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REGIONAL COUNCIL
Te Pane Matua Taiao

Hutt River City Centre Upgrade Project

River Corridor Options Report

Quality Information

Document Hutt City Centre Upgrade Project – River Corridor Options

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Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
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Draft Edition 2	17 August 2014	Revised Options (including for a RB floodwall)	Greater Wellington Flood Protection	
Draft Edition 2a	12 September 2014	Strategic Business Case preparation	David Jeffrey, GHD Michael Siazon, NZTA	
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Final Edition	27 July 2015	Inclusion of Options Evaluation Report and Flexible Flexibility	Greater Wellington Flood Protection	

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Executive Summary

Hutt River City Centre Upgrade Project

The Hutt River City Centre Upgrade Project (HRCCUP) is a joint initiative between Greater Wellington Regional Council (GW), Hutt City Council (HCC) and New Zealand Transport Agency (NZTA) to improve flood protection, urban landscape, roading and transport through the City Centre of Lower Hutt.

The Hutt River Floodplain Management Plan (2001) established the status of the flood protection system and an improvement strategy. Climate Change, land constraints within the City Centre reach, and the river flow capacity of the Melling Bridge impact on the level of flood protection proposed by the Hutt River Floodplain Management Plan. HCC and NZTA have other interests that are related to the flood protection improvements, including infrastructure, transport and roading. There are urban development opportunities that can be integrated with the flood improvements.

The Hutt River Floodplain Management Plan

The Hutt River Floodplain Management Plan (2001) recorded the condition and capability of the Hutt River flood protection system. Recommendations were set out in the plan for upgrading the system to the “2,300 cumec risk based standard” adopted in the plan. Provision was made to achieve a 2,800 cumec standard as a hedge against climate change.

The Plan sets out proposed river works improvements (by river reach) and the priorities to complete the work. Since 2001 implementation has progressed well and is approximately 30% complete. Completed work has aligned well with priorities set in the Hutt River Floodplain Management Plan.

Purpose of this Report

The purpose of this report is to provide an overview of the various options for flood protection system improvement in the Hutt City Centre reach of the Hutt River. The current flood protection security of this section of the system has consequences for intense urban development through and below the CBD. A single breach event has potential damages greater than $1 billion, on each side of the river.

The options proposed include flood protection options in the river corridor, increasing waterway capacity at the current Melling Bridge location, with opportunities to integrate urban development, roading and transport opportunities. Key factors in evaluating these options are the design capacity and capability of each flood protection option, and the opportunity to respond to climate change. The preliminary options developed in this report will:

- bring the options to a common level of understanding,
- present technical information and identify key issues,
- summarise the advantages and disadvantages of respective options
- identify where further investigation is required.

Context of this Report

This report will contribute the technical detail and costs of the flood protection improvement options, and Melling Bridge waterway improvement opportunities. The HRCCUP Working Group has prepared a separate integrating report, for consulting with the community (*Options Evaluation Report, for Greater Wellington Regional Council.* Boffa Miskell. 25 June 2015 [8]). This integrating report covers long term flood protection for the City Centre reach and the lower valley, opportunities for Melling Bridge replacement or waterway improvement, urban development (Making Places), roading, transport, environmental, visual and recreational opportunities.

This flood protection river corridor options report addresses the wider opportunities (e.g. Making Places) only to the extent that they directly relate to the flood protection options.

Climate Change

Since completion of the Hutt River Floodplain Management Plan, Climate Change has accelerated and challenged the design standard assumptions made for the City Centre reach. The City Centre river corridor has very tight land constraints. An improved flood protection system within the existing corridor land can pass the 2,800 cumec climate change provision at a lower level of security than can be achieved for the rest of the flood protection system.

HCC and NZTA Interests and Initiatives

Alongside flood protection, HCC and NZTA have a vital interest in the HRCCUP. Their interests include:

- A current urban development project “Making Places” has an objective to explore opportunities and links between the city and the river corridor.
- The interface between State Highway 2 and management of the city’s roading network, including bridging the river.
- Major infrastructure that runs within the river corridor, for example the trunk sewer and stormwater outlets.
- Public transport services and facilities within the City, and the interconnection between these services.
- With GW the recreational, landscape, ecological, historical and cultural values and opportunities available in the river corridor.

Flood Protection Options

Five river corridor design options are considered for improving flood protection in the City Centre reach of the Hutt River, from Ewen Bridge to Kennedy Good Bridge. These options include the Hutt River Floodplain Management Plan (2001) “risk-based 2,300 cumec standard” corridor, and four other opportunities that progressively provide increased corridor width, a larger channel and wider berms to accommodate climate change impacts.

This report sets out and evaluates the issues, benefits and disadvantages of the five flood protection options. The project Working Group report recommends two of the five options for further consideration.

Table 4.1 in the body of this report provides a summary of the key features and costs of the five flood protection improvement options considered. **Table 4.2** summarises the positive and negative features of each option. **Table 4.3** sets out the alignment of each of the options with the flood protection objectives established at the start of the project.

Two bridging options for improving flood flow capacity at Melling are being progressed in parallel with the flood protection assessments. The first option is an upgraded waterway with the existing Melling Bridge retained, the second a replacement bridge.

Consultation

The project Working Group has prepared an integrated report, consultation strategy and programme that coordinate the various work streams comprising the City Centre project. The report, strategy and programme will cover the various improvement options and issues and will be the basis for consulting with stakeholders and the community.

Risk Considerations and Decision Making

Reaching a decision on the preferred river corridor option and bridging strategy will require further information.

To assist decision making, Councillors will require costings for the various options, economic assessments, risk explanations, and knowledge about what the community thinks, and what the community can afford to pay for. Another influence is whether the community is in a position to recover if a catastrophic event occurs.

The next stage of work for the HRCCUP will include detailed investigation of selected options to provide this information.

1. Introduction to City Centre Project

1.1 Purpose of Report

The purpose of this report is to provide an overview of the various strategies and options for flood protection in the Hutt City Centre reach of the Hutt River. The security of this section of the system impacts on intense urban development through and below the CBD. There are potential single event breach damages greater than $1 billion, on each side of the river.

The strategies include flood protection options for the river corridor and increasing waterway capacity at the current Melling Bridge location. A key factor in evaluating these options is the design capacity and capability of each option. The preliminary options developed in this report will:

- bring the options to a common level of understanding,
- present technical information and identify key issues,
- summarise the advantages and disadvantages of respective options
- identify where further investigation is required.

This report incorporates feedback from key stakeholders on initial drafts. The stakeholders include the Hutt Valley Flood Management Sub-Committee (comprising councillors from HCC and GW and representation from local Iwi) and the Management and Working groups (comprising officers from UHCC, HCC, GW, and officers from the New Zealand Transport Authority).

This report will provide the technical detail and costs of the flood protection improvement options, and Melling Bridge waterway improvement opportunities. The HRCCUP Working Group will prepare a separate integrating report for consultation with the community. This integrating report will cover long term flood protection for the City Centre reach and the lower valley, opportunities for Melling Bridge replacement or waterway improvement, urban development (Making Places), roading, transport, environmental, visual and recreational opportunities.

This flood protection river corridor options report addresses the wider opportunities (e.g. Making Places) noted only to the extent that they directly relate to the flood protection options.

1.2 The Hutt River Floodplain Management Plan

The Hutt River Floodplain Management Plan [1] was completed and published in October 2001. The Plan established strategy and policy for the long term development and operation of the Hutt River flood protection system. In partnership with Upper Hutt City (UHCC) and HCC, the plan also assists regulation and emergency management associated with river flooding and land use on the Hutt floodplain. The work to prepare the plan was overviewed by the Hutt River Advisory Committee, the latter comprising Councillors from HCC, UHCC, and GW, and also Iwi representation. Recommendations from the Advisory Committee were reported for decision to the

[1] Hutt River Floodplain Management Plan**.** For the Hutt River and its Environment. Flood Protection Group. Wellington Regional Council. October 2001.

regional council. The Hutt River Floodplain Management Plan, signed by the Mayors and Chair of the respective councils, formalises an agreement to implement responsibilities set out in the Plan.

Chapter 4 of the Hutt River Floodplain Management Plan sets out the "structural measures" identified for eleven reaches of the Hutt River from the Estuary to Gemstone Drive (above the Akatarawa Bridge). Each reach is discussed, an outline of the anticipated structural works is described, cost estimates along with priority and target dates for completing each work component are provided. Since 2001, with minor exceptions, implementation works have aligned well with priorities set out in the Plan. Departures are generally for logistical reasons.

1.3 Hutt City Centre Upgrade Project Overview

The Hutt River City Centre Upgrade Project (HRCCUP) is a combination of works remaining from the **CBD / Alicetown** and **Melling to Kennedy Good** reaches defined in the Hutt River Floodplain Management Plan. **Figure 1.1** shows the two reaches, work completed to date and work to be completed.

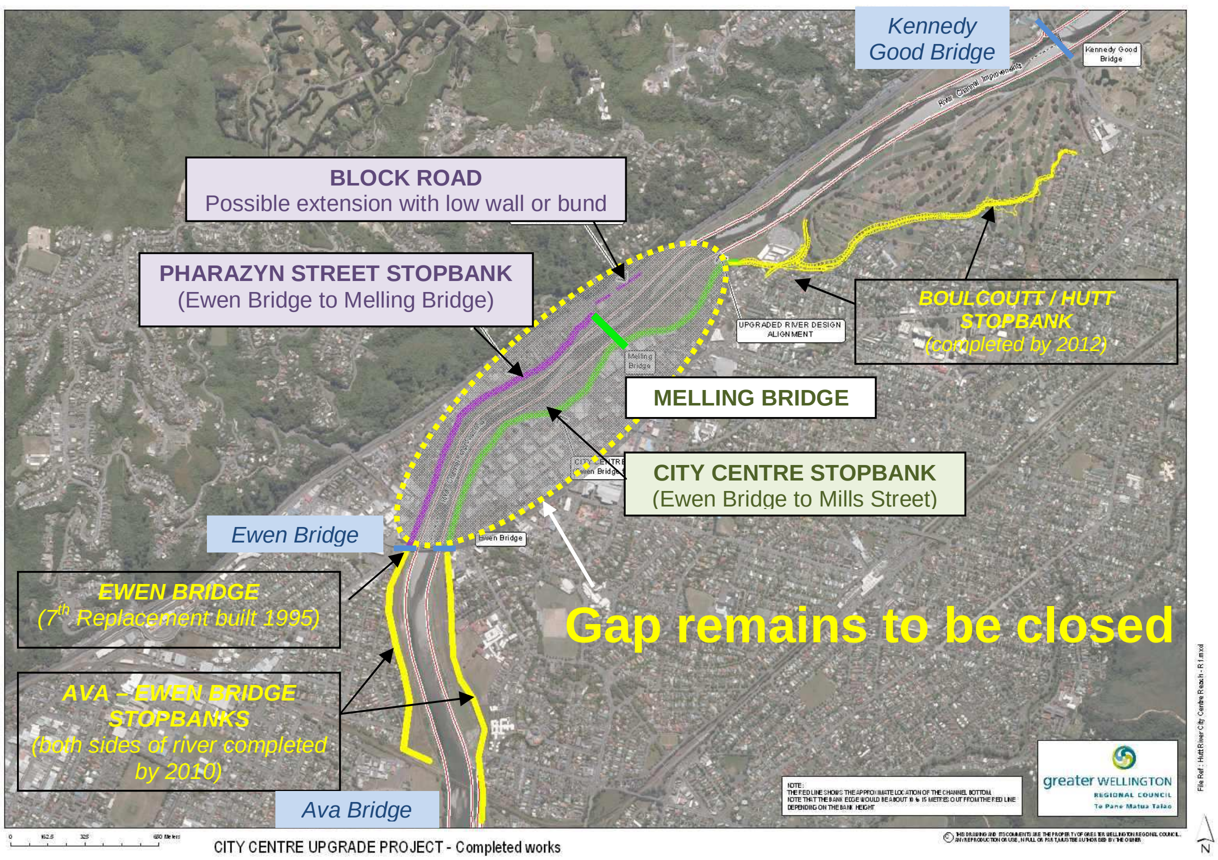

Figure 1.1 Hutt River Reach from Ava Bridge to Kennedy Good Bridge

The CBD / Alicetown reach extends from Ava Railway Bridge to Melling Bridge and includes the Hutt City Centre. Upgrades between Ava Railway and Ewen bridges are Priority 1 and have been completed. The remaining stopbank, channel and edge protection upgrades from Ewen Bridge to Melling Bridge are part of this HRCCUP. Remaining work to be completed includes Daly Street left bank (LB) stopbank upgrade, Marsden Street right bank (RB) stopbank upgrade, and Marsden Bend (RB) and Riverside Carpark (LB) channel and edge protection works.

The Melling Reach extends from Melling Bridge to Kennedy Good Bridge. The Priority 1 Boulcott / Hutt Golf Course stopbank and part of the Connolly Street stopbank upgrades are completed. The balance of the Connolly / Mills Street (LB) and the Melling Bridge (RB) stopbank upgrades will be completed as part of this HRCCUP. The Melling to Kennedy Good channel works will also be completed as part of the HRCCUP.

Melling Bridge investigations commenced several years ago and continue as part of the HRCCUP. Decisions on bridging options in this reach need to be concluded as part of this City Centre Upgrade to allow river works and stopbank alignments to be finalised so that they will accommodate the preferred bridging option.

1.4 HCC and NZTA Interests

As noted in Section 1.1 HCC and NZTA have vital interests in the HRCCUP. Their interests include:

- Hutt City has a longstanding aspiration to create a transition and interface between the city, its development and the Hutt River. A current urban development project "Making Places" has an objective to explore opportunities and links between the city and the river corridor.
- With NZTA, Hutt City has responsibility for the interface between State Highway strategy and management of the city's roading network, including bridging the river.
- Hutt City has responsibility for major infrastructure that runs within the river corridor, for example the trunk sewer and stormwater outlets.
- Hutt City has a vital interest in public transport services and facilities within the City, and the interconnection between these services. Many commuters travel to and within the city for employment and retail purposes, and many travel from the city to other areas in wider Wellington region.
- With GW the recreational, landscape, ecological, historical and cultural values and opportunities available in the river corridor.

1.5 Representation

To achieve the objectives of the Hutt River Floodplain Management Plan and meet the city's aspirations, HCC and GW are working together through the Hutt Valley Flood Management Sub-Committee, and the Management Group (that includes NZTA). The Management Group reports progress to the Sub-Committee which in turn reports to GW. The HRCCUP Working Group provides technical support to the committees. Representatives on the Committees report back to their parent organisations.

1.6 Project Objectives

The comprehensive objectives set for the HRCCUP are attached in **Appendix A**. These are applied to evaluate the various corridor and bridging options discussed later in this report.

2. Background to the City Centre Project

2.1 City Centre Project – Flood Protection Work

As noted in Section 1, the Hutt River Floodplain Management Plan river works components to be completed in the City Centre Project are:

- Daly Street (LB) stopbank that will extend from above Ewen Bridge to Melling Bridge
- Connolly Street (LB) stopbank that will extend from Melling Bridge to Mills Street
- Marsden / Pharazyn (RB) stopbank that will extend from above Ewen Bridge to Melling Bridge
- Melling (RB) stopbank above Melling Bridge
- Riverside Carpark (LB) channel and edge protection works
- Marsden Bend RB channel works
- Melling to Kennedy Good channel works
- Works to facilitate the chosen bridging option/s

The Hutt River Floodplain Management Plan developed feasibility designs and costings for flood improvement options. The HRCCUP will further develop flood protection concepts and integrate the various multi discipline opportunities for consultation with the community. Expected flood protection outcomes from the consultation and political processes are:

- formal feedback from Hutt City, Iwi, NZTA, GW, the community and other interest groups on the issues and opportunities for flood protection options,
- HVFMS direction
- direction on standard/s to be adopted for ongoing design
- views on non-structural options and their relationship to design standard
- community perspective on stopbank alignments and ancillary works
- feedback on channel widths, alignments and edge protections
- feedback on bridging option/s including acceptable bridge flow capacity
- impacts of infrastructure and services relocation, for services currently in the river corridor and stopbanks
- feedback on recreational, landscape, ecological, historical and cultural opportunities

The timeframe for implementing flood protection works will be determined by the final river corridor and bridging strategy adopted, and any staging of the works. Timeframes for completing the various options could extend from 10 to 25 years or more.

2.2 Hutt River Floodplain Management Plan Design Standard

The Hutt River Floodplain Management Plan established the **"risk-based 2,300 cumec standard"** as the design basis for Hutt River flood protection. For the major Upper Hutt and Lower Hutt floodplains this means that the 2,300 cumec flow will be passed through the system with a high level of security. The "level of security" is the ability of and confidence in the system to pass the design flood without failure of the flood defences.

The return period or ARI (Average Recurrence Interval) of the 2,300 cumec event is 440 years. This means the 2,300 cumec flood event has a 1 in 440 chance of occurring in each and every year.

Under the risk based standard the combination of bank edge protections and berms (that protect the stopbanks from being eroded) are designed to the <u>2,300</u> cumec design standard. The bank edge protections and berms can be strengthened to a higher standard in the future without increasing risk or causing excessive disruption to the community.

The risk based standard makes provision for new or reconstructed stopbanks to be designed and constructed to pass a <u>2,800</u> cumec flow. (2,800 cumecs is the original design flow adopted for the major stopbanks above Kennedy Good Bridge, these stopbanks were constructed in the 1960's). There are minor exceptions above Kennedy Good Bridge that do not have the 2,800 cumec standard – for example Belmont Domain has no stopbanks, and contained stopbanks at Totara Park and Gemstone Drive provide a lower level of protection.

The Hutt River Floodplain Management Plan rationale for stopbanks below Kennedy Good Bridge to be built to the 2,800 cumec capacity was:

- the potential impacts of climate change
- uncertainties about flood behaviour
- eliminating additional future physical and environmental disruption by improving a section only once
- the additional cost of the higher capacity stopbanks, over the lower valley is $4 million (2001). This assumption then was that the higher 2,800 cumec capacity stopbanks are constructed in the existing river corridor land
- from a community perspective it would be incongruous for the more intensely developed floodplain, below Kennedy Good Bridge, to have a lower standard than above the bridge

Chapter 3 of the Hutt River Floodplain Management Plan gives a full explanation of the adopted design standard, and the rationale behind it.

When the "risk based 2,300 cumec standard" was adopted it was recognised, at the 2,800 cumec flow, some areas of the system would provide lower security against failure than others. The majority of the stopbanks, including those reconstructed to the 2,800 cumec flow, will provide a near equivalent high security during a 2,800 cumec flow as the 2,300 cumec design standard. However several areas in the system, particularly where constrained by a narrow corridor, will provide a lower level of security during the 2,800 cumec event.

2.3 City Centre Constraints

The City Centre corridor is severely constrained by the width of land currently available. This reach can be designed to pass a 2,300 cumec flow with a high level of security. To complete these designs within the current river corridor will require methods of construction that are not traditional – high retaining walls to reduce stopbank footprint, steep stopbank batters, hard or reinforced stopbank surfaces, reinforced berms, deep and heavy rock edge protections, possibly alternative edge protections. Through the City Centre the 2,300 cumec corridor can be designed to pass the 2,800 cumec flow, but at a lower level of security.

To provide a very intuitive security analogy - if the "high level of security" when passing a 2,300 cumec flood is in the order of 95% confidence (in containing the 2,300 cumec flood without breach of the upgraded stopbank), then the corresponding lower level of security for the City Centre when passing a 2,800 cumec flood may be in the order of 10% less, at about 80 - 85%. Presented another way, if the chance of failure of the upgraded stopbank in the 2,300 cumec event is 5%, then the chance of stopbank failure in a 2,800 cumec event would increase to 20%.

Prior to the Hutt River Floodplain Management Plan being finalised, these matters were discussed and consulted on in relation to the City Centre. It was judged that the cost to purchase additional land, to construct a wider corridor that would pass the 2,800 cumec flow with high security, could not at that stage be justified.

The flood protection options considered, to pass the 2,300 cumec design standard and the 2,800 cumec flow, and corresponding levels of security, are covered in Section 4 of this report.

2.4 "Making Places"

There is a long held view within Hutt City that the CBD has turned its back on the Hutt River. Extensive consultation has confirmed a strong desire to remedy this and to strengthen the relationship between the CBD and the river. Hutt's CBD development framework 'Making Places' identified an opportunity to achieve this through integrating future building development with flood protection upgrades. This would provide a direct interface between the CBD and river, shift reliance away from retail and toward apartment based mixed-use development, and leverage a widened range of commercial and social connections with the river.

Modelled upon other cities it is hoped that Lower Hutt can create its own `waterfront' with a promenade to lead a lifestyle shift in Lower Hutt, turn the CBD around to face the river, and to drive a more resilient city economy based upon people living in the CBD.

A number of options were considered by the working group to develop links between the CBD and the river. They include a Rutherford Street interface, a Daly Street interface, and a kiosk/promenade transition. The preferred option involves a number of properties on Daly Street, between Andrews Ave and Margaret Street. The concept is for medium rise construction (mixed-use residential and commercial) with first floor access via a riverside promenade and terracing down into the river corridor. **Figure 2.1** and **Figure 2.2** show schematics of the investigated options (prepared by Boffa Miskell). To date property owners and developers have indicated positive interest in this potential.

The "linkage" is formed by filling over the city-side batter of the reconstructed stopbank and over a flood defence buffer to form a first floor level promenade. The buffer is to secure and protect the stopbank foundation in the event of future redevelopment. A key river management requirement is that a traditional stopbank can be rebuilt if for any reason the proposed use is reverted. To maintain flood protection integrity, there would be a number of river related conditions attached to the development.

Although the preferred option is confined to a limited area it is possible in the long term that building development could extend from southern-most Daly Street, through northern Daly Street, and north into Rutherford Street.

Because of the long potential life of this type of development, the high improved value of the land and the potentially high number of affected parties to deal with, further upgrading of flood defences and river works on this left bank would not be possible for a long time. Hence any concessions to develop this concept must secure a long-term solution for the flood protection system.

The City Centre section of the Hutt River is extremely narrow and constrained. The existing corridor is the minimum to pass the Hutt River Floodplain Management Plan "2,300 cumec risk-based design standard" with high security. The present river corridor land cannot accommodate a corridor that will convey a 2,800 cumec event with the same high security. The Hutt River Floodplain Management Plan included provision to convey the 2,800 cumec event as the hedge against climate change, although it was accepted that for the city reach it was at a lower level of security. Sections 3.2 (Climate Change) and 3.3 (Response to Change) discuss these interrelated issues - the design standard, climate change, provision for climate change and adaptability.

Hutt City has put forward a proposal to enable the left bank Daly Street stopbank to be reconstructed to meet a long term flood protection solution, and to facilitate the Making Places development. Hutt City has indicated that land in Daly Street will be made availabl Original site boundary sting river corridor for stopbank and promenade construction.

