Technical report

Methods used to define flood risk management areas

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1. Introduction

This report explains the methods used to define the extent of flood risk management areas, which are included in the Milton 2060 flood risk management strategy for Milton and the Tokomairiro plain (ORC/CDC, 2012a).

These areas have been shown to be susceptible to flooding. Areas with similar flood hazard characteristics have been grouped together. These characteristics include the depth of inundation, the velocity of water at the peak of the flood, and the length of time flooding may persist. The flood risk management areas within which land use controls have been proposed as part of the Milton 2060 strategy are listed below.

Area 1: The Tokomairiro River floodplain.

- Area 1A is the floodplain area which can be flooded by the north and west branches of the Tokomairiro River.
- Area 1B is the part of the floodplain where flood flows are sufficiently fast and / or deep to cause a significant safety risk. For the purposes of this report, the term 'floodway corridor' has been used to describe areas with these characteristics.

Area 2: Low-lying ponding areas. These are urban areas where water ponds during prolonged heavy rainfall events. They are located at the southern end of Milton.

- Area 2A is to the north and west of SH1.
- Area 2B is to the south and east of SH1.

Area 3: Milton urban area.

- Area 3B comprises the floodway corridors which drain internal runoff and water from the floodplain and eastern hill catchments through the Milton urban area.

Area 4: Rural and semi-rural areas on the Tokomairiro plain.

- Area 4B comprises the floodway corridors which drain water from the floodplain and eastern hill catchments.

It is noted that other areas on the plain may also have a level of flood hazard. This includes land within the strategy study area[1] and mapped as areas 3A and 4A. Although this land lies on the plain and surrounding foothill areas, the level of flood hazard was not deemed significant enough to justify enabling additional land use controls within the Clutha District Plan. However, the strategy does propose a range of other control mechanisms which should apply within these areas. Flood hazard in the upper tributary catchments, and on the floodplain areas to the west of Clarkesville has not been mapped as part of the study.

2. Process to define the extent of the flood risk management areas

A three-step process was used to define the extent of these areas:

1. Flood hazard characteristics definitions and mapping based on existing data and information (see next section for details);
2. Public presentations of the Milton 2060 draft strategy including the flood risk management area maps. Public feedback was requested and collected through written submissions and;
3. The extent of the flood risk management areas was adjusted before the final documents and maps were produced.

As the flood hazard characteristics can change with time, they need to be reviewed regularly (it is proposed to review every three years and after a significant flood event) to reflect these changes. The review can also include additional knowledge of the flood characteristics (e.g. new data and observations collected during and after a flood event).

[1] The Milton 2060 study area comprises the Milton urban area (including Tokoiti and Helensbrook) and the full width of the Tokomairiro floodplain between Clarkesville and Milburn.

3. Tools used to assist the definition of the flood characteristics and the mapping

The definition of the flood characteristics and the mapping of the flood risk management areas were arrived at by considering:

- Topography: river channel surveys carried out in June and July 2010 for the Tokomairiro River, the north branch and Salmond's Creek; and LiDAR (Light Detection And Ranging) data captured in the summer 2005/2006. LiDAR data is essentially a mass of spot height information captured over a wide area using an aircraft-mounted laser. The accuracy of the raw data (spot heights) is 0.14m vertically and 1m horizontally;
- Ground features and land use (proximity of roads, existing parcel boundaries, drains etc);
- Water level and flow velocity calculations (including hydraulic modelling when practical);
- As no adequate rainfall and flow recording sites were available, national hydrological datasets provided by the National Institute of Water and Atmospheric Research (NIWA) were used. They include HIRDS (High Intensity Rainfall Design System) and WRENZ (Water Resources Explorer New Zealand, http://wrenz.niwa.co.nz/webmodel/);
- Information collected during past flood events (including photographs) and;
- Discussions with local residents after significant flood events (the most recent being April 2006 and July 2007), during public meetings held in April 2012 and during site visits of specific properties.

4. Characteristics of the flood risk management areas

The characteristics used to define the flood risk management areas included the depth of inundation, the velocity of water at the peak of the flood, and the length of time flooding may persist. During floods, the potential hazard to people and building can be expressed as the product of the velocity and depth. A higher product indicates an increased risk. This means that areas with relatively deep, slow moving, or still water (ponding areas) can potentially be as hazardous to people and buildings as relatively shallow, fast moving water (floodway corridors). However, the nature of the flood damage can differ depending on the flood hazard characteristics. Figure 1 provides an example of flood hazard classification based on the product of the velocity and depth.

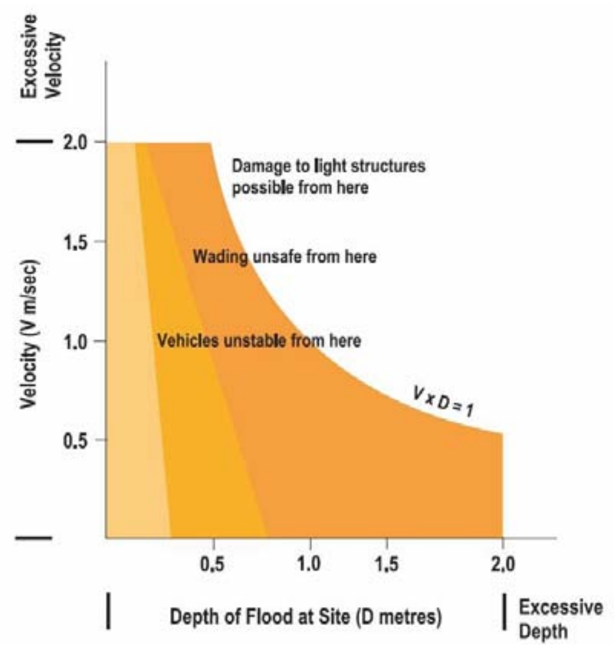


Figure 1. Example of flood hazard classification based on the product of the velocity and depth (New South Wales Government, 2005)

5. The Tokomairiro River floodplain (areas 1A and 1B)

The Tokomairiro River floodplain is the area which can be flooded by the north and west branches of the Tokomairiro River. It extends from Toko Mouth upstream to where each of these branches flows onto the floodplain from the steeper hill country in their upper catchments. The part of the floodplain where flood waters are sufficiently fast and / or deep to cause a significant safety risk has been identified separately as area 1B (floodway corridor, Figure 3).

Different methods were used to map these areas depending on the availability of topographic information (including LiDAR and surveyed cross-sections) and estimates of maximum water level during flood events.

North branch between the foothills to 900m upstream of North Branch Road (i.e. the floodplain upstream of the area covered by the LiDAR survey, Figure 2)

Area 1A

No detailed topographical information and water levels estimates are available for this section of the north branch. The extent of area 1A was derived from the ORC (1999) floodplain study. In this study, the flood hazard extent was based on the maximum known historical levels of the 1957, 1978, and 1980 floods derived from aerial photographs, discussions with local residents and field visits. No additional information was compiled since 1999 in this area in order to update the existing extent of the flood hazard.

Area 1B

The extent of area 1B covers the majority of area 1A as the floodplain is relatively confined for this section of the north branch. Small areas where flood waters would tend to pond rather than flow were excluded.

North branch between 900m upstream of North Branch Road (i.e. the part of the floodplain where the LiDAR survey commences) and Table Hill Road Bridge (Figure 2)

Area 1A

LiDAR information is available for this section of the north branch. The extent of area 1A was derived from the ORC (1999) floodplain study and was refined using LiDAR information and basic water level estimates.

Area 1B

The extent of area 1B in this section covers parts of the north branch floodplain where the estimated flood waters velocity exceeds 0.25m/s and the estimated depth exceeds 0.3m. Flood waters with velocity and depth equal or greater than the previous values are sufficient to cause a significant safety risk for people and / or buildings (Figure 1).

