WAIMAKARIRI FLOOD PROTECTION PROJECT: BUILDING BANKS AND RAISING INTEREST

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ABSTRACT

The Waimakariri Flood Protection Project is a 10 year programme to improve the level of flood protection for the districts of Waimakariri, Selwyn and Christchurch. Recognising the devastating effects that would occur from a large breakout of the primary flood protection system, this project is creating a secondary line of defence that will give these communities one of the highest levels of theoretical flood protection in the country.

This paper looks at the benefits this project is bringing to improve community resilience not just in the extreme flood event, but also the wider resilience benefits achieved during its implementation phase and prior to the "big one" occurring. These include improved understanding, awareness and preparedness of those on the floodplain through the development of a Flood Warning and Emergency Evacuation Plan; contributing to ecological resilience by coordinating physical works with planting improvements; designing and constructing improvements to the recreational assets within the affected area; and using the project's delivery to upskill and develop a pool of contractors with a detailed knowledge of the river and the flood protection scheme.

This paper takes a holistic approach to resilience. It demonstrates that the flood protection benefits which need to be realised in the event of a large flood rely on the community having an understanding of river behaviour, having a connection to the river corridor, and understanding and valuing the role of flood protection assets. These connections provide a system-resilience that will ensure the flood protection assets currently being constructed will be maintained and "fit for purpose" when a large flood occurs in the future.

KEYWORDS

Waimakariri River; stopbanks; flood protection; resilience

PRESENTER PROFILE

Annette is an Environmental Engineer and Planner specialising in the consenting and delivery of infrastructure projects. She was personally responsible for undertaking the consultation on the Waimakariri Flood Protection Project and has since been retained to assist in the project implementation phase. Annette is a Principal of Good Earth Matters.

1 INTRODUCTION

"The Waimakariri could be the most historically interesting of all our rivers, … it has threatened – and continues to threaten – more people and property than any other in the country."

Waimakariri, An Illustrated History
Robert Logan, 2008

The Waimakariri River, with a total catchment area of 3,564 km^2, has its source in the Southern Alps to the west of Christchurch, with a length of approximately 46 km of the Alps draining in to the Waimakariri (Logan, 2008). The River flows across the Canterbury Plains and passes to the north of Christchurch, with its current mouth to the Pacific Ocean being between Christchurch and Kaiapoi. Historically, however, the braided River has moved across the alluvial Canterbury plains and has, prior to European settlement, had its mouth as far south as Lake Ellesmere to the south of Banks Peninsula. The city of Christchurch therefore sits within the northern and southern bands of where the River has historically flowed.

Since the mid 1800s, successive attempts have been made to keep the Waimakariri River in its current position and away from Christchurch. The period between the earliest recorded flood protection efforts in the 1860s and the construction of what is now known as the primary flood protection system in the 1960s-1980s is described in a history of the River as "The Hundred Years War" (Logan, 2008).

A 1989 review of the scheme (Reid et al, 1989) identified there was a residual risk of breakout of the primary system and a suite of works which became to be known as the Waimakariri Flood Protection Project (WFPP) was developed. These works were initially unable to be fully implemented due to planning and regulatory constraints. Following devastating 2004 floods in the North Island (Manawatu, Bay of Plenty), the Canterbury Regional Council prioritised the improvements and charged the project team with securing resource consent and commencing implementation as soon as possible.

Resource consents for the WFPP were secured in June 2009 and construction works commenced October 2010. The Project is now in its sixth year of the 10 year physical works programme.

This paper considers how the design and project implementation is contributing to increasing the resilience of the communities living on, and adjacent to, the Waimakariri River floodplain.

2 BACKGROUND

2.1 HISTORY OF FLOOD PROTECTION ON THE WAIMAKARIRI RIVER

The threat to Christchurch City from the River's movement was understood early in the period of European settlement which lead to the City. In 1860, Samuel Butler described early attempts to tame the river, noting that the River could easily move from its current position and move through Christchurch (Logan, 1980, emphasis added):

> *"Besides this old channel it has others which it has **discarded with fickle caprice** for the one in which it happens to be flowing at present, and which there appears some reason for thinking it is soon going to tire of. If it eats about a hundred yards more of its gravelly bank in one place the river will find an old bed several feet lower than its present. This bed will conduct it into Christchurch. Government had put up a wooden defence, at a cost of something like two thousand pounds, but there was no getting any firm standing ground, and a few freshes carried embankment, piles and all, away, and ate a large slice off the bank into the bargain; **there is nothing for it but to let the river have its own way**."*

The period between the 1860s and the 1960s has been described by Logan as "The Hundred Years War" which was "to make the Waimakariri go, not where it wanted, but where the engineers dictated" (Logan, 1980). Work in the late 1800s was successful in keeping floods out of Christchurch, although the focus at the time was protection of land on the southern side of the River only. It wasn't until the Waimakariri River Improvement Act of 1992 that official efforts became focused on protecting both sides of the River.

Significant advancements in the level of protection were achieved in the late 1920s with the Eyre River Diversion; early 1930s with stopbanks on the south branch from Halkett to Harewood and the cutting-off of the South Branch by the construction of Crossbank. However, two large floods in the 1950s which resulted in break-outs of the river and flooding of adjoining land led to a major scheme review and a works programme commencing in the 1960s, at an estimated cost of £1.6million.

The 1960s scheme – eventually completed in the early 1980s – resulted in a continuous line of primary stopbanks between the mouth of the Waimakariri River and upstream of Mcleans Island. Further upstream from this point, the River became naturally constrained by topography with assistance from the construction of some spur groynes.

The 1960s scheme is shown in Figure 1.

