Report

Dudley Creek Flood Remediation

Downstream Options Report

Prepared for Christchurch City Council

Prepared by Beca Ltd (Beca), Opus International Consultants Ltd (Opus) and EOS Ecology

12 June 2015

Revision History

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3			
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Document Acceptance

Action	Name	Signed	Date
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on behalf of	Beca Ltd, Opus International Consultants Ltd and EOS Ecology		

Executive Summary

Between 2012 and 2014 Christchurch City Council (the Council) and its sub-consultants considered a range of options to reduce the flood risk in the Dudley Creek catchment, including the Flockton Street area, to pre-earthquake levels. This work culminated in a recommended option for the project, which included:

- Upstream works (west of Stapletons Road): widening Dudley Creek, St Albans Stream and Shirley Stream; and
- Downstream works (east of Stapletons Road): constructing a piped Dudley Creek bypass along Warden Street and through Shirley Intermediate School, and widening Dudley Creek along Banks Avenue.

At its December 2014 Council meeting, the Council approved the upstream concept. However in response to community concern about the impact the downstream works would have on landscape and property, the Council directed staff to further develop the downstream options. This included developing an alternative bypass pipe along Warden Street, through Shirley Intermediate School, Marian College, Richmond Park and the Residential Red Zone to the Avon River.

This report describes the development of the downstream options and puts forward three options for public and stakeholder consultation scheduled for June and July 2015. This report does not recommend an option, as the Council wishes to consult the community before selecting its preferred option. After consultation, a Multi-Criteria Analysis (MCA) (which scores each option against a series of predetermined criteria and which considers community feedback) will be used to identify a preferred option.

While the Council's direction was to further develop two options (the previously preferred option and the alternative bypass), further work identified that a third option should be included in the consultation. The three options now put forward for consultation are:

- Option A – piped bypass pipe along Warden Street and through Shirley Intermediate School, re-joining Dudley Creek at the intersection of North Parade and Banks Avenue, with localised channel works in the Dudley Creek waterway adjacent to Banks Avenue;
- Option B – piped bypass pipe along Warden Street, through Shirley Intermediate School, Marian College, Richmond Park and through Residential Red Zone to the Avon River (with an alternate Option B route avoiding the Residential Red Zone, running through Richmond Park south to Medway Street and then east to the Avon River); and
- Option C – localised channel widening works to the Dudley Creek waterway adjacent to Stapletons Road, with a piped bypass pipe south along Petrie Street and east along Randall Street and Medway Street, to the Avon River.

Figure 1.1 overleaf shows a diagram of the three options.

For each route (Options A, B or C) two ways of constructing the bypass are being considered - the bypass could either be a large gravity pipeline, or a pump station feeding a smaller pressure pipeline. The risks and costs associated with each arrangement vary and the final decision (gravity or pumped) will be made after the route is confirmed and further design development and costing is undertaken.

