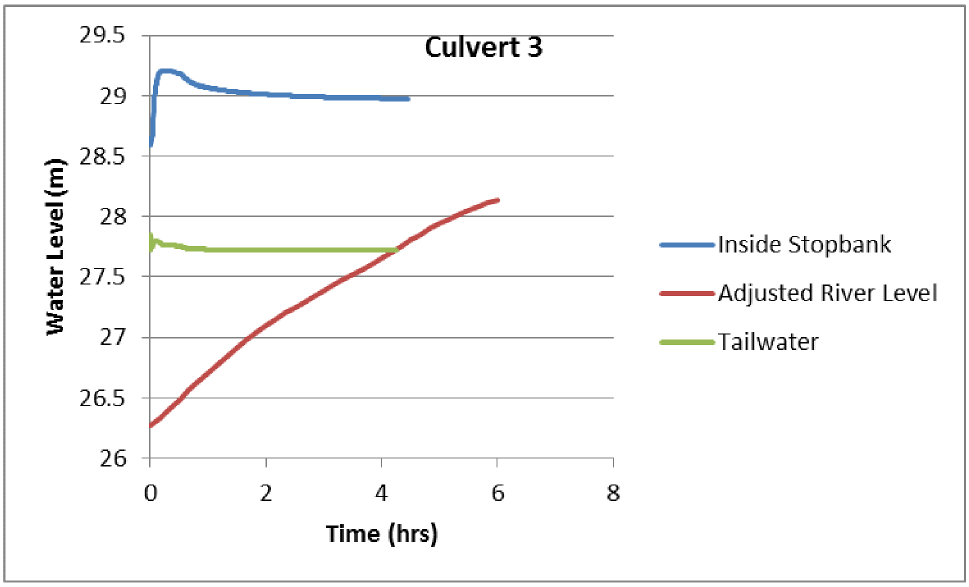

Figure 9 – Water Level vs time – Culvert 3

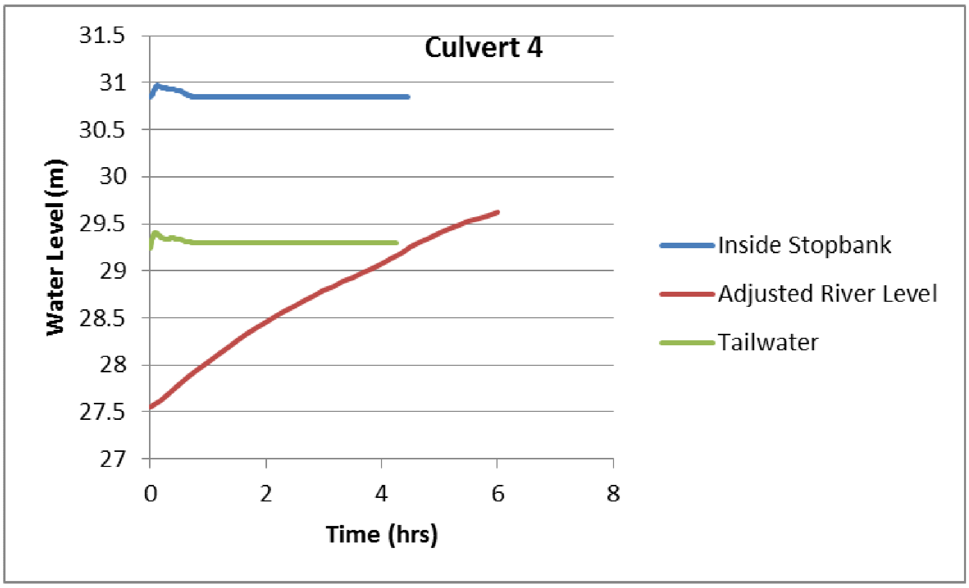

Figure 10 – Water Level vs time – Culvert 4

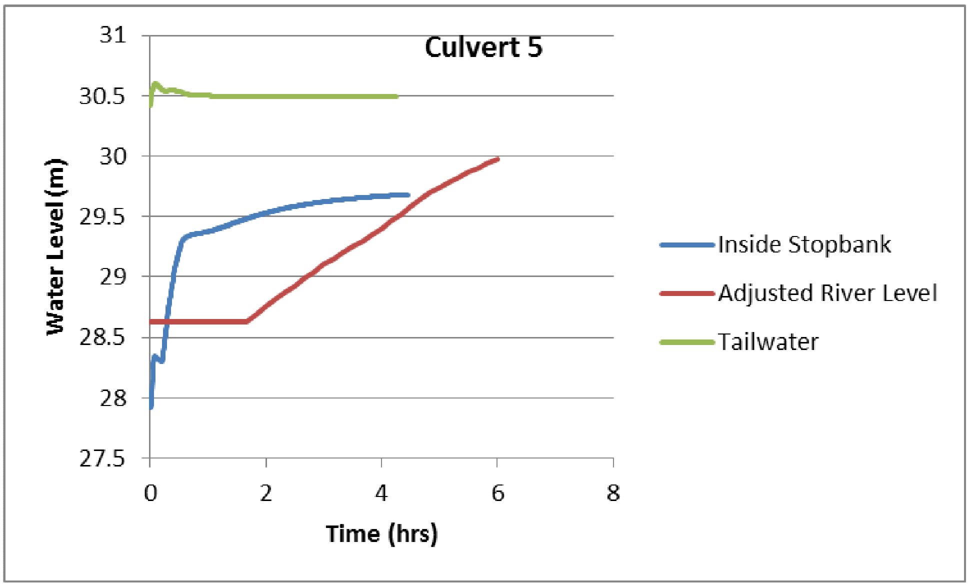

Figure 11 – Water Level vs time – Culvert 5

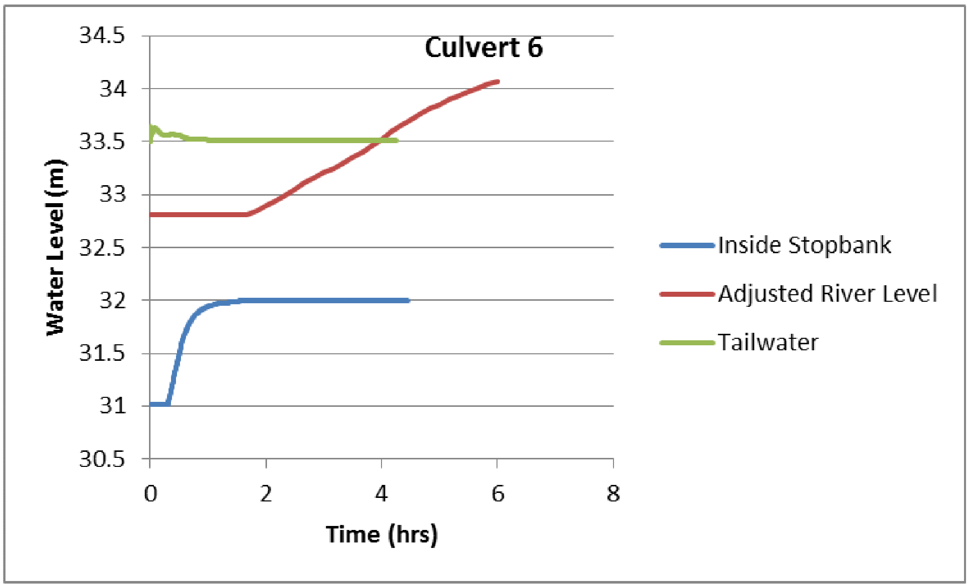

Figure 12 – Water Level vs time – Culvert 6

Culverts 3 and 4 appear to be inlet control driven, with significant head loss through the culverts and hence, the difference between the Manawatu River levels used in the modelling and the "adjusted" river levels are unlikely to impact flood levels inside the stopbanks. Consequently, no adjustment was made to the ponding behind these culverts.

At culvert 6, both the modelled river levels and adjusted river levels are greater than water levels inside the stopbank. Consequently, the flap gate would remain closed and no adjustment to ponding levels inside the stopbanks was made.

At culverts 1, 2 and 5, the modelled river levels are higher than the adjusted river levels. This results in CBD floodwaters being "trapped" behind the stopbanks in the rapid hazard modelling when, in reality, some of this water would escape into the Manawatu River.