North branch/Tokomairiro River between Table Hill Road bridge and 900m downstream of Dunns bridge (Figure 2)

Area 1A

This section of the river is critical as it is adjacent to the Milton urban area and Tokoiti (more densely populated areas with urban infrastructure). More detailed information is available for this section, allowing a more comprehensive description of flood hazard characteristics such as depth, flow velocity, and extent. The topographical information available included LiDAR data (captured in the summer 2005/2006) and surveyed river cross-sections (surveyed in June and July 2010). Debris marks survey from the May 2010 flood event (the latest significant flood event in the area) are also available at a few locations along this section of the river (Appendix 1).

The maximum water level estimates for this section are based on the results of a simple computational hydraulic model (see Appendix 2 for details). The extent of area 1A was then derived by combining the maximum water level estimates with the LiDAR information.

Area 1B
The extent of area 1B in this section covers parts of the north branch floodplain where the estimated flood waters velocity exceeds 0.25m/s and the estimated depth exceeds 0.3m.

Tokomairiro River from 900m downstream of Dunns Bridge to Toko Mouth (Figure 2)

Area 1A
No detailed topographical information and water level estimates are available for this section of the river. However, the floodplain for this section is confined due to the river entering gorges. The extent of area 1A was derived from ORC (1999) floodplain study.

Area 1B
The extent of area 1B covers the majority of area 1A as the floodplain is relatively confined for this section of the Tokomairiro River. Areas where flood waters would tend to pond rather than to flow were excluded from area 1B.

West branch of the Tokomairiro River between the foothills to the confluence with the north branch (Figure 2)

Area 1A
LiDAR information is available for most of this section of the north branch. The extent of area 1A was derived from the ORC (1999) floodplain study and was further refined using LiDAR information, site visits and discussion with local residents.

Area 1B
The extent of area 1B in this section covers parts of the west branch floodplain where the estimated flood waters velocity exceeds 0.25m/s and the estimated depth exceeds 0.3m.

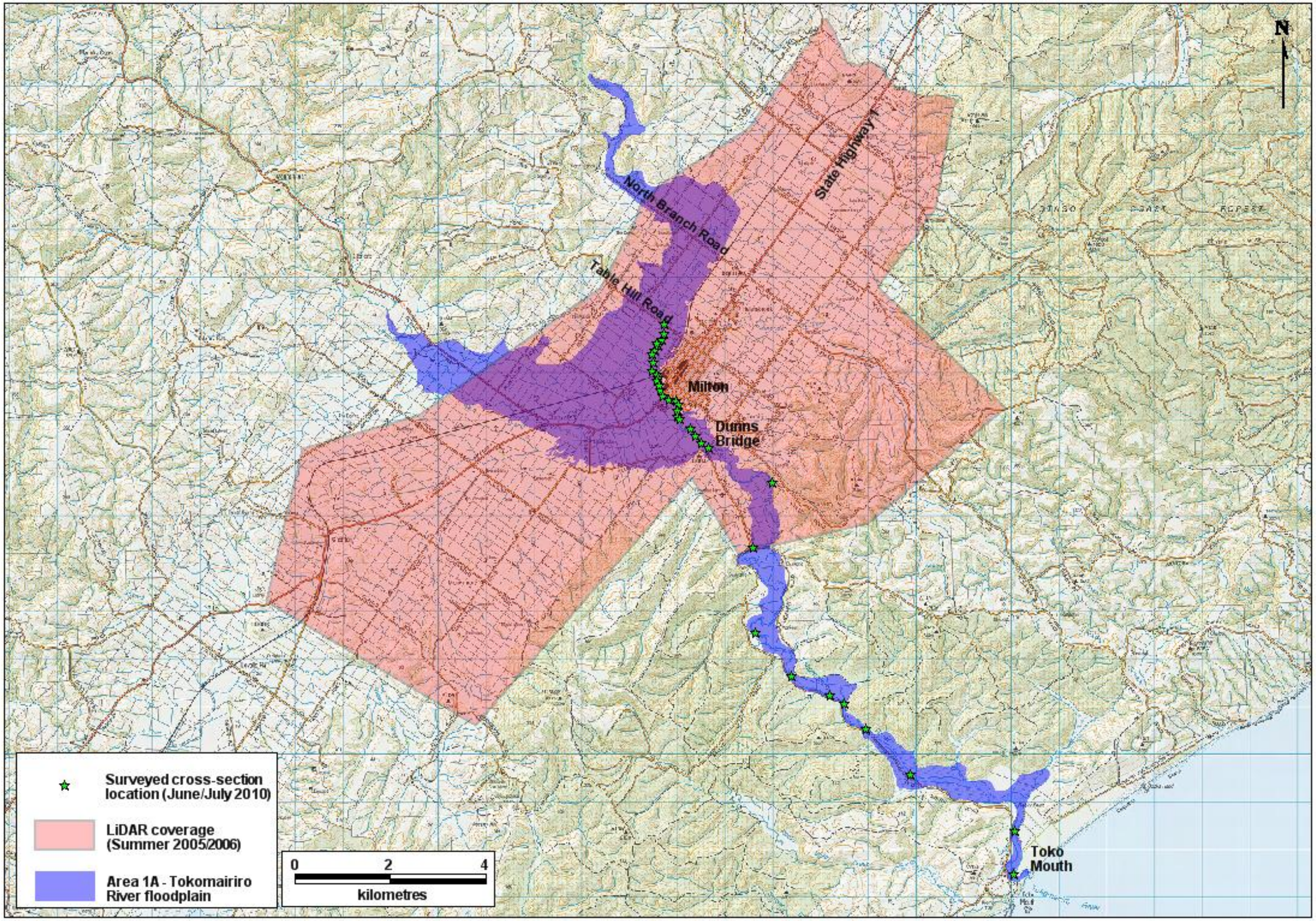


Figure 2. LiDAR coverage (captured in the summer 2005/2006) and cross-section location (surveyed in June/July 2010)