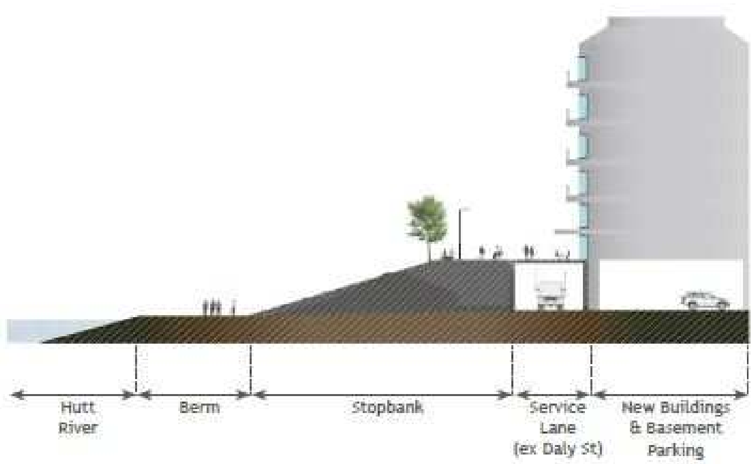

Figure 2.1 Daly Street Promenade Interface

Figure 2.2 Daly Street Promenade Steps and access to River

2.5 Bridging in the City Centre

A number of studies have been conducted over the years to assess wider options for linking SH2 and the west bank of the river to the City. The studies included public and road transport, and bridging the river. The work has been variously Hutt City's own initiatives, part of wider transportation studies, parallel assessments in combined projects (e.g. the Ewen Floodway Project), and in conjunction with NZTA (and predecessors).

Some of the locations that have been assessed include:

- From Bridge Street to High Street
- SH2 / Pharazyn Street to Waterloo Road
- Melling (south) to Queens Drive
- Melling (north) to Connolly Street
- Parallel to the existing Melling Bridge (north side)
- Road and light rail option at existing Melling Bridge site
- Road and light rail option with the road bridge and Melling Station relocated to the south
- The current Ewen Bridge

The current Ewen Bridge was constructed adjacent to the "sixth Ewen Bridge" in 1996. A number of locations and options were considered. At that stage the Hutt River Floodplain Management Plan was in early stages of preparation, and design standards were not set. The Ewen Bridge was constructed to pass a 2,200 cumec flow. Recent analysis confirms this capacity. With raised stopbanks or with crest walls Ewen Bridge can be expected to pass 2,800 cumecs, with minor compromise of debris clearance criteria, but with high security.

Melling Bridge has been the subject of a number of investigations. Studies were carried out to assess scour vulnerability at piers and abutments, and to assess structural stability under seismic loads. Scour protection to the in-channel piers and structural strengthening of the bridge structure have been implemented.

The current Melling Bridge hydraulic capacity is in the order of 1,800 cumecs. With left abutment and waterway strengthening in conjunction with proposed Hutt River Floodplain Management Plan widened channel works, the bridge hydraulic capacity can be improved to 2,100 cumecs. The latter is below the Hutt River Floodplain Management Plan risk based 2,300 cumec design standard and considerably below the 2,800 cumec flow that includes provision for climate change. In the event of a 2,100 cumec flood event or greater the bridge soffit will build up debris and will progressively submerge, creating an increasing risk of left bank stopbank and bridge abutment failure. **Appendix B** shows two photos and the impact of debris build up on a bridge.

The cost estimate for river and abutment strengthening works to raise Melling Bridge capacity to 2,100 cumecs is $7.7 million. This includes $1.5 million for the left abutment protection works.

NZTA and Hutt City have also considered options at several locations for a new Melling Bridge replacement crossing. If constructed to criteria set out in the Hutt River Floodplain Management Plan a new bridge will have very little impact on the waterway, and the risk of a new bridge causing failure of the flood system would be extremely low.

Section 5 (Bridging Options) discusses options for improving the performance of the existing Melling Bridge, the residual potential damages associated with that option and economic comparisons to constructing a new bridge.

3. Provision for the Future (Future Proofing)

3.1 Sustainability

The Objectives (**Appendix A**) adopted for the Project cover matters that relate to: linkages to the Hutt River, space and amenity, recreation, cultural and landscape values, ecology and water quality, flood risk, roading and traffic management, coordination of strategies and project coordination, and consultation with the community.

Provided they are integrated as anticipated, the Objectives will work to achieve outcomes that are robust, resilient and environmentally acceptable. The objectives will provide the expected benefits to the community and stakeholders in both the medium and long term. There will be inevitable short term impacts and disbenefits associated with a project of this size.

The specific flood protection objectives aim to provide a long term solution that will ensure community security from flooding. This may be achieved by a solution that will progressively achieve the flood related objectives, or a long term solution that may be put in place now rather than later. By putting in place a long term solution now, flood resilience will be higher and uncertainty for potentially affected residential and commercial land owners is removed. However land purchase disruption, trauma and economic impacts must then be faced in the short term. A progressive approach allows some of the impacts to be deferred, but the effects on property owners who will ultimately lose their properties will be ongoing. A progressive approach also requires costly reconstruction.

Section 2.2 above discussed the Design Standard, and Sections 3.2 (Climate Change) and Section 3.3 (Adaptability) discuss the issues that need to be addressed in reaching a decision on the corridor option. Section 4 looks at the River Corridor design options available to meet the intent of the “risk-based design standard”.

3.2 Climate Change

In 2001, at the time of preparation of the Hutt River Floodplain Management Plan, making provision for Climate Change effects in engineering design was at a relatively early stage. Based on the evidence then available, the typical view was that provision should be included <u>in the event that Climate Change did accelerate</u>.

For flood protection design the two key parameters are sea level rise and increased rainfall that produces higher design flows.

Sea level rise impacts on the Hutt River backwater profile reduce quickly with distance upstream, so it is not considered a major issue for the Hutt River flood protection system. Stormwater, sanitary services and roading infrastructure are more affected by sea level rise.

At that time climate change recommendations for design flood flows suggested that the return period (or average recurrence interval – ARI) of a design event would halve over 35 years, and halve again over a further 35 years.

If Climate Change did accelerate to this guideline, the 440 year return period of the 2,300 cumec risk based flow would be 110 year in 70 years. When applied to the 2,800 cumec long term flood standard (which happens to have a return period of approximately 2,800 years), the resulting return period would be 700 years in 70 years. For the Hutt River Floodplain Management Plan the rationale for Climate Change provision was that the 700 year projected return period for the 2,800 cumec flow was in the same order as the then current 440 year 2,300 cumec flow for the immediate planning horizon.

The level of security, in the order of 80 to 85% through the City Centre for the 2,800 cumec event (refer Section 2.3), was at that time considered adequate for a natural phenomenon that might happen in the future.

The New Zealand Climate Change Centre (NZCCC) produces periodic assessment reports that cover research and findings related to New Zealand. The 2014 NZCCC report, based on the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report, records:

- ***"warming of the climate system is unequivocal,***
- ***climate change is already influencing the intensity and frequency of many extreme weather and climate effects globally,***
- ***human influence on the climate system is clear,***
- ***continued emissions of greenhouse gases will cause further warming and climate changes".***

The NZCCC (2014) report is attached in **Appendix C**.

Based on the NZCCC information the projected return period for the 440 year 2,300 cumec risk based design flow will over 100 years become:

- **30 year to 100 year event, under a high emission Climate Change scenario,**
- **50 year to 300 year event, under a stringently controlled emission scenario.**

3.3 Response to Change – Adaptability

Since 2001 when the Hutt River Floodplain Management Plan was finalised Climate Change has accelerated, unquestionably as noted in the NZCCC report. Decisions on provision for Climate Change are now more imminent.

The question has now been raised whether the 2,800 cumec corridor design for the City Centre should be to the same high level of security as the 2,300 cumec risk based standard. This high level of security prevails for the 2,800 cumec corridor over the rest of the system (main floodplains).

Put simply, should the design of the City Centre reach make immediate provision to construct a river corridor to the 2,800 cumec flow with the same high level of security as the 2,300 cumec flow?

This would require major land purchase in the near future. Construction costs would be approximately the same.

Or should the design of the corridor through the City Centre reach be based on a staged programme to reach the higher level of security for the 2,800 cumec flood? The latter would mean living with higher risk for a longer period, with the advance of Climate Change. It would involve works duplication and high cost reconstruction. Owners of land needed for the long term corridor would live in uncertainty, not knowing if and when their land would be required.

Section 4 describes five River Corridor options, and evaluates the opportunities they provide to address the long term flood security.

4. River Corridor Options

Five river corridor design options are considered for the reach from Ewen Bridge to Kennedy Good Bridge, including the City Centre. These options include the 2001 Hutt River Floodplain Management Plan "risk-based 2,300 cumec standard" corridor, options that accommodate city redevelopment, increased channel widths and wider berms, to an option that reflects the high security level that prevails over the majority of the Hutt River system.

To provide some background and to put the various channel options and features into perspective, the core components of a flood protection system are shown in **Figure 4** and briefly discussed.

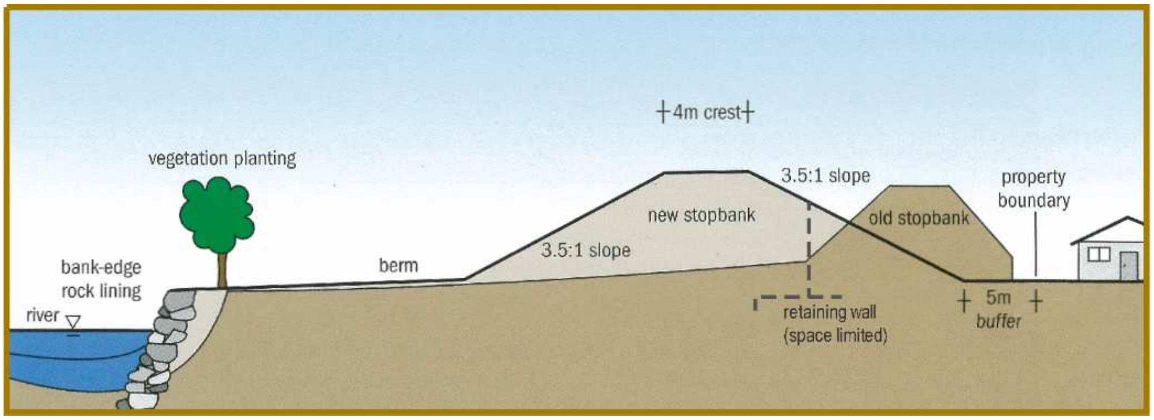

Figure 4: Flood Protection Components

Flood defences

Flood defences are the barriers that separate floodwaters from the developed floodplain. The most robust form is stopbanks that are constructed with compacted earth / gravel materials. For the Hutt River they are constructed with a crest width of 4 metres and batters of 3.5 to 1. This configuration provides: adequate stability under flood load, resistance to leakage and piping, adequate seismic resistance, access for heavy equipment during a flood emergency and economic maintenance operations.

Where river corridor space is constrained the stopbank can be constructed with steeper batters, and a flood wall and/or a retaining wall can replace some or all of the bulk of the stopbank, as shown in **Figure 4**. However for a given height a smaller stopbank footprint or a flood wall reduces stability, reduces seepage and seismic resistance, limits direct access to the crest or floodway, increases maintenance costs and provides a lower level of security than the equivalent standard stopbank. For the City Centre the Hutt River Floodplain Management Plan Options 4 and 5 propose steeper stopbank batters and a series of retaining walls, up to 4 metres high, on both sides of the river in order to keep flood defences within the existing corridor. Retaining walls create a distinct barrier between the river and adjacent development.

Flood defences are protected from erosion failure by the combination of a well-designed channel, bank edge protections of adequate strength, the width and mass of the river berm and as a last resort bulk within the stopbank itself. In an extreme flood the damage to the system is an expected outcome; the combination of components described above have done their job providing the floodwaters do not reach the protected floodplain.

Berm width and berm function

The berm is designed to be if necessary a sacrificial erosion buffer to protect the stopbank or other flood defences. In general the greater the berm width the higher the security given to the stopbank.

For the Hutt River the minimum design berm width adopted by the Hutt River Floodplain Management Plan is 20 metres, and at this width heavy rock bank edge protection is necessary. Where the available berm width is less than 20 metres other special treatment is required. The special treatment may be extremely heavy and deep rock riprap in the bank edge protections, the berm may need to be reinforced with rock, or other techniques to increase resistance to erosion may be required.

For the City Centre Hutt River Floodplain Management Plan (Option 5), berm widths are as low as 15 metres over significant lengths of the river and on both banks.

The “ideal” berm width adopted by the Hutt River Floodplain Management Plan is 80 metres, and this width already exists over the majority of stopbank length for the main floodplains, outside the City Centre.

Bank edge protections

Where there is not sufficient room to allow a river to freely meander, and there are flood defences that must be protected, bank edge protections are constructed. Their purpose is to resist scour and erosion of the berm and stopbanks. Normal Hutt River bank edge protection materials are rock riprap, vegetative materials (willow, flax, toitoi) and physical techniques to reinforce the vegetation e.g. snub rock groynes, angled railway iron and wire rope fences (debris fences). Occasionally other forms of reinforcement and protections are used such as linear fences and gabions.

Rock protection is placed in a linear blanket against the bank edge, and buried to a pre-set scour level. Rock may also be placed in snubs or groynes spaced at intervals along the river bank. Rock edge protections are flexible and are designed to subside and “heal” the bank edge when scour develops adjacent to the rock lining or groynes. The face of a rock lining creates a layer of favourable turbulence immediately adjacent to the lining.

Where the berm behind the bank edge is less than 20 metres wide, very heavy rock is placed in a linear blanket. For the narrow (70 metre) Hutt River corridor options very heavy rock is required for a large proportion of the City Centre reach. Other forms of bank edge protections may be used where there is a narrow berm, these may include sheet piling and cantilevered walls. They are not favoured for the Hutt River because of their rigidity, high construction cost, visual appearance and adverse hydraulic performance.

Where the available berm is greater than 20 metres and up to 50 metres, a combination of rock protections and reinforced vegetation may be used. Where the available berm is above 50 metres, reinforced vegetative bank edge protections are generally adequate.

Channel width and shape

A well designed channel will safely pass flood flows, allow natural meanders to take place within the channel, and will transport sediment through the system without exaggerating scour of the bed or encourage deposit of sediment. The design channel width attempts to reflect the natural meander patterns of the river, steepness of the river, reach location and the volume of bed material that will transport through the system. The channel width heavily influences the type and strength of the bank edge protections.

HRCCUP Channel Design

The City Centre corridor of the Hutt River is very constrained. To achieve a balance between berm width, bank protection strength and land to construct flood defences within current ownership the Hutt River Floodplain Management Plan opted for a 70 metre channel though the City Centre, with transitions to 90 metres at the Ewen Bridge and above Melling Bridge. Subsequently and as part of the Mills Street stopbank design the Melling channel transition (from 90 metres to 70 metres) was moved to below Melling Bridge. The relocated channel transition is shown on **Figures 4.4 and 4.5**.

The 70 metre channel through the City Centre can be designed to cope with the 2,300 cumec flow and provide high security. The higher velocities, turbulence and scour that occur in a 70 metre channel and 2,800 cumec flow create higher potential for bank edge, berm and stopbank erosion.

<u>An optimum long term channel width for the City Centre reach is 90 metres.</u>

HRCCUP River Corridor Options

Five river corridor options considered for the Central City reach are discussed in Sections 4.1 to 4.5. These options include the opportunity to provide a very high level of security in a 2,800 cumec flood (Option 4.1) through to the HRFMP option that provides lower security from flooding at 2,800 cumecs.

4.1 Option 1 (90 metre channel, 50 metre berms, standard stopbanks)

Refer to **Figure 4.1**. The system provides high security at both 2,300 cumec and 2,800 cumec flows. This option is put forward as a benchmark to compare with the other options. This corridor reflects the arrangement and high level of security that prevails or is exceeded over the majority of the rest of the Hutt River flood protection system, when the overall upgrade programme is completed. Both left and right bank stopbanks are built to the standard Hutt River configuration. There are major impacts for property and infrastructure on both sides of the river. Widened corridor has a 90 metre channel and 50 metre berms. Making Places is not specifically defined but the same concept is transferrable to new stopbank/city boundary.

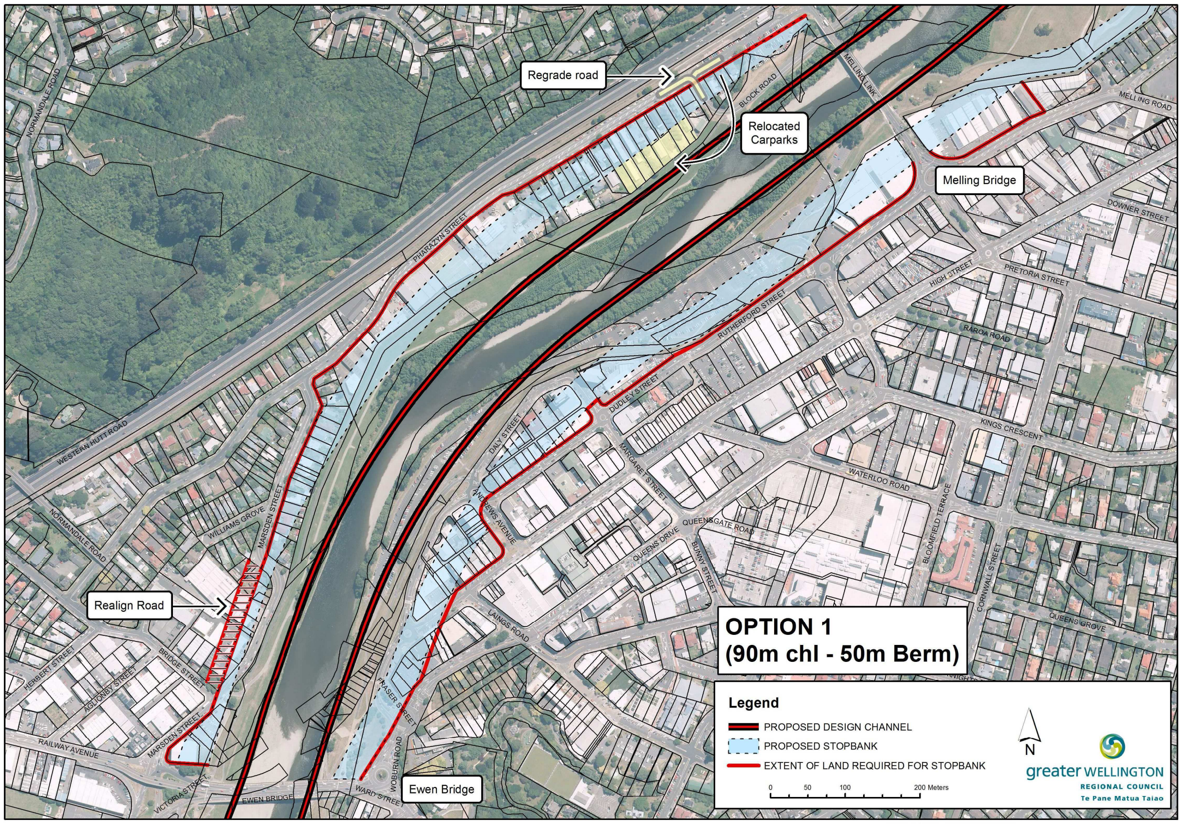

Figure 4.1 - Option 1 (90 metre channel, 50 metre berms, standard stopbanks)

Flood Defences

- left bank (City) stopbank constructed to standard Hutt River configuration, meets long term requirements for 2,800 cumec flow and can accommodate a revised concept for Hutt City's "Making Places" project,
- right bank stopbank constructed to standard Hutt River configuration, meets long term requirements for 2,800 cumec flow.

Berm Width

- minimum 50 metre berms.

Bank edge protections

- standard rock protections for 50 metre berms.

Channel Widths

- 90 metre channel over complete reach,
- lower velocities, turbulence and scour as a result of wider channel and berms.

Hydraulics

- Option 1 gives the lowest levels upstream of cross-section 360 (refer Figure 6.1) of all the options. In a 2800 cumec flow, levels are up to 500mm lower than for options 4 and 5, and up to 150 mm lower than for option 2,
- Option 1 leads to the lowest velocities throughout the Melling to Ewen reach, up to 2.84 m/s (channel-averaged). Locally, velocities up to 4.5 m/s could be expected (for example on the outside of the meanders), compared to 6 m/s for options 4 and 5.

Risk / Security

- system will provide a high level of security at both the 2,300 cumec and 2,800 cumec flows,
- high security attributable to wider corridor, channel and berms,

Landscape, ecological, historical and cultural opportunities

- wider corridor, channel and berms allow development of these opportunities to very high standard,
- Making Places (revised concept) can be accommodated and left bank stopbank can be terraced and permit passive recreation and linkages to the river,
- High potential to develop quality visual appearance.

Roading and traffic impacts

- North Daly Street closed. Traffic to Melling Link via Queens Drive, Laings Road, High Street, Andrews Avenue and Dudley Street,
- High Street, Andrews Avenue and Margaret Street truncated at stopbank location.

Cost estimate

- total flood protection $194.4 million including;
  - flood protection works $32.4 million (includes Melling to KGB channel works),
  - trunk sewer relocation not required,
  - property purchase $162 million

Positive features

- system provides a high level of security at both 2,300 cumec and 2,800 cumec flows,
- accommodates provision for current climate change projection,
- accommodates revised Hutt City's "Making Places" project,
- realigned Marsden Street will provide better traffic flow,
- corridor would appear spacious, attractive and balanced in shape and form,
- wider corridor offers very high potential for developing recreational, landscape ecological, and other opportunities,
- no further works or upgrade expected for life of assets,
- could be staged but would require substantial reconstruction,
- a staged option, indicating future land requirements, could be notified through planning, instruments,
- lower maintenance costs.

Negative features

- higher capital cost, $117 million higher than Option 2,
- creates land impacts on both sides of the river with very high dislocation
- major land impacts, 168 properties affected, includes 80 residential and commercial units,
- North Daly Street closed and other roading impacts.

4.2 Option 2 (90 metre channel, 25 metre berms, standard stopbanks)

Refer to **Figure 4.2**. This system provides high security at both 2,300 cumec and 2,800 cumec flows. The left bank stopbank is constructed over north Daly Street, providing greater space to achieve standard Hutt River stopbank configuration. Provision for a 3 metre wide service lane in Daly Street is available. Part of a left bank property at Melling is required. Option 2 accommodates Hutt City's "Making Places" project. North Daly Street is closed. No other significant impacts on CBD. Right bank stopbank constructed to standard Hutt River configuration, but requires major land take on right bank of river, with high impact on Pharazyn / Marsden Street properties. Widened corridor allows high security 90 metre channel and 25 metre or greater berms to be constructed.

There is no alternative to the Option 2 right bank property take to accommodate the required 90 metre channel, 25 metre berms and the stopbanks. An alternative left bank property take would result in an unacceptable channel alignment between Melling Bridge and Andrews Avenue.