Consequently, water levels in the ponding areas behind culverts 1, 2, and 5 were adjusted to account for an *indicative* volume of floodwaters that may have flowed into the River. The following process was carried out for each culvert to determine this indicative volume:

1. Calculate localised volumes in ponding area.
2. Assuming a constant water level upstream of the culvert, determine the indicative flow rate through the culvert and, hence, the volume of flow.
3. Reduce the localised volume in the ponding areas by the volume of flow calculated in step 2.

The results of the above approach are presented in section 4.3.

CulvertW, a software application developed by B.D. Parkinson and M.J. Boyd, was used to carry out the culvert flow analysis. Ponding water volumes were calculated using waterRIDE™ FLOOD Manager.

4.3 Summary of Water Level Changes

The following table presents the overall change in peak water levels calculated using the approximate method described in section 4.2.

Culvert	Calculated Change in Peak Water Level (m)	Percentage Change in Ponding Water Volume
1	-0.23	-25%
2	-0.50	-49%
3	-	-
4	-	-
5	-0.12	-8%
6	-	-

5. DELIVERABLES

Accompanying this report are the following electronic deliverables for the project:

- PNCC-Composite-WaterSurface.wrr (refer Figure 13
- PNCC-Composite-WaterSurface-WaterLevel.asc (refer Figure 14)
- PNCC-Composite-WaterSurface-WaterDepth.asc (refer Figure 15)
- Indicative Flooded Areas.shp (refer Figure 16)
- Relative Accuracy.shp (refer Figure 17)