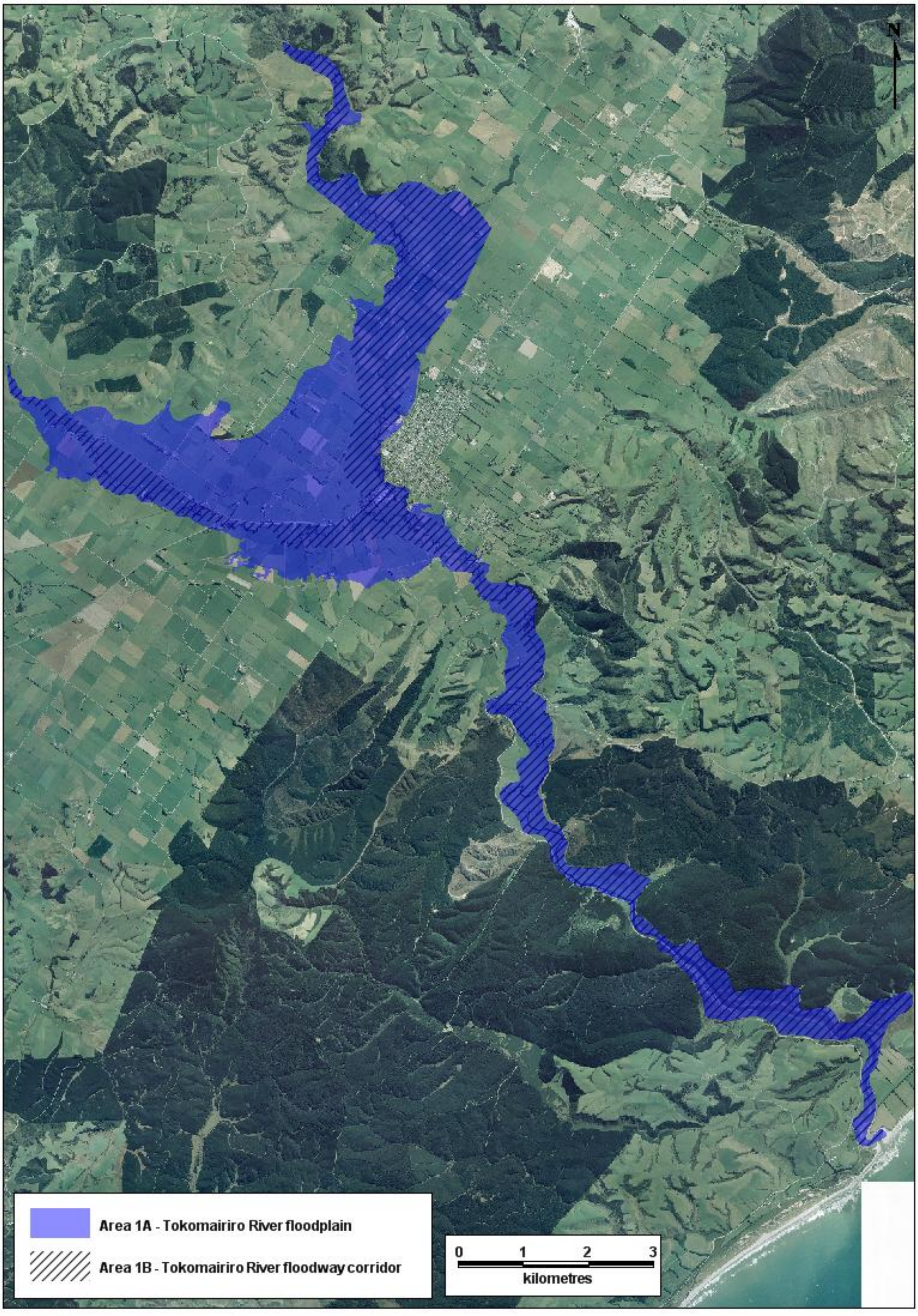


Figure 3. Extent of areas 1A and 1B

6. Ponding areas (areas 2A and 2B)

There are two separate low-lying areas within the Milton urban area where water can pond significantly during prolonged heavy rainfall events. For the purposes of the Milton 2060 strategy, these areas have been labelled Area 2A and Area 2B.

Area 2A is bordered by Union Street (State Highway 1) to the east, the South Island main trunk railway line to the west, and the north branch of the Tokomairiro River to the south (Figure 4). LiDAR data was used to determine that when water ponding within area 2A reaches a height of 12m above mean sea level (msl), it will begin to flow south across State Highway 1 towards area 2B, and also west towards the river. This means that when water exceeds 12m, an outlet from area 2A starts to form. However, water will continue to rise above the level of the outlet if inflows to the ponding area exceed what is flowing out. In this case, ponding would extend above the 12m contour. The boundary of area 2A is then defined by the 13m contour. Water in the upper part of area 2A (i.e. towards the northeast) may also pond at a higher level than in the lower section, as its ability to drain towards the outlet will be impeded by buildings, fences, roads and other structures.

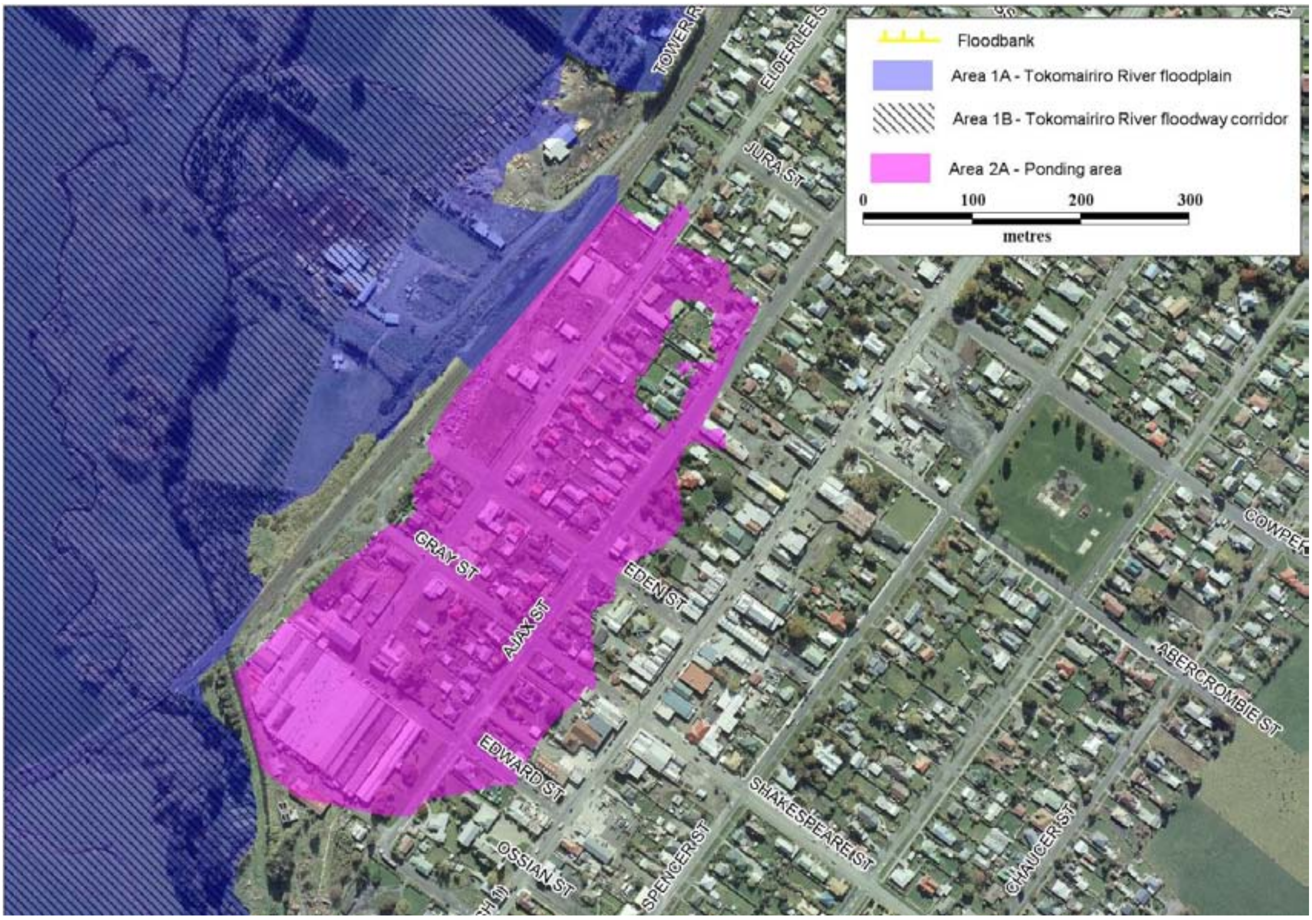


Figure 4. Extent of area 2A ponding area.

Area 2B includes land which lies at or below 12m (relative to msl), and is bordered by Union Street (State Highway 1) to the west, Burns Street to the east, and the Tokomairiro River to the south (Figure 5). A floodbank between SH1 and the Milton waste water treatment plant separates the river from area 2B. The floodbank works in conjunction with the Mill Street pump station which is intended to pump flood water from low-lying land in area 2B into the river. The extent of area 2B has been determined by assessing the volume of water which would flow from the river and pond in this low-lying area if a breach of the floodbank were to occur. The LiDAR data was then used to estimate the extent of area 2B in relation to the calculated volume of water. Calculation details are provided in Appendix 3.