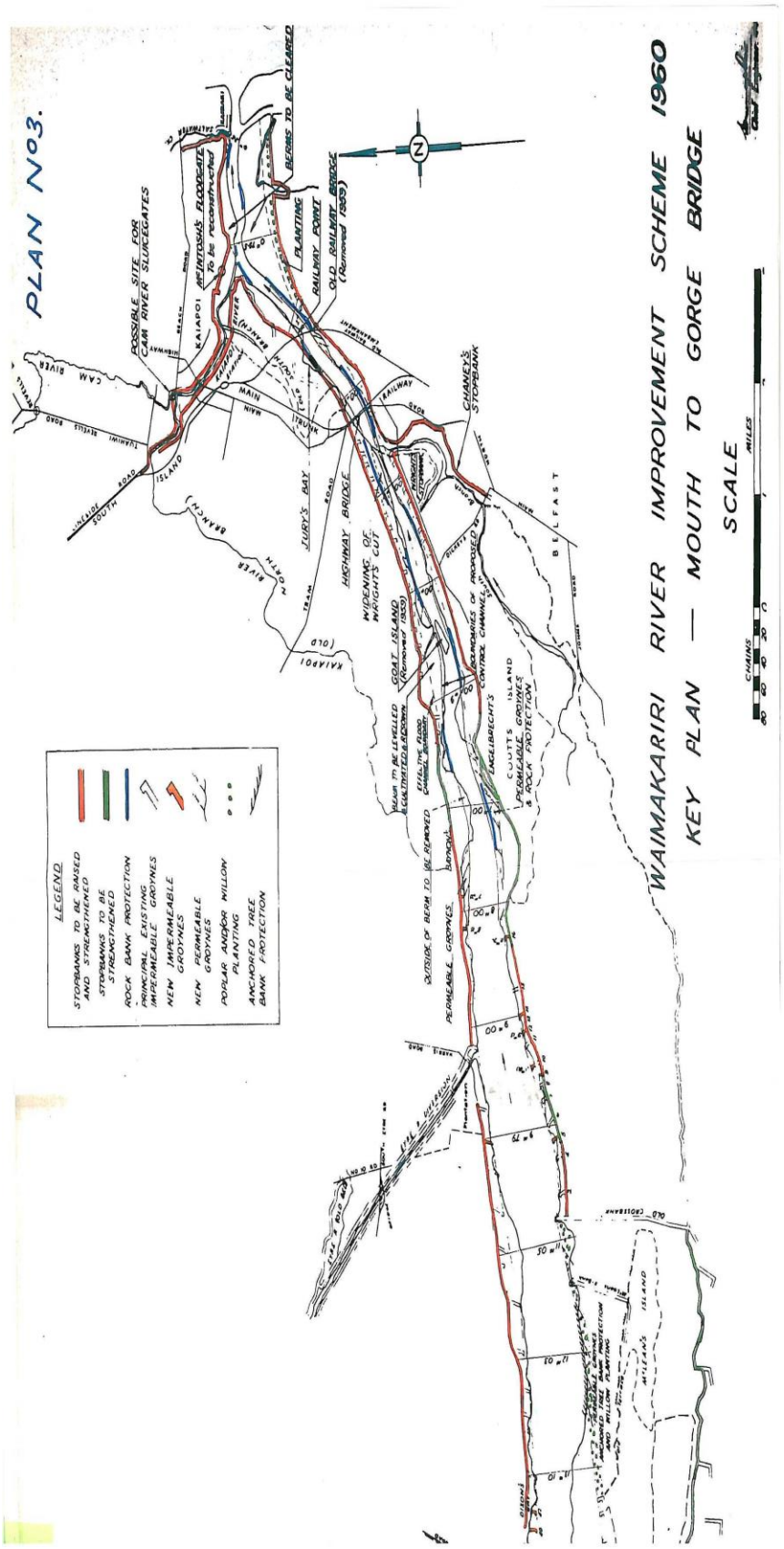

Figure 1: 1960s Waimakariri River Improvement Scheme

2.2 RISKS AND CONSEQUENCES OF A LARGE FLOOD EVENT

The 1960s scheme, completed in the 1980s, resulted in a design flood protection level of 4,730 m^3/s for the north and south sides of the Waimakariri River. This equated approximately to a 450-500 year level of protection.

Upon completion of the scheme, a review was undertaken to identify future needs and priorities. This review (Reid et al, 1989) identified:

- erosion failure could occur anywhere and at flows significantly below the design flow; and
- risks and consequences of primary bank failure and the significance that such a failure would have on the residents of Selwyn, Waimakariri and Christchurch.

The review identified that a major breakout of the Waimakariri River could occur via one of four breakout zones on the true right of the River, which could lead to floodwaters through urban and central Christchurch. Similarly a breakout through potential failure zones on the true left of the River could lead to flood waters through Kaiapoi. (Refer Figure 2).