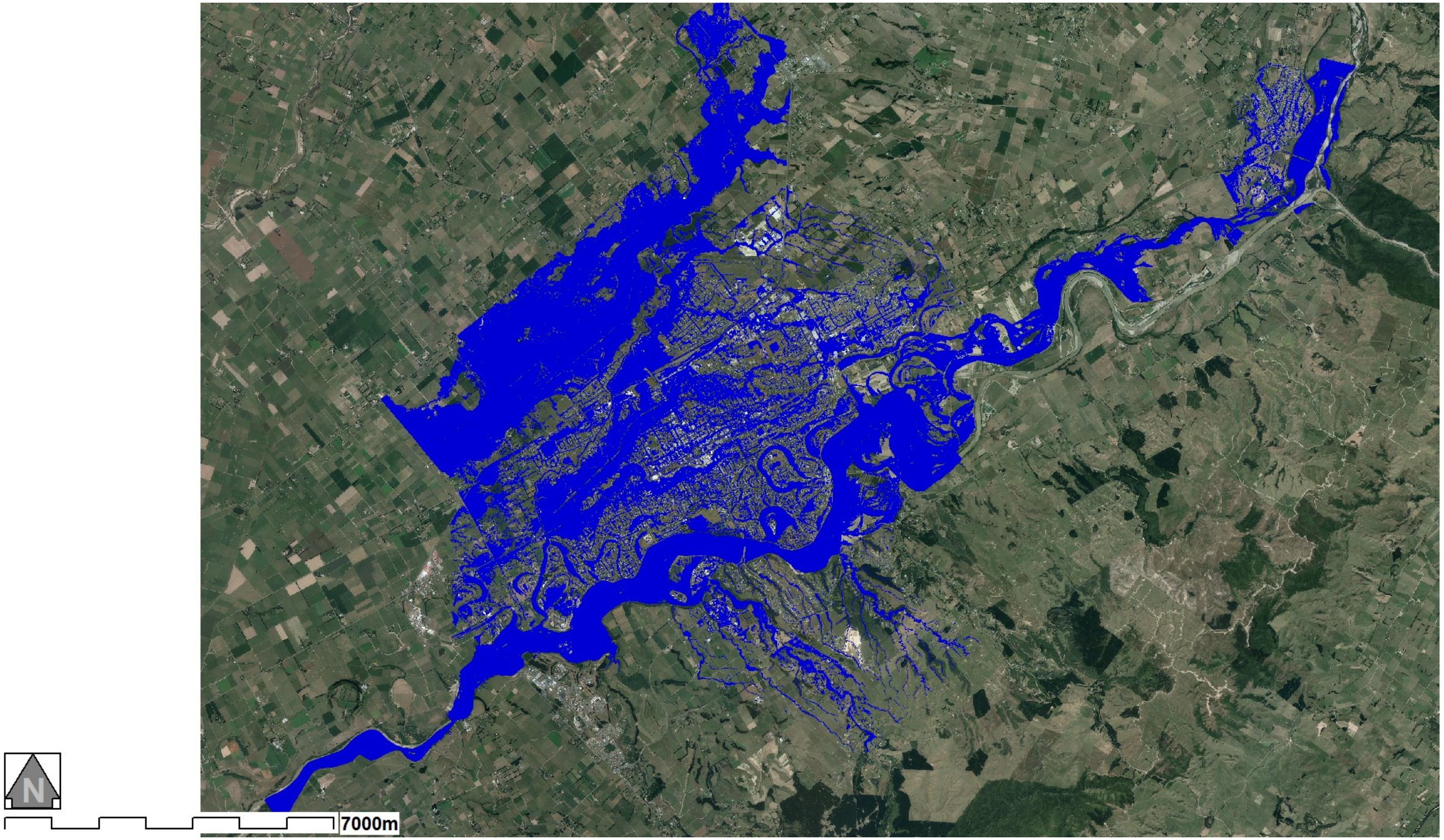

Figure 13 – Composite Flood Surface

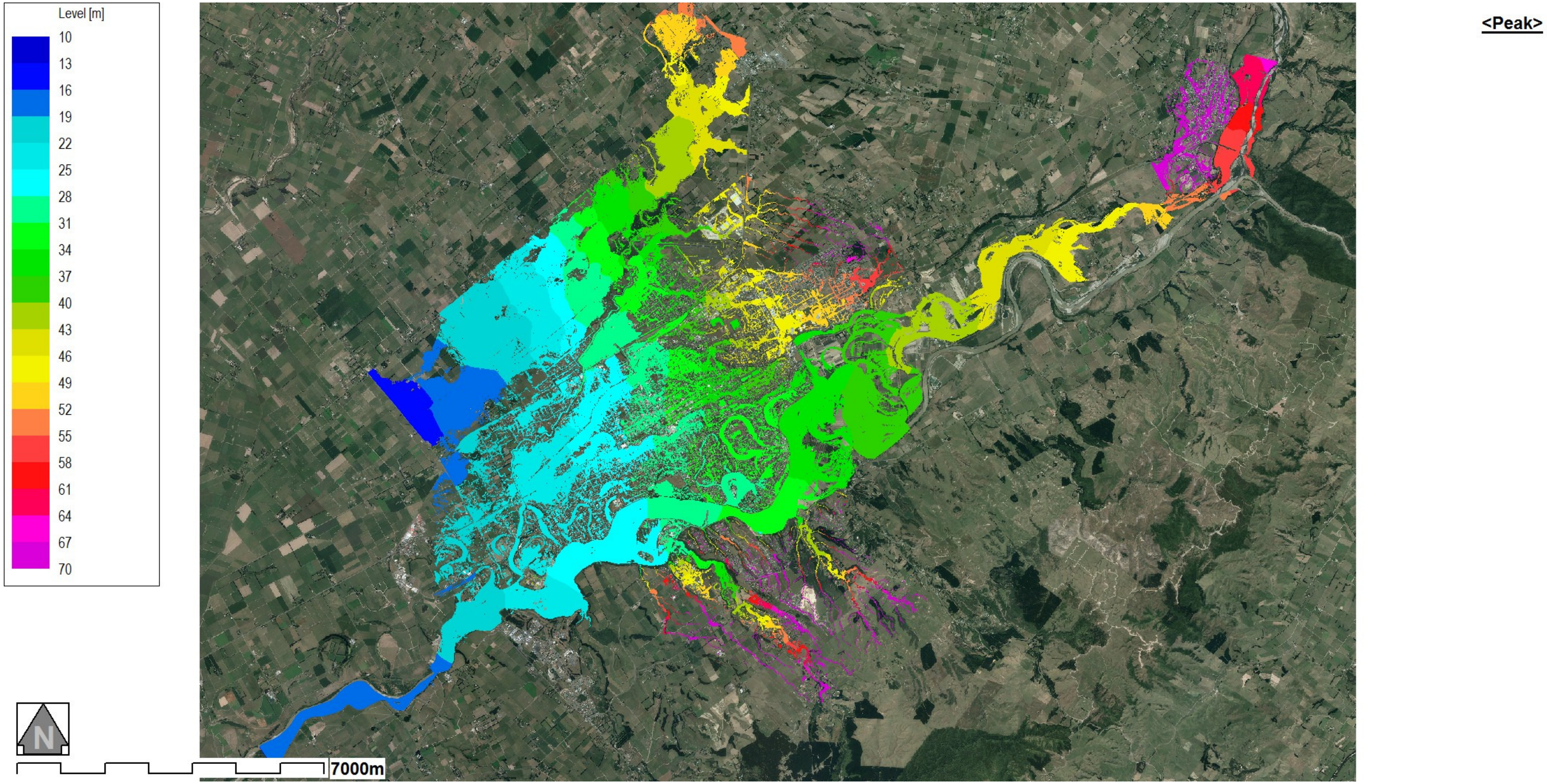