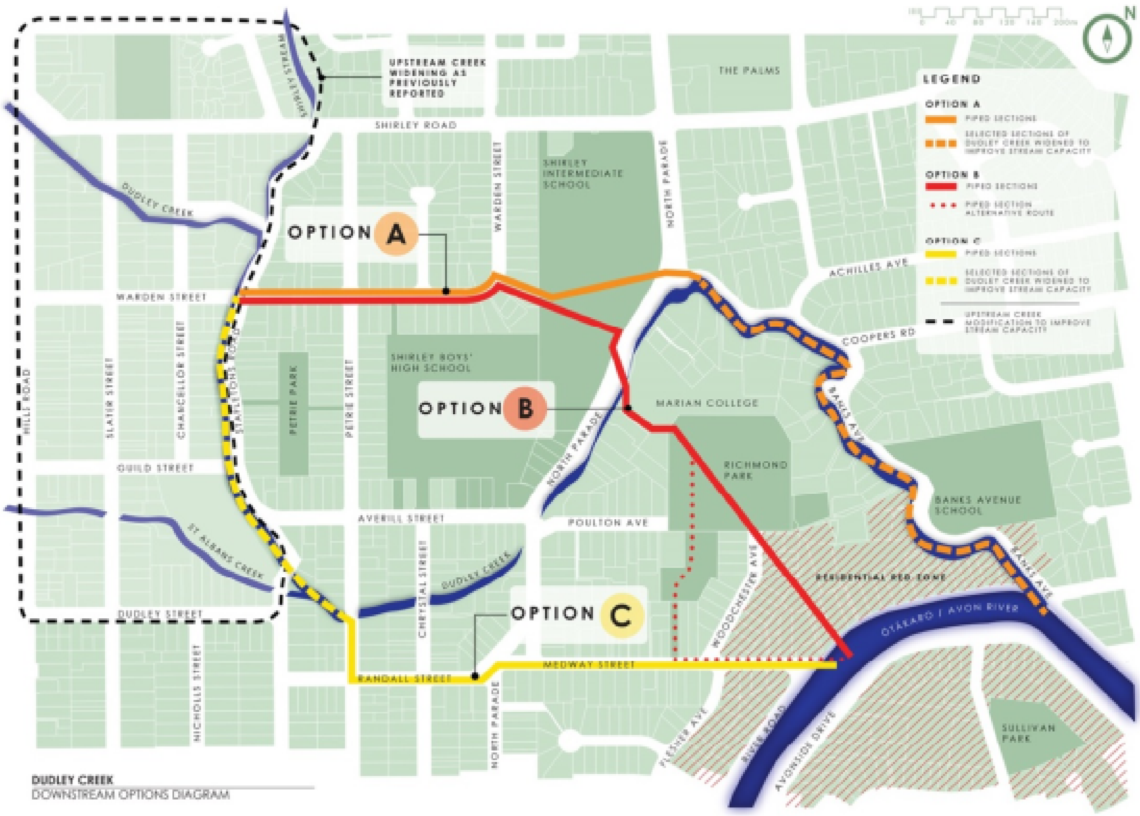

Figure 1-1 Option Overview

All three options are predicted to return the Dudley Creek catchment, including the Flockton Street area, to pre-earthquake levels of flood risk, measured in terms of consented residential floor levels predicted to flood in the 1 in 10 year and 1 in 50 year storm events. The hydraulic performance of each option has been tested using the hydraulic model developed by the Council and its consultants, which uses a combination of MIKE Urban, MIKE 11 and MIKE FLOOD software.

Table 1-1 summarises the comparative concept level cost estimates for each option (including contingency, land costs and fees, but excluding GST). The cost of the upstream work is excluded.

Table 1-1 Cost Summary (All Costs Exclude GST)

Option A		**Option B**		**Option B alternative**		**Option C**	
A1 Gravity	A2 Pumped	B1 Gravity	B2 Pumped	B3 Gravity	B4 Pumped	C1 Gravity	C2 Pumped
$27.7m	$32.5m	$28.8m	$35.9m	$32m	$39.2m	$26.2m	$30.5m

This report is intended to describe the development of the downstream options without determining a preferred option. An MCA process and community consultation feedback will be used to determine the recommended option that will be considered by the Council in August 2015. Following the consultation period and MCA scoring workshop, this report will be updated to reflect the outcomes of this process and the final recommended option.

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Note that these appendices are provided as separate links.

1 Introduction

1.1 Overview

Since the Canterbury Earthquake Sequence (CES) many residents in the Dudley Creek catchment, including parts of St Albans, Richmond and Shirley, have been severely impacted by flooding. The primary purpose of this project is to:

Return the Flockton Street area to pre-earthquake levels of flood risk.

Flood risk has been measured by the number of consented residential floor levels that are predicted to flood in the 1 in 10 year (10% Annual Exceedence Probability (AEP)) and 1 in 50 year (2% AEP) return period storm events.

This project forms part of the Council's Land Drainage Recovery Programme. Work to alleviate post-earthquake flooding in the catchment has been underway since the earthquakes in the following forms:

- Emergency and make-safe works immediately following the earthquakes to remove silt from stormwater networks, culverts, roads and waterways to free up drainage paths
- Emergency works identified by the Mayoral Taskforce to increase the capacity of waterways by creek works and removing discrete restrictions (such as redundant and damaged private bridges)
- SCIRT horizontal infrastructure rebuild works to rebuild roads and primary (piped) stormwater systems
- Construction of the Tay Street Drain Pump Station to divert flows from this part of the Dudley Creek catchment through to the Dudley Diversion and Horseshoe Lake.

Technical investigations and design work have been completed by the Council as part of the emergency response, the Mayoral Taskforce, and most recently by SKM/Jacobs.

1.2 Project Objectives

The Council has provided the following **Primary Project Objective**:

> *Return the Flockton Street area to pre-EQ levels of flood risk measured by the number of consented residential floor levels that are modelled to flood in the 1 in 10 year (10% AEP) and 1 in 50 year (2% AEP) storm.*

The Council has confirmed the following **project objectives**:

- Achieve the primary objective of returning flood risk to pre-EQ levels in the Flockton St area
- Meet the timelines imposed on the project. These are to:
  - Commence construction by August 2015
  - Achieve the primary objective and substantially complete construction by August 2017
- Obtain Resource Management Act (RMA) and building consents to undertake the works
- Solution to maintain compliance with RMA and building consents
- Secure property and access required for the project
- Work within a budget (currently set by the Council at $48M but to be confirmed)
- Solution to meet the requirements of the CCC Waterways, Wetlands and Drainage Guide
- Develop solutions which consider the operation of the entire drainage network over the whole of its life

The Council has confirmed the following **secondary project targets**:

- Improve amenity value along waterways
- Consider and report on additional flood risk benefits over and above the primary objective
- Provide enhanced ecological habitats along waterways.