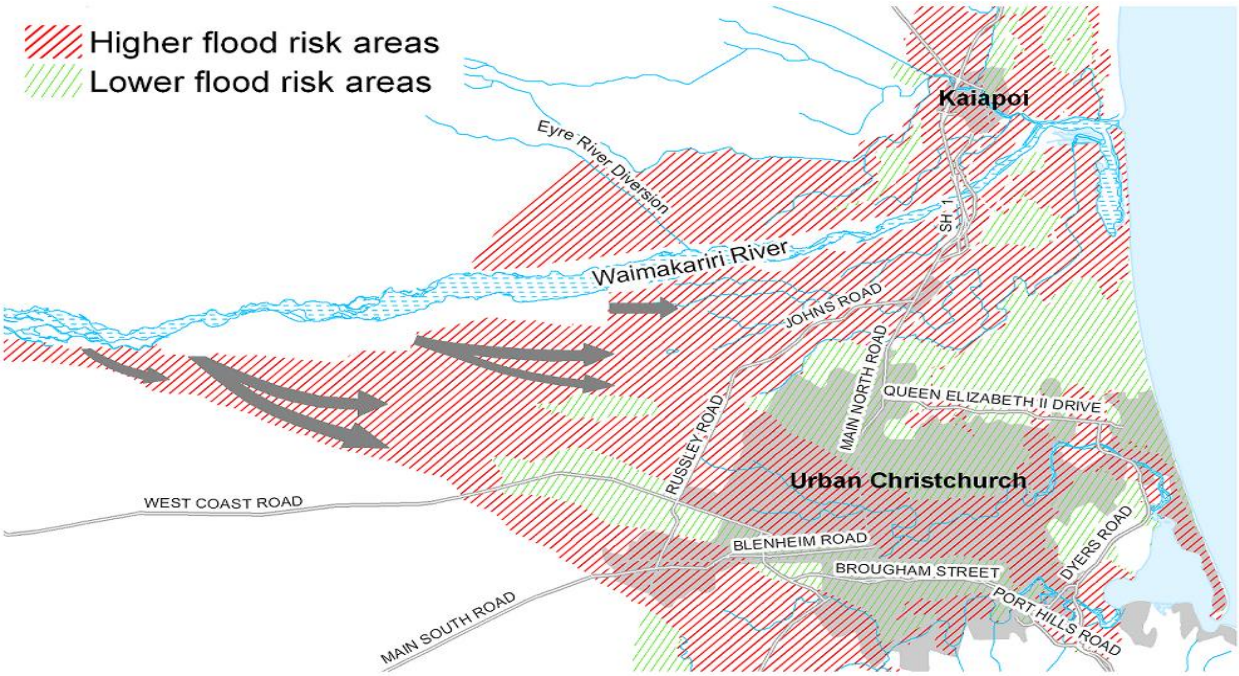

Figure 2: Potential Failure Zones and Risk Areas

It was estimated that, in any one year, there was a 4% risk that water could break out on to the floodplain, and that a major flood could inundate extensive residential and industrial areas, causing up to $8,000 million worth of damage and affecting up to 300,000 people (Burke, 2006).

Local Government New Zealand has published data for the total insurance payouts in New Zealand due to major hazard events between 1969-2013 (LGNZ, 2014). This is shown in Figure 3 below and the estimated potential damage from a major breakout of the Waimakariri River has been overlaid.

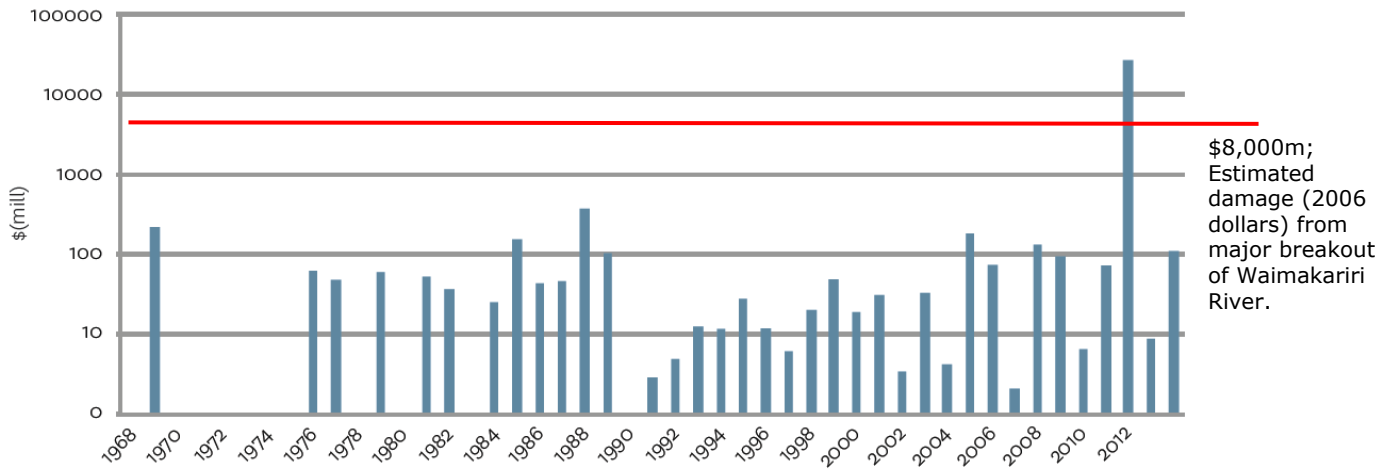

Figure 3: Estimated Damage From Major Breakout of Waimakariri River compared to Total Nationwide Insurance Payout for Major Hazard Events 1969-2013 (2011 dollars) Graph is Figure 1 from LGNZ, 2014

Local Government New Zealand (LGNZ, 2014) also considers a large urban flood as a national risk likely to occur at least once a century and with major consequences for New Zealand (refer Figure 4).

A breakout of the Waimakariri River through Christchurch would be such a large urban flood and would also threaten three assets identified as nationally significant for resilience, namely State Highway 1 road bridges, Transpower grid exit points, and Christchurch International Airport including Christchurch Air Traffic Control centre which controls all airport approaches to New Zealand (Fairclough, 2012).