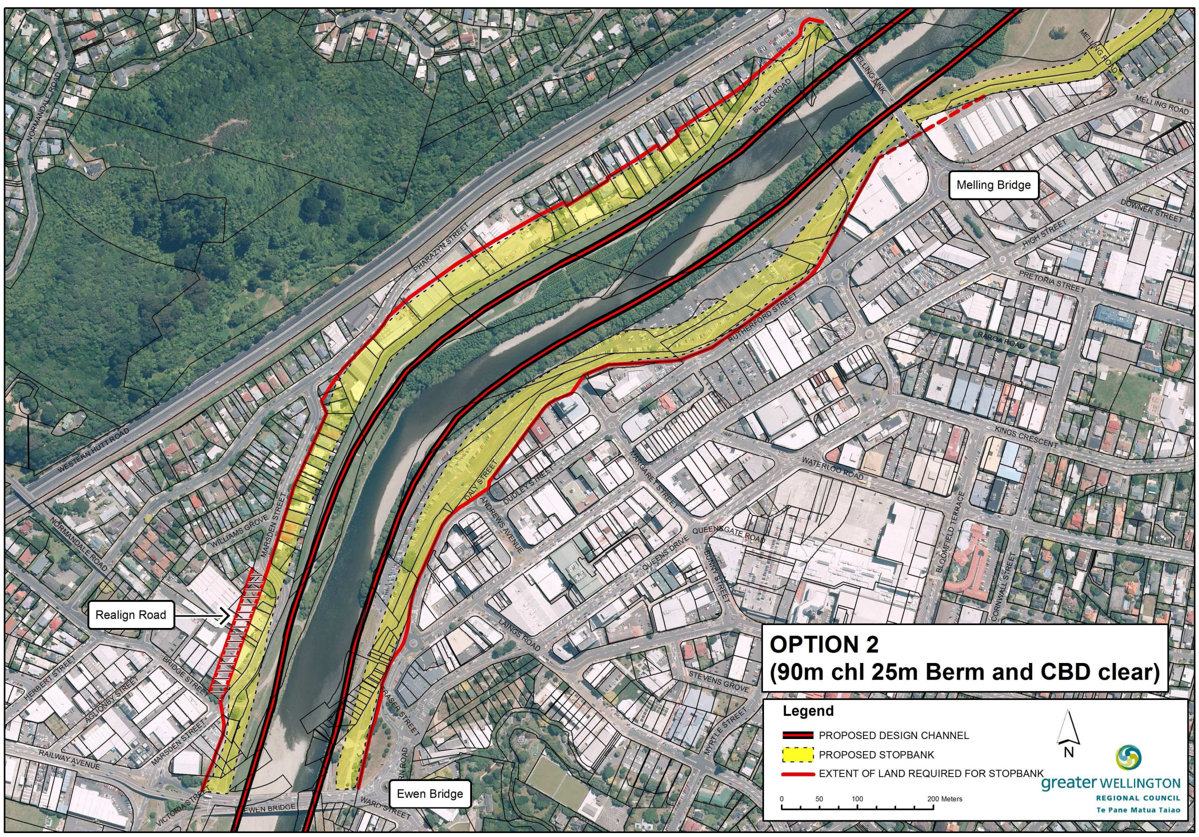

Figure 4.2 - Option 2 (90 metre channel, 25 metre berms, standard stopbanks)

Flood Defences

- left bank (City) stopbank constructed to standard Hutt River configuration, meets long term requirements for 2,800 cumec flow and can accommodate Making Places,

- right bank stopbank constructed to standard Hutt River configuration, meets long term requirements for 2,800 cumec flow.

Berm Width

- minimum 25 metre berms, except for some short sections.

Bank edge protections

- standard rock protections for 25 metre berms.

Channel Widths

- 90 metre channel over complete reach,
- acceptable velocities, turbulence and scour as a result of wider channel and wider berms.

Hydraulics

- Option 2 gives levels up to 320mm lower than for options 4 and 5 in a 2800 cumec flow, upstream of cross-section 360,
- Velocities throughout the Melling to Ewen reach are up to 3.4 m/s (channel-averaged). Locally, velocities over 5 m/s could be expected (for example on the outside of the meanders).

Risk / Security

- system will provide a high level of security at both the 2,300 cumec and 2,800 cumec flows,
- high security attributable to wider corridor, channel and berms.

Recreational, landscape, ecological, historical and cultural opportunities

- wider corridor, channel and berms allow development of these opportunities,
- Making Places can be accommodated and left bank stopbank can be terraced and enable passive recreation and linkages to the river,
- good potential to develop quality visual appearance,

Roading and traffic impacts

- North Daly Street closed. Traffic to Melling Link via High Street, Andrews Avenue and Dudley Street,
- Marsden Street realigned for 175 metres north of Bridge Street.

Cost estimate

- total flood protection $77.5 million including;

- flood protection works $35.5 million (includes Melling to KGB channel works),
- trunk sewer relocation not required,
- property purchase $42 million.

Positive features

- system provides a high level of security at both 2,300 cumec and 2,800 cumec flows,
- accommodates provision for current climate change projection,
- accommodates Making Places,
- realigned Marsden Street will provide better traffic flow,
- corridor would appear attractive and balanced in shape and form,
- wider corridor has potential for developing recreational, landscape, ecological, and other opportunities,
- no further works or upgrade expected for life of assets,
- could be staged but would, depending on extent of current work would be similar to Option 4 i.e. require substantial reconstruction,
- a staged Option 2, indicating future requirement for right bank land, could be notified through planning instruments,
- lower maintenance costs.

Negative features

- higher capital cost,
- major land impacts, mainly on right bank,
- 76 properties affected including 37 residential units,
- North Daly Street closed.

4.3 Option 3 (90 metre channel, standard left bank berm, minimal right bank berm, standard left bank stopbank, diaphragm flood wall right bank)

Refer to **Figure 4.3**. This system provides high security at both 2,300 cumec and 2,800 cumec flows. The left bank stopbank is constructed over Daly Street, providing greater space to achieve standard Hutt River stopbank configuration. Provision for a 3 metre service lane in Daly Street is available. Part of a left bank property at Melling is required. Option 3 accommodates Hutt City's "Making Places" project. North Daly Street closed. No other significant impacts on CBD. A right bank deep founded diaphragm flood wall is constructed; no additional right bank land is required. 25 metre left bank berm, minimal to no right bank berm. 90 metre channel.

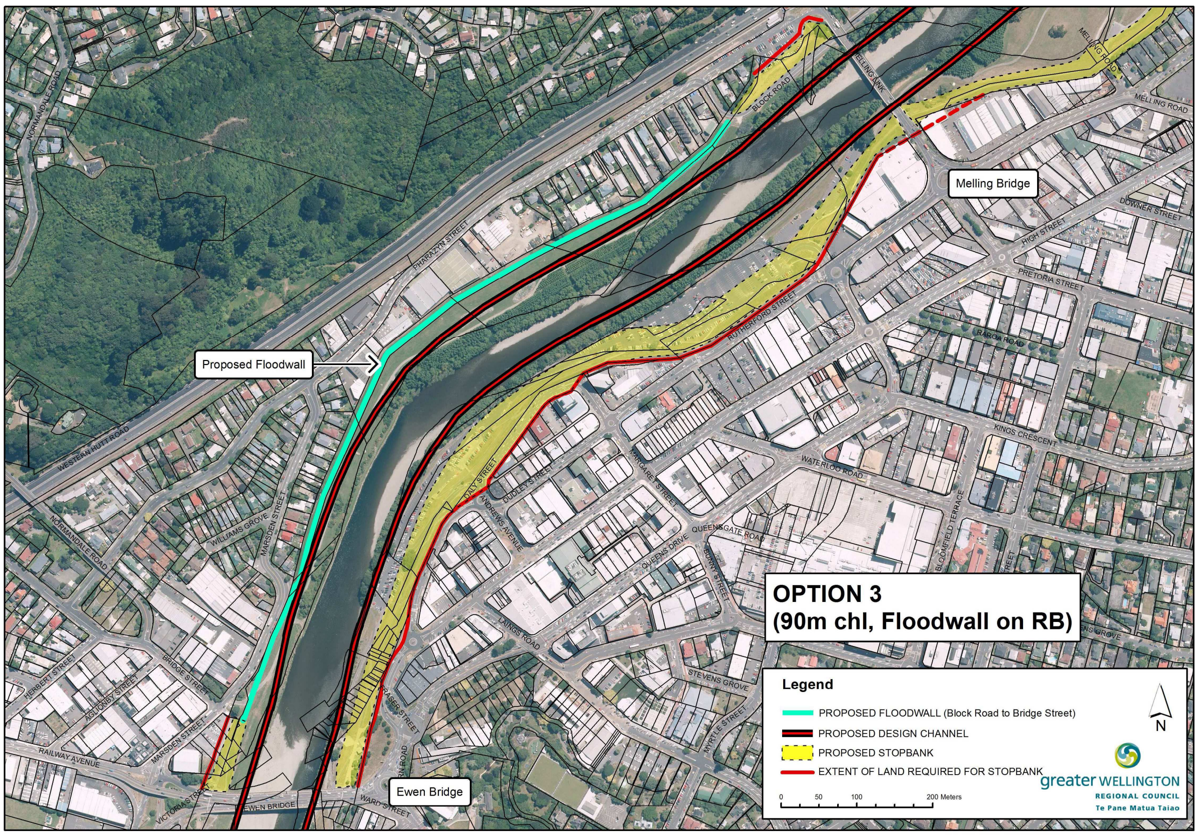

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Figure 4.3 - Option 3 (90 metre channel, standard left bank berm, minimal right bank berm, standard left bank stopbank, diaphragm flood wall right bank)

Flood Defences

- left bank (City) stopbank generally constructed to standard Hutt River configuration includes retaining walls at critical sections. Meets long term requirements for 2,800 cumec flow and can accommodate Hutt City's "Making Places" project,
- right bank deep founded (approximately 8 metres below bed) diaphragm flood wall,
- smaller right bank flood wall footprint permits 90 metres channel.

Berm Width

- 25 metre berms or greater on left bank,
- minimal to no berm on majority of right bank, channel against flood wall.

Bank edge protections

- standard rock protections for left bank 25 metre berm,
- very heavy rock protection against right bank flood wall.

Channel Widths

- 90 metre channel over complete reach,
- acceptable velocities, turbulence and scour as a result of wider channel.

Hydraulics

- Option 3 gives levels up to 330mm lower than for options 4 and 5 in a 2800 cumec flow, upstream of cross-section 360,
- Velocities throughout the Melling to Ewen reach are up to 3.4 m/s (channel-averaged). Locally, velocities over 5 m/s could be expected (for example on the outside of the meanders).

Risk / Security

- system will provide a high level of security at both the 2,300 and 2,800 cumec flows.

Recreational, landscape, ecological, historical and cultural opportunities

- diaphragm flood wall on right bank will provide walking path along crest of wall. Wall would require imaginative finishing treatment to blend into urban environment. Flood wall does not align with Hutt River Floodplain Management Plan environmental policy. With high flood wall, same safety issues as a bridge,
- minimal right bank berm limits amenity,
- "Making Places" can be accommodated, left bank stopbank can be terraced and permit passive recreation and linkages to the river,
- reasonable opportunities for left bank amenity planting and features in corridor,
- overall corridor visual appearance average.

Roading and traffic impacts

- North Daly Street closed. Traffic to Melling Link via High Street, Andrews Avenue and Dudley Street,
- No roading impacts on right bank.

Cost estimate

- total flood protection is $112.2 million including;
  - flood protection work $21.7 million (includes Melling to KGB channel works),,
  - diaphragm flood wall along western bank with edge protection $85 million,
  - relocation of trunk main sewer outside the floodway $3 million,
  - property purchase $2.5 million.

Positive features

- high security at 2,300 and 2,800 cumec flow,
- requires minimal land purchase
- accommodates “Making Places”,
- system will not need further upgrade in the near future,
- can be staged, but right bank constructed first.

Negative features

- high cost,
- flood wall and lack of right bank berm visually unattractive,
- limited enhancement opportunities on right bank due to lack of space
- does not meet Hutt River Floodplain Management Plan environmental objectives and policies,
- higher maintenance costs,
- 1 property part affected,
- North Daly Street closed.

4.4 Option 4 (70 metre channel, narrow berms both banks, standard left bank stopbank, steep batters and retaining walls right bank)

Refer to **Figure 4.4**. The system provides high security at 2,300 cumec and lower security at 2,800 cumec flows. This option has the same right bank stopbank arrangement as Option 5. The left bank stopbank is constructed over Daly Street, providing greater space to achieve standard Hutt River configuration. Provision for a 3 metre service lane in Daly Street is available. Part of a left bank property at Melling is required. Option 4 accommodates Hutt City's "Making Places" project.

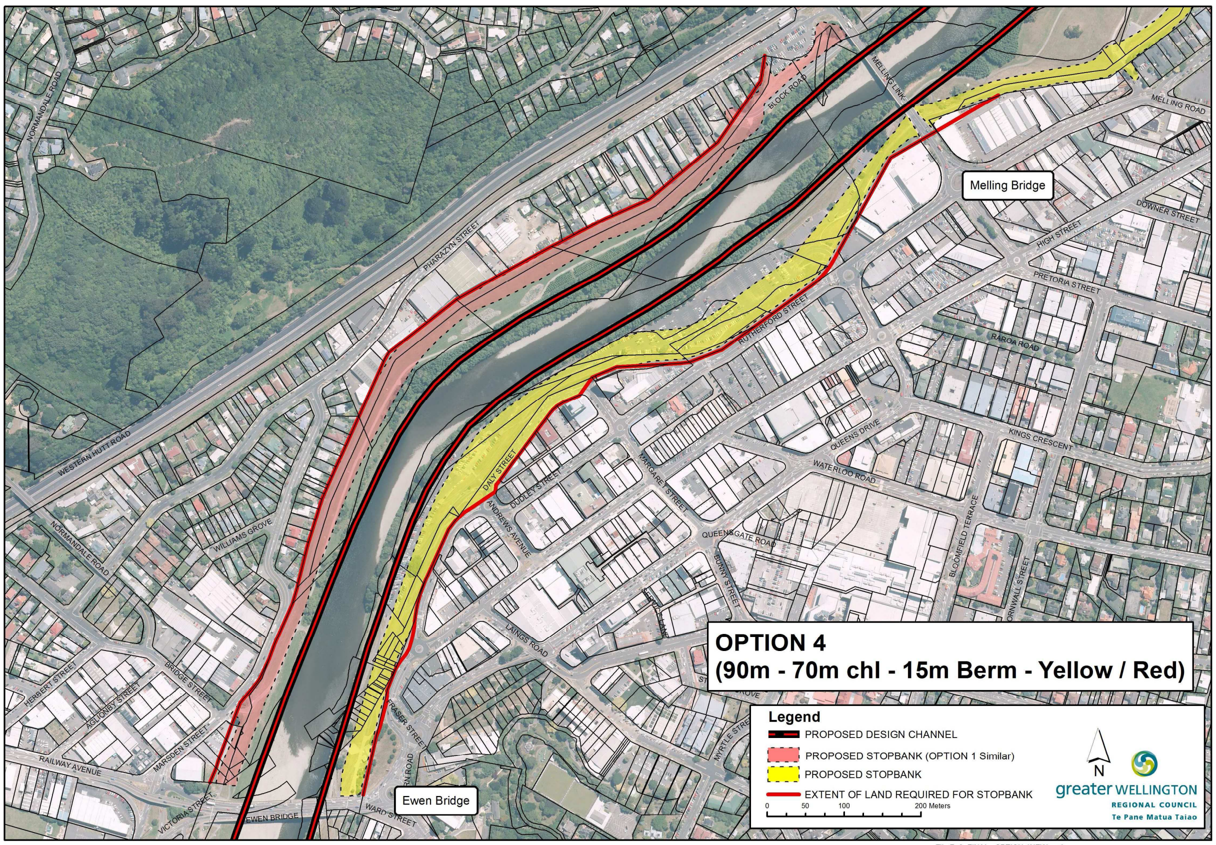

Figure 4.4 - Option 4 (70 metre channel, narrow berms both banks, standard left bank stopbank, steep batters and retaining walls right bank)

Flood Defences

- left bank (City) stopbank generally constructed to standard Hutt River configuration includes retaining walls at critical sections. Meets long term requirements for 2,800 cumec flow and can accommodate Hutt City's "Making Places" project,
- right bank dual section stopbank/retaining wall with steeper batters, and stopbank with steeper batters (steeper than 3.5:1) over most of the reach, resulting in,
- smaller right bank stopbank footprints and lower security.

Berm Width

- narrow 15 metre berms over approximately 500 metres on the left (city side),
- approximate 15 - 20 metre berms over 50% of right bank in City reach.

Bank edge protections

- will require very heavy deeply founded rock riprap at 15 metre berm locations,
- will require heavy rock protection at 20 metre berm widths.

Channel Widths

- narrow 70 metre channel over the majority of the City reach, transitions to 90 metre channel above Ewen Bridge and below Melling Bridge,
- narrow channel and corridor will result in high velocities, turbulence and scour creating higher potential for bank edge and berm erosion.

The same description of the City Centre corridor, noted for Option 5 (the original Hutt River Floodplain Management Plan option) applies to Option 4.

Hydraulics

- Although not explicitly modelled, Option 4 would give similar hydraulic outcomes to Option 5. Flood levels in a 2800 cumec flow would be up to 350mm higher than for Option 2,
- Velocities throughout the Melling to Ewen reach would be up to 4 m/s (channel-averaged) Locally, velocities up to 6 m/s could be expected (for example on the outside of the meanders),
- The higher flood levels and the higher velocities reduce the level of security of the river corridor in a 2800 cumec flow.

Risk / Security

- system will provide a high level of security at the 2,300 cumec flow,
- system will provide lower security at the 2,800 cumec flow, attributable to narrow berms, narrow channel and right bank flood defences,
- left bank stopbank will not require a future upgrade for 2,800 high security.

Recreational, landscape, ecological, historical and cultural opportunities

- narrow channel and berms, smaller right bank stopbank plan area and steep batters limit development of these opportunities,
- Making Places can be accommodated and left bank stopbank can be terraced and permit passive recreation and linkages to the river,

- no substantial opportunities for amenity planting and features in corridor. Paths on river berms and onto right bank retaining wall / stopbanks limited.
- overall visual appearance average

Roading and traffic impacts

- North Daly Street closed. Traffic to Melling Link via High Street, Andrews Avenue and Dudley Street.

Cost estimate

- total flood protection $42.1 million includes;
  - flood protection work $36.6 million (includes Melling to KGB channel works),
  - relocation of trunk main sewer outside the floodway $3 million,
  - property purchase $2.5 million.

Positive features

- lowest equal cost option, covered by current budgets,
- high security at 2,300 cumec flow,
- minimal land purchase required,
- accommodates Making Places,
- left bank stopbank will not need further upgrade if decision made in future to upgrade berms, channel and right bank,
- future channel and right bank upgrade can be staged but majority of current work (except city stopbank) will need to be reconstructed, some economies from previous works.

Negative features

- lower security at 2,800 cumec flow, less secure climate change provision,
- corridor and retaining walls visually unattractive,
- very limited enhancement opportunities due to lack of space,
- higher maintenance costs,
- 1 property part affected,
- North Daly Street closed.

4.5 Option 5 (70 metre channel, 15 metre berms, steep batters and retaining walls left and right banks)

Refer to **Figure 4.5**. This option is the 2001 Hutt River Floodplain Management Plan “risk-based 2,300 cumec standard” corridor. The system provides high security at 2,300 cumec and lower security at 2,800 cumec flows. All works are generally within the current river corridor, with minor encroachment on public parking spaces in north Daly Street. Part of a left bank property in Melling is required. Because it is an historic option no specific provision is made for Hutt City’s “Making Places” project.

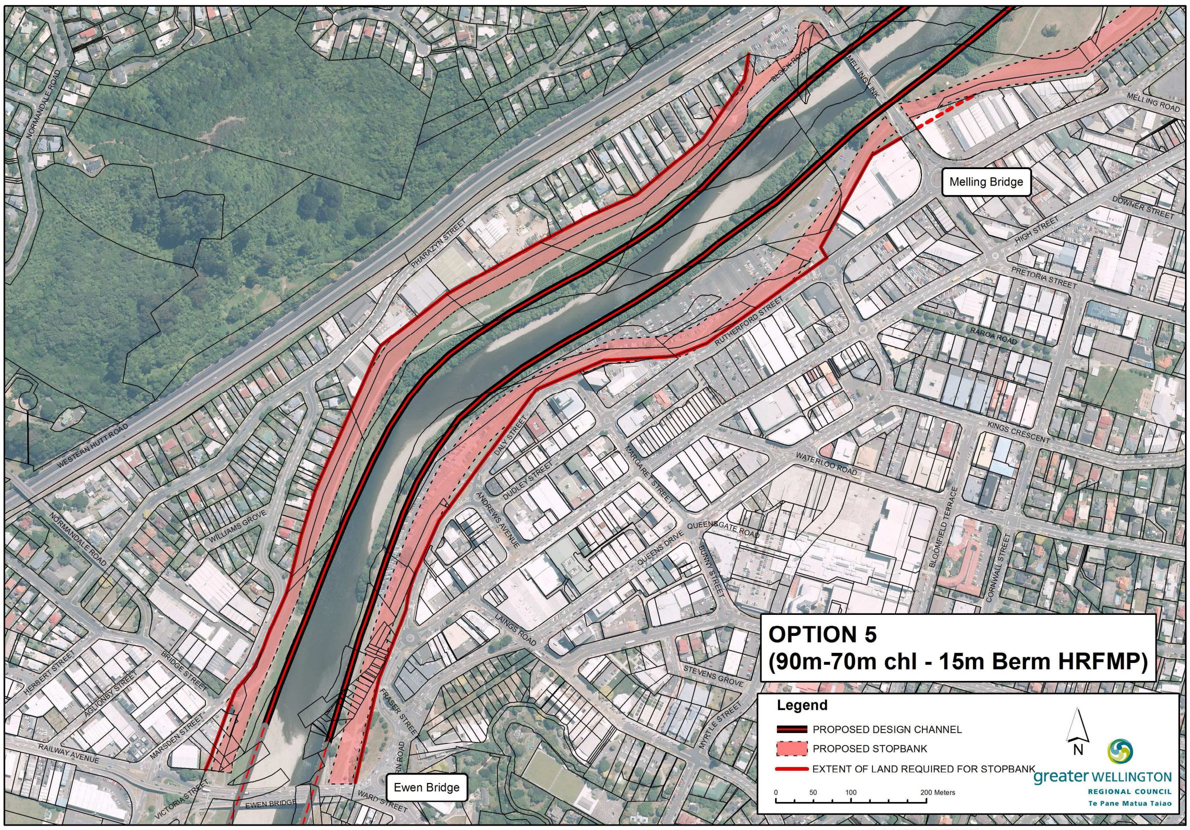

Figure 4.5 - Option 5 (70 metre channel, 15 metre berms, steep batters and retaining walls left and right banks)

Flood Defences

- land constraints in the City Centre reach require dual section (stopbank/retaining wall) flood defences, on both sides of the river over long sections,
- stopbanks will have batters steeper than 3.5:1 along sections of both banks and in dual section stopbanks, resulting in,
- smaller stopbank footprints and lower security.