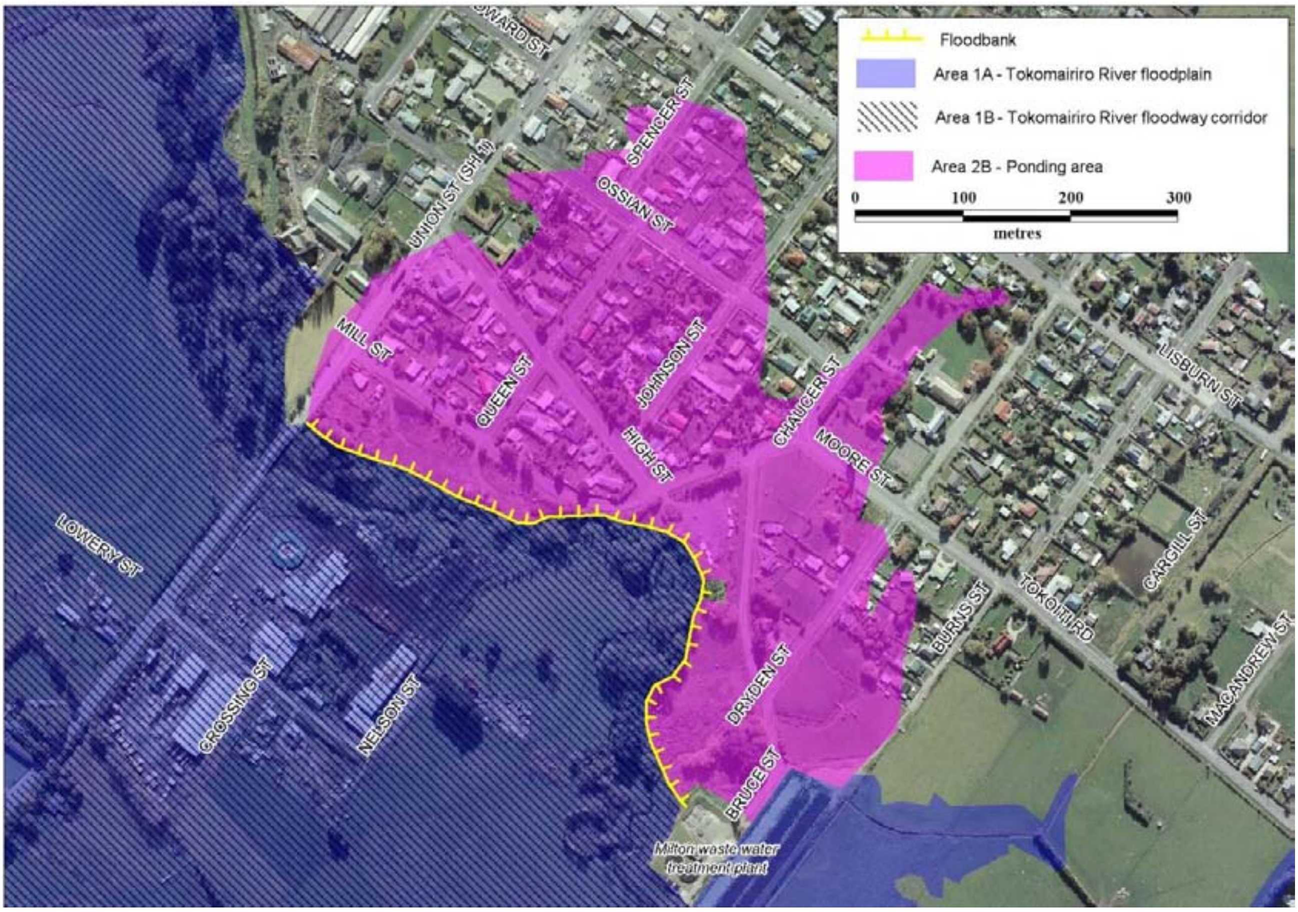


Figure 5. Extent of area 2B ponding area

7. Floodway corridors (areas 3B and 4B)

The floodway corridors which have been mapped for the Milton 2060 Strategy comprise overland flow paths which drain surface runoff from the floodplain and eastern hill catchments during heavy rainfall events. The extent of the proposed areas 3B and 4B floodway corridors are shown in Figure 6. The mapped floodway corridors include ephemeral drainage features (often referred to as 'swales'), streams and creeks which drain hillslope catchments areas, and the margins of the ORC's scheduled drainage network.

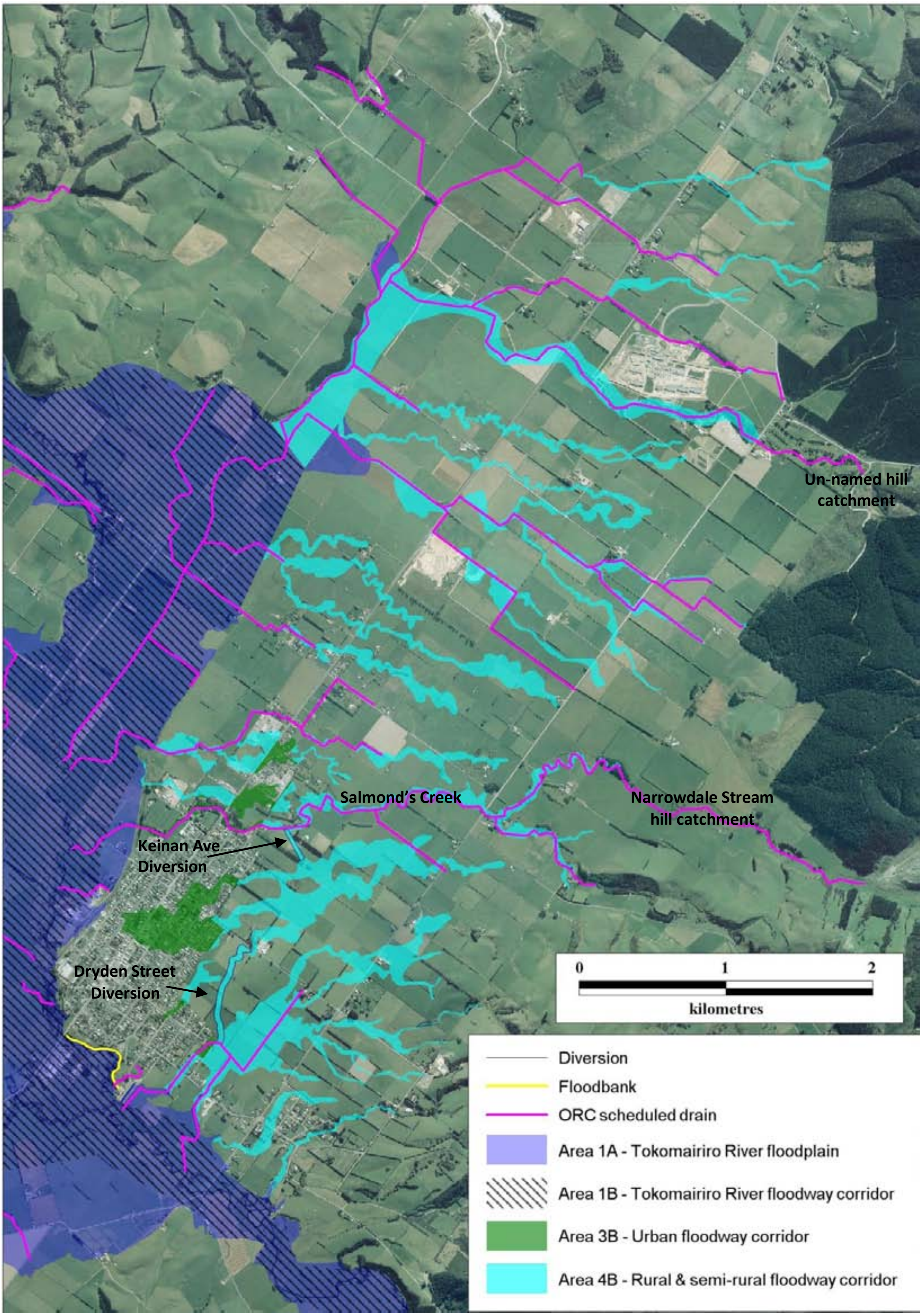


Figure 6. Extent of areas 3B and 4B floodway corridors. Locations referred to in the text are also shown, including the Keinan Ave and Dryden Street diversions, and two hill catchments which drain onto the Tokomairiro Plain.