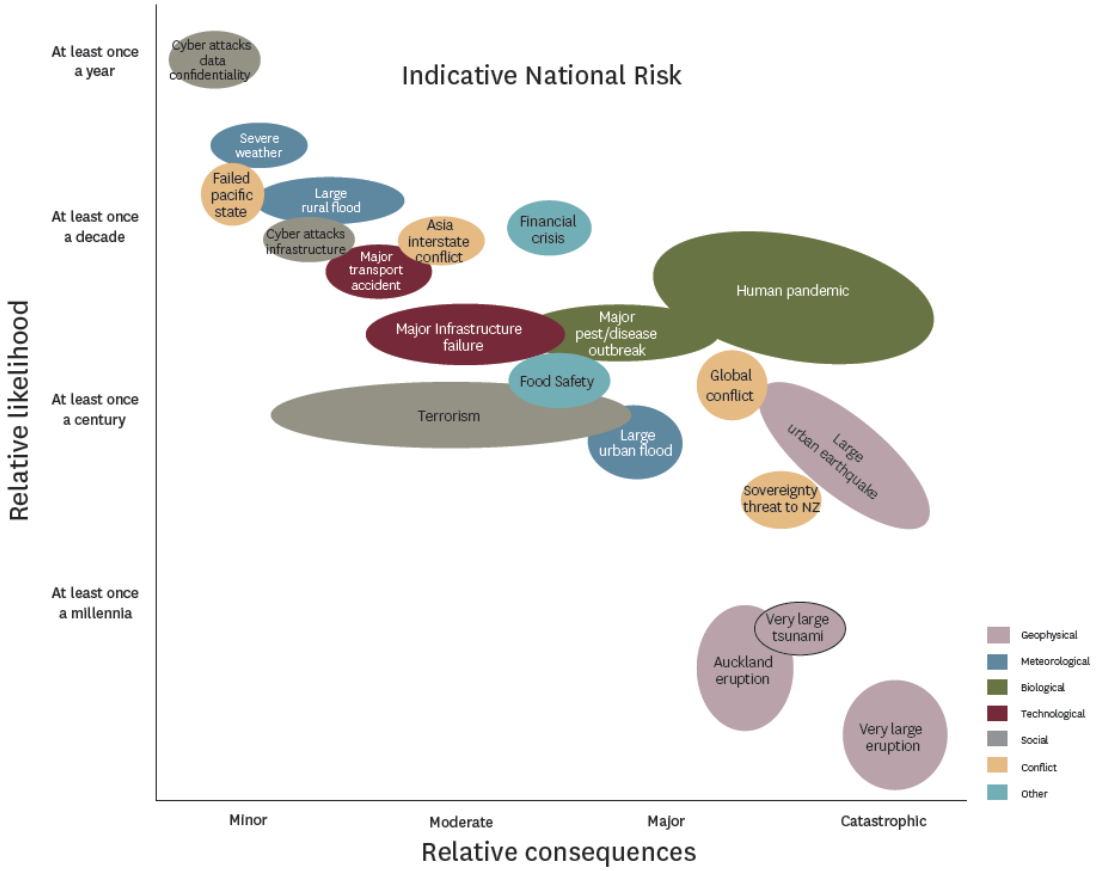

Figure 4: Indicative National Risks
Appendix 2a from LGNZ, 2014.

2.3 OVERVIEW OF WAIMAKARIRI FLOOD PROTECTION PROJECT

Since the 1989 review, Canterbury Regional Council has been progressively upgrading the flood protection scheme, in line with the review recommendations, as far as possible under permitted activity rules. However, completion of the recommendations required land use consents for construction works and water permits for damming and diversion of flood waters. These were obtained in June 2009 and the 10 year programme of works comprising the WFPP commenced in October 2010.

2.4 PHYSICAL WORKS

The WFPP's principal objective is to increase the level of protection afforded to the residents of Waimakariri, Selwyn and Christchurch in the event of a large (6,500 m^3/s) flood, without transferring or causing an increase in the risk of a stopbank failure elsewhere within the system.

The project involves (refer Figure 5 and Appendix A):

- extension or upgrade of the existing secondary stopbank, along the south side of the historic South Branch, from McLeans Island to Dickeys Road in Coutts Island;
- construction of a new secondary stopbank from Halkett to McLeans Island;

- upgrade of sections of the existing primary stopbanks, on both the north and south bank, which are below the desired design standard;
- rock lining of, and rock groynes on, the northern and southern river banks as required; and
- ensuring the internal stopbank at the end of Coutts Island Road meets the scheme design standards.

The works are being undertaken over a 40 km stretch of river and involve stopbanks upgrades on the primary and secondary stopbank system; new secondary stopbank construction; and placement of approximately 200,000 tonnes of rock.

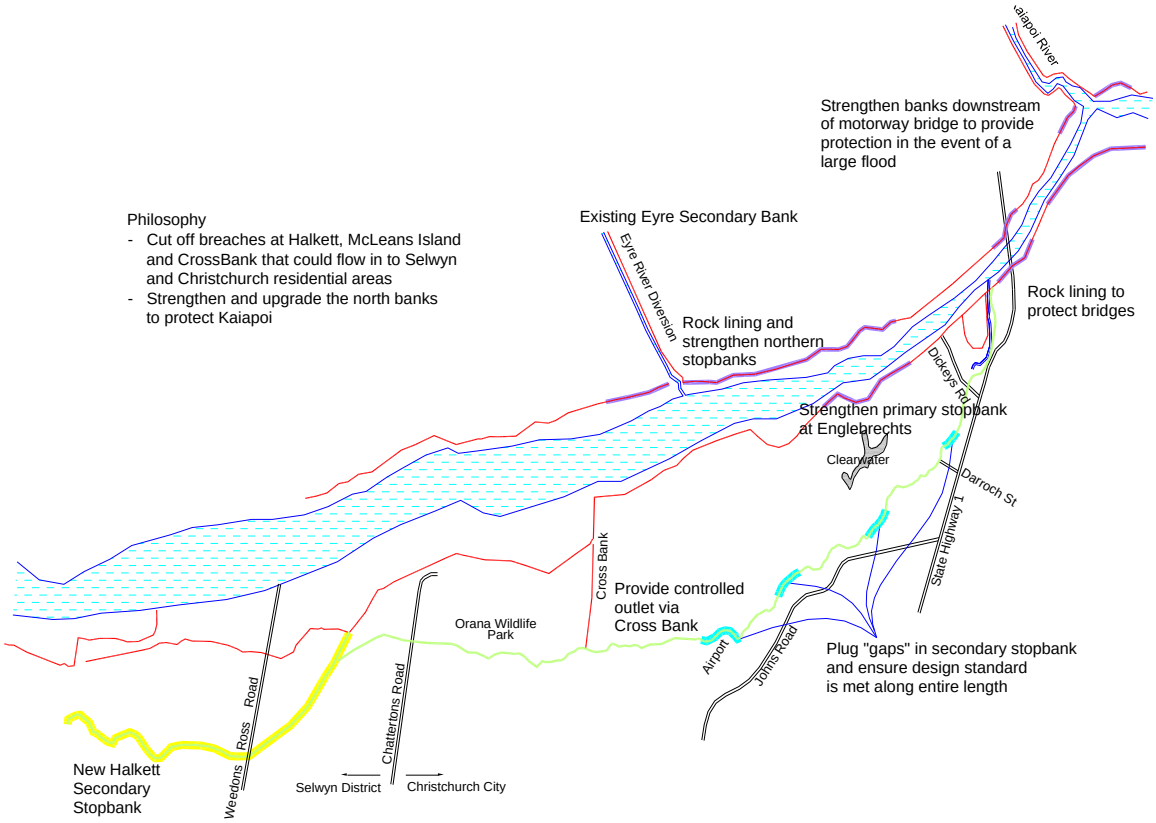

Figure 5: Overview of Waimakariri Flood Protection Project

2.4.1 FLOODPLAIN OWNERSHIP AND OCCUPATION

On the southern side of the River, the WFPP creates a continuous secondary stopbank line between Halkett and the State Highway 1 bridge. This secondary stopbank line involves a new secondary stopbank at Halkett, and upgrading, reshaping and "filling the gaps" in the existing secondary stopbank. This existing secondary stopbank which runs behind Mcleans Island, Coutts Island and Templars Island is the historic primary stopbank of the South Branch of the River.