1.3 Purpose of This Report

This purpose of this report is to present the development of the downstream options and document them for consultation and further consideration through a Multi Criteria Analysis process. The report includes the following sections:

- Background – refer to Section 2
- Project Scope and Decision Making Process – refer to Section 3
- Data Collection and Site Assessment – refer to Section 4
- Consent Strategy and Risk Assessment – refer to Section 5
- Options – refer to Section 6
- Option Design Development – refer to Section 7
- Options Analysis – refer to Section 8
- Costs – refer to Section 9
- Conclusion and Recommendations – refer to Section 10

In addition, this report records the concept design process, outcomes and status behind the options summary which will be used for public and stakeholder consultation in June and July 2015.

This report does not recommend an option at this stage as the Council wishes to consult the community before selecting its preferred option. After consultation a Multi-Criteria Analysis (MCA) (which scores each option against a series of predetermined criteria) will be used to identify a preferred option. Feedback received during the consultation process will feed into the process.

2 Background

2.1 Flood Events

The 2010 / 2011 Canterbury Earthquake Sequence caused widespread damage to the Canterbury area, including land settlement in a number of locations. Many areas of Christchurch were previously vulnerable to flooding, seen in numerous historic flooding events such as those in 1945, 1968, 1975 and 1986. Flooding has worsened in a number of areas since the earthquakes, due to liquefaction, land settlement and changes to waterway profiles.

Flood events in the Dudley Creek catchment after the earthquakes, and particularly in March and April 2014, resulted in significant flooding of land and residential floors and has led to a need to assess potential options for flood remediation.

2.2 Work Completed to Date

In its report titled *'Dudley Creek Catchment: Issues and Options* Report' (Revision F, November 2013), Sinclair Knight Mertz (SKM) undertook a:

- High level options assessment for repairing the waterway to restore the hydraulic capacity and other values, considering the pre-earthquake condition as a baseline, and
- High level assessment of options for providing resilience and betterment with respect to hydraulic capacity and other values.

The report presented the process of identifying 14 options, and made assessments of the cost of damage to property versus the cost of the works, providing a cost : benefit analysis to determine the best options for remediation. The report recommended that two of these options, Option 1: Channel Widening and Culvert Upgrades, and Option 7: Warden Street Bypass with Culvert Upgrades be taken forward for further assessment. This recommendation was based upon discussions in the Council Project Control Group meeting in October 2013.

In March 2014 these two options were presented to Council, and a Mayoral Task Force was developed to help identify a short, medium and long term plan. The Task Force recommended some immediate works such removal of silt and small culverts from the waterways, localised clearing and bank widening and the Tay Street Drain / Kensington Ave Pump Station. It also helped the Council develop a heavy rainfall response plan for early warning, preparation and emergency flood management.

The Task Force provided its first report to the Council in May 2014 and the short-term works noted above were put in place. The Tay Street Drain Pump Station was commissioned in May 2015.

Building on their previous work, the Jacobs report titled *'Dudley Creek Options Optimisation: Option Optimisation and Selection Report'* (Revision 1, November 2014), presented the optimisation of the two preferred options including adjusting the options to reflect the effect of the short-term remediation works undertaken by the Task Force. The report recommended that Optimised Option 2: Warden Street Bypass and Channel Upgrades be taken forward as the preferred option.

2.3 Consultation to Date

The community was consulted in November 2014 on the two options for flood alleviation, with a third option of retreating presented. The flood alleviation options were Optimised Option 1 – Major Upgrade of Waterway Capacity Using Gravity, and Optimised Option 2 – Gravity Piped Diversion and Lesser Upgrading of the Waterway Capacity, with Optimised Option 2 presented as the preferred option.

Submitters were asked to state whether they agreed or disagreed with the preferred option and whether they preferred retained (engineered) or naturalised banks. In addition, four drop-in sessions were held between 12 and 24 November to allow residents to ask questions and seek specific information on their properties. In addition to the general consultation document, directly affected residents were offered one-on-one meetings.

The responses were varied, but key themes were concern about the speed at which the work could be undertaken, as well as the impact on property, landscape and amenity values of the existing waterway, and ecology.

2.4 Council Decision

Following the recommendation of Optimised Option 2 and subsequent consultation, the outcomes were presented to Council in December 2014. The upstream portion of works, including works to St Albans Creek, Shirley Stream and Dudley Creek upstream of the confluence with St Albans creek were approved.