7.1 Origin and nature of floodway corridors

An appraisal of the origin of the swale features on the Tokomairiro Plain was obtained from GNS Science in Dunedin. In their opinion, swales are likely to be former stream channels across the various alluvial fan surfaces which together comprise the Tokomairiro Plain. The GNS appraisal concludes that swales were probably formed when the main flow from the larger catchments took different paths down the alluvial fans, during periods when the fans were more active. Those channels that currently have no connection to steeper hillslope catchment areas are likely 'fossil' stream channels that now solely carry overland flow from their part of the fan surface, and thus transport little if any sediment. They are unlikely to evolve further under present conditions.

Continuously flowing waterways (such as Narrowdale Stream/Salmond's Creek) still connected to hillslope catchments are likely to still carry some sediment, and thus be more commonly associated with narrow courses, due to progressive accretion of flood silts within the drainage corridor. Some of the larger stream courses may have sufficient power to erode and maintain their channel widths.

7.2 Mapping of floodway corridors for the Milton 2060 strategy

The extent of the floodway corridors as shown in Figure 6 was determined using LiDAR data, combined with a general overview of the local topography and historical flood photos. The first step was to map the height of the land, relative to the land around it. Figure 7 shows a map of the Tokomairiro Plain, where land which is lower than the surrounding area (and therefore more likely to be more susceptible to flooding during a heavy rainfall event) is shaded blue.[2] This map was used to identify continuous corridors or channels across the plain, which may be ephemeral, but which can carry water during flood events. The sequence of lowest points (thalweg) of each floodway corridor was also defined based on the LiDAR data and using a computer based software to calculate the flow direction at each location (eight-direction pour point algorithm).

The floodway corridors of Salmond's Creek and of a major unnamed tributary of Gorge Creek (Figure 6) were mapped separately. Based on the available data (including surveyed river cross-sections) a simplified hydraulic model was used for Salmond's Creek. The ORC (1999) floodplain study included the unnamed tributary of Gorge Creek and was used to map its corresponding floodway corridor. These creeks were mapped separately because of their importance: Salmond's Creek and Gorge Creek have relatively well defined channels, and Salmond's Creek flows across the northern side of the Milton urban area.

The criteria used to select floodway corridors for mapping includes:

- Features which drain hillslope catchments areas. Two examples are labelled on Figure 6. Note that these features often carry water continuously throughout the year, and that the thalweg of these features has often been identified as an ORC scheduled drain (ORC Flood Protection Management Bylaw 2008).
- Features which drain floodwater from catchments on the Tokomairiro Plain itself (i.e. that are no longer connected to an upper hillslope catchment).
- The more obvious drainage features, identified by channels incised by a metre or more.

[2] Note that the colour scheme used in Figure 7 does not define the actual height of the land, but rather its height relative to the surrounding topography.

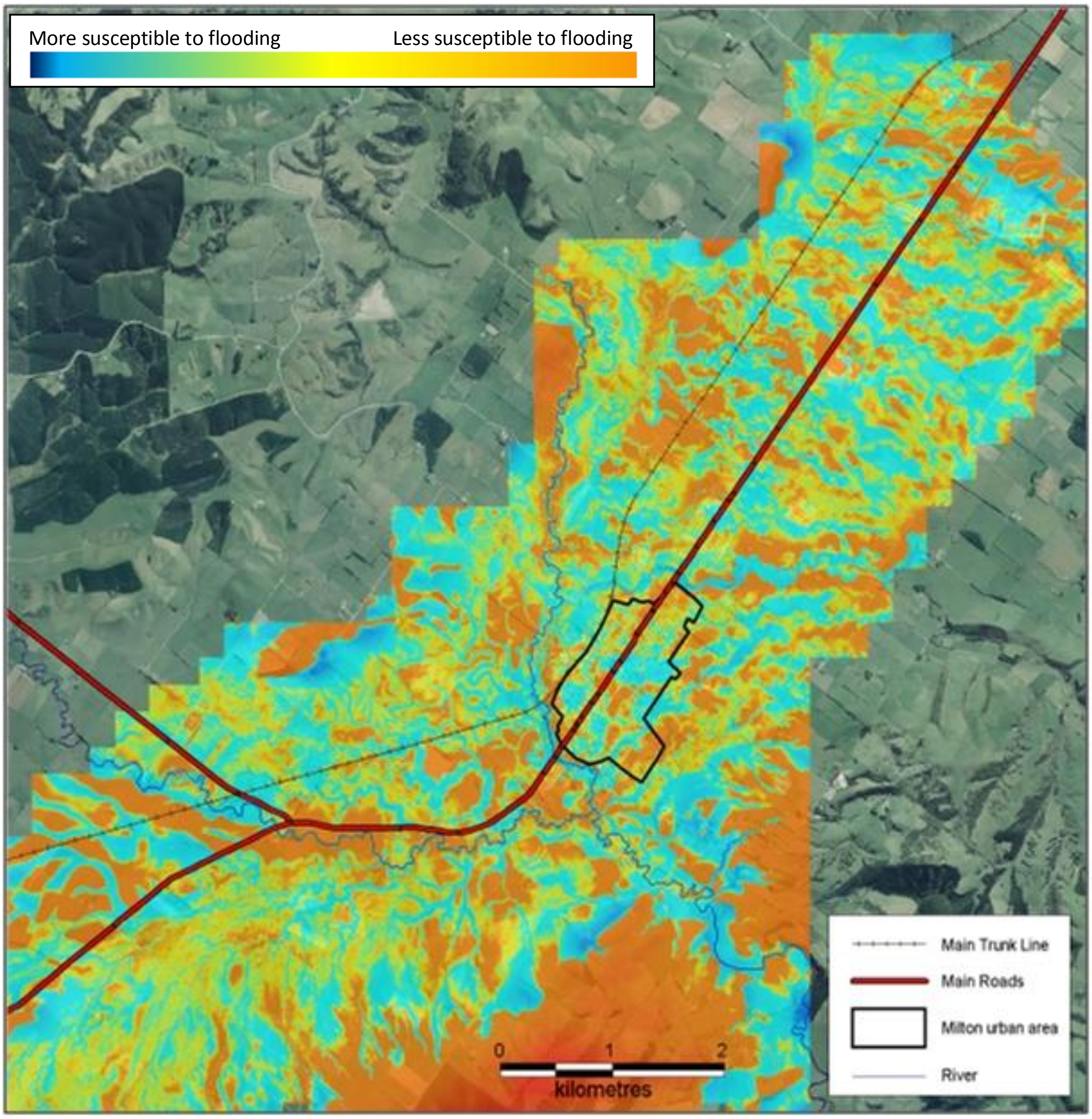


Figure 7. The height of land on the Tokomairiro plain, relative to surrounding land. Land coloured blue is lower than surrounding areas, and may be more susceptible to flooding, depending on where water flows during a flood event.

The lateral margins of floodway corridors were identified as the point where flood water would begin to overtop the swale, and spill out onto the wider floodplain (i.e. the point where the swale becomes 'bank-full'). These 'spill-over' points were defined by taking cross-sections along the length of identified floodway corridor. The cross sections were obtained from ORC's LiDAR dataset, collected in the summer of 2005/2006. Any changes in topography since the end of 2005 (such as localised earthworks) will therefore not be shown on these cross sections.

An example of how a cross-section through a typical floodway corridor was used to define its lateral margins is demonstrated in Figure 8 and Figure 9. Note the distorted horizontal and vertical scales.