The area between the primary and secondary stopbank is a mixture of public and private land, with ownership and occupation generally as follows:

- In the Halkett area, the land is either Canterbury Regional Council owned land, leased to farming operations, recreational groups and the Aeroclub or the New Zealand Defence Force land comprising the Burnham Military Camp.

- In the Mcleans Island area, the land is owned by Canterbury Regional Council, but subject to a number of long term leases primarily to recreational and community groups, as well as Orana Wildlife Park. This area is also promoted for recreational use as part of the Regional Park and the facilities within the leased areas make this a popular recreation area for the city.

- In the Coutts / Templars Island area, the land is predominantly private land and is a mixture of quarrying / contracting; farming; lifestyle properties; and the Clearwater Golf resort.

There are limited routes in and out of the area between the primary and secondary stopbank.

The Waimakariri River Regional Park is a significant recreational asset in which the majority of the scheme's assets are located. The Regional Park follows the River and includes a number of cycle ways, walkways, and areas for recreational activities such as horse riding, trail biking, mountain biking, picnicking, and fishing.

2.4.2 OBJECTIVES OF THE WFPP'S IMPLEMENTATION

As stated above, the principal objective of the WFPP was to increase the level of flood protection afforded to the residents to the north and south of the River. In addition, the organisation had some capacity building objectives to be achieved during the implementation phase. These were:

- To ensure that the stopbank and flood protection assets created as part of the project were recognised and provided for in the future.

- To continue to develop positive relationships with persons occupying the floodplain area and to increase their level of understanding and awareness of potential flood risk.

- To improve the quality of flood protection asset construction undertaken by the organisation and ensure it continues to meet or exceed best practice.

- To develop a pool of competent, experienced, quality contractors who are familiar with the Waimakariri River and the flood protection scheme.

The remainder of this paper describes how, by working towards these objectives, the project implementation has been able to contribute to the resilience of the scheme and assist the community to prepare for, and respond to, flood risks associated with the Waimakariri River.

3 RESILIENCE IN THE CONTEXT OF THE WFPP

3.1 DEFINING A MODEL OF RESILIENCE

The WFPP is being undertaken largely under the Regional Council's mandate under the Soil Conservation and Rivers Control Act to minimise and prevent damage by floods and erosion; as well as its duty under the Local Government Act to meet current and future needs for good quality infrastructure.

In recent years, there has been a shift in focus to consider resilience of public infrastructure, largely arising from the experience of the Canterbury earthquakes and increasing awareness around potential effects from climate change.

The National Infrastructure Plan (National Infrastructure Unit, 2015) identifies that there is a "need to increase the sophistication of how we think about resilience, shifting beyond a narrow focus on shock events or infrastructure failure and thinking more about interdependencies, levels of service and community preparedness".

While "resilience" was not a stated goal of the WFPP when it was conceived, the project can be considered against the National Infrastructure Plan's model of the resilience, as set out in the following diagram.

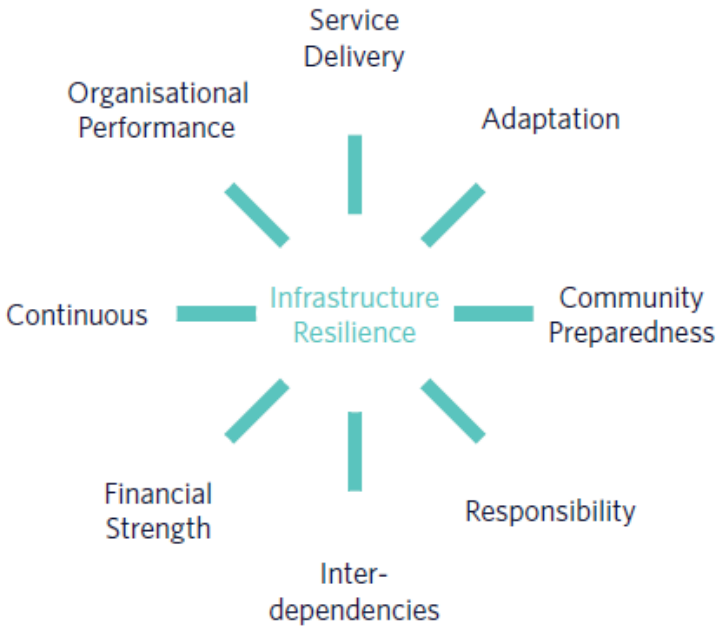

Figure 6: Resilience Attributes
Source: National Infrastructure Unit, 2015

These attributes are defined in Fairclough, 2012. Considering the WFPP in the context of this model for resilience, the remainder of this paper discusses how the approach adopted by the WFPP Project Delivery Team has delivered on these attributes of resilience.

3.2 RESILIENCE ATTRIBUTE: ADAPTATION

The ADAPTATION attribute is defined as follows (Fairclough, 2012):

"National infrastructure has the capacity to withstand disruption, absorb disturbance, act effectively in a crisis, and recognises changing conditions over time"

The WFPP represents a significant change in approach to the management of flood risk from the Waimakariri River. As discussed in Section 2.1 above, the historic approach reflected the attitude of the time, in that the role of providing flood protection was described as a "war" against the River and the need to "tame the River". The construction of the Harewood Crossbank – a 3-4 metre high, 2.3 km long stopbank constructed at right angles to the natural flow of the river – is an example. It was an attitude of working against, and attempting to defeat, the natural tendencies of the River.

In contrast, the WFPP attempts to work with the natural topography, and river behaviour as far as is practicable, by recognising and working with the geomorphology of the area. Elements of this include:

- A Secondary system which is designed to "pick up" breached flows and return these to the main river using the natural terraces and topography to gather and return the flows.
- Removal of a section of Crossbank to create a natural flow path for breach flows taking account of the natural geomorphology. This is in contrast to the existing situation that would see breach flows dammed behind Crossbank in the hope that a second uncontrolled breach does not occur.
- Reducing the length of Crossbank that is at right angles to the flow of river, thereby reducing its vulnerability.
- Recognising the history of the South Branch of the Waimakariri River and using this to capture and return flows to the main branch of the River.