However due to significant community concern regarding the proposed waterway widening along Banks Avenue, the Council did not approve the downstream portion including the Warden Street bypass and widening of Dudley Creek adjacent to Banks Avenue. The Council instructed staff to further develop the preferred option and an alternative bypass option along Warden Street, through Shirley Intermediate School, Marian College, Richmond Park and the Residential Red Zone.

3 Project Scope and Decision Making Process

In January 2015 the Council issued a Request for Proposal for engineering consultants to finalise the downstream options and take the whole project through to completion. In March 2015 it commissioned Beca, Opus and EOS Ecology.

The wider Dudley Creek project has been separated into two sections:

- The upstream portion of works – which is to proceed to construction as soon as possible; and
- The downstream portion of works – incorporating a study of options to enable the Council to select the most appropriate option for the downstream section.

Figure 3-1 shows the split of upstream and downstream works.

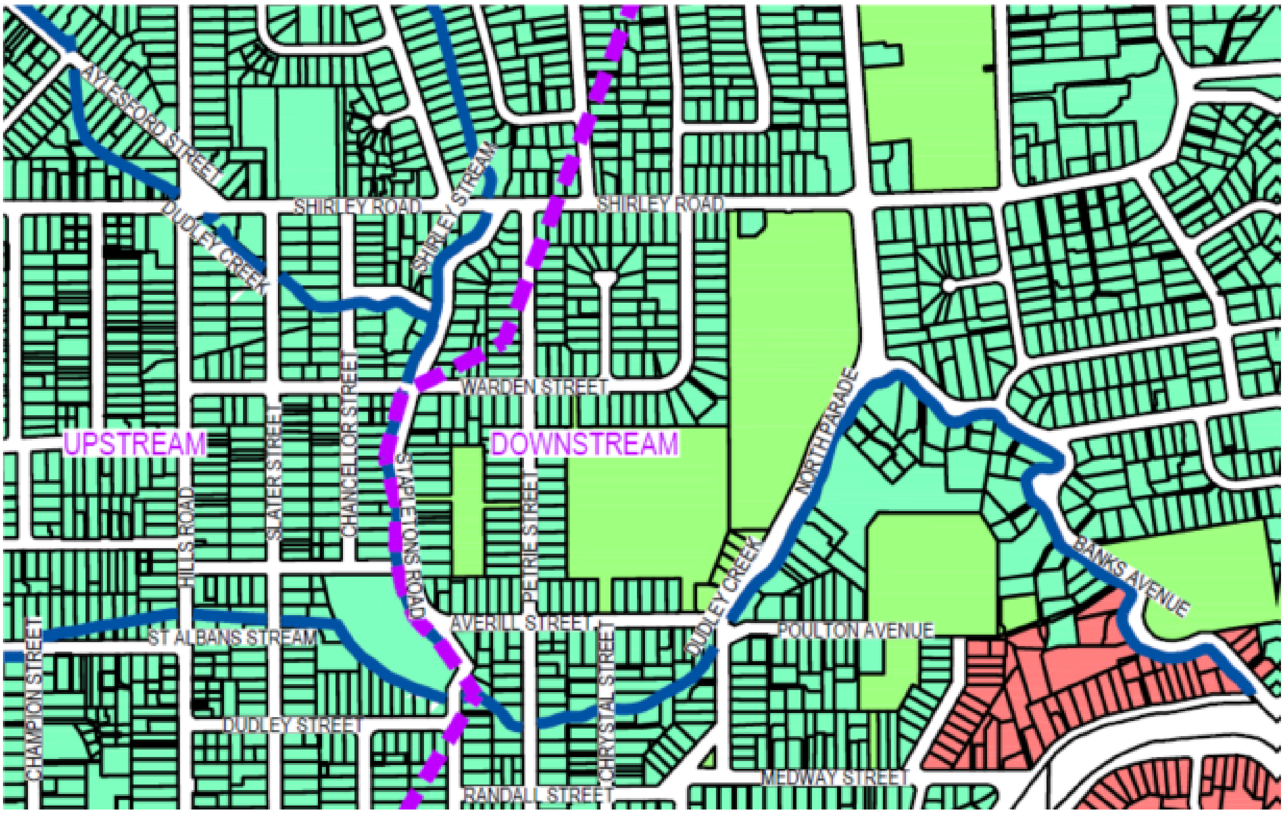


Figure 3-1 Split of Upstream and Downstream Works

3.1 Scope of This Report

This purpose of this report is to present the downstream optioneering process and develop options for consultation. The report includes the following sections:

- Data Collection and Site Assessment – refer to Section 4
- Consent Strategy and Risk Assessment – refer to Section 5
- Options – refer to Section 6
- Option Design Development – refer to Section 7
- Options Analysis – refer to Section 8
- Costs – refer to Section 9
- Conclusion and Recommendations – refer to Section 10

This report records the concept design process, outcomes and status behind the options summary which will be used for public and stakeholder consultation in June and July 2015.