Figure 14 – Composite Flood Surface – Water Level

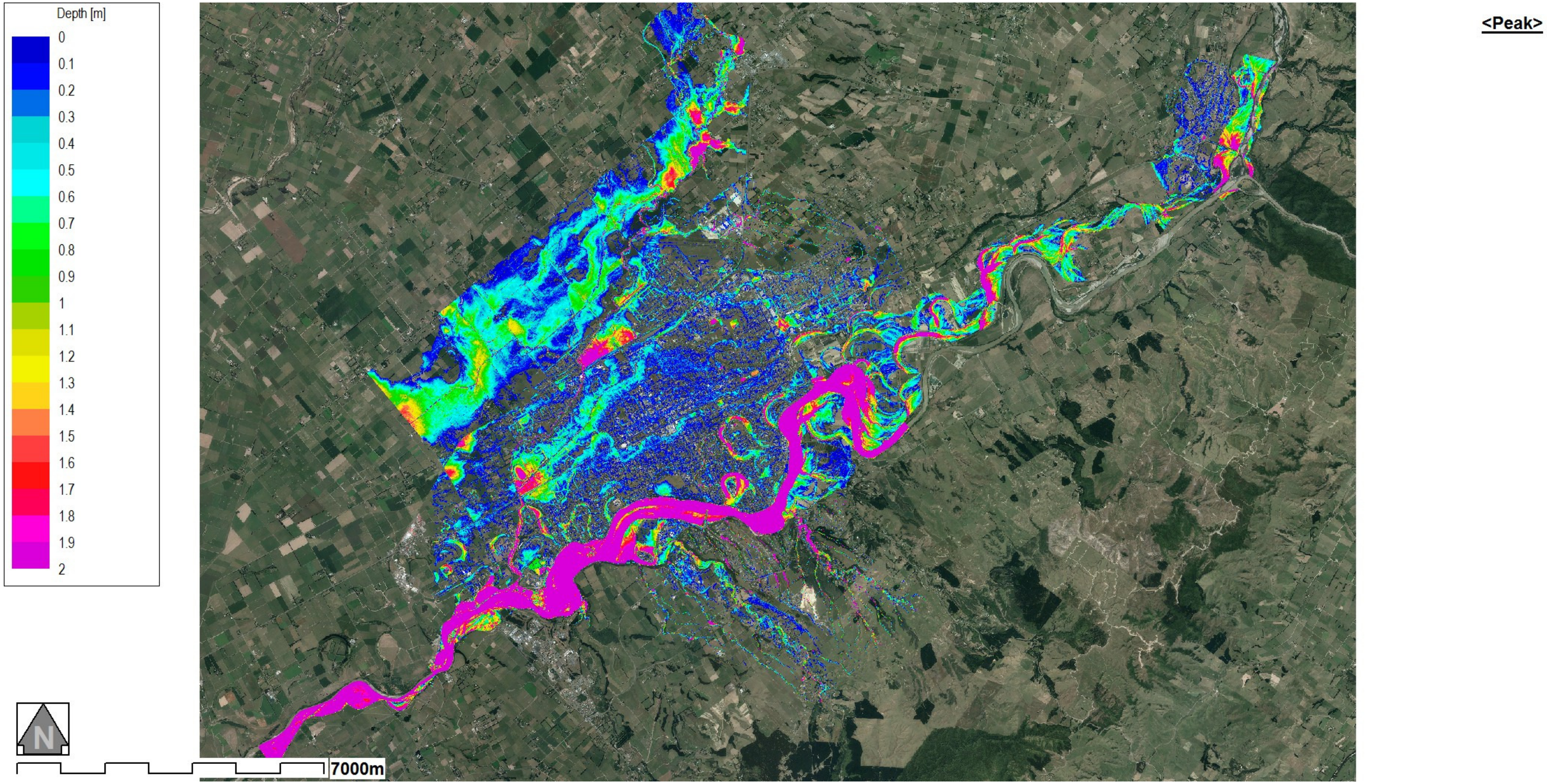