Inherent in the adoption of the WFPP is the recognition that stopbanks can, and do, fail in flood events below their design capacity and that the system therefore needs to be able to withstand and absorb breaches of the primary scheme. Canterbury Regional Council's flood risk assessment (Boyle, 2005) recognises that there is a 10% risk of a stopbank breach at flows in the order of 3,000 m^3/s which is well below the primary scheme standard of 4,730 m^3/s. This breach risk is due to factors such as localised erosion and scour, with the flattening of the bed gradient at Halkett contributing to uneven gravel settlement and localised perching of river channels. Acknowledging the potential failure, in addition to overtopping, assists to prevent an over-reliance and potentially false sense of security that comes from the mere presence of a constructed stopbank.

A further element of the design of the WFPP was the careful consideration of the construction sequence and methodology in order to avoid potential transference of risk. As the design concept is to capture and return breach flows to the main river, all elements of the flood protection scheme downstream of the return point need to be confirmed as being of suitable integrity and capacity to contain the main flows and the returned flows. Without such assurance, works would simply transfer risk from one side of the river to the other. The construction methodology's sequencing necessary to avoid

transference of risk was set out in the consent application and compliance enforced via setting of consent conditions.

Climate change and sea level rise were key considerations which were raised by stakeholders during the consultation process. Modelling of the system found that the scheme was relatively insensitive to potential sea level rise as, except in the furthermost downstream reaches, the large flows are the key determinant and sea level boundary condition changes are easily within freeboard tolerances. Effects of climate change in terms of severity and frequency of flood flows has been addressed by establishing the scheme design standard in terms of a flood flow magnitude (in this case, 4,730 m^3/s for the primary scheme and 6,500 m^3/s for the secondary scheme), as opposed to a return period frequency.

3.3 RESILIENCE ATTRIBUTE: COMMUNITY PREPAREDNESS

The COMMUNITY PREPAREDNESS attribute is defined as follows (Fairclough, 2012):

> *"Infrastructure providers and users understand the infrastructure outage risks they face and take steps to mitigate these. Aspects of timing, duration, regularity, intensity and impact tolerance differ over time and between communities".*

As part of the consenting process, the project team engaged with owners and occupiers on the floodplain on a one-to-one basis, several times over a six month period. Generally, those parties fell in to one of three categories:

- those who had a long association with the floodplain (several had experienced the last breakout flood in 1957), were aware of potential flood risks associated with occupying the area and were generally well prepared or well placed to cope with a flood event;
- those that were conscious of, and concerned about, occupying the area adjacent to the River, but did not have the information or tools to be able to understand the risks or prepare for a flood event; and
- those that were essentially oblivious to the fact that there was any flood risk.

Taking the time to speak one-to-one with these parties over several occasions provided a unique opportunity to raise awareness and understanding. Discussions with long term residents of the area helped the project team understand the river behaviour while engaging with those less aware of the potential risks enabled them to understand current risks, how they personally may be affected in a flood event, and what the implications of the project were for them. The engagement at this time was focused on raising awareness and understanding of the flood risks. At no stage did the project team seek or ask for written approvals for the consent process. Rather, the focus was on ensuring people understood the consenting process and how they may be involved in a meaningful way.

It is my opinion that the approach taken in consultation assisted people to come to terms with the flood risks that existed prior to the project and built good relationships which

have benefited the implementation of the project moving forward. For example, we are now in to the sixth year of the physical works programme and have been able to stay engaged with the majority of stakeholders such that the project team and contractors enjoys good quality working relationships with owners and occupiers of land which is affected by the physical works.

During the consultation process it also became clear that the community considered a Flood Warning and Emergency Evacuation Plan would be of value. This was offered as a mitigation measure as part of the consenting process and has since been developed and adopted. The Plan is a voluntary plan targeted at assisting owners and occupiers to have a high level of preparedness and provides early warning of a potential flood event, well before any civil defence emergency would be declared.

The Plan sets out likely breach risks and scenarios for various flood flows and provides information for users to translate published flood flow information in to what that means for them, in their location.

A Flood Warning and Emergency Evacuation Plan was a new undertaking for Canterbury Regional Council and it was important to the Council that the Plan struck the appropraite balance between raising the level of individual awarness and preapraedness, and the Regional Council's commitment to send notifications and initiate evacuations at a time when resources are stressed responding to flood events. The Plan involves a voluntary enrolment scheme in a text warning message and includes templates and information for indvidiudals to prepare their own emergency response plan. A key trigger level in the system is the level at which flows cut off entry and exit points to the floodplain which occurs even if there is no breach of the primary system and when there is only a 10-20% chance of stopbank failure.

At the most recent test of the system, there were approximately 50 persons signed up for the system, and the response rate (reply to confirm message received) was 86%. Annual testing of the system enables the Regional Council to maintain contact which contributes to maintaining awareness of flood risks.

3.4 RESILIENCE ATTRIBUTE: CONTINUOUS

The CONTINUOUS attribute is defined as follows (Fairclough, 2012):

"On-going resilience activities provide assurance and draws attention to emerging issues, recognising that infrastructure resilience will always be a work in progress"

Flood protection assets are unique in that they are constructed in the hope that they will never be fully tested and the understanding that (again hopefully) any such test of the scheme will be a long time in the future. This is particularly true of the WFPP which, if ever fully tested, would see flows close to the current estimate of the Maximum Probable Flood.

To ensure the assets constructed now are fit for purpose in the future requires their functionality to be recognised, protected and maintained. Several elements of the WFPP have been required because this has not always been the case in the past. Having been discarded from active management as a result of the trust put in the primary system, the

historic flood protection stopbanks which kept the south branch at bay and form the core of the WFPP's secondary stopbank line were not recognised for any flood protection benefit. This has resulted in holes being pushed through (eg for the lengthening of the Christchurch Airport, see Figure 7); and stopbanks overwhelmed by vegetation (see Figure 8).

Figure 7: Christchurch Airport Secondary Stopbank Gap
(Yellow line represents new stopbank required to fill gap in secondary stopbank line)

Figure 8: Heavy Vegetation Growth on Historic Stopbank

Flood protection assets also require ongoing maintenance to ensure their integrity and functionality is maintained. Funding of such ongoing maintenance relies on the community's willingness to pay for such activities as determined via the Long Term Planning process.

The Council is therefore very focused on ensuring that the flood protection assets are not only protected and maintained, but that the community recognise and value the purpose of those assets. This has involved:

- Protecting the secondary stopbank footprint via Land Improvement Agreements, planning regulations and a bylaw to control buildings and earthworks in close proximity to the footprint.