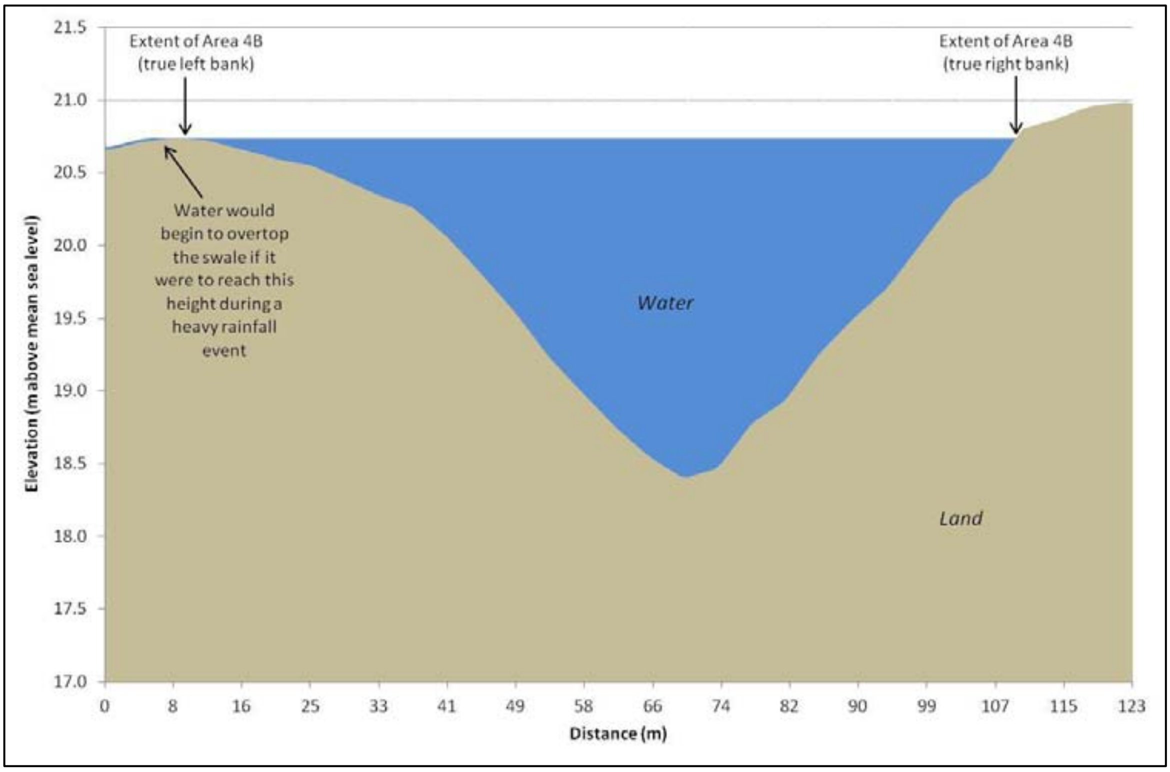


Figure 8. Typical cross section through an area 4B floodway corridor. The location of this cross-section upstream of Springfield Road is shown in Figure 9. Note the distorted horizontal and vertical scales.

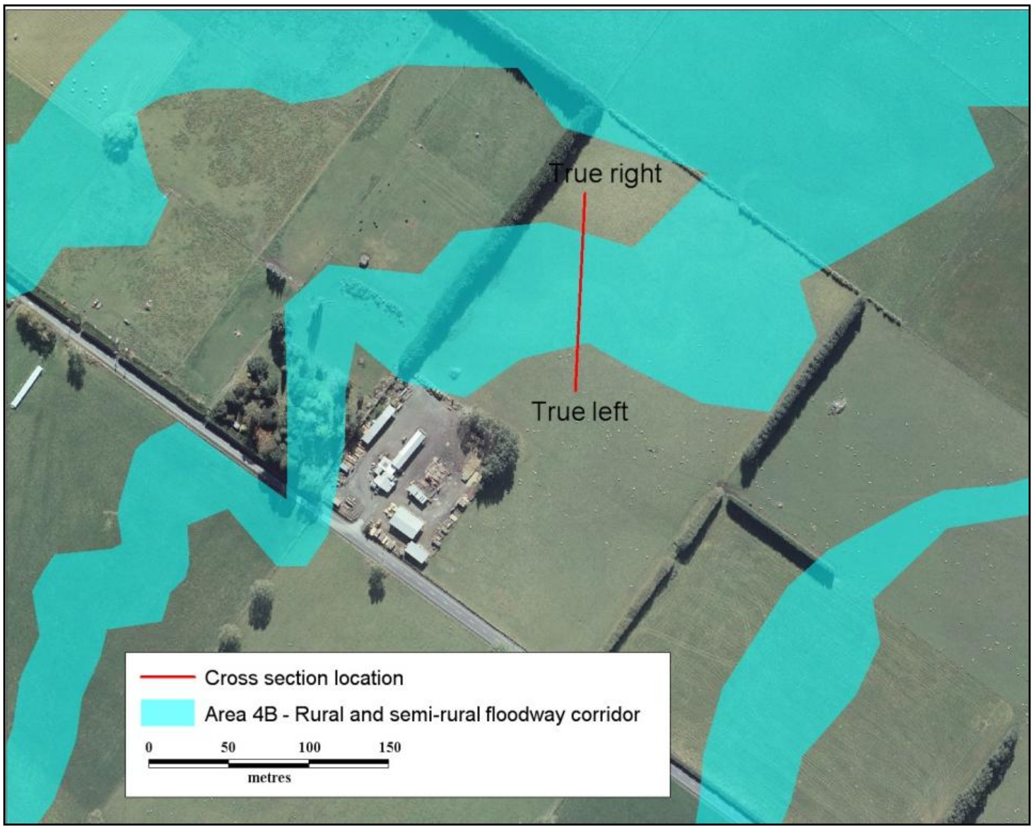


Figure 9. Location map of the cross section shown in Figure 8.

7.3 Flood hazard associated with mapped floodway corridors

The flood hazard in the areas 3B/4B floodway corridors varies across the plain. Water depth during heavy rainfall events ranges from zero at the margin, up to 0.5m across berm areas, and up to 2m in some incised channels. The velocity of floodwater carried in these corridors generally ranges from 0.25 to 0.5 m/s.

The flow required to overtop these floodway corridors (or the likelihood of such a flow occurring) was generally not estimated – rather, the swales simply show the lower-lying areas which will begin to carry water during a heavy rainfall event. In some cases, the limited catchment area upstream may mean that it is unlikely that the swale will become completely 'bank-full'. However, the extent and the ability of these floodway corridors to carry floodwater have been verified where possible using historical photos, and discussions with residents. This verification process has shown that the extent of the floodway corridors is suitable under the strategy. Figure 10 provides an example of where a photo taken during a flood event has been used to verify the location and extent of a floodway corridor.

Figure 10. Example of a floodway crossing Springfield Road. The location and direction of the photo (inset) taken during a rainfall event in July 2008 is also marked on the image. The photo does not show floodwater covering the full extent of the floodway corridor, although the July 2008 event was a reasonably small magnitude event (an analysis using flow record from 1981 to 2012 at the Tokomairiro at the west branch bBridge site shows this event was slightly larger than an annual flood).

Localised checks including field visits and photos taken during flood events indicate that the horizontal accuracy of the mapped floodway corridors is approximately 15m to 20m, although this margin of error cannot be accurately assessed and is generalised to the whole area of interest.

7.4 Land use controls in area 3B and area 4B

Where floodway corridors pass through the Milton urban area they have been identified as area 3B, and where they pass through rural and semi-rural land on the Tokomairiro Plain they have been identified as area 4B (Figure 6). This differentiation between urban and rural areas is made because different sets of land-use controls are proposed for areas which have already been developed (i.e. urban), and those which currently lie outside the urban area and generally remain undeveloped (ORC/CDC, 2012a, pp28-

31). The floodway corridors tend to have similar physical characteristics, regardless of whether they are located within urban or rural areas. However, drainage within urban floodway areas may have been modified due to roads, drains, and other minor earthworks. These earthworks may alter the overland flow of water during flood events at the 'micro' scale (1-10m). However, they generally do not re-direct water out of the floodway corridor. The overall drainage pattern will remain the same, but there may be some small scale impedance and re-direction of water within the urban floodway corridor, particularly during small to medium-sized floods.