This report does not recommend an option at this stage as the Council wishes to consult the community before selecting its preferred option. After consultation a Multi-Criteria Analysis (MCA) (which scores each option against a series of predetermined criteria) will be used to identify a preferred option. Feedback received during the consultation process will feed into the process.

3.2 Multi Criteria Analysis

The preferred option is to be selected using a Multi Criteria Analysis. Appendix A contains the MCA report which provides a description of the process and the criteria selected for this project.

An MCA has been chosen for this project as it is a suitable for use when an intuitive approach is not appropriate, for reasons including because the decision maker(s) feel the decision is too large and complex to handle intuitively; because it involves a number of conflicting objectives; or it involves multiple stakeholders with diverse views. The process is a formal procedure which is open and transparent.

The steps of the MCA are as follows:

1. Establish the decision context – the purpose of the MCA, identify the decision maker(s) and other key players, design the assessment system

2. Identify the options to be assessed to achieve the objectives

3. Identify the criteria that will be used to evaluate the options

4. Scoring – describe the consequences of the options, score the options on the criteria, check the consistency of the scores on each criteria

5. Weighing – assign weights and scores to each option to reflect their relative importance to the decision

6. Combine the weights and scores for an overall value

7. Undertake sensitivity analysis

8. Examine the results

At this stage Steps 1 to 3 have been undertaken, and the criteria identified are shown in Table 3-1.

Table 3-1 MCA Criteria

	Outcome	Criteria	Definition	Measurement
FLOOD REDUCTION	The degree to which the project provides mitigation of the flood risk	D1 – Vulnerability	Reliability of the option including any residual flood risk - design	The degree of robustness of the option and consequence of failure during a flood event
		D2 - Hydraulic performance / opportunity	Flood risk reduction over and above the primary objective of flood risk reduction in the Flockton St area	The number of properties that have improvements above the pre earthquake risk
COST	The capital and ongoing costs of the project	C1 - Capital cost	Cost of design, consenting, property access/acquisition and construction	Construction cost estimate based on concept level design
		C2 - Whole of life cost	Whole of life costs including operation, maintenance and renewals	Whole of life cost estimate
ENVIRONMENT	The project integrates well with the environment and any adverse effects on the ecology, landscape, recreation, heritage and culture are minimised	E1- Ecology - instream	The impact on the self-sustaining process and inter-relationships among plants, animals and insects	The degree of the adverse impact (instream and riparian) with the required mitigation in place
		E2 – Ecology: terrestrial	The impact on the self-sustaining process and inter-relationships among plants, animals and insects	The degree of the adverse impact with the required mitigation in place
		E3 - Landscape	The impact on the special character of sites and places, their aesthetic qualities and their meaning to the community	The degree of the adverse impact with the required mitigation in place
		E4 - Recreation	The impact on the active and passive recreation, play and the structures that support these activities	The degree of the adverse impact with the required mitigation in place
		E5 - Heritage	The impact on sites and activities of historical and natural significance	The degree of the adverse impact with the required mitigation in place
		E6 - Culture	The impact on Ngai Tahu and the community's perception of a resource and its values, indicated by community involvement in management, celebration of past events and planning for the future	The degree of the adverse impact with the required mitigation in place
	The health and wellbeing of the community has been considered	E7 – Community impact (social)	The option provides for peoples wellbeing and sense of community	Qualitative assessment of impact – quality of life, community cohesion, health & wellbeing. This will be measured

	Outcome	Criteria	Definition	Measurement
				through consultation feedback
	Temporary effects from construction are managed	E7 - Construction	Effects of constructing the option including the natural environment, traffic, pedestrians, noise, disruption to public and services, health and safety risks, damage to other assets, access to private property.	The degree of adverse effect from construction activities
LONG TERM SUSTAINBILITY	The project is considered sustainable in the long term	S1 - Long term sustainability	Ability to future proof the solution whether that be for climate change, increased levels of service or resilience to damage in a future natural hazard	Qualitative assessment of the ability of the option to be future proofed
RISK	Risks have been managed to the extent practical	R1 - Legal Risk	The extent to which there is risk around legal action	The degree of unmanageable risk
		R2 - Timeframes	Not meeting timeframes due to consenting or property access agreements	The degree of unmanageable risk
		R3 – Red Zone land	Red Zone land - ability to acquire or access and use the land	The degree of risk around access to Red Zone land – purchase or easements and ongoing use

Steps 4 to 8 from the process outlined above are scheduled to take place after the consultation period finishes, with the scoring workshop scheduled for 14 July 2015.