Berm Width

- narrow 15 metre berms over approximately 500 metres on the left (city side) bank,
- 15 - 20 metre berms over 50% of right bank in City reach.

Bank edge protections

- will require very heavy deeply founded rock riprap at 15 metre berm locations,
- will require heavy rock protection at 20 metre berm widths.

Channel Widths

- narrow 70 metre channel over the majority of the City reach, transitions to 90 metre channel above Ewen Bridge and below Melling Bridge,
- narrow channel and corridor will result in high velocities, turbulence and scour creating higher potential for bank edge and berm erosion.

A description of the Hutt River Floodplain Management Plan City Centre corridor 70 metre design channel, taken from a Hutt River Floodplain Management Plan technical report (Reference Channel Management and Protection Works Vol. 1 Dec 1999) [2], records:

*" - - - . This design channel is based on a smooth transition between the narrow meander form (70 metre wide channel) upstream of the (*Ewen*) Bridge and the wider channel form (90 metres wide) downstream. It is the minimum waterway which satisfies the river channel management requirements and provides an acceptable level of security for the 2,200 cumec design flood. The 2,200 cumec design flood was used as this was assessed to be the prevailing capacity of the flood protection system downstream of Kennedy Good Bridge".*

To provide equivalent security through the City Centre in a 2,800 cumec event the channel width needs to be 90 metres, the same as the channel widths above and below the City Centre.

Hydraulics

- Option 5 gives the highest levels upstream of cross-section 360 (refer Figure 6.1) of all the options. In a 2800 cumec flow, levels are up to 390mm higher than for Option 2,
- It gives lower levels between cross-section 360 and Ewen Bridge, but at the expense of higher velocities. Option 5 leads to the highest velocities throughout the Melling to Ewen reach, up to 3.84m/s (channel-averaged). Locally, velocities up to 6 m/s could be expected (for example on the outside of the meanders),
- The combination of higher flood levels and the higher velocities reduce the level of security of the river corridor in a 2800 cumec flow.

[2] Wellington Regional Council, Hutt River Channel Management and Protection – Channel Management and Protection Works Volume 1 & 2. September & December 1999

Risk / Security

- will provide a high level of security at the 2,300 cumec flow,
- system will provide lower security at the 2,800 cumec flow, attributable to narrow berms, narrow channel and both left and right bank narrow flood defences.

Recreational, landscape, ecological, historical and cultural opportunities

- narrow channel and berms, smaller stopbank plan area and steep batters limit development of these opportunities,
- no substantial opportunities for amenity planting and other features in corridor. Paths on river berms and onto right bank retaining wall / stopbanks limited,
- overall visual appearance average to low.

Roading and traffic impacts

- land currently used for parallel parking along north Daly Street will be integrated into river corridor,
- otherwise no other impacts.

Cost estimate

- Total flood protection $45 million includes;
  - flood protection work $39.5 million (includes Melling to KGB channel works),
  - relocation of trunk main sewer outside the floodway $3 million,
  - property purchase $2.5 million.

Positive features

- lowest cost option, covered by current budgets,
- high security at 2,300 cumec flow,
- minimal land purchase required,
- minor roading and traffic impacts,
- future upgrade possible but would require substantial land purchase and complete reconstruction of major proportion of Option 1 works.

Negative features

- lower security at 2,800 cumec flow, less secure climate change provision,
- corridor and retaining walls visually unattractive,
- very limited enhancement opportunities due to lack of space,
- higher maintenance costs,
- 1 property part affected,
- no provision for HCC “Making Places” project, but possible with reconstruction.

4.6 River Corridor Options: Summary

Table 4.1 summarises features of the various river corridor options. The table contains:

- channel and berm dimensions,
- security ratings,
- an estimate of the number of properties required if the option is implemented,
- costs of various components of the options,
- for each corridor option, the corridor hydraulic capacity with the Melling Bridge retained (with an improved channel), and Melling Bridge replaced with a new bridge,
- the impacts of the corridor options on roading.

Table 4.2 summarises the positive and negative features for each river corridor option, repeated from Sections 4.1 to 4.6.

Section 4.8 and **Table 4.3** contain discussion and summarise the alignment of each corridor option with the flood related objectives contained in **Appendix A**.

Option	Design Channel Width Metres	Minimum Berm Width Metres	Flood security in 2,800 cumec flood event	No. of private properties required	Estimated Costs $ million (Rough Order of Magnitude)					Channel Capacity Cumecs		Comment	Impacts on existing roads
					Estimated property purchase costs	Flood Protection costs	Trunk Sewer Relocation	New Melling Bridge, or (improved waterway)	Total	Existing Melling Bridge with improved waterway	New Melling Bridge		
Option 1 **New Melling Bridge**	90	50	Very High	168 includes 80 residential and commercial units	162	32.4	–	28.4	**222.8**	2,100	2,800	Properties required on both banks. Allows for adaptation to future changes	North Daly Street closed. Part of High Street closed. Traffic to Melling link has to follow Queens / Laings / Andrews / Dudley
Option 2 **New Melling Bridge**	90	25	High	76 includes 37 residential units	42	35.5	–	28.4	**105.9**	2,100	2,800	CBD clear except for closing Daly Street. Properties required on RB.	North Daly Street closed. Traffic to Melling link has to follow High / Andrews / Dudley Marsden Street realigned
Option 3 **New Melling Bridge**	90	0-25 RB 25 LB	High	1 property (part)	2.5	106.7 (incl. RB floodwall)	3	28.4	**140.6**	2,100	2,800	Daly Street and part of a property at Melling will be required	North Daly Street closed. Traffic to Melling link has to follow High / Andrews / Dudley Marsden Street realigned
Option 4 **New Melling Bridge**	70 (90 Under Melling Bridge)	15	Lower	1 property (part)	2.5	36.6	3	28.4	**70.5**	2,100	2,300	Daly Street and part of a property at Melling will be required	North Daly Street closed. Traffic to Melling link has to follow High / Andrews / Dudley
Option 5 **New Melling Bridge, or (improved waterway)**	70 (90 Under Melling Bridge)	15	Lower	1 property (part)	2.5	39.5	3	28.4 (7.7)*	**73.4** **(52.7)**	2,100	2,300	All works are generally within the existing river corridor (Daly Street carparks and part of a property at Melling will be required)	All roads open, Removal of Daly Street carparks for the new stopbank.

Table 4.1 Summary of River Corridor Improvement options

*Notes: * Cost of upgrading the waterway under the existing bridge and strengthening bridge abutments to achieve a 2,100 cumec capacity is $7.7 m*

Hutt River City Centre River Corridor Options: Summary of Positive and Negative Features				
Option 1	**Option 2**	**Option 3**	**Option 4**	**Option 5**
Positive features • system provides a high level of security at both 2,300 cumec and 2,800 cumec flows, • accommodates provision for current climate change projection, • accommodates revised Making Places, • realigned Marsden Street will provide better traffic flow, • corridor would appear spacious, attractive and balanced in shape and form, • wider corridor offers very high potential for developing recreational, landscape, ecological, and other opportunities, • no further works or upgrade expected for life of assets, • could be staged but would require substantial reconstruction, • a staged option, indicating future land requirements, could be notified through planning instruments, • lower maintenance costs, **Negative features** • higher capital cost relative to lower security Options 4 & 5 • creates land impacts on both sides of the river with very high dislocation, • major land impacts, 168 properties affected, includes 80 residential and commercial properties, • Daly Street closed and other roading impacts.	**Positive features** • system provides a high level of security at both 2,300 cumec and 2,800 cumec flows, • accommodates provision for current climate change projection, • accommodates Making Places, • realigned Marsden Street will provide better traffic flow, • corridor would appear attractive and balanced in shape and form, • wider corridor has potential for developing recreational, landscape, ecological, and other opportunities, • no further works or upgrade expected for life of assets, • could be staged but would, depending on extent of current work, be similar to Option 2 i.e. require substantial reconstruction • a staged Option 3, indicating future requirement for right bank land, could be notified through planning instruments, • lower maintenance costs. **Negative features** • higher capital cost relative to lower security Options 4 & 5 • major land impacts, mainly on right bank, • 76 properties affected including 37 residential units, • Daly Street closed.	**Positive features** • high security at 2,300 and 2,800 cumec flow • requires minimal land purchase • accommodates Making Places • system will not need further upgrade • can be staged, but right bank constructed first **Negative features** • highest capital cost Option • flood wall and lack of right bank berm visually unattractive • limited enhancement opportunities on right bank due to lack of space • Does not meet Hutt River Floodplain Management Plan environmental objectives and policies • higher maintenance costs • 1 property part affected • North Daly Street closed	**Positive features** • lowest equal cost option, covered by current budgets, • high security at 2,300 cumec flow, • minimal land purchase required, • accommodates Making Places, • left bank stopbank will not need further upgrade if decision made in future to upgrade berms, channel and right bank, • future upgrade can be staged but majority of current work (except city stopbank) will need to be reconstructed, some economies from previous works. **Negative features** • lower security at 2,800 cumec flow, less secure climate change provision • corridor and retaining walls visually unattractive • very limited enhancement opportunities due to lack of space • higher maintenance costs • 1 property part affected • Daly Street closed.	**Positive features** • lowest equal cost option, covered by current budgets, • high security at 2,300 cumec flow, • minimal land purchase required, • minor roading and traffic impacts, • future upgrade possible but would require substantial land purchase and complete reconstruction of major proportion of Option 1 works. **Negative features** • lower security at 2,800 cumec flow, less secure climate change provision • corridor and retaining walls visually unattractive • very limited enhancement opportunities due to lack of space • higher maintenance costs • 1 property part affected • no provision for Making Places, but possible with reconstruction

Table 4.2 Summary of River Corridor Option – Positive and Negative Features

4.7 River Corridor Options 1 to 5: Alignment with Objectives

The Project Objectives were referenced in Section 1.2, and are included in **Appendix A**. The specific Flood Risk objectives are set out below. Below each objective an interpretation is provided. **Table 4.2** evaluates the alignment of each option with each objective.

Flood Risk Objectives

1. Improve the Hutt Valley's resilience to flood hazard by a river channel, structures clearance, and corridor design that provides for a 2800 cumec flood flow.

Objective 1 is interpreted as how well the river corridor / channel option can to pass a 2,800 cumec flow with high security. The words relating to "structures clearance" are transferred to be included in Objective 2 i.e. related to infrastructure. The assessment of Objective 1 is an evaluation of the corridor only and assumes there are no significant bridge impacts on the 2,800 cumec flow.

2. Improve the Hutt Valley's resilience to flood hazard by managing development and infrastructure elements within the corridor (e.g. SH2 and any widening of it, stormwater and other pipe networks, or integrated building edges in the town centre) that can reduce the effective floodway, or affect stopbank integrity.

Objective 2 considers the impact of infrastructure on the security of the options. The key infrastructure considerations are:

1. The trunk sewer runs below the existing right bank stopbank. For Options 3, 4 & 5 the trunk sewer is re-located outside the floodway. For options 1 & 2 the new stopbank will be constructed outside / around the existing sewer line that will remain in place.
2. Stormwater outlets will be consolidated and reconstructed for all corridor options.
3. Other pipework and cables will be relocated outside the floodway.
4. Impact of the Melling Bridge – to indicate channel capacity a separate column is included in Table 4.1 where the Melling Bridge is retained with an upgraded channel (90 metres) and where the Melling Bridge is replaced with a new bridge and 90 metre channel.
5. The widening of SH2 on the right bank above Melling Bridge

3. Plan for future increases in floodplain resilience by considering now the future options (such as the broadening of the corridor and increasing the height of the new stopbanks) to ensure that these are not precluded by the currently planned upgrades.

Objective 3 assesses the ability to upgrade each river corridor option to meet future design standards, perhaps at or higher than the 2,800 cumec flow. The criteria used to assess each option are.

1. The extent of reconstruction required.

2. The need to purchase property, and the impacts on affected property owners.
3. The cost to achieve the new standard.
4. The difficulty in achieving a new standard.
5. The resulting security provided by the option

4. ***Improve the river channel edge protection so as to minimise the risk of failure of flood defences from erosion during a flood."***

Objective 4 is interpreted as the ability of the combined edge protections, berm and stopbank bulk to resist erosion and prevent stopbank failure. The assessment is based on a 2,800 cumec event.

Assessment Scale

Table 4.2 shows an evaluation of the level of alignment between the corridor options 1 to 6 (covered in Sections 4.1 to 4.6) with each of the "Flood Risk" objectives.

The scale used to assign alignment of the corridor options against objectives is:

Alignment	Numerical assessment
Very high	(96% to 100% alignment)
High	(91% to 95% alignment)
Medium to High	(86% to 90% alignment)
Medium	(81% to 85% alignment)
Low to Medium	
Low	

The "percentage" is provided purely to give an intuitive numerical feel for the rating. A similar approach was provided for the "Security" measure in Section 2.3.

Summary from Table 4.2

- Option 1 is clearly the highest rated option (but at a cost of $194.4 million). It aligns at VERY HIGH with all of the objectives and accommodates all eventualities, if Melling Bridge is replaced.
- Option 2 provides HIGH security at 2,800 cumec flow. The majority of property impacts are on the right bank.
- Option 2 has the potential to accommodate some increase in capacity above the 2,800 cumec flow, if climate change estimate is low.
- Options 1, 2 and 3 have LOW alignment with objectives until Melling Bridge is replaced. When Melling Bridge is replaced Option 1 VERY HIGH, Options 2 HIGH and Option 3 MEDIUM-HIGH alignment.
- When Melling Bridge is replaced corridor Option 1 VERY HIGH, Options 2 & 3 HIGH security at the 2,800 cumec flow.
- Option 3 provides HIGH security at 2,800 cumec flow, but the mass and length of the diaphragm wall compromises future proofing initiatives.
- Option 4 has an overall MEDIUM alignment with objectives if Melling Bridge is replaced. The river corridor will pass a 2,300 cumec flow with a high level of security, but 2,800 cumec flow with a lower level of security. It has an advantage that the left (CBD) stopbank will not require reconstruction if the rest of the corridor is upgraded in the future.
- Option 5 also has an overall MEDIUM alignment with objectives if Melling Bridge is replaced, for the same reasons as Option 4.
- Option 5 does not readily accommodate future needs.
- With the channel width at Melling Bridge upgraded to 90 metres (Melling Bridge is not replaced), <u>all of the options have LOW alignment with the objectives (until the bridge is ultimately replaced)</u>. This is because the waterway capacity through the bridge (with an upgraded 90 metre channel) is restricted to 2,100 cumecs, compared to the Hutt River Floodplain Management Plan 2,800 cumec bridge capacity.

Table 4.2 indicates that to achieve a corridor that can pass the 2,800 cumec flow, with a high level of security, and provide the desired long term hedge against climate change:

- a decision would need to be made to adopt any of options 1, 2 or 3,
- Melling Bridge would need to be replaced,
- there are options to stage progress to meet the objectives,
- All options can be staged but the right bank works may need to be constructed first (may not align with Making Places timeframe,
- Other staging may be possible but would require step by step assessment.

Corridor Option	Flood Risk Objectives					Overall Weighting (with upgraded Melling Bridge)	Overall Weighting (with replacement Melling Bridge)	River works cost (excluding other works) $ million
	Objective 1	Objective 2		Objective 3	Objective 4			
	Corridor excluding bridges	Infrastructure		Future proofing	Edge protections			
		With upgraded Melling Bridge	With replacement for Melling Bridge					
1	Very high	Low	Very High	Very high	Very High	Low	Very High	**194.4**
2	High	Low	High	High	High	Low	High	**77.5**
3	High	Low	High	Medium	High	Low	Medium-High	**112.2**
4	Medium	Low	Medium	Low	Medium	Low	Medium	**42.1**
5	Medium	Low	Medium	Low	Medium	Low	Medium	**45.0**

Table 4.3 Option alignment with Flood Risk Objectives

Objectives Précis

Objective 1: A river corridor design that provides for high security in a 2,800 cumec flood flow,

Objective 2: Resilience to flood hazard by relocating infrastructure and managing development in river corridor,

Objective 3: Future floodplain resilience to allow for higher design standards if they are required,

Objective 4: Combined bank edge protections / berm/ stopbank will resist erosion and stopbank failure in a 2,800 flood.

5. Bridging Options

5.1 Hutt City and New Zealand Transport Agency (NZTA) responsibilities

NZTA is responsible for the operation of the State Highway network in New Zealand. Its responsibility includes the interface with local authority roading networks and design and construction of interchange arrangements. NZTA also provides support funding for key roading infrastructure within the city roading network.

Hutt City is responsible for the city side of this interface. At Melling this includes bridging arrangements from the SH2 intersection, across the Hutt River and into the city.

Hutt City and NZTA have over the last 20 years assessed a number of options and locations to create pedestrian, roading and light rail links from SH2 and the western side of the Hutt River to the city and central Hutt Valley.

NZTA recently indicated that the optimum location for a future state highway interchange into the city is the current Melling location. There are no alternative interchange and bridging options under investigation.

5.2 Current Bridges

The two bridges within the City Centre reach of the Hutt River are Ewen and Melling bridges.

Ewen Bridge

Ewen Bridge (the 7th bridge at this location) links the southern end of the Hutt CBD with Alicetown, Petone and the Dowse interchange (SH2). A joint project between HCC and GW, spanning 1989 to 1996, addressed the problem of a very narrow and confined waterway and a structurally deficient 6th Ewen Bridge (susceptible to earthquake loading). Construction of the new bridge, widened channel and new flood defences (200 metres upstream and downstream on each side of the Ewen Bridge) were completed in 1996.

Ewen Bridge has four traffic lanes, two cycle lanes and two pedestrian footpaths and is understood to provide adequate traffic capacity. The bridge is 170 metres long, oriented obliquely on the channel, and is 23 metres wide. The distance between stopbank crests is approximately 163 metres at the bridge location, and the channel is approximately 90 metres wide.

In 1992 when the bridge hydraulic design capacity was decided, the Hutt River Floodplain Management Plan was not completed and no standards had been set to guide bridge design. The bridge was designed for a 2,200 cumec flow.
Bridge hydraulic capacity is related to bridge height. For the Ewen Bridge this required a compromise between the height of adjacent roading and the height of the bridge. A higher bridge soffit gives more opportunity to pass debris floating on the water surface.

The bridge was designed with a high arch, at the centre 2.5 and 2.7 metres respectively above left and right bank stopbank landing levels, to meet roading transitions. The high arch provides an additional opportunity to pass debris and increase waterway capacity, over part of the span.

Recent analysis confirms the 2,200 cumec design capacity. With raised stopbanks or with crest walls Ewen Bridge can be expected to pass 2,800 cumecs, with minor compromise of debris clearance criteria, but with high security.

Melling Bridge

The Melling Bridge links SH2 to the northern end of the CBD at Rutherford Street and via the Melling link to High Street. The bridge was constructed in 1958 and replaced the Melling suspension bridge at Melling Road, approximately 200 metres upstream.

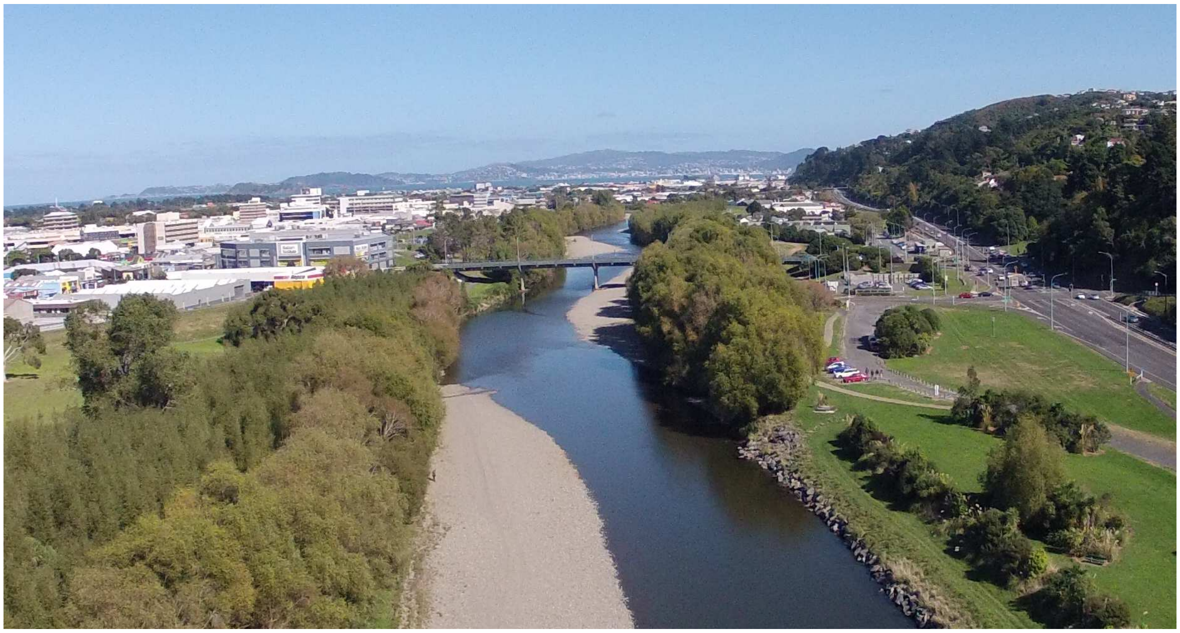

Figure 5.1 Melling Bridge from Left Bank Upstream

The bridge is 140 metres long and 10 metres wide. The river corridor at the bridge site is approximately 155 metres wide and the channel width is approximately 65 metres. The proposed flood protection works will increase the channel width to 90 metres.

The original two lane traffic design for the bridge has been modified to accommodate three lanes. The resulting narrow lanes give motorists lower than standard clearance and the arrangement is hazardous for cyclists. The bridge has two pedestrian footpaths.

Hutt City notes that with three lanes the traffic capacity of the bridge is adequate for the next 10 years, but there are traffic limitations at the east and west intersections. NZTA in conjunction with Hutt City propose to reduce these limitations if Melling Bridge is retained.

5.3 Melling Bridge Investigations and Remedial Works

Melling Bridge has been the subject of a number of investigations. Studies were carried out to assess scour and vulnerability of piers and abutments, and to assess structural behaviour under seismic and hydraulic loads.

Seismic analysis of the Melling Bridge assessed two scenarios; the Wellington Fault rupture event and a severe Regional earthquake. The Wellington Fault passes directly under the bridge and it is not feasible to secure the bridge against horizontal and vertical displacements in the fault rupture scenario. A new bridge designed to modern standards would also be severed by the anticipated movement on the Wellington Fault. In a Wellington Fault rupture there would also be high risk of liquefaction of material around the eastern (left) abutment, with consequent risk of damage to the abutment structure.

In a significant Regional earthquake, the eastern abutment is vulnerable to damage due to the potential for lateral spreading.