Figure 15 – Composite Flood Surface - Depth

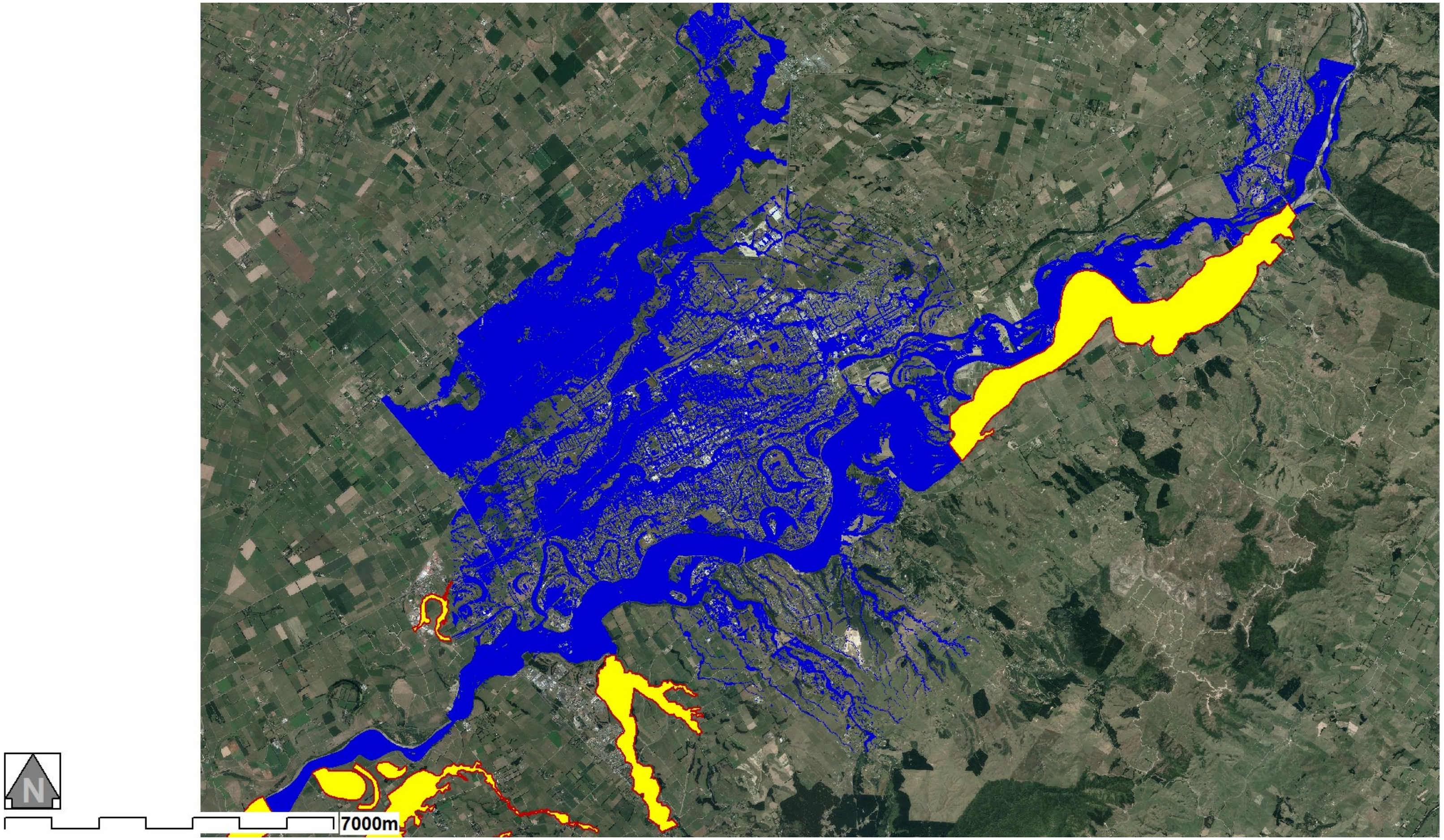