4 Data Collection & Site Assessments

4.1 Data Collection and Review

Existing data from the following sources was used:

- Topographical stream survey from the Council and Woods Ltd
- Existing hydraulic models and hydraulic modelling reports (including pre-earthquake models, current models and option models developed by SKM/Jacobs in its earlier work)
- Previous work undertaken by SKM/Jacobs including options reports
- Tay Street Drain Pump Station design information prepared by SKM/Jacobs
- Consultation feedback from the previous consultation held in November 2014
- Cost estimates on previous options undertaken by Bond CM
- Tree assessments undertaken during previous design stages (Arbor Vitae on behalf of the Council)
- Water and sediment quality data provided by the Council, consisting of one long-term water quality monitoring site, and one sediment and biofilm quality site
- Fish survey information by Boffa Miskell, November 2013 (Blakely, 2014)
- City-wide Bank Stability and Treatment Options and Guidelines (Upstream Waterways) CCC Jan 2013
- Existing global consents held by the Council that may be relevant to the work
- Geotechnical information from existing sources including the Canterbury Geotechnical Database.

In addition this study has collected the following new data:

- SCIRT survey and services data (12d files)
- Site visits including site measurements and refinements of channel, culvert and bridge dimensions
- Additional topographical survey, particularly tree locations and sizes
- Ecological data (refer below)
- Specialist arborists assessment of potentially affected trees (refer below).

4.2 Landscape and Tree Assessment

4.2.1 Tree Assessment

Landscape Architects and Arborists carried out detailed assessments of the trees and shrub groups in the potential work areas.

Each tree was assessed for the following characteristics - native or exotic, trunk and canopy size, age, condition (very poor/poor/fair/good) and life expectancy. The Arborist's report provided in Appendix B describes the assessment methodology and outcomes and the potential numbers of trees to be removed. For further detail on tree removal refer to Section 6.

In summary, the following findings from the landscape assessment are noted.

4.2.2 Variety and Life Expectancy

The existing trees are a mix of native and exotic trees, with approximately 60% of all trees surveyed being exotic and 40% natives. The life expectancy of trees is also quite varied, with approximately 30% having a short life expectancy (less than 10 years), 30% medium (10-20 years) and 40% long (great than 20 years).

4.2.3 Earthquake Effects on Existing Trees

Changes in ground conditions caused by the earthquakes have seriously affected a number of existing trees along Banks Avenue and, to a lesser degree, Stapletons Road, and more trees may die in the near future. If Option A or C is selected the proposed works will be designed to significantly improve the landscape values of Banks Avenue or Stapletons Road by replacing trees that will die in the short term. Section 7.2 Landscape and Ecology Design for a more detailed explanation of the design philosophy behind the opportunities to improve the landscape and ecological values of the waterways and riparian zone.

4.2.4 Landscape Assessment - Existing Character

The following section describes the character of the two areas of Dudley Creek where bank widening is proposed.

The **Banks Avenue** stretch of Dudley Creek is characterised by a number of key elements that together give the impression of a mature, well planted, predominantly exotic woodland and riparian edge landscape and streetscape. The most significant elements that contribute to this character are:

- The relatively narrow and sinuous nature of Dudley Creek itself, replicated in the alignment of Banks Ave which because of its form and alignment lends itself more to a ‘slow street’ environment, which then reinforces the linear park–like setting of the Creek
- The changing elevation of Banks Ave relative to the Creek edge provides variation in experience of the Creek and other influences such as traffic and the residential area on the north side of Banks Ave
- The combination of predominantly large exotic deciduous trees and open lawn areas on the Banks Ave side replicated by the open lawns and mature plantings of the residential side on the south bank
- The relative lack of constructed bank edges, so strengthening the perception of the ‘naturalness’ of the waterway itself
- The riparian edge planting of predominantly native plants
- The relatively easy, though varied and informal, accessibility to the waters’ edge
- The lack of any formal footpath along the bank edge and Creek margin
- Lack of consistent and significant separation of vehicles and pedestrians along the top of the bank / road edge
- The mostly open views from Banks Ave of the creek bank and, in places the Creek itself
- The set-back distances and/or screening, of the existing residences on the south bank give the impression of a much wider park-like setting.