Scour protection works to the in-channel piers and remedial works to the bridge structure, to improve seismic resistance, have been completed. No further seismic upgrading work is programmed.

5.4 Melling Bridge Traffic Capacity

Hutt City notes that the three lane traffic capacity of the existing bridge, in conjunction with road and traffic improvements to the east and west intersections, will provide acceptable traffic management for the next 10 years.

NZTA propose improvements to the SH2 Melling and Block Road intersections to address conflicting demands and congestion. The estimated cost of this work is $7 million.

5.5 Melling Bridge Hydraulic Capacity

The hydraulic capacity of Melling Bridge is 1,800 cumecs which is around the 50 year ARI event. This is a low standard that limits the level of flood protection available for proposed and completed flood protection works downstream of the bridge.

The proposed flood protection works for this City Centre reach include widening the river channel at the Melling Bridge location from 65 metres to 90 metres. With channel lining and bridge abutment river works, these channel improvements will enable the bridge to pass a 2,100 cumec event, about 125 year ARI.

The minimum capacity of the river corridor options (Options 1 to 5, Sections 4.1 to 4.5) is 2,300 cumecs with a high level of security. With capacity improved to 2,100 cumecs Melling Bridge will not achieve the minimum 2,300 cumec design standard, and will be much lower than the desired 2,800 cumec capacity for a replacement bridge.

In an event of a 2,100 cumecs or greater event, the bridge soffit will build up debris, progressively obstruct the bridge opening and increase water levels. With flow increasing above 2,100 cumecs this combination will create a high risk of left bank stopbank failure. In turn the bridge left abutment has a high risk of failure if the stopbank were to breach above the bridge.

Appendix B contains an historical account and photos that illustrate and describe the impact of debris on bridges (with inadequate debris clearance) during large flood events.

5.6 Options to Improve Melling Bridge Hydraulic Capacity

Melling Bridge with upgraded waterway

As noted in Section 5.6, with channel widening, heavy rock linings in the channel, bank edges and abutments the current Melling Bridge hydraulic capacity can be improved to 2,100 cumecs, a 125 year return period event.

Replacement Bridge

To obtain the desired 2,800 cumec hydraulic capacity at Melling a new bridge would need to be constructed. If constructed to hydraulic criteria set out in the Hutt River Floodplain Management Plan, a new bridge will have very little impact on the hydraulic performance of the river corridor Replacement Bridge

Interface with SH2 Melling Intersection Improvements by the NZ Transport Agency

NZTA have indicated that a replacement Melling Bridge can be constructed in a way that will fit in with future arrangements for a SH2 interchange at Melling. NZTA indicate that the optimum location for a future bridge is at the current Melling bridge location. NZTA and Hutt City proposes interim improvements to the current SH2 intersection, the eastern intersection from the bridge and to adjacent roading to improve traffic flows. These proposed improvements are estimated to ease the traffic congestion for at least 10 years, at a point where the NZTA will commence planning for a SH2 interchange at Melling.

Joint Project Strategy

Currently the Joint Project is progressing the investigation of two bridging strategies. The first is to complete river channel and abutment strengthening and extend the life of Melling Bridge by around 30 years, and defer construction of a new bridge.

The second strategy is proceeding in parallel with a business case to present to NZTA, requesting funding support for a replacement bridge. Preparation for this business case is underway.

Further investigation is required to reach a decision on either of the bridge options. While the major benefit of a replacement bridge is improved flood protection, there are considerable bridge security and traffic benefits to the City. The key issue then becomes a matter of timing for replacement of the Melling Bridge. The decision criteria become:

- Wait until the existing bridge has lived out remaining viable life (Hutt City estimate this could be up to 30 years), or wait until NZTA construct a new Melling interchange with a replacement Melling Bridge, or
- Replace the Melling Bridge concurrently with the flood protection works, and achieve the desired level of flood protection.

The advantage of the "wait" options is that capital expenditure is deferred for possible decades until either of the options is implemented. The "wait" option could also optimise the linkage of a new bridge to the interchange. From a risk perspective the wait option would mean living with lower 125 year ARI flood protection (high potential flood damages and corresponding high community disruption in a one off event) from the time flood protection works are completed until the bridge is replaced. The bridge also has the potential to fail by liquefaction in the 250 year ARI Regional earthquake. Loss of Melling Bridge utility would have major inconvenience for road travel.

The advantage of replacing the bridge concurrently with the flood protection works is that a high level of flood protection would be provided and the potential for a bridge induced debris failure in this reach, with a corresponding community disaster, would be virtually eliminated. The replacement bridge would be secure in a regional earthquake.

5.7 Bridging Options – Economic Indicators

Section 7 sets out the methodology and determines potential flood damages for the existing bridge and the two options to improve hydraulic performance at the current Melling Bridge waterway. The improvement options are:

- Melling Bridge retained, with a widened and rock lined channel, and rock lined left abutment
- a replacement Melling Bridge

The potential damages included in Table 5.1 are taken from the work described in Section 7. The potential damages comprise direct and indirect damages associated with flooding, but they do not make provision for intangible damages. The various damages categories are described in Section 7.

Potential saved damages are the difference between the potential damages for the existing bridge and the respective bridge improvement option. The potential saved damages do not account for traffic benefits of either improvement option, and make no provision for bridge damage, failure and dislocation subsequent to a stopbank failure above the bridge. To compare the two bridging options the saved average annual damages over a 30 year "life" are brought back to a current $ value (Net Present Value or $NPV).

Economic Analysis Summary

Table 5.1 indicates that a retained and upgraded Melling Bridge in a widened channel has NPV saved damages of $9.23 million compared with $19.41 million for a replacement bridge. A new bridge shows saved flood damage difference of $10.18 million.

The saved damages for the options do not include traffic benefits and do not take account of costs to repair a failed abutment or bridge. These benefits, ignored in this analysis, could influence economics in a bridge option decision. The approximate capital costs of the two bridging options are included in Table 5.1.

As noted in Section 5.7 the Joint Project is progressing the two bridging options assessments. A comprehensive evaluation of the options and a business case is underway.

5.8 Melling Bridge Failure

A Melling Bridge left bank abutment failure is possible if the left bank stopbank above the bridge fails. A left bank stopbank failure is possible if the upgraded 2,100 cumec waterway capacity of the bridge is exceeded. The existing bridge is also vulnerable to failure in a large 250 Year ARI Regional earthquake that causes liquefaction at the bridge piers and left abutment.

A right bank stopbank failure due to Melling Bridge is unlikely.

A bridge failure would mean that entries to the Central Hutt Valley and the City from the west, north and south would be Petone Overbridge, Dowse Interchange, Kennedy Good Bridge and via the Eastern Hutt Road from the north. The dislocation, lengthened journeys and associated costs caused by loss of entry at Melling are likely to be significant. Repair of a failed abutment would be a lengthy operation.

The damages noted in Table 5.1 for the Melling Bridge upgraded waterway option do not take into account the costs of abutment or bridge failure, following stopbank failure, in the period before Melling Bridge is ultimately replaced. Figure 7.1 shows the flood spread for a breach on the left bank at Melling. The breach has potential damages in the order of $1 billion.

A decision on whether to retain and upgrade the existing Melling Bridge, or replace the bridge, will also take into account the ability of the city and community to cope with and continue after a one-off catastrophic event.

These matters will be addressed through the NZTA Business Case process and the economic assessment [9] carried out through the integrated project reporting.

Bridge Improvement Option	Flood Damages				Capital Cost
	Average Annual Damages (AAD)	NPV of AAD	Saved AAD	NPV of Saved Flood Damages	Bridge Option
	$	$	$	$	$
Existing Melling Bridge & channel	1,263,000	19,412,000	0	0	
Upgraded Melling Bridge & 90 metre channel	662,000	10,180,000	600,500	9,231,400	7,700,000
New Bridge	0	0	1,262,800	19,412,000	28,400,000

Table 5.1 Economic Evaluation of Bridge Improvement Options

Notes:

1. Damages are based on the risk of left bank stopbank failure created by debris build-up on the bridge.
2. Average annual damages reflect the potential damage weighted to take account of the probability of the flood event and the probability of stopbank failure, in any one year.
3. NPV represents Net Present Value of the annual potential saved damages discounted over 30 years.
4. Saved Average Annual Damages (AAD) is the difference between the potential damages for the existing bridge and the respective bridge improvement option. Saved AAD indicate the economic effectiveness of the bridge option to reduce potential flood damage.
5. The Net Present Value of future saved damages, brings the annualised damages over 30 years back to present worth.
6. The discount rate used to compute NPV is 5%.
7. The analysis makes no provision for traffic benefits or for bridge damage, failure and dislocation subsequent to a stopbank failure above the bridge

6. Supporting Hydraulic investigations

In order to compare the hydraulic effectiveness and impacts of each of the five river corridor options (4.1 to 4.5 as set out in Section 4), simulations were run through a recently updated computer model of the Hutt River. The model uses MIKE FLOOD software and covers the river downstream of Taita Gorge, as well as the Lower Hutt and Petone floodplains on the left and right banks respectively. The model has been calibrated to the flood event of 27 - 28 October 1998, with verification against flood events in June 2002 and January 2005.

The design scenario runs incorporate works carried out since these events, including the Boulcott stopbank works and the Ewen to Ava stopbank and floodway works. The design scenario runs also incorporate the following assumptions:

- The Ava Bridge is upgraded, with a raised soffit (clear of the 2800 cumec flood event) and fewer and better aligned piers. The same bridge dimensions were previously assumed in setting the 2800 cumec stopbank levels for the Ava to Ewen reach,
- The main river channel bed levels are kept to 1998 levels
- Melling Bridge is replaced so that it causes no impact on flood levels (i.e. has raised soffit and minimal piers). Option 5 however has been modelled with and without a new bridge at Melling

The design flow scenarios were for a flow peak of 2800 cumec at Taita Gorge and a tidal boundary condition of 1.3m RL (approximately a 20 year storm surge), with the flow peak in the lower river reaches occurring at around the time of high tide. No allowance has been made for sea level rise due to climate change, but as the river is reasonably steep; tests have confirmed that the sea level conditions do not have any significant effect on flood levels in the city centre reach.

Each of the corridor options has cross-sections at and downstream of Ewen Bridge, and upstream of section 440, in common. (Figure 6.1 shows the river cross-section locations.) Otherwise, the cross-section dimensions for the options are as shown in Figures 6.2 – 6.7 for selected locations. The dimensions are taken from the alignments shown in Figures 4.1, 4.2 etc. Option 4is not shown in Figures 6.2 - 6.7 nor modelled, but its hydraulic performance will be sufficiently close to that of Option 5 (with a new bridge at Melling) for the purposes of this exercise.

A rock lining is assumed along both banks of the entire reach between Melling and Ewen Bridges (although in practice the wider berms of Option 1 will mean that only partial lengths will require rock lining for that option). No vegetative protection is assumed for modelling purposes.

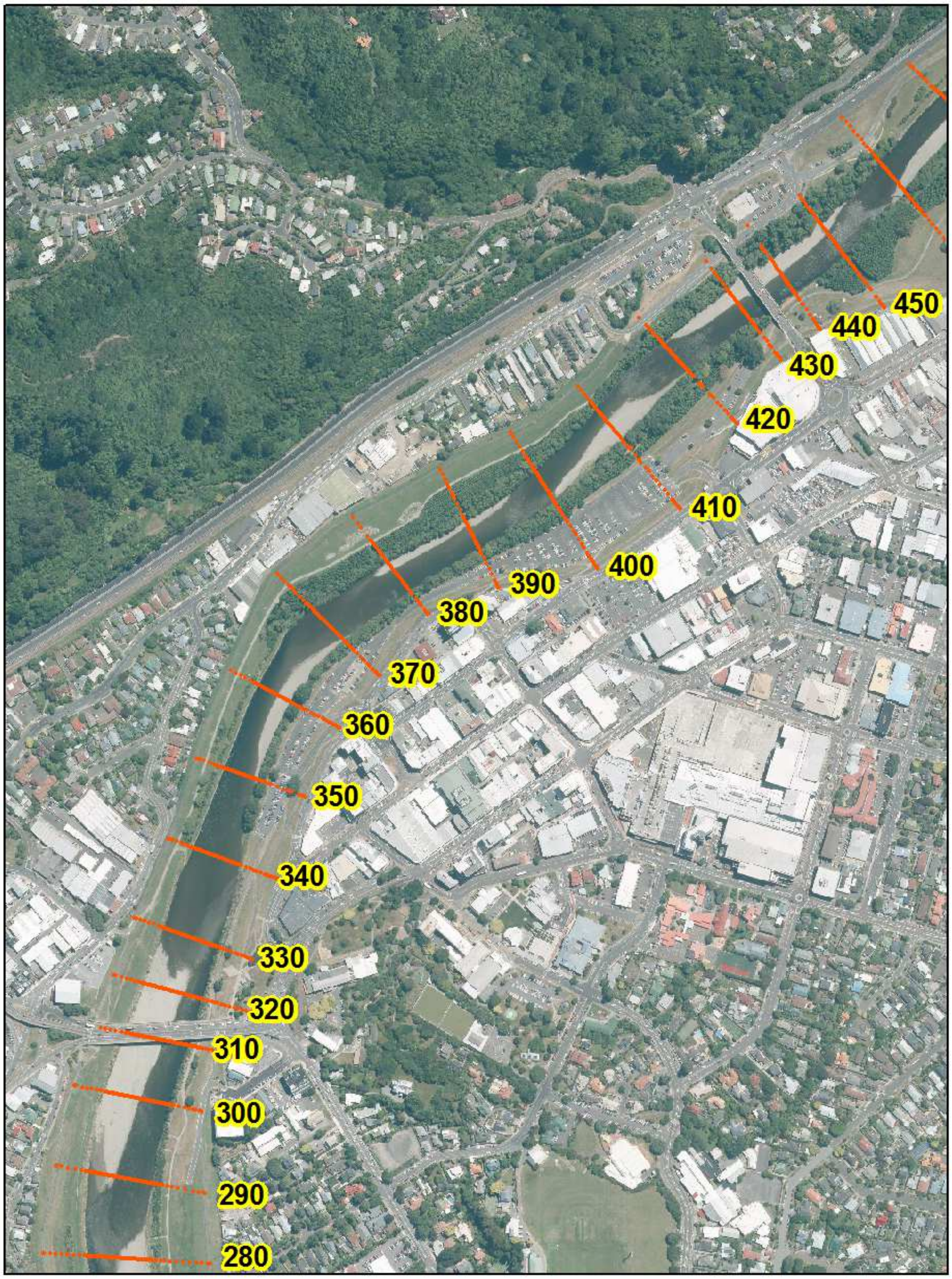

Figure 6.1 River cross-section locations

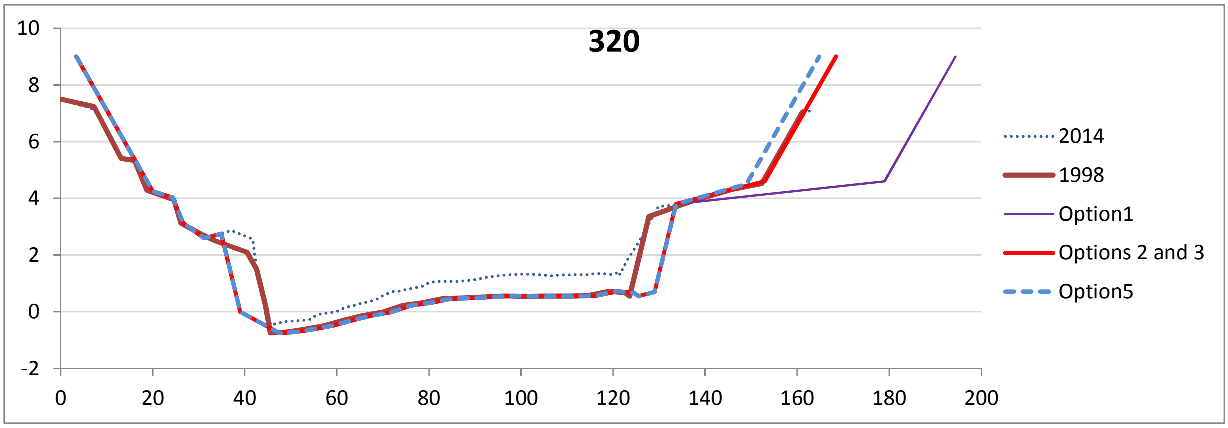

Figure 6.2 Cross-section 320: 1998, current (2014) and options

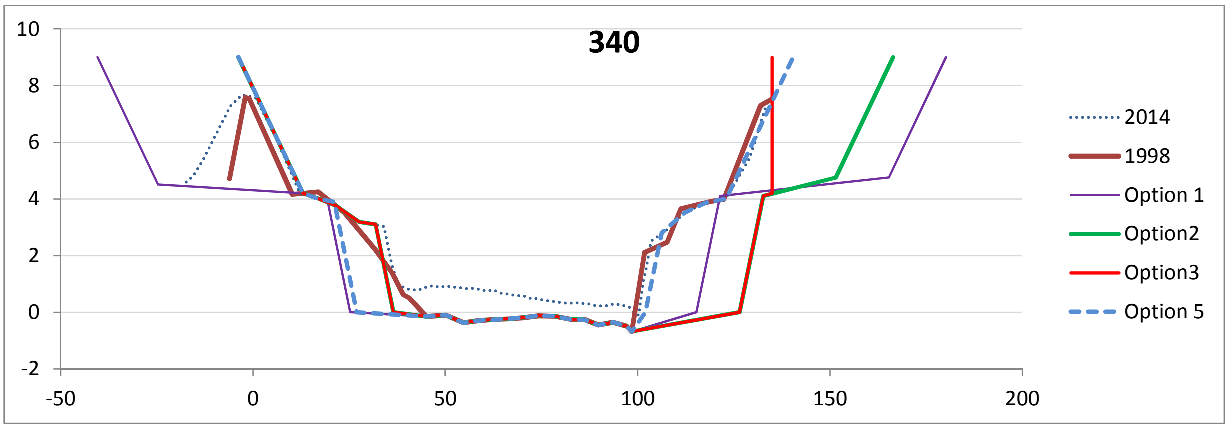

Figure 6.3 Cross-section 340: 1998, current (2014) and options

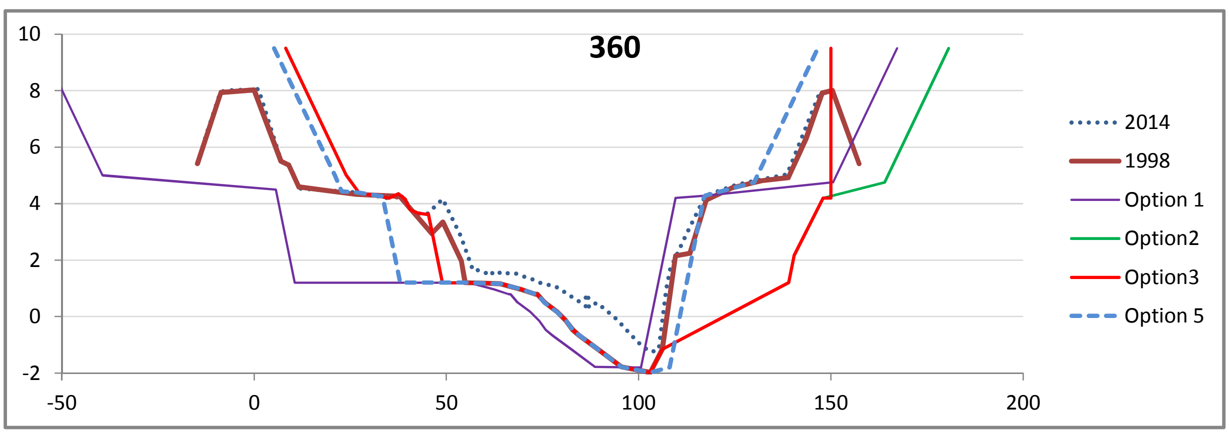

Figure 6.4 Cross-section 360: 1998, current (2014) and options

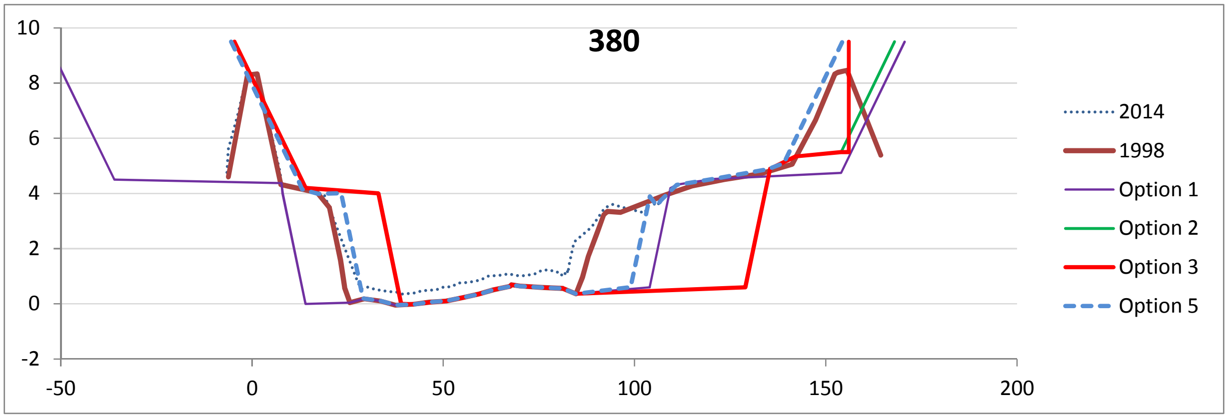

Figure 6.5 Cross-section 380: 1998, current (2014) and options

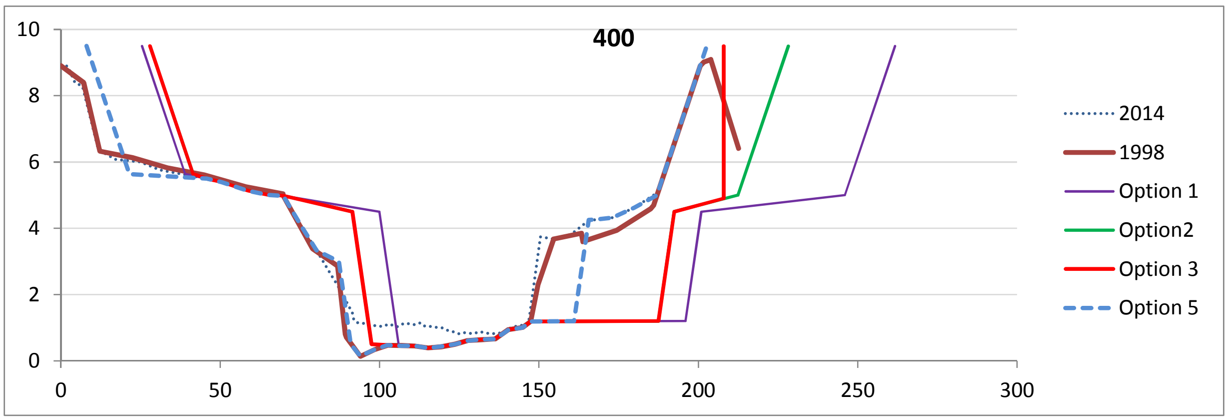

Figure 6.6 Cross-section 400: 1998, current (2014) and options

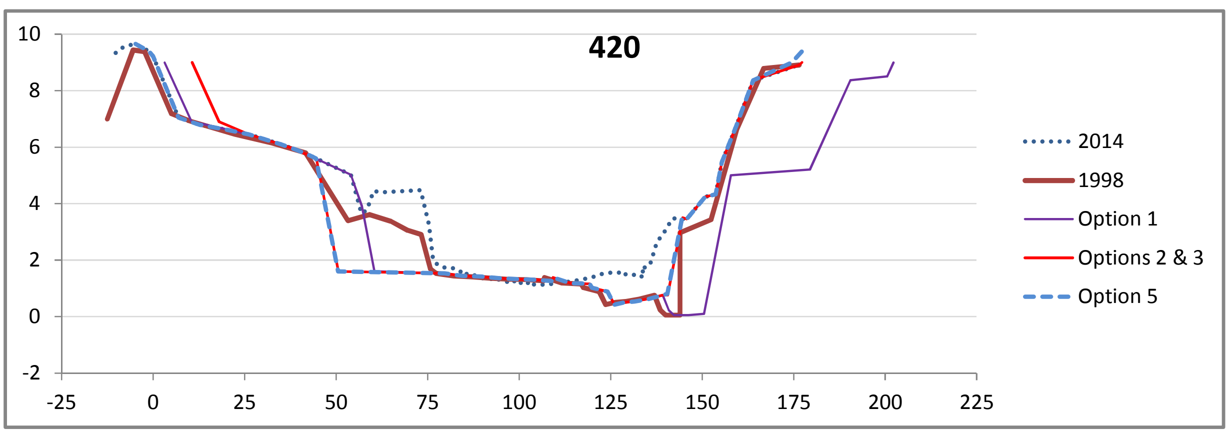

Figure 6.7 Cross-section 420: 1998, current (2014) and options

Figures 6.8 and 6.9 show profiles of the peak flood levels and channel-average velocities along the Melling to Ewen reach. While Figure 6.8 shows that peak levels just upstream of Ewen Bridge are lower for Options 2 and 3 than the Option 1, and in turn levels for Option 5 are lower than for Option 2 and 3, this is a result of higher velocities occurring in the more restrictive channel options as flow approaches Ewen Bridge. Further upstream, the levels are higher (and velocities lower) for Option 5. Option 5 results in consistently higher total head levels than the other options (Figure 6.10). Results at selected locations are tabulated in Table 6.1.