References

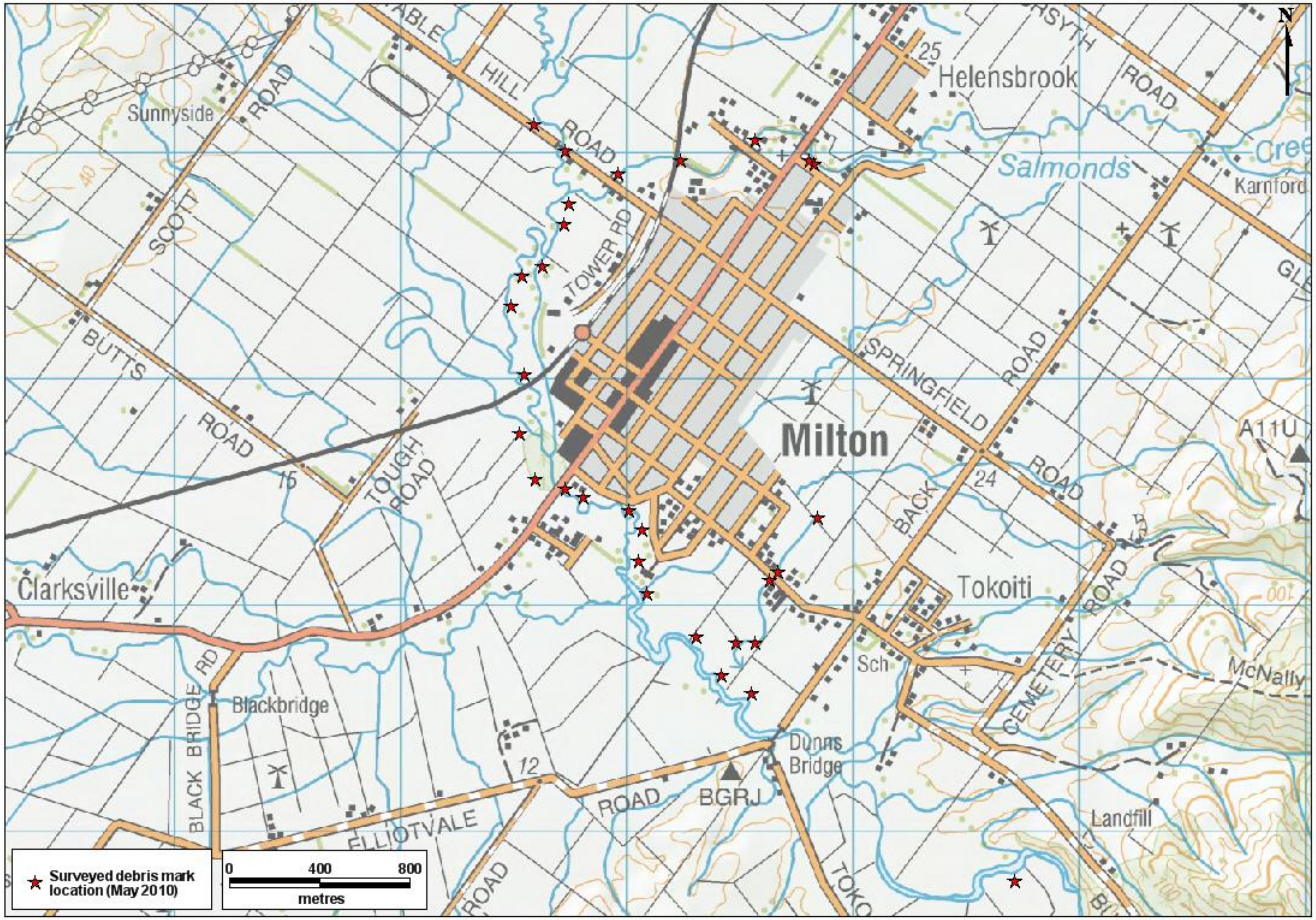
New South Wales Government, Department of Infrastructure, Planning and Natural Resources, 2005. Floodplain Development Manual: the management of flood liable land

Otago Regional Council and Clutha District Council, 2012a. Milton 2060 - Flood Risk Management Strategy for Milton and the Tokomairiro Plain

Otago Regional Council and Clutha District Council, 2012b. Milton 2060 - Summary of the Draft Flood Risk Management Strategy for Milton and the Tokomairiro Plain

Otago Regional Council, 1999. Clutha District Floodplain Report

Appendix 1: May 2010 flood event - Surveyed debris mark location



Appendix 2: Description of the computational hydraulic model used to estimate the maximum water level in the north branch/Tokomairiro River between Table Hill Road bridge and 900m downstream of Dunns bridge

Model characteristics

- One-dimensional hydraulic model (Mike 11);
- Steady flow (i.e. not varying with time) as the focus is on estimating the maximum water level along this reach of the river. Only the peak level of the flood is required;
- Only the north branch/Tokomairiro River was modelled as a unique channel (Figure 11). The tributaries, including the west branch, were not specifically modelled, but their peak discharge were estimated and injected along the modelled channel. The model extends from Table Hill Road bridge down to the sea. Although the cross-section spacing is very coarse downstream of Dunns bridge, the model extends to the sea so that the estimated downstream model condition would not affect the results in the modelled section of the North Branch/Tokomairiro River. The model results downstream of Dunns bridge were disregarded.