The **Stapletons Road** stretch of Dudley Creek is characterised by a number of elements that together give the impression of a mature, well planted, predominantly exotic woodland landscape and ‘linear park’, set within the bounds of an established residential area and road corridor. The key elements that characterise this section of Dudley Creek include:

- The narrow and gently curving nature of Dudley Creek is replicated by the alignment of Stapletons Road, which in turn re-emphasises the form of the waterway and sinuous nature of the river bank ‘park’
- The mostly open views from Stapletons Road of the waterway bank and, in places, the waterway itself
- The combination of predominantly large exotic deciduous trees, relatively ‘natural’ banks, and open lawn areas on the Stapletons Road side of the waterway is not replicated on the residential side of the west bank. A number of residences are sited within 10-15 metres of the waterway and/or have significant lengths of massed screen planting or fencing along the waterway boundary itself, so giving the impression of a more enclosed and ‘built-edge’ to the character of the river bank
- This impression of enclosure and ‘built-edge’ is further emphasised by the range of constructed retaining edges along the residential west bank in varying forms of age, materiality (for example: rock, stone, steel plate) and earthquake damage

- The pedestrian paths, though still earthquake damaged, provide relatively easy pedestrian access along the top of the bank at the same level as the road
- The lack of physical or height separation between road and river bank/pedestrian path reduces the feeling or experience of a totally separate linear park-like character for pedestrian users
- The comparatively balanced proportions of road and waterway bank widths increases the impact of road corridor character (road materials, traffic noise and speed) on the waterway bank and 'linear park' character
- The steepness and height differential of the waterway bank between the existing footpath and the waterway itself limits the opportunities for easy pedestrian access to the waters' edge
- The maintained grass bank edge and lack of riparian edge planting on the Stapletons Road side of the waterway emphasises the relative uniformity of landscape treatment and lack of ecological diversity of this side
- The visual impact of Warden Street crossing Dudley Creek imposes added traffic movements and 'road-like' character on the waterway setting.

4.3 Ecology Assessment

4.3.1 Ecological Survey

To supplement the limited existing ecological information on Dudley Creek noted in the Section 4 above, EOS Ecology undertook a range of field investigations. Site walkovers were undertaken in April and May 2015 to characterise the general habitat of Dudley Creek and its wider terrestrial environs. The tree survey data was also used to provide a more accurate account of the current state of the riparian zone along Dudley Creek.

Fish and invertebrate surveys were undertaken along Dudley Creek between the Avon River and Shirley Stream confluences, including two aquatic invertebrate sites and six fish sites. A map of these locations is provided in Figure 4-1.