Note that velocities will vary within the channel at any cross-section, with the result that local velocities can be higher than the channel-averages. Velocities on the outer bank edge can be around 50% higher than the channel-average, with implications for riprap protection.

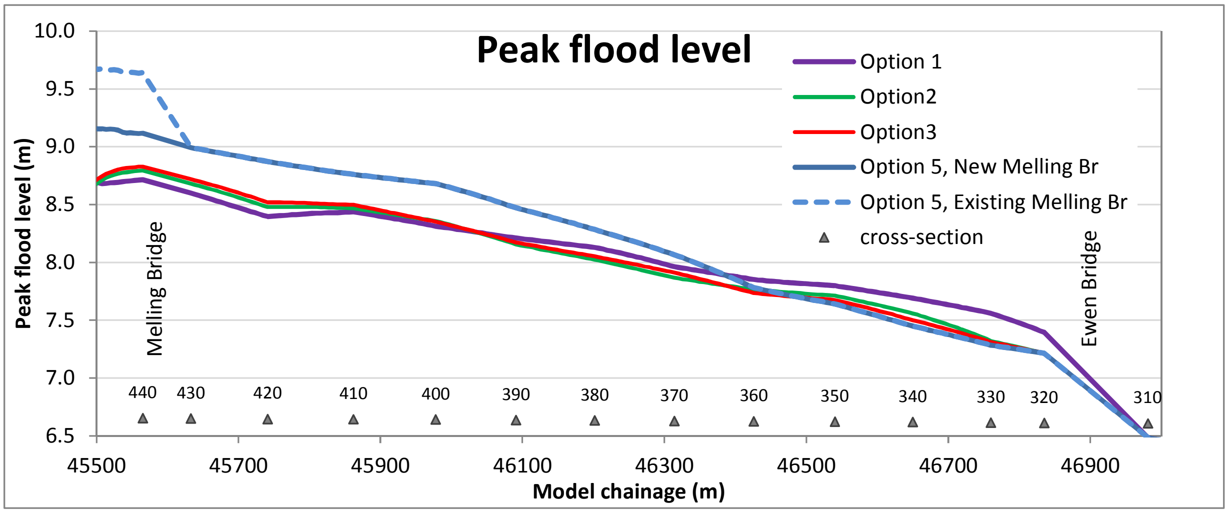

Figure 6.8 Peak flood level profiles, 2800 cumec flood

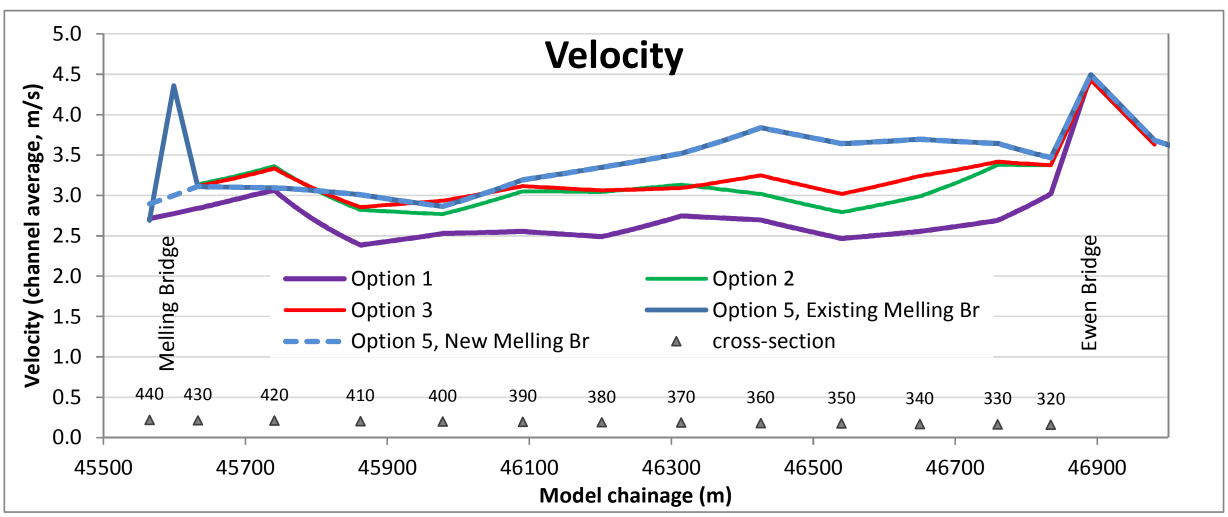

Figure 6.9 Peak channel-average velocity profiles, 2800 cumec flood

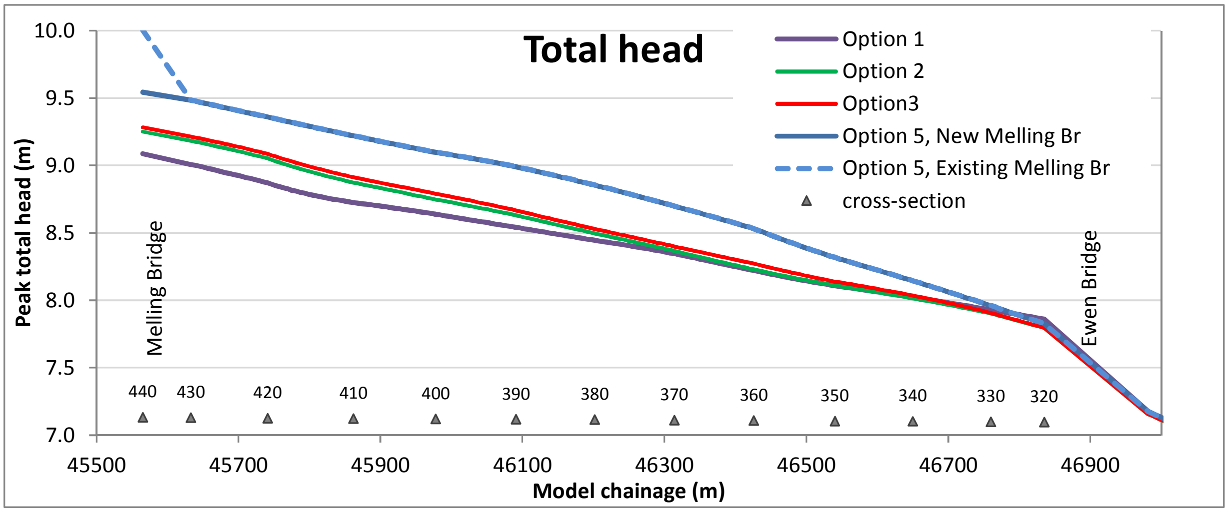

Figure 6.10 Total energy head profiles, 2800 cumec flood

Cross-section	Level (m)				Velocity (m/s) (channel average)				Total Energy Head (m)			
	1	2	3	5	1	2	3	5	1	2	3	5
330	7.56	7.32	7.31	7.28	2.69	3.38	3.42	3.64	7.93	7.90	7.91	7.96
360	7.85	7.77	7.74	7.78	2.70	3.02	3.25	3.84	8.22	8.23	8.27	8.53
400	8.31	8.36	8.35	8.68	2.53	2.77	2.93	2.86	8.64	8.75	8.79	9.10
430	8.60	8.68	8.72	8.99	2.84	3.14	3.12	3.11	9.01	9.18	9.21	9.48

Table 6.1 Comparison of peak level, velocity and total energy head at selected locations, 2800 cumec flood

Melling Bridge capacity

The soffit of Melling Bridge varies in level from 9.42 m to 10.27 m, with an average soffit level of 10.01 m (weighted by the channel area underneath).

Allowing for 1m debris accumulation at the soffit, and allowing a further 700 mm of freeboard at the bridge, the capacity is defined as the flow when the water level on the upstream side of the bridge reaches 8.3 m (i.e. 10 m – 1 m – 0.7 m).

For the existing bridge waterway, and with the existing channel dimensions downstream of Melling Bridge (and 1998 bed levels) the bridge capacity is around 1815 cumecs (Figure 6.11). This equates to about a 65 year return period.

Widening the channel to 90m under the bridge, along with the associated channel lining and bridge abutment works, would increase the capacity to around 2120 cumecs (Figure 6.22), equating to about a 200 year return period event.

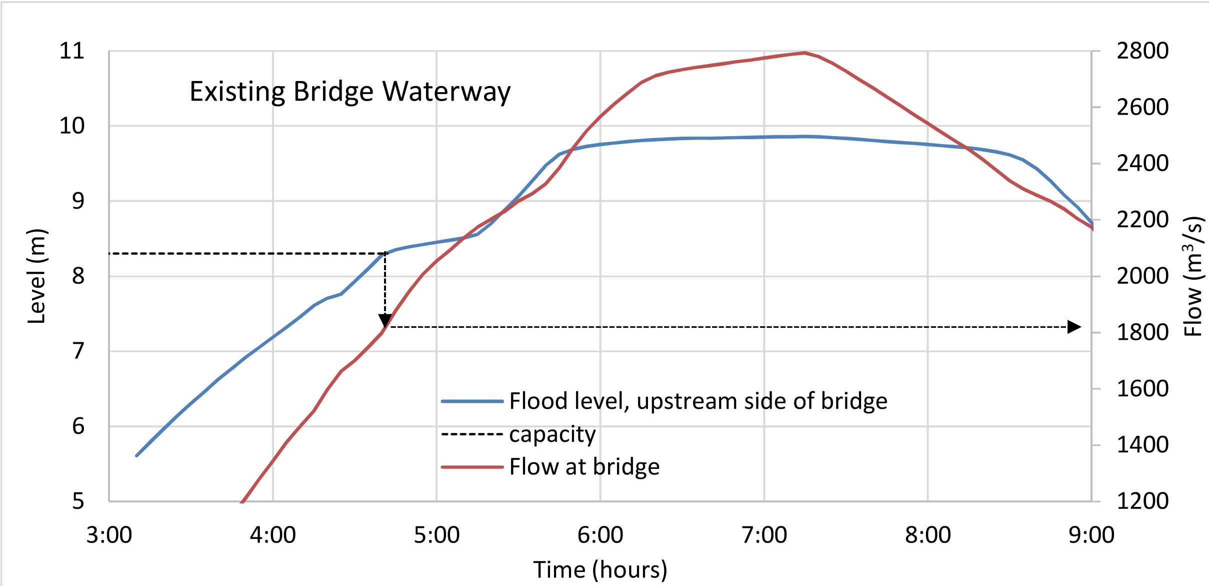

Figure 6.11 Melling Bridge capacity, existing waterway

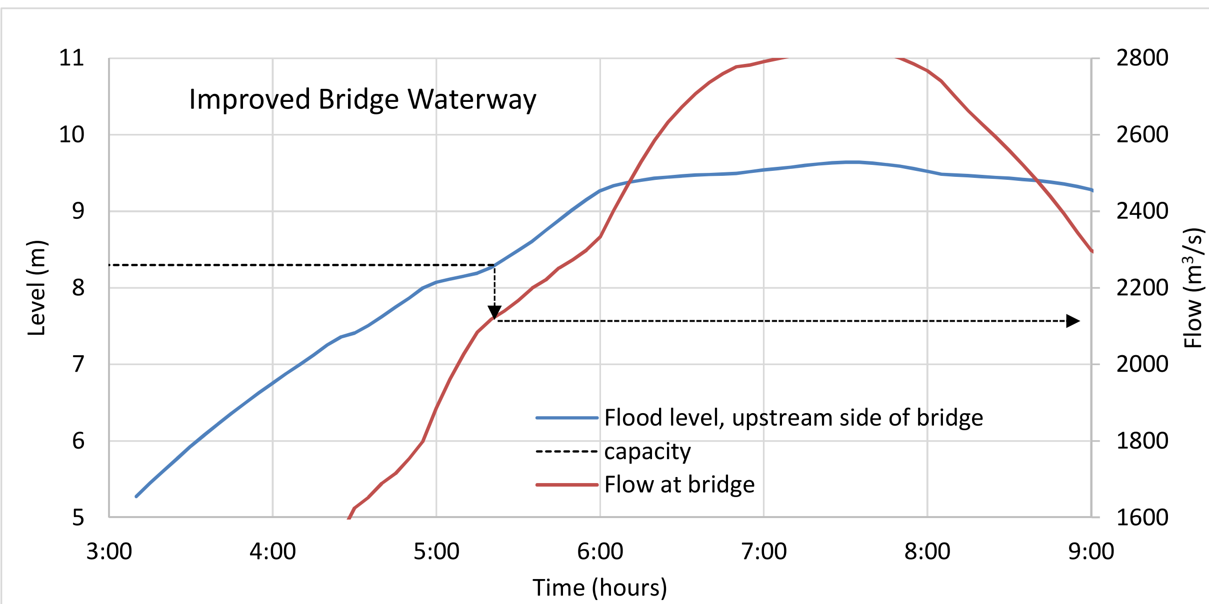

Figure 6.12 Melling Bridge capacity, improved waterway

7. Supporting Risk / Damages / Economic Indicators

An analysis of the flood damages that could be avoided by improvements to or replacement of the Melling Bridge has been carried out. This analysis considers both the flood damages that a left bank breach just upstream of the bridge would cause and the reduction in breach probability resulting from bridge improvements or replacement.

(For this purpose, a left bank breach is considered more relevant and likely; there is no stopbank as such on the right bank upstream as the river bank rises into high ground. Nonetheless, as described below, a right bank breach has been separately modelled downstream of the bridge where the berm narrows and the thalweg runs on the right side near the stopbank. The contribution of Melling Bridge to the probability of such a right bank breach is considered minimal.)

7.1 Stopbank Breach Scenarios and Probability

Stopbank breaches have been modelled at two locations: one on the left bank just upstream of Melling Bridge and the other on the right bank just downstream of Melling Bridge. Within the study reach, these locations would cause the greatest extent of flooding (assuming that breach size and timing would be independent of location).

Three flow scenarios have been modelled for the left bank breach: 1900 cumec, 2300 cumec and 2800 cumec peaks. Figure 7.1 shows the predicted flood depths and extent resulting from the assumed left bank breach scenario, for a 2800 cumec event.

Although not part of the Melling Bridge upgrade analysis, a right bank breach has also been modelled, located just downstream of the bridge. This has only been modelled with a 2800 cumec flood event, and the predicted flood depths and extent are shown in Figure 7.2.

The breaches have been assumed to occur just before the peak of each flood.

Although breach probability is an ill-defined function of many variables, such as river level and height above the floodplain, flow velocity, stopbank material and geotechnical conditions, and stopbank slope, for this analysis it is assumed as a simple function of freeboard to the top of the stopbank. The function assumed is that used in early analysis for the Hutt River [3], developed during a workshop involving experienced river engineers, and is as presented below (Figure 7.3). This allows a relative assessment of the probability of breach failure for each of the options.

Note that the graph has been modified here, for the existing bridge and waterway scenario only, by shifting it vertically by 0.2m, to account for expected extra turbulence associated with the restricted waterway at the bridge. The figures in red on the right hand side of Figure 7.3 show this modification.

[3] Wellington Regional Council. Hutt River Flood Control Scheme Review: Summary Topic 18 – Risk Assessment Process, Method and Results. 1993

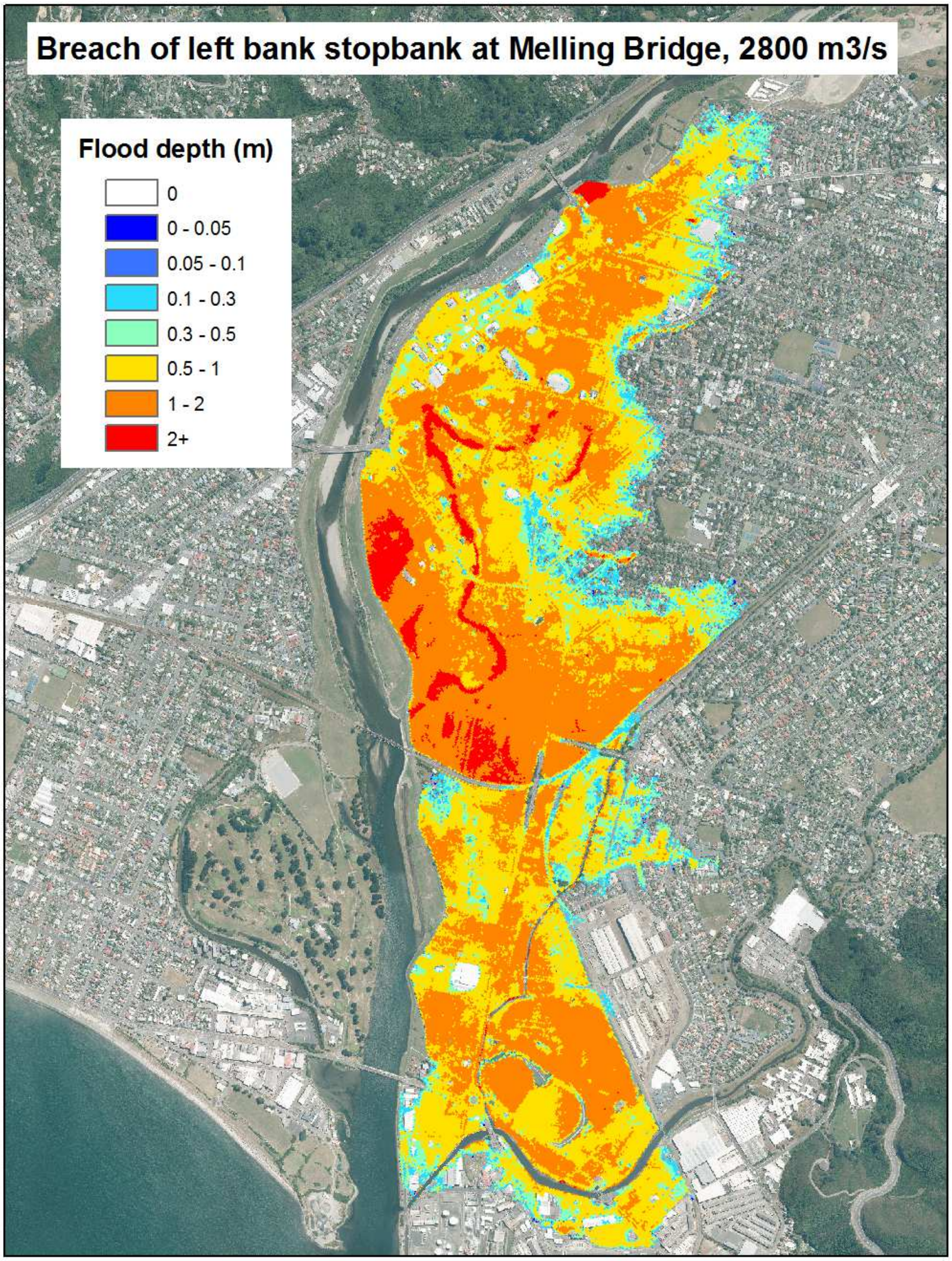

Figure 7.1 Predicted flood depths and extent, assumed left bank breach, 2800 cumec event