- Ensuring the constructed asset has a defined stopbank profile. In some areas, natural undulating ground levels are close to required levels for flood protection purposes. However, experience has shown that these levels can easily be lost. In these areas, the project has involved constructing low level stopbanks with defined profiles so that they are easily recognisable as stopbanks. This makes it easier for Council to have an ongoing presence in terms of maintenance and means landowners recognise the flood protection function and are more likely to engage with Council to seek approvals for any works that may affect the stopbanks.

- Ensuring the works are visible and explained to the users of the area. Much of the rock protection works undertaken involves buried rock lining. For engineering purposes, the scheme would function if the entire lining were buried with no works being visible. As these linings are throughout the Regional Park area, the approach has been to leave the upper portion of the rock linings exposed, with specific crossing points provided for specific users (eg horses, trail bikes). Groynes throughout the Regional Park have also been constructed. Ensuring the rock works are visible raises the general public's awareness of the Regional Park as a highly dynamic area, the need for flood protection works and the understanding of potential flood risks associated with enjoying and living next to the Waimakariri River. Interpretative panels and additional recreational areas designed to highlight the flood protection assets have been provided as part of the project to assist in this regard.

- Enhancing experience of users of the Regional Park as a result of the project works. The works have caused disruption to the Regional Park as areas have been closed in order to manage safety during construction. However, the project team's approach has been to work in close collaboration with the Regional Parks team to ensure areas are enhanced and provided additional value once reopened. This includes establishing new native riparian plantings, creation of new parking and picnic areas, improved cycleway and roading entrances under the road and rail bridges (south side).

Figure 9: Separation of cycle way and road way at entrance to park on south side undertaken in conjunction with Rock Protection work

Figure 10: Parking and Bike Track Development in conjunction with Rock Protection Work

It is considered that the above factors will assist to increase and maintain the community's awareness of the River as a dynamic system which requires ongoing maintenance of flood protection assets in order to manage flood risk.

3.5 RESILIENCE ATTRIBUTE: ORGANISATION PERFORMANCE

The ORGANISATION PERFORMANCE attribute is defined as follows (Fairclough, 2012):

"Leadership and culture are conducive to resilience, including; Resilience Ethos, Situational Awareness, Management of Keystone Vulnerabilities and Adaptive Capacity. Future skills requirements are addressed."

The organisation had a clear goal of upskilling both internally and externally as part of the WFPP. Aspects which have been adopted to achieve upskilling and subsequently contributed to the organisational performance include:

- A project specific procurement approach aimed at achieving best value for money and resulting in a pool of competent, qualified contractors who are familiar with the project, the Waimakariri River context, and work to enhance the Principal's objectives. This work has included standardising on technical specifications required for stopbank construction and rock lining, standard contract conditions, and a consistent project team which gives contractors certainty as to how contracts will be managed. The result has been receipt of high quality tenders, increasing quality performance throughout the project (eg as evidenced by contract performance evaluations) and achievement of physical works projects below budget and ahead of timeframes.

- Technical specifications and performance expectations have been raised throughout the project through a mixture of improvements to specifications and

added-value initiatives offered by contractors. This includes, for example, quality control measures for rock quantity and placement, capture of as-built data, quality assurance testing of stopbank construction, and collaborative work with Regional Parks to manage stakeholder safety during the physical works and provide improved recreational assets upon completion.

- Capital investment and development of the Regional Council's View Hill Quarry in order to improve quality and rate of rock production for flood protection work. This has benefits beyond the project in terms of provision of rock for flood protection maintenance activities.

- Upskilling within the Regional Council by involvement of young engineers, operations team and Regional Parks team in the design and delivery of individual work packages.

3.6 OTHER ATTRIBUTES

While this paper has only analysed four of the attributes of resilience defined by the National Infrastructure Unit, the WFPP also contributes to the other attributes as follows:

- Service delivery: in that the project takes an immediate and long term view of the flood protection risks and needs of the community

- Responsibility: in that the responsibilities of Canterbury Regional Council to provide flood protection measures are explicit in the project, and the responsibilities of individuals to not disturb flood protection measures are set out in Land Improvement Agreements and bylaws, and individual responsibility to prepare for a flood event is managed through the Flood Warning and Emergency Evacuation Plan.

- Interdependencies: in that the project has clearly identified and attempts to manage risks in a way that considers the management of the river as a whole (eg bed level management is detailed in the design standard for the scheme), and in a way that does not transfer risks from one part of the scheme to another.

- Financial Strength: the project has been developed to provide an extremely high level of flood protection (up to the 6,500 m^3/s event, roughly a 10,000 year event on current return period estimates) for a total capital cost of less than $40 million. The time taken between granting of consent and commencement of physical works was the period during which the rating area for the scheme was confirmed and funding secured for the entire project to be completed.

4 CONCLUSIONS

The WFPP project manages risks that could result in a major national hazard event with significant consequences for the Canterbury community and with the potential to severely impact at least three nationally significant infrastructure assets identified by the National Infrastructure unit.

The project commenced prior to the current focus on resilience in delivery of infrastructure projects. The approach adopted for the project was to undertake the analysis, design, and construction in a manner which had regard for the natural geomorphology and river behaviour, understood risk and adopted a best-value approach for mitigating risks. Inherent in the approach was also the recognition that structural measures can fail and the community needs to understand the risks associated with occupying a floodplain, be able to interpret how specific events may transpire for their individual circumstances and plan accordingly. Further, the project team's approach has been to engage with stakeholders in an open, honest, and respectful manner, and ensure that any disruptions experienced due to the project were mitigated by providing improvements to the affected areas.

Analysis of the project against the resilience framework established in the National Infrastructure plan demonstrates that resilience is provided by such an approach.

ACKNOWLEDGEMENTS

Ian Heslop, Principal Rivers Engineer and Waimakariri Flood Protection Project Manager, Environment Canterbury Regional Council.