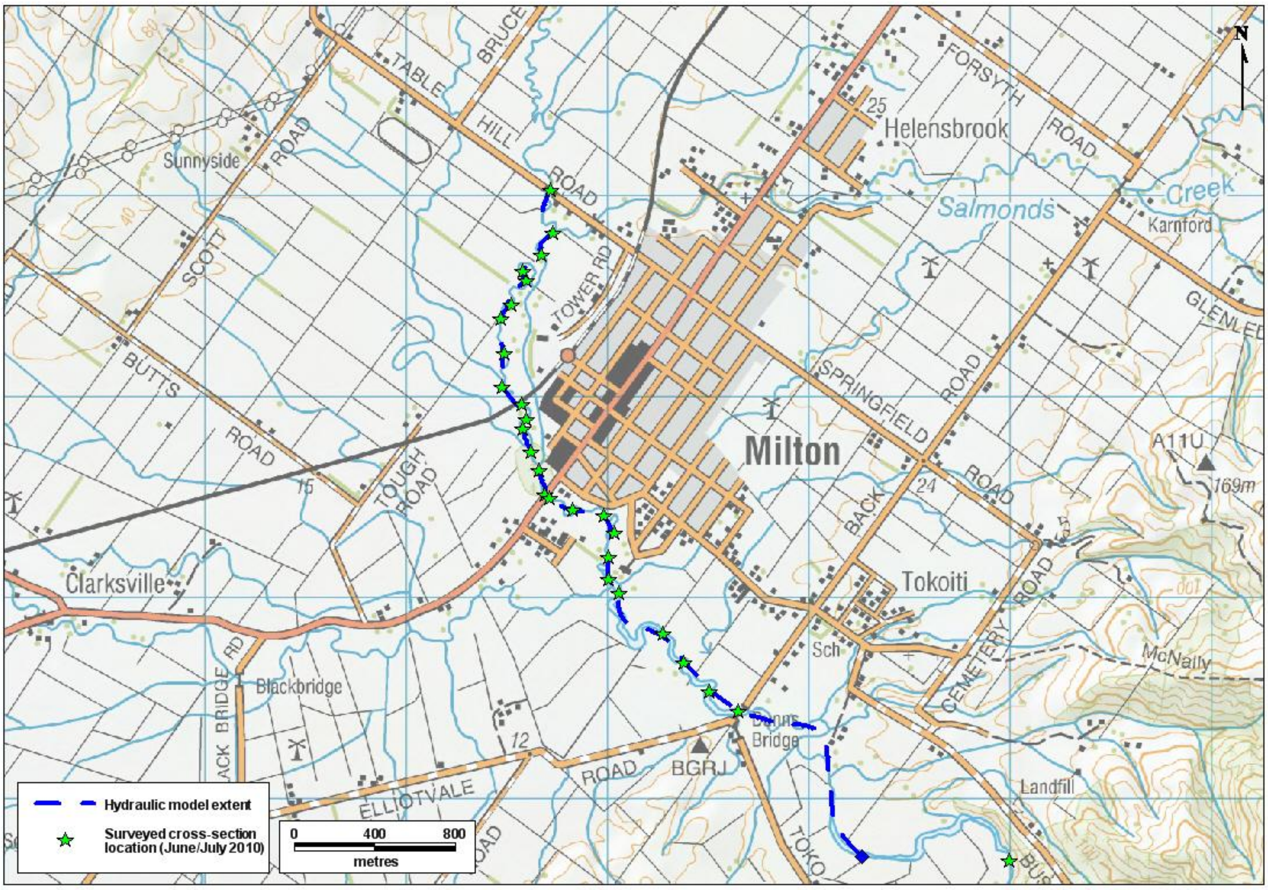


Figure 11. Hydraulic model extent and surveyed cross-section location (June and July 2010 survey).

Input data

- Topographical information: surveyed river cross-sections (surveyed in June and July 2010) extended with LiDAR data (captured during the summer 2005/2006) to cover the floodplain;
- Input flows: 100 year Average Recurrence Interval (ARI) peak flows for the North Branch, Tokomairiro River and tributaries were derived from Regional Analysis (NIWA WRENZ based on McKerchar and Pearson, 1989) as no adequate gauging sites are available;
- Downstream model condition: the model was extended to the sea and a fixed sea level (101m, Otago datum) was used.

Manning roughness coefficient

The Manning roughness coefficient was derived from a simplified calibration process using debris mark levels surveyed after May 2010 flood event. The estimated coefficient was also checked against typical values for similar rivers. It is noted that the May 2010 flood event is a small size flood event (approximately 10-year ARI flood based on data from the west branch recorder).

Hydraulic structures

Specific hydraulic structures that could constrict the flow such as bridges were not specifically accounted for in the model. Given the available data and the simplified modelling approach adopted, accounting for specific hydraulic structures was considered superfluous.

Model verification

Due to flood data scarcity, it was not possible to assess the model performances on a dataset different from the one used for calibration (May 2010 surveyed debris marks). The comparison between observed maximum water levels from the May 2010 flood event and calculated water levels shows however, that the maximum difference is 350mm, which is acceptable given the available data and the simplified modelling approach adopted. Additionally, simple sensitivity checks on model input flows showed minor differences in the flood hazard extents.

References

McKerchar and Pearson, 1989. Flood Frequency in New Zealand – Publication No. 20 of the Hydrology Centre.

Appendix 3: Estimation of the volume of water which would flow into and pond in area 2B if a breach of the floodbank were going to occur

Assumptions and selected parameters

- The floodbank breach will happen at the peak of a 100-year Average Recurrence Interval (ARI) flood. The corresponding maximum water level was estimated with the hydraulic model described in Appendix 2;
- The breach characteristics are based on a scenario assuming the breach in the floodbank will occur adjacent to the sharp bend (higher velocities) in the North Branch channel upstream of the concrete retaining wall (upstream of the of the pump station) (Figure 12). At this location there is a 30m long section where the land was relatively lower than the surrounding before the construction of the floodbank (based on LiDAR data). It was assumed that the breach is 30m long and 0.7m deep (the estimated maximum depth of water over the natural ground at the 30m failed section of floodbank during a 100 year ARI flood);
- The breached section of floodbank behaves as a broad crested weir;
- The water will overflow from the breached section of floodbank to area 2B over three hours. This duration was derived from the hydrograph characteristics of past events recorded at the west branch flow recorder. Sensitivity checks showed that the extent of area 2B is not very sensitive to the assumed duration of spill (Figure 13);

Figure 12. Floodbank breach location for the selected breach scenario.

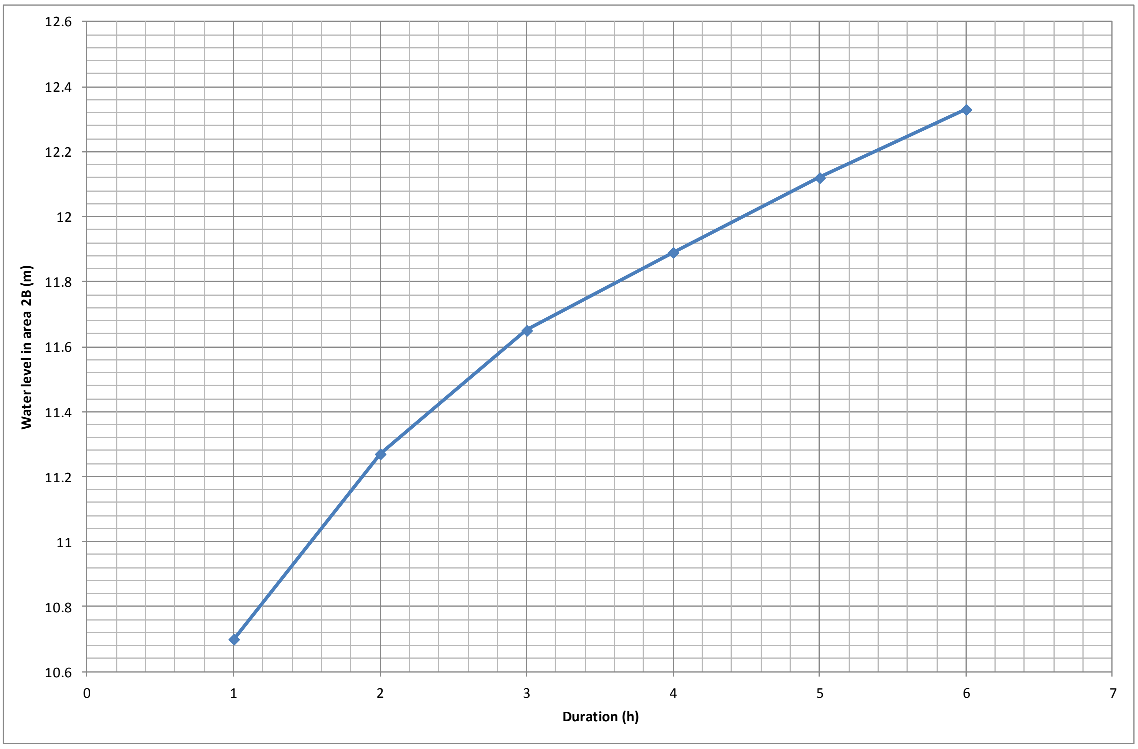


Figure 13. Water level variations with different spill durations.

With the previous values and assumptions the total volume of water overflowing from the breached section of floodbank to area 2B is estimated to be 146,000m^3 corresponding to a water level of 11.65m rounded to 12m.

Other floodbank failure scenarios with different characteristics can be selected to estimate the volume of water that can pond in area 2B. However, LiDAR data shows that when water ponding within area 2B reaches a height of 12m above mean sea level, it will begin to flow North across State Highway 1 towards area 2A, and also south towards the Tokomairiro River. This means that when water exceeds 12m an outlet from area 2B starts to form and the extent of area 2B will not change significantly.

It is noted that the floodbank breach scenario does not rely on any geotechnical assessment of the existing floodbank.