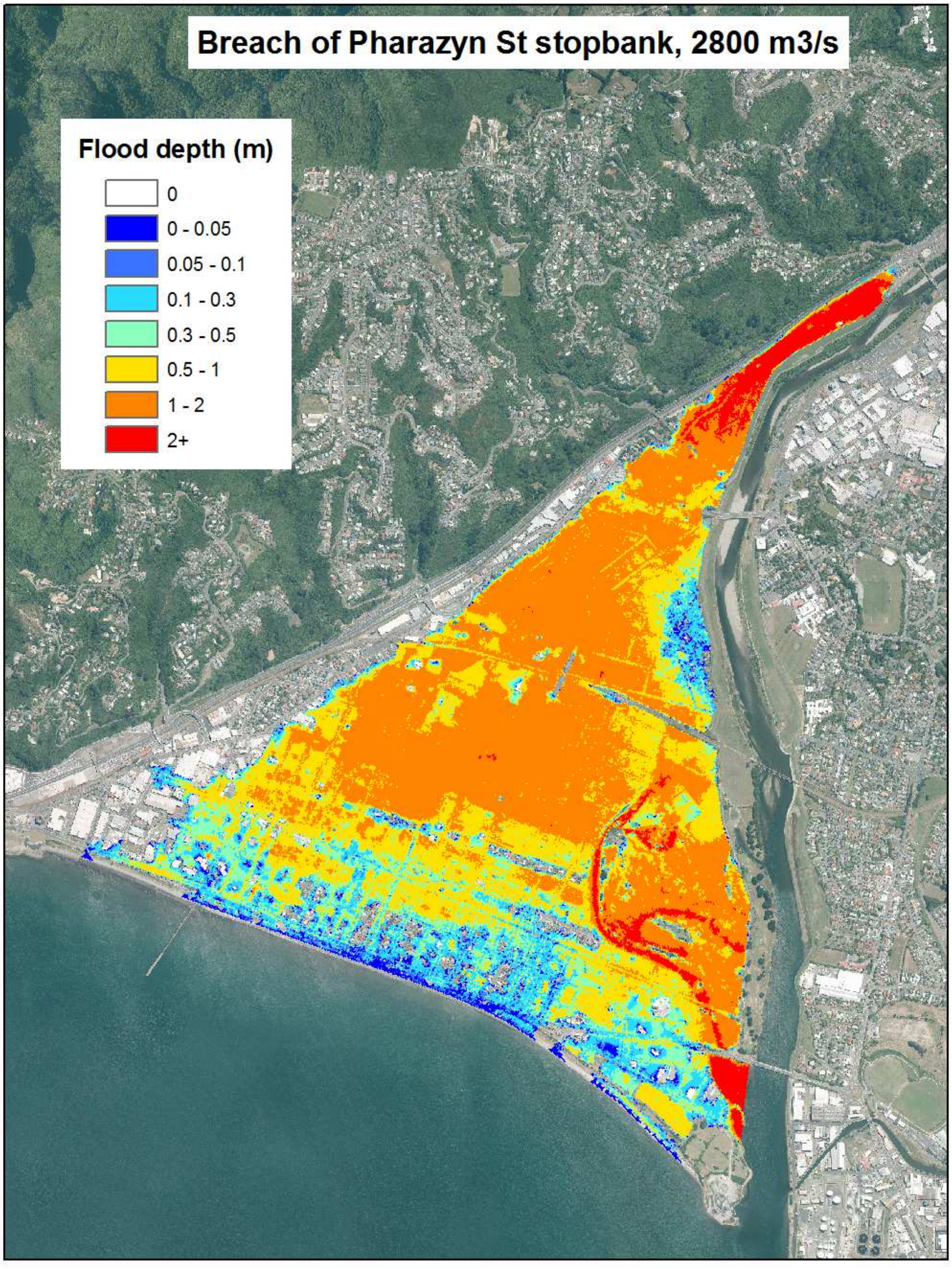

Figure 7.2 Predicted flood depths and extent, assumed right bank breach, 2800 cumec event

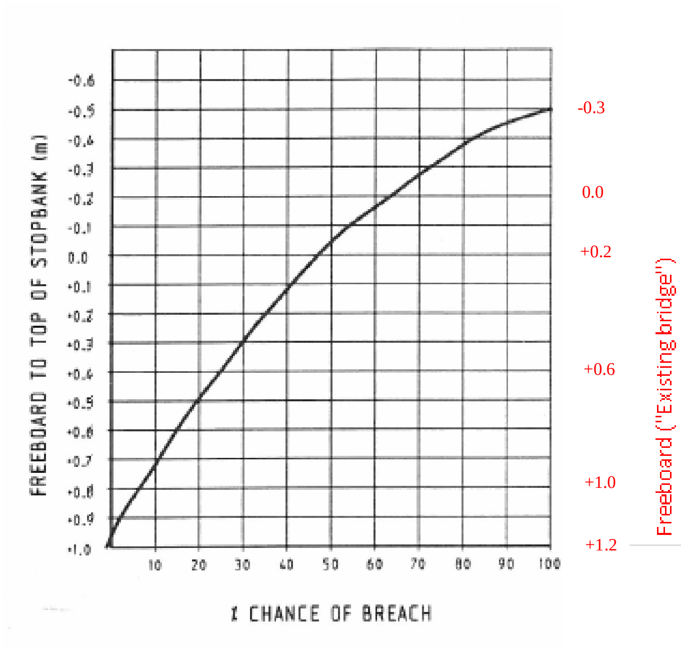

Figure 7.3 Assumed relationship between freeboard and breach probability (from ref 1)

7.2 Damages

Flood damages can be categorised according to the breakdown shown in Figure 7.4. Tangible losses include direct costs, i.e. damage to property and other assets, and indirect costs such as loss of production.

Intangible losses include social and environmental losses. No intangible losses have been presented in this current assessment, but it is possible that the magnitude of these could be equivalent to the tangible losses.

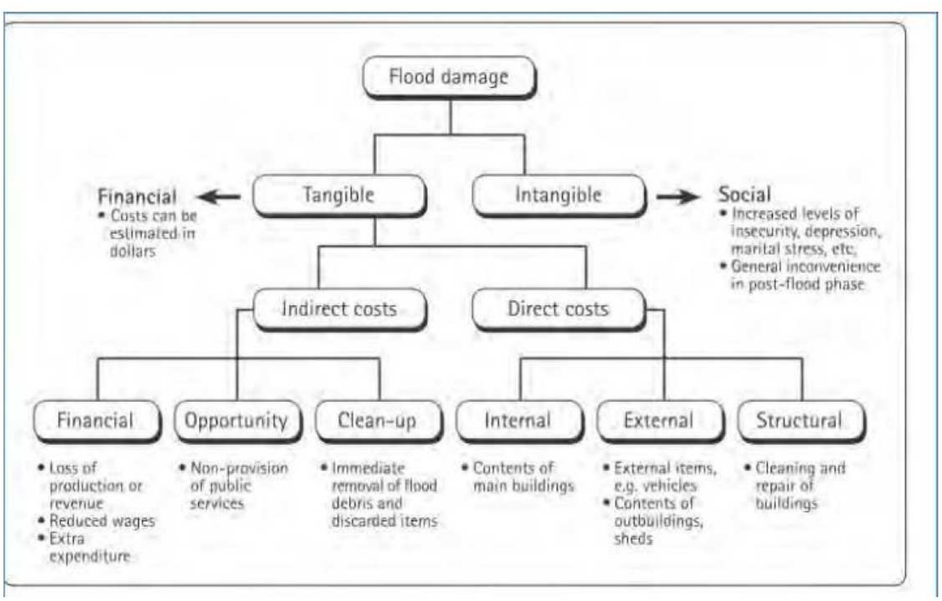

Figure 7.4 Types of Flood Damage (From GHD)

7.2.1 Direct Damages

Direct damages for each of the breach scenarios have been estimated using "stage-damage" relationships, the number of properties expected to be inundated and the depths at each. The stage-damage relationships are based on assessments carried out by loss adjustors for the Bay of Plenty Regional Council for the Whakatane area in 2004 [4]. Specific assumptions are as follows:

Residential Damages

- Costs included building repair costs (removal of debris, drying out, cleaning, repair/replacement of structure, cladding, flooring, insulation etc, plumbing costs, electrical costs, architect/engineer/certification fees etc), as well as contents/chattels costs.
- It includes alternative accommodation costs while dwellings are uninhabitable.
- Costs also included GST.
- Costs for each of several depth categories were produced
- Costs were adjusted to current day (late 2013) costs by an average of the CPI and CGPI movements since 2004. (CPI = consumer price index, CGPI = capital goods price index).
- This assessment does not take into account any resultant land loss, land damage or damage to retaining walls which may occur as a result of such an event and which would normally be covered if the property is insured under the Earthquake Act other than for debris removal from below a raised timber floor.

Commercial & Industrial Damages

These were lumped together and are based on estimates from local Whakatane businesses.

- Costs included building repair costs, and stock damage costs
- For each of the source businesses, the floor area was recorded, to give building repair and stock losses as $/m^2.
- Hence average damage per m^2 of floor area was estimated
- The building footprint areas for Lower Hutt commercial/industrial buildings in the area of interest were digitised.
- Costs for each of 4 depth categories were produced
- Again, costs were updated to current day costs by the average of the CPI and CGPI movements since 2004.

[4] Robin Britton. Whakatane Waimana Floodplain Management Strategy: Stage 1 – Flood Damage Costs for Residential Properties. June 2008

Schools

- Only the building replacement costs were estimated. No contents damages are included
- The building footprint area was recorded, so that an average damage /m^2 was estimated
- The building footprint areas for Lower Hutt educational buildings in the area of interest were digitised.
- Costs for each of 4 depth categories were produced
- Again, costs were updated to current day costs by the average of the CPI and CGPI movements since 2004.

Infrastructure costs

A simple estimate of 15% of the sum of the above direct damages has been made (based on references in Australian studies [5] and ref 2). This is assumed to cover damage to roads, sewerage, gas reticulation, electricity and telecom networks.

Motor vehicle damage

This has not been estimated.

7.2.2 Indirect Damages

"The evaluation of these indirect losses presents greater problems, both conceptually and practically" [6].

Definitions and scope of indirect damage differ amongst different references. In some references, indirect damages are estimated for the residential sector as well as the commercial/industrial sector. For instance, an allowance of 20% of residential direct damage is made for residential indirect damage in Australian literature (ref 4). However that indirect damage includes the cost of alternative accommodation which in this current study has been included in the direct residential damages.

In other references, indirect damage refers only to the commercial/industrial sector. For this current exercise, indirect damage is only estimated for the commercial/industrial sector.

A 1992 report [7] on potential flood losses for the Hutt Valley, based on a survey of local businesses, indicated that the ratio of indirect to direct damages for commercial/industrial was on average 17-18%, although there was some variation depending on business type and flood depth. For example, the average for Lower Hutt commercial businesses was 24%. The report included a comment that the indirect losses were lower than predicted by UK research.

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[5] Bewsher Consulting Pty Ltd, Macquarie Park FRMS&P Final Report, February 2011
http://www.ryde.nsw.gov.au/_Documents/Dev-FloodStudies/Mac+Park+Floodplain+Risk+Mgmt+Plan+Chapter+5.pdf

[6] V. Meyer, F. Messner, E. Penning-Rowsell, C. Green, S. Tunstall, A. van der Veen. Evaluating flood damages: guidance and recommendations on principles Executive Summary. March 2009, Floodsite Project Report TP-09-07-03 Revision 2_2_P01

[7] Hutt River Floodplain Management Plan: Phase 1 Report No. 9, Flood Damage Assessment. 1992.

Estimates from a recent assessment in Queensland (ref 2) were that on average the ratio of indirect to direct commercial/industrial damages would be 55%, while in another Australian study a ratio of 20% was assumed (ref 4).

Considering these results, for this current assessment, it is assumed that indirect damages are 50% of the direct commercial/industrial damages.

The estimated damages and number of properties inundated for each breach scenario are as in Table 7.1.

	Left Bank Breach				Right Bank Breach	
	1900 m^3/s	2300 m^3/s	2800 m^3/s		2800 m^3/s	
	$ Damage	**$ Damage**	**$ Damage**	**No. of properties**	**$ Damage**	**No. of properties**
Commercial	$134,000,000	$199,000,000	$321,000,000	462	$45,000,000	126
Residential	$97,000,000	$226,000,000	$377,000,000	2111	$494,000,000	3115
Schools	$5,000,000	$11,000,000	$16,000,000	4	$8,000,000	5
Industrial		$3,000,000	$69,000,000	91	$246,000,000	596
Infrastructure	$35,000,000	$66,000,000	$118,000,000		$119,000,000	
Indirect	$67,000,000	$101,000,000	$195,000,000		$146,000,000	
TOTAL	**$338,000,000**	**$604,000,000**	**$1,097,000,000**		**$1,058,000,000**	

Table 7.1 Estimated flood damages and number of inundated properties, breach scenarios

7.3 Saved damages

The probability of (left) stopbank breach, for each bridge option and at various flows, has been determined from model results and Figure 7.3. For each, it is assumed that the stopbanks would be constructed to the levels predicted by the 2800 cumec new bridge case (with 700mm freeboard immediately upstream of the bridge), regardless of which bridge option was adopted in the meantime. The probabilities have then been multiplied by the damages in Table 7.1 to provide estimates of annual average damages for each option (Table 7.2).

The sum of the annual average damages over time (30 year period) have then been converted to a net present value, based on an assumed discount rate (5%). Results are presented in Tables 5.1.

Bridge/waterway	Flow	Representing range							FB to 2800 design	p(breach)				
	Scenario	Q1		Q2	p(Q1)	p(Q2)	p(Q1)-p(Q2)	WL	(=9.116+0.7)	Fig 7.3[1]	Net p	Damage	pxDamage	NPV[2]
Existing	1965	1800	to	2100	0.01528	0.004954	0.010325722	8.36	1.456	0	0	$338,278,509	$0	
	2300	2100	to	2550	0.004954	0.000909	0.004044568	9.29	0.526	0.28	0.001132	$604,394,250	$684,464	
	2800	2550	plus		0.000909	0	0.000909216	9.861	-0.045	0.58	0.000527	$1,096,687,263	$578,333	
	Annual Average Damage												**$1,262,797**	**$19,412,279**
Improved	0	1800	to	2100	0.01528	0.004954	0.010325722	8.08	1.736	0	0	$338,278,509	$0	
	2300	2100	to	2550	0.004954	0.000909	0.004044568	9.16	0.656	0.12	0.000485	$604,394,250	$293,342	
	2800	2550	plus		0.000909	0	0.000909216	9.639	0.177	0.37	0.000336	$1,096,687,263	$368,936	
	Annual Average Damage												**$662,278**	**$10,180,838**
New Bridge	1965	1800	to	2100	0.01528	0.004954	0.010325722	7.77		0	0	$338,278,509	$0	
	2300	2100	to	2550	0.004954	0.000909	0.004044568	8.38		0	0	$604,394,250	$0	
	2800	2550	plus		0.000909	0	0.000909216	9.116		0	0	$1,096,687,263	$0	
	Annual Average Damage												**$0**	**$0**

Note 1: Use right hand y-axis for existing
2: 30 year period, 5% discount rate

Table 7.2 Calculations for AAD

7.4 Integrated Project Economic Assessment

The economic indicators for bridge and flood protection options are presented at a high level in order to show potential damages and saved damages for the various flood improvement options. The project Working Group has arranged a comprehensive economic assessment. The intent is to bring economic decisions for all components of the project to a common economic basis. The report is *"Flood Protection: Option Flexibility and its Value"* [9].

8. Decision Making: River Corridor and Bridging Options

Section 4 of this report describes five river corridor options for improving flood protection through the Hutt City Centre and lower Hutt Valley. The issues relating to the river corridor options are discussed in Sections 3.2 and 3.3 and Section 4

Section 5 of the report outlines two options for improving current waterway capacity at the Melling Bridge. The issues related to bridge options are discussed in Section 5.

Section 8 identifies work streams to further investigate the options. This information is necessary to enable evaluation of the options and making a decision on a preferred option.

8.1 Status of the Options

River Corridor Options

The engineering process and detail applied so far to preparation of the river corridor options is described as “feasibility design”. Feasibility is a process for focussing on the viability of preferred options and eliminating unlikely options. This process generally reduces the options down to approximately three to five. The City Centre feasibility design phase is completed by this report, subject to issues arising from consultation. The corresponding costings associated with this level of engineering are called feasibility or sometimes “rough order” costs. Feasibility costing accuracy is in the order of ±30%.

Feasibility design and rough order costing of options is considered adequate to commence community consultation on the options.

To progress decision making the strategy and level of information associated with each corridor option needs to be refined. This next phase of engineering investigation is called Preliminary Design. The corresponding costing accuracy is in the order of ±25%

Bridging Options

The two bridging options being progressed are: an upgraded waterway with the existing Melling Bridge retained; and a replacement bridge.

The upgraded Melling Bridge waterway design is approximately at the same feasibility level as the river corridor options, and will progress with the river corridor options.

The replacement bridge option is proceeding through the NZTA business case process.

8.2 River Corridor Options: Preliminary Design

The work streams that will occur following consultation during the preliminary design phase for those options endorsed by the HVFMS are:

- Consultation feedback and adjustments to process
- Engineering site detail and survey
- Interaction with bridging, roading, transport and other components of the project
- Preliminary design, drawings
- Construction methodology
- Staging of options
- Recreational, landscape, ecological historical and cultural opportunities
- Property detail
- Preliminary design costings
- Regulatory Planning issues, planning controls
- Resource Consent related issues
- Detailed economics of options
- Timeframe and programme for implementing respective options

8.3 Melling Bridge Options

The work streams that will proceed for the two identified Melling Bridge options are:

- Upgraded Waterway - left abutment and river works strengthening. Process and design will be carried out to the same level of detail, and in the same timeframe as the preliminary design of the river corridor options.

And in parallel with preliminary design of the upgraded Melling Bridge waterway:

- Replacement Bridge – progress on application to RLTP and with the Business Case to NZTA (based on the Treasury's preferred Investment Logic Mapping approach). Supporting engineering, planning, costing, related matters as required for the business case.

8.4 Consultation

The joint project Working Group has prepared an integrated report, consultation strategy and programme that coordinates the various work streams comprising the City Centre project. The strategy report and the programme will cover the various options and issues and will be the basis for consulting with stakeholders and the community.

The report gives stakeholders and the community the context for the overall City Centre project, a plan and programme that covers implementation of each of the five river corridor and the two bridge options, and records two options preferred by the HVFMS. This longer term programme will indicate when the design / planning / consenting / construction phases of the various options will be completed. This step is important because the timeframes for Options 4 and 5 (existing corridor and upgraded bridge) may be in the order of 10 to 20 years and the timeframe for Option 1, 2 and 3 (land purchase, wide corridor, and new bridge) in the order of 10 to 50 years.

8.5 Risk Considerations and Decision Making

Reaching a decision on the preferred river corridor and bridging options will focus on cost, risk, economics, affordability and community resilience.

Does the community accept the lower level of flood protection provided by options 4 and 5, and is it able to manage an over design event. Does the community accept that the level of protection offered by Options 4 and 5 will be eroded by Climate Change? A key difference over the river corridor options is their ability to meet, or in the future be adapted to meet, the impact of Climate Change on runoff and peak flood flows.

Climate Change and design standard issues are discussed in Sections 3.2, 3.3 and Section 4.

Similarly for the bridge options, the Melling Bridge waterway can be upgraded to 2,100 cumecs capacity (not meeting either the risk based 2,300 cumec standard or the 2,800 cumec climate change provision). This option defers capital expenditure, but constrains the flood protection capacity offered. The alternative is to fund and build a new bridge, improve flood protection, traffic safety and bridge security, but commit to high capital expenditure now.

To assist the options decision, Councillors will require costings for the various options, economic information, risk explanation, and knowledge about what the community thinks and what the community can afford to pay for. Another influence is whether the community is in a position to recover if a catastrophic event occurs.

To assist the decision making process the Project will balance the complexities and assess the benefits of tools such as multi criteria analysis and weighted attribute approaches.

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2. **Hutt River Channel Management and Protection.** *Channel Management and Protection Works Volume 1 & 2*. Wellington Regional Council. September & December 1999

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4. **Waimana Floodplain Management Strategy*:*** *Whakatane Stage 1 – Flood Damage Costs for Residential Properties.* Robbin Britton. June 2008

5. **Floodplain Risk Management Study and Plan;** *Macquarie Park study area,* Bewsher Consulting Pty Ltd. February 2011
http://www.ryde.nsw.gov.au/_Documents/Dev-FloodStudies/Mac+Park+Floodplain+Risk+Mgmt+Plan+Chapter+5.pdf

6. **Evaluating flood damages: guidance and recommendations on principles Executive Summary** *Floodsite Project Report TP-09-07-03 Revision 2_2*_P01. V. Meyer, F. Messner, E. Penning-Rowsell, C. Green, S. Tunstall, A. van der Veen. March 2009,

7. **Hutt River Floodplain Management Plan.** *AEI.: Phase 1 Report No. 9, Flood Damage Assessment. Flood Protection Group.* Wellington Regional Council.1992

8. **Hutt River City Centre Section Upgrade Project*:*** *Options Evaluation Report, for Greater Wellington Regional Council.* Boffa Miskell. 25 June 2015

9. **Flood Protection: Option Flexibility and its Value.** *For Greater Wellington Regional Council.* Infometrics / PSConsulting. July 2015

APPENDIX A - PROJECT OBJECTIVES

Hutt River City Centre Upgrade Project
Design Objectives

Purpose

To establish common understanding of outcomes sought

Overarching Aim

To deliver a completed project within the Hutt River city section, which, with the joint cooperation of NZTA, HCC and GWRC, optimises public and private benefits.

Flood Risk

1. Improve the Hutt Valley's resilience to flood hazard by a river channel, structures clearance, and corridor design that provides for a 2800m^3/s flood flow.
2. Improve the Hutt Valley's resilience to flood hazard by managing development and infrastructure elements within the corridor (eg SH2 and any widening of it, stormwater and other pipe networks, or integrated building edges in the town centre) that can reduce the effective floodway, or affect stopbank integrity.
3. Plan for future increases in floodplain resilience by considering now the future options (such as the broadening of the corridor and increasing the height of the new stopbanks) to ensure that these are not precluded by the currently planned upgrades.
4. Improve the river channel edge protection so as to minimise the risk of failure of flood defences from erosion during a flood.

Linking and Development

5. Improve the walking, cycling and other active mode linkages to and along the river corridor from the city centre, public transport nodes, and wider Hutt Valley urban area.
6. Facilitate development opportunities for sites that front to the river corridor in the city centre.
7. Create a direct frontage between river front sites in the city centre and a new river promenade.

Traffic Movement

8. Identify and provide for the modifications to the wider transport network as required to accommodate Linking and Development objectives.
9. Improve the functioning, safety and accessibility of the intersection between SH2 and local road network and off road paths including residential areas on the hills.
10. Understand and recognise the need for car parking in strategic locations, including for recreational, commuter and shopper use

Community, Amenity and Ecology

11. Recognise and provide for the viability and amenity of public and private properties adjacent to or adjoining the river corridor and stopbanks.
12. Generate spaces and places along the river corridor that reflect Hutt River Environmental Strategy (Linear Park) and Making Places initiatives that that are reflective of user's needs, cultural and landscape values.
13. Improve the ecological performance and biodiversity of the river corridor in respect of stormwater management, riparian and terrestrial habitat values recognising the needs for flood protection works.
14. Engage with iwi with mana whenua of the river in regard to cultural values and those values' representation in the project outcomes.

Implementation, Strategy and Economic Sustainability

15. Enable a staged implementation process such that developments can occur over time as practicable.
16. Ensure the design outcome is affordable in terms of its ability to be implemented and maintained.
17. Engage with communities of interest and seek their feedback as to the design options and costs of implementation.
18. Recognise that any design options developed will require consideration relative to existing statutes, strategies and plans.

APPENDIX B - DEBRIS ON BRIDGES

Photo 1 - Wairau river, Marlborough over SH1 (May 1995). Falling stage of about a 2-year return period flood (photograph courtesy of Brin Williman).

Photo 2 - SH54 Aorangi road and rail bridges over the Oroua River, Fielding, February 2004. Permission of Civil Defence

MetService

Recalling the Clutha Flood of 1878

The Waikato may be our longest river, but the Clutha is swifter, has the largest catchment and carries the most water. With its headwaters in the rain-factory of the Southern Alps, the Clutha also produced, in 1878, one of New Zealand's greatest floods.