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Reid et al, 1989, Waimakariri River Floodplain Management Plan, Structural Strength of Existing Works

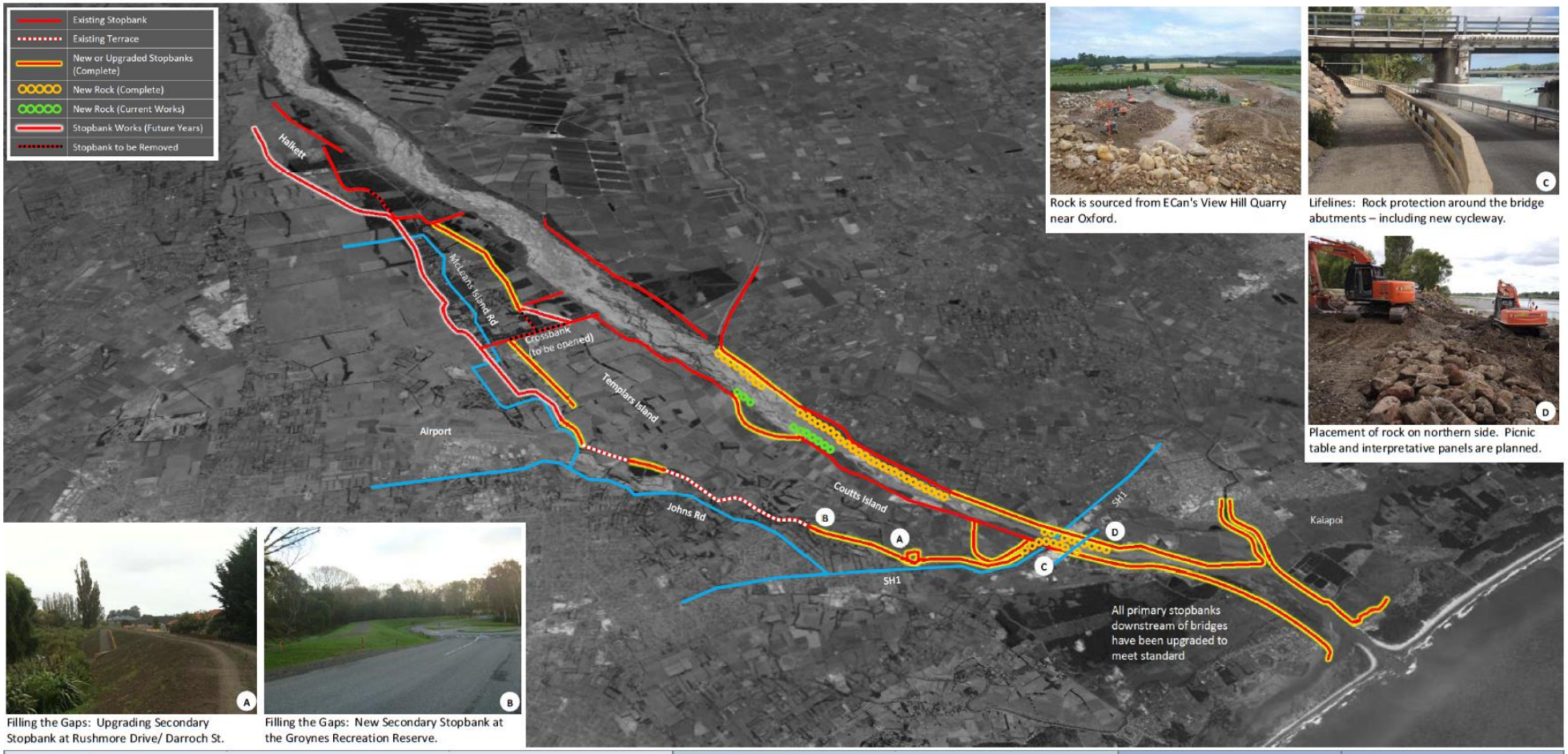
APPENDIX A

OVERVIEW OF WAIMAKARIRI FLOOD PROTECTION PROJECT
PROJECT UPDATE, JULY 2015

Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

WAIMAKARIRI FLOOD PROTECTION PROJECT

Project Overview; July 2015:
The project objective is to provide Primary (500 year return period) and Secondary Waimakariri River flood protection to Waimakariri and Selwyn Districts and Christchurch City. It is a 10 year works programme to provide two layers of flood protection. Works are focused on stopping four potential breach paths where there is potential to flood Kaiapoi; Coutts/Templars Island, Belfast, Kainga and Styx Mill areas; Northern Christchurch; and Central and greater Christchurch. The two layers of flood protection differ along the north and south sides due to the natural topography and expected river behaviour. On the north side, the two layers are a rock lining and primary stopbank system. On the south side, the two layers are a primary and secondary stopbank system, with rock protection at potentially vulnerable locations.



Rock is sourced from ECan's View Hill Quarry near Oxford.

Lifelines: Rock protection around the bridge abutments – including new cycleway.

Placement of rock on northern side. Picnic table and interpretative panels are planned.

Filling the Gaps: Upgrading Secondary Stopbank at Rushmore Drive/ Darroch St.

Filling the Gaps: New Secondary Stopbank at the Groynes Recreation Reserve.

Years 1 to 3 (Complete)

Filling the Gaps:
Making the most of remnant stopbanks and natural river terraces, secondary stopbanks were constructed to create a continuous secondary line from Crossbank to SH1 on the south side. This provides protection to Christchurch.

Lifeline Protection:
Rock protection around the north and south abutments of the SH1, Main North Road and Railway bridges.

Downstream Primary System:
In conjunction with earthquake repair works, the primary system stopbanks from the SH1 to the sea were repaired and upgraded to design standard.

Years 4-5 (In Progress)

Rock Strengthening:
Creating a continuous rock lining on the northern side of the river including groynes between the bridges to provide protection of the berm and stopbank. Rock lining at historic breach zone on south side (Engelbrechts).

Preparing for Crossbank Works:
Making sure the entire system downstream of Crossbank meets the scheme standard. Works include Stoneyhurst Sawmill Ring Bank, Isaac stopbank, minor upgrade of primary stopbanks and McLeans Island primary stopbank.

Years 6-8

Crossbank and McLeans Island:
Part removal of Cross Bank and realignment of primary stopbank to create controlled flow path between primary and secondary stopbanks. Upgrading secondary stopbanks.

Years 9-10

Halkett:
Construction of a new secondary stopbank to capture and return potential breach flows which, if uncontrolled, could lead to significant flooding in central and greater Christchurch.