Figure 16 – Indicative Flooded Areas

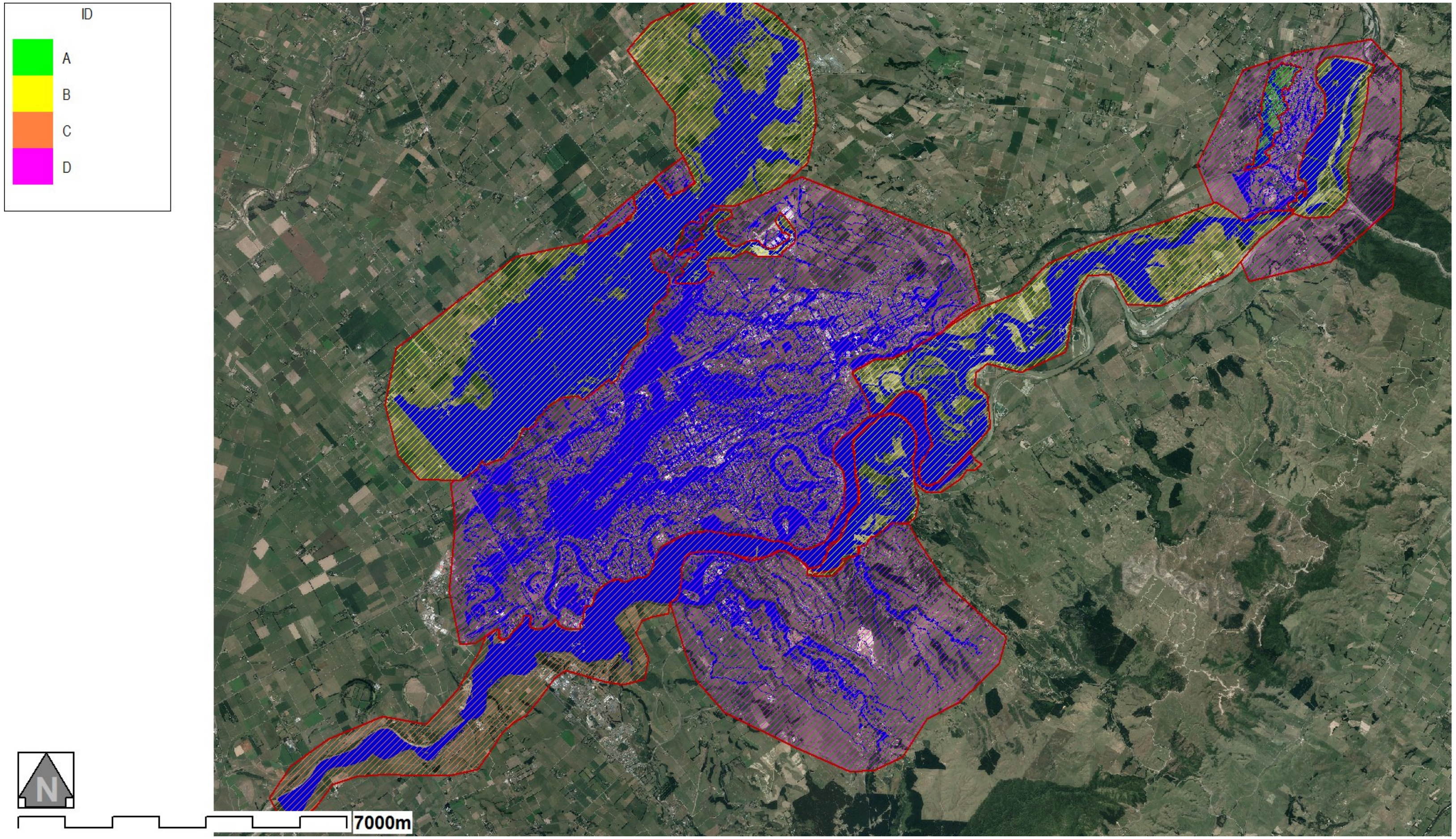

Figure 17 – Relative Accuracy Zones