The stage was set when heavy snow fell over Otago for several days in early August. Snow lay 45 centimetres deep over paddocks on the lower Shotover and two to three metres deep on the ridges. In one gully in the Carrick Range near Cromwell, snow drifted 25 metres deep. Days of bitter frost followed, turning the top of the snow into a layer of hard ice that the weak winter sunlight bounced off ineffectively. On one sheep-run, 60,000 sheep died.

The danger of flooding from a quick thaw was clear. A letter published in the Clutha Leader warned residents of Balclutha to be ready to evacuate on notice telegraphed from towns higher up the river.

On Tuesday, September 24, warm north-westerly winds set in, along with 36 hours of torrential rain in the Alps, followed by another burst for 16 hours on the Saturday. Snow began to melt and the river to rise. Widespread flooding occurred in central Otago. Farm buildings were submerged to their rooftops and rivers filled with dead sheep and horses, timber from farms and mine workings and trees a metre in diameter. Lake Wakatipu rose to its second-highest level on record. Partially submerged buildings in Queenstown were wrecked as waves drove floating timber like battering rams through walls.

Word was telegraphed to Balclutha and people began to evacuate. Early hopes that the river would stay out of the town were dashed as the flood rose over a metre deep among the houses. The large island of Inch Clutha, formed by a split in the river just below Balclutha, was also mostly inundated.

Image courtesy of Alexander Turnbull Library.

As the Clutha swelled, it began to threaten the bridges upriver. At Roxburgh, the water level approached the peak of the arch of the new laminated wooden bridge. Floating debris contributed to turning the bridge into a partial dam, with a drop in water level of one and a half metres between the upstream and downstream sides.

On September 29, the bridge further upstream, at Clyde, collapsed and the wreckage floated down to Roxburgh. When it struck the bridge there, it too gave way. The combined wreckage of the two bridges now headed downstream towards Balclutha. On the way, it snagged on the river-bank and two men secured it with a rope. While they were away getting more rope, the wreckage broke free and set off again.

People in Balclutha had been warned, and waited in trepidation for the collision with their own bridge. When the wreckage hove into sight on the Monday morning, there was a brief moment of hope when it snagged on some willows. It soon came free, but fortunately the willows had turned it parallel with the flow of the river. As it approached the Balclutha bridge end-on, the tangled mass of timber was sucked into the accelerating flow between two piers and, to the cheers of the gathered crowd, shot through without touching the bridge supports.

The wreckage did collide with the railway bridge downstream, but this had solid concrete piers encased in steel and was unharmed.

As the waters receded, it seemed as though the Balclutha road bridge would be spared. However, heavy rain fell on October 4 and again a week later, returning the river to near-record levels. Finally, on October 13, the Balclutha bridge succumbed to blows from debris and collapsed.

Because of the timely evacuation, there was only one death in Balclutha. On October 6, a carter drowned in a three-metre hole the river had dug in the town. A man exploring the receding floodwaters on horseback had a lucky escape when his horse stepped into another hole hidden by the water. After revolving gently once, horse and rider began to float downstream, but after travelling some distance, the horse managed to grab the side of a dray with its teeth. The rider was able to dismount and clamber into shallower water and the horse followed.

A floating log collided with the house of Mr Rehberg, driving it off its foundations. As the house floated downstream, he clung to the roof, along with his housekeeper, crying out for help. Eventually chased by a boat, they were both rescued about 20 minutes before the house was carried out to sea. The schoolhouse on Inch Clutha was also carried out.

As the Clutha powered to the coast, it cut a new channel and filled in the old. Consequently, Port Molyneux, from where paddle steamers had run a service up to Balclutha, ceased to be a port. On Inch Clutha, sediment dropped by the flood raised the level of farmland by more than two metres.

The Clutha was not the only river affected. Rivers in Southland flooded many kilometres wide, and there was another fatality when a farmer, stranded on a haystack, drowned attempting to reach dry ground. Canterbury rivers were also in flood, covering farmland, drowning stock and undermining bridges. The flow from Lake Tekapo into the Waitaki River has been estimated by hydrologists to occur just once every two thousand years.

The snowfall of 1878 appears far greater than anything in the 20th or 21st centuries and may not be repeated in a warming world. But rainfall rates are expected to increase. In November 1999, heavy rain in the Alps raised Lake Wakatipu, breaking the record level of 1878 by 15 centimetres. Although the flow of the Clutha was less than in 1878, flooding in Alexandra was worse because sediment building up behind the Roxburgh dam had raised the riverbed.

Our most powerful river remains a danger to those living nearby.

(Originally published in New Zealand Geographic, November 2013)

If you like reading about the impact of weather on New Zealand's history, take a look at our weather history website: www.iwonderweather.co.nz.

Recalling the Clutha Flood of 1878

Erick Brenstrum

The Waikato may be our longest river, but the Clutha is swifter, has the largest catchment and carries the most water. With its headwaters in the rain-factory of the Southern Alps, the Clutha also produced, in 1878, one of New Zealand's greatest floods.

APPENDIX C - NZCCC (2014) CLIMATE CHANGE REPORT

Climate Change

IPCC Fifth Assessment Report
New Zealand findings

NEW ZEALAND
CLIMATE CHANGE CENTRE

The Intergovernmental Panel on Climate Change (IPCC) periodically assesses knowledge of climate change, using the evidence and analyses published in peer-reviewed journals and other credible sources.

The IPCC's Fifth Assessment involved 803 scientific authors and more than 3500 expert reviewers. It comprises four related reports:

1. The Physical Science Basis (September 2013)
2. Impacts, Adaptation and Vulnerability (March 2014)
3. Mitigation of Climate Change (April 2014)
4. Synthesis Report (October 2014).

The report on impacts, adaptation and vulnerability includes a chapter about Australia and New Zealand. Unless otherwise specified, this is a summary of some key findings for New Zealand from that chapter.

The big picture

As temperatures increase, so do risks of serious and irreversible damage.

The September 2013 report on the physical science of climate change found:

- warming of the climate system is unequivocal. Since the 1950s, many of the observed global changes are unprecedented over decades to millennia
- climate change is already influencing the intensity and frequency of many extreme weather and climate events globally
- human influence on the climate system is clear
- continued emissions of greenhouse gases will cause further warming and climate changes
- limiting climate change will require substantial and sustained reductions of greenhouse gas emissions.

New Zealand is already experiencing climate change

The climate is changing, with long-term trends toward higher temperatures, more hot extremes, fewer cold extremes, and shifting rainfall patterns in some regions.

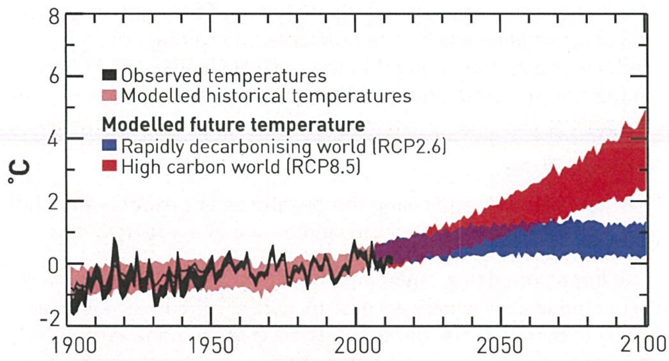
More change is expected

- Average temperatures expected to rise further, depending on future greenhouse gas emissions (more details below).
- Spring and autumn frost-free land area expected to at least triple by 2080s.
- Up to 60 more hot days per year (over 25°C) for northern areas by 2090.
- Significant shifts in rainfall patterns (more details on next page).
- Rise in extreme rainfalls (up to 8% more intense rain for every 1°C of warming, but with significant regional variations).
- Time spent in drought in eastern and northern New Zealand projected to double or triple by 2040.
- Global sea level rise by 2100 of about 0.5–1 metre above the 1986–2005 average in a high carbon world, or about 0.3–0.6 metre if there is rapid decarbonisation. Even if temperatures peak and decline, sea level is projected to continue to rise for many centuries at a rate dependent on future emissions. Sea level rise around New Zealand may be up to 10% higher than the global average.
- Increase in days with 'very high' and 'extreme' fire danger index in some locations by up to 400% by 2040 and 700% by 2090.
- Shifts in wind speed and direction, with the average westerly flow projected to increase in spring and winter, but decrease in summer and autumn by 2090.
- Decline in peak snow accumulation by about 30–80% at 1000 metres and by about 5–50% at 2000 metres by 2090.

Temperature rise

This graph, adapted from the report, shows projected changes compared to New Zealand's average temperature over the period 1986–2005. It shows:

- New Zealand has warmed by about 0.9°C since 1900
- New Zealand's temperature is expected to rise by another 0.8°C or so above the 1986–2005 average if the world rapidly implements stringent measures to limit greenhouse gas emissions (the blue band)
- by contrast, New Zealand's temperature is expected to keep on rising throughout this century – by about 3.5°C above the 1986-2005 average – in a high carbon world (the red band).



Based on IPCC Working Group II Fifth Assessment Report Chapter 25, Figure 25–2; for more details and data sources see Chapter 21 Suppplementary material, section SM21.1 and Table SM21.5.

Photo: Dave Allen, NIWA

How will climate change affect New Zealand over the 21st century?

Freshwater

The best evidence available so far suggests lower flows in rivers originating in the northeast of the South Island and the east and north of the North Island but more in those from near and west of the main divide.

Natural ecosystems

There have been very few studies of climate change impacts on biodiversity in New Zealand. These suggest that threats such as invasive pests and weeds, and habitat loss, are more serious risks in the short to medium term than climate change, but more research is needed.

Coastlines and flood plains

Rising sea levels and increasing heavy rainfall are projected to increase flooding and erosion in many coastal areas and particularly near river mouths, with escalating risks to many low-lying ecosystems, infrastructure and housing. This is cause for serious concern given patterns of development and population distribution.

Oceans and fisheries

The report says it is "virtually certain" (more than 99% probability) that the oceans will continue to acidify, which is expected to affect many marine organisms. Specific studies from New Zealand are sparse but risks have been identified, notably to deep-sea corals.

A strengthening East Auckland Current in northern New Zealand is expected to allow some vagrant fish species to establish here. This suggests potentially substantial effects on wild fisheries and aquaculture.

Forestry

Projections for forestry include increased *Pinus radiata* growth in cooler regions where soil nutrients and rainfall allow it, reduced *Dothistroma* blight in the central North Island but more in the South Island, and significantly increased fire risk in some areas.

Agriculture

Rainfall changes and rising temperatures are expected to shift agricultural production zones and timing of some activities.

The impact on dairy, sheep and beef pasture production is expected to vary widely across the country. Some areas are likely to benefit from climate change, if farm management practices change to make the most of increased pasture production. Other regions face increased drought risk and uncertain changes in pests, weeds and diseases.

New Zealand could increase its wheat yields with appropriate choices of cultivars and sowing dates. Some cooler and elevated sites could become suitable for wine grapes.

Erosion could become an even bigger problem on farms, but that depends on how rainfall, and especially storm frequency, changes.

Energy

Annual average peak electricity demand is expected to reduce by 1–2% for every 1°C of warming, with less demand for heating in winter.

Tourism

It is hard to predict future tourist behaviour but New Zealand ski tourism could benefit from less snow in Australia.

Health

There are few New Zealand health findings in the report:

- Water- and food-borne diseases are projected to increase.
- There may be fewer cold-related deaths in some parts of the country.
- A wider area could become climatically suitable for transmission of dengue fever though non-climate factors such as water supply are likely to be more important in whether the disease spreads.
- An increase in climate-related disaster risk is expected to exacerbate mental health issues.

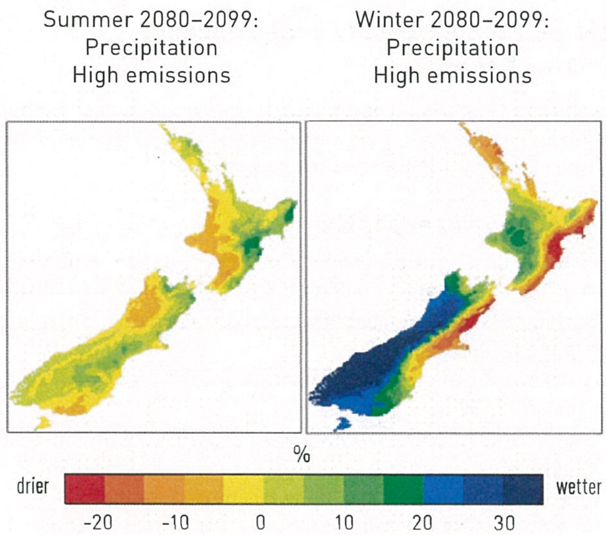
Māori

The impacts on Māori society are expected to vary widely. The Māori economy relies heavily on climate-sensitive primary industries, and Māori disproportionately face many challenges that constrain adaptation. On the other hand, strong social networks and culture give some Māori resilience. Combining traditional ways and knowledge with new policies and strategies will be key to long-term sustainability.

Getting drier AND wetter

The best evidence currently projects lower annual average rainfall in the northeast South Island and northern and eastern districts of the North Island, with higher annual average rainfall elsewhere. But uncertainty in projected rainfall changes remains large for many parts of New Zealand, which creates significant challenges for adaptation. Also, seasonal variations often matter more than the annual average, especially in agriculture.

The maps here show projected rainfall change (in %) for summer and winter, comparing the period 1980–1999 to 2080–2099, for a high emissions scenario. So, for instance, parts of East Cape would get wetter by 5–20% in summer and drier by up to 25% in winter, but the opposite direction of change for Taranaki. If the world adopts a low emission path, the change is expected to be similar but much smaller.



These maps show results from global climate models used in the Fourth Assessment. Results for New Zealand from the latest generation of models are expected to be similar, but the detailed analysis has not been done yet.

How well will New Zealand cope?

As a temperate maritime country, New Zealand may not face some of the worst effects of climate change this century, unlike parts of Australia where many more days with peak temperatures over 40°C are projected.

New Zealanders are generally well-equipped in principle to adapt to climate change, and some adaptation is already occurring. Planning for sea-level rise is becoming more common, for example, although implementation of specific policies remains piecemeal, subject to political changes, and open to legal challenges.

Overall, however, adaptation faces major constraints arising from:

- absence of a consistent information base and uncertainty about projected impacts
- limited financial and human resources to assess local risks and to develop and implement effective policies and rules
- limited integration of different levels of governance
- lack of binding guidance on principles and priorities
- different attitudes towards the risks associated with climate change
- different values placed on objects and places at risk.

Action despite uncertainty

Responding to climate-related risks involves making decisions and taking action in the face of continuing uncertainty.

In many cases, reducing vulnerability and exposure to present climate variability and extremes is a practical first step.

But exclusive reliance on near-term benefits is not always the most effective approach longer term. For example, enhancing protection measures after major floods, combined with rapid rebuilding, accumulates fixed assets that can become increasingly costly to protect as climate change continues.

Key adaptation challenges

Two "key and related challenges" for adaptation are identified:

- When and where adaptation may imply transformational rather than incremental changes.
- Where specific interventions could overcome adaptation constraints, e.g., better coordination between central and local government.

One example of transformational change is shifting from flood protection through reliance on stopbanks to accommodation or avoidance of flood risk, including retreat from eroding coasts.

Photo: @mychillybin.co.nz/Jo Currie

Adapting to changes overseas

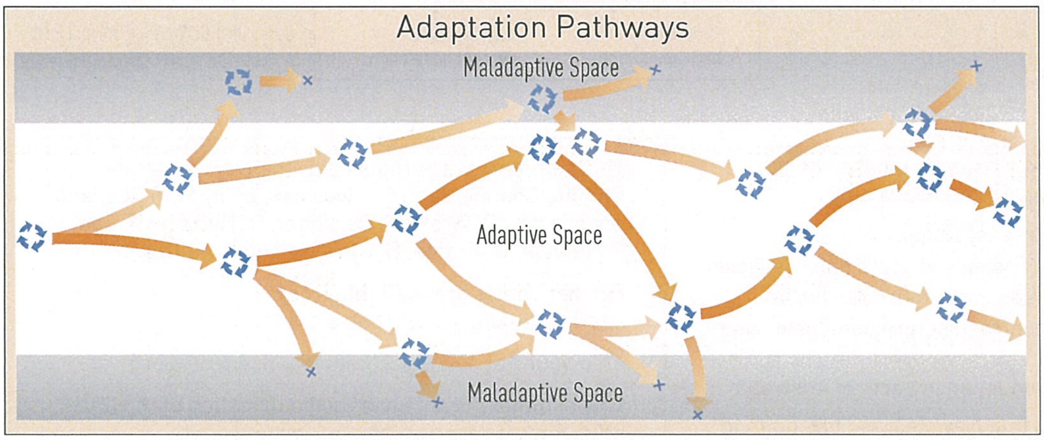
To fully understand how big an issue climate change is for New Zealand, one must consider flow-on effects from climate change impacts and responses outside our region. These could be significant for trade-intensive sectors (agriculture and tourism in particular), potentially outweighing some direct climate change impacts within New Zealand, but little work has been done to fully understand their implications.

Insurance

In New Zealand, floods and storms are the second-most costly natural hazards after earthquakes.

Insurance helps buffer the risk presented by such hazards and can also act as an incentive for policy holders to reduce their risk, e.g., through resilience ratings on buildings. But it can also discourage adaptation if people living in climate-risk prone areas pay discounted or cross-subsidised premiums or policies fail to encourage betterment after damaging events by requiring replacement of 'like for like'. The effectiveness of insurance thus depends on the extent to which it is linked to a broader national resilience approach to disaster mitigation and response.

> "Without adaptive measures, projected increases in extremes and uncertainties in these projections will lead to increased insurance premiums, exclusions and non-coverage in some locations, which will reshape the distribution of vulnerability, e.g., through unaffordability or unavailability of cover in areas at highest risk."



Based on IPCC Working Group II Fifth Assessment Report Chapter 25, Figure 25-3. Adaptation is not a one-off action but an iterative risk-management process. There is no single correct adaptation pathway, although some sets of decisions are more likely to produce positive outcomes long term – especially those that retain flexibility to deal with changes in community expectations and climate. Some decisions, e.g., planning for settlements and major infrastructure, have significant long-term consequences; in such cases, their ability to deal with a range of climate futures needs to be considered at the planning stage.

Key risks for New Zealand

The report identifies three "key risks" for New Zealand from climate change during the 21st century. A "key risk" is one where:

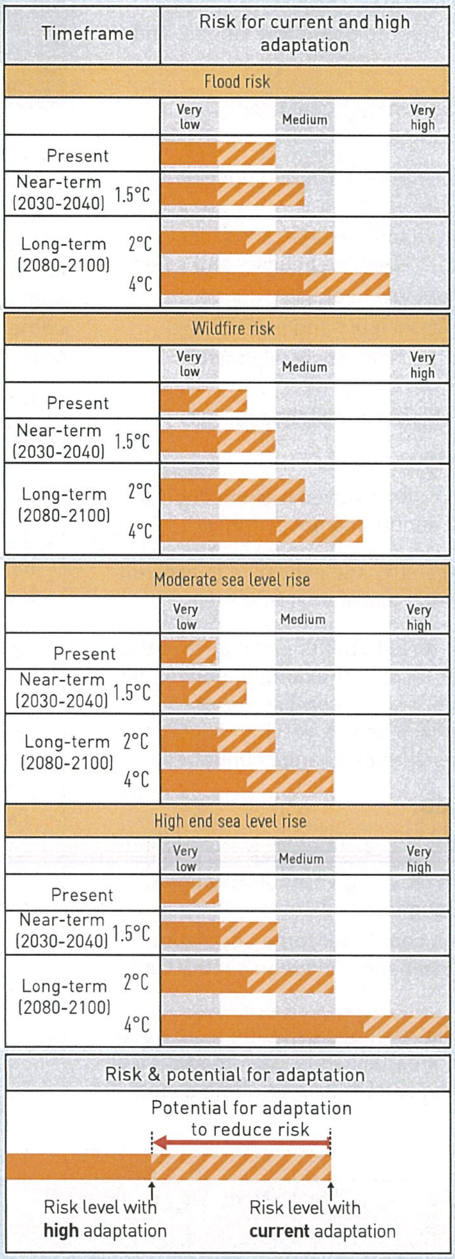
- there is strong, reliable research with multiple lines of evidence
- the potential impacts could be severe
- some affected systems may be unique
- adaptation could be difficult.

The diagrams on this page show how severe the key risks are now for New Zealand and Australia combined (from 'very low' to 'very high'), and how they would increase if the world warms by 1.5°C, 2°C and 4°C above pre-industrial levels, based on expert judgement. The shaded section of the bar roughly represents the difference more adaptation could make if people use the full range of options available (such as retreat from the most vulnerable areas).

Increased frequency and intensity of flood damage to settlements and infrastructure. Effective adaptation includes land-use controls and relocation as well as protection and accommodation of increased risk; in many locations, reliance on increased protection alone will become progressively less feasible.

Increased damage from wildfires – to ecosystems and settlements, economic losses and risks to human life in many parts of New Zealand. Local planning mechanisms, building design, early warning systems and public education can help with adaptation. This risk is already very real in Australia. Since the risk levels in the diagram are for both countries, the wildfire risk for New Zealand alone is probably lower than shown.

Increasing risks to coastal infrastructure and low-lying ecosystems from continuing sea level rise, with widespread damage if the more severe projections are realised. Some communities are already struggling with coastal erosion and inundation risk, and successive building and protection cycles constrain flexible responses. Coastal retreat is a long-term adaptation strategy but challenging to implement; options for some natural ecosystems are limited due to the speed of change and lack of suitable space. Sea level will continue to rise beyond 2100 even if global warming is limited.



The future impacts of both these key risks (flood and wildfire) can be reduced substantially by globally effective measures to curb greenhouse gas emissions combined with adaptation. The more the climate changes, the more adaptation will have to rely on novel ways of dealing with risks, such as retreating from the most affected areas.

The diagram shows both a moderate and a high-end sea level rise. The impacts would be very serious if the worst projections eventuate.

Based on IPCC Working Group II Fifth Assessment Report Chapter 25, Table 25-8.

What about Australia?

The report identifies five other key risks that, based on the currently available evidence, apply to Australia only:

- Damage to Australian coral reef systems.
- Shrinking mountain habitats and loss of some native species.
- Constraints on water resources in southern Australia.
- Increased illness, death and infrastructure damage during heat waves.
- Reductions in agriculture production in parts of Australia.

This does not necessarily mean that New Zealand has nothing to worry about in these areas; in some cases, there is simply not enough New Zealand research.

This summary was produced by the New Zealand Climate Change Centre. It was written by M. Hollis, and reviewed by D. Wratt, A. Reisinger, R. Nottage, A. Tait, P. Newton, D. Frame, B. Glavovic and F. Sullivan.

Further copies are available from: info@nzclimatechangecentre.org

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