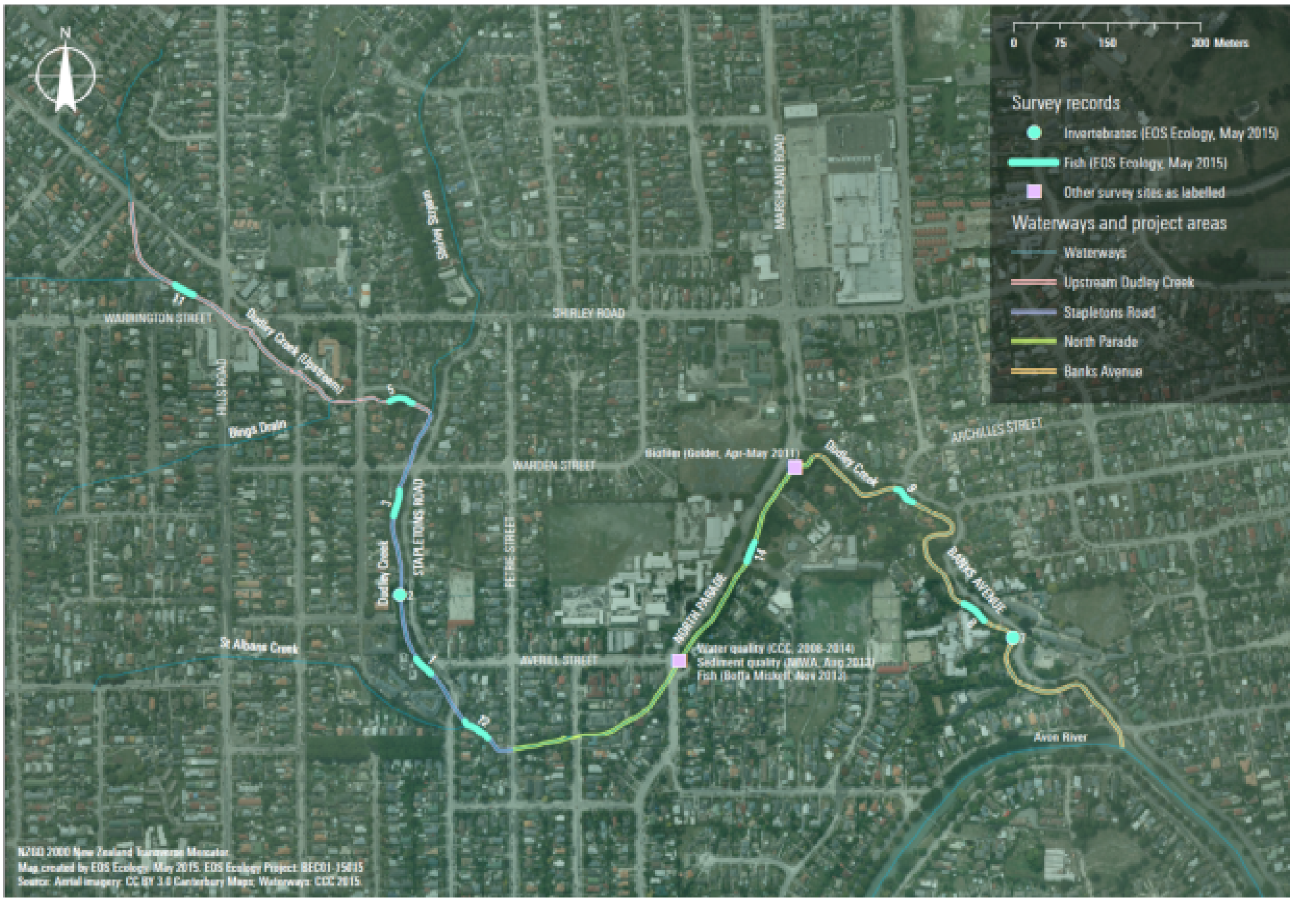


Figure 4-1 Map Showing Locations of Ecological Data

As fish are migratory, an additional two sites were also surveyed by electric fishing in Dudley Creek outside of the immediate project area, upstream of the Shirley Stream confluence. The aquatic invertebrate sampling entailed the collection of a combined kicknet sample (covering approximately $0.45m^2$ of streambed). The samples were taken to the laboratory for processing and identification to species level where practicable. Fish surveys were undertaken via a 'single pass electrofishing' method using a backpack operated Kainga EFM 300 electrofishing machine. Fish were identified and measured prior to returning them live to the stream.

A more detailed account of the ecology assessments undertaken can be found in the Ecological Condition of Lower Dudley Creek report, provided by EOS Ecology (refer to Appendix C).

4.3.2 Existing Ecological Condition

Dudley Creek is a slow flowing, heavily silted stream, with moderately contaminated stream sediments and reasonable water quality at low flow. The section between the Avon River and the Banks Ave-North Parade intersection is also tidal. The stream banks are predominantly grassed. The large trees help to shade the stream and would help to keep aquatic plant growth down (although channel maintenance including the removal of sediment and associated aquatic plants is also undertaken by the Council), but the preponderance of larger exotic trees does pose a risk to the health of this stream during autumn leaf fall, when the accumulation and breakdown of such large amounts of leaves can reduce oxygen levels in the stream. There is a high diversity of native and exotic plants and trees along the stream, with some larger clusters of native vegetation that attract native birds such as fantails. In general there is a reasonably even mix of native and exotic tree species along the Banks Ave section, while the Stapletons Road section is mainly exotic on the public road-side (i.e., the true-left) and mainly native on the private (true-right) side.

However, the majority of large stature trees are exotic, including sycamore and silver birch along Banks Ave and swamp cypress along Stapletons Road (which are used by monarch butterflies as winter roost sites). The native trees tend to be smaller stature and shorter-lived species, such as cabbage tree, lemonwood, ribbonwood, and other Pittisporums.

The aquatic invertebrate community is dominated by invertebrate taxa that are typical of heavily urbanised streams with fine bed sediments and slow water velocities, and thus reflective of poor quality habitat. Empty shells of New Zealand's largest freshwater bivalve, the freshwater mussel/kakahi, were found along Banks Ave. While we cannot be certain if there are any live specimens in Dudley Creek, the presence of empty shells is strong evidence that this stream was once in better condition than it is today. It is possible that the invertebrate community of Dudley Creek was also badly impacted by the large deposits of liquefaction sand that smothered the stream channel following the 2010 Canterbury Earthquake Sequence.

In contrast to the poor quality invertebrate community, the fish community is diverse, supporting seven native fish species (in order of abundance, common bully, shortfin eel, upland bully, longfin eel, giant bully, bluegill bully, inanga), of which three have a national threat classification of 'at risk – declining'. Greater densities of fish were found at sites where there is better cover (such as larger instream substrate like rocks, logs and tree roots, overhanging bank vegetation, and gaps in rock edgings or undercuts along earth banks). The discovery of the 'at risk' diminutive bluegill bully at one fast-flowing riffle section along Banks Ave identifies this section as a high-value habitat that should be protected and if possible, enhanced. Reasonable numbers of large longfin eels, another 'at risk' fish species that is also culturally significant, were found upstream of Petrie Street and always associated with areas of stream with good fish cover. There was a good representation of larger eels, with both large longfin and shortfin eels being regularly fed by residents along Dudley Creek. The future of this large and particularly long-lived species, as well as other fish species such as inanga and giant bully, is certainly dependent on providing sufficient cover (in the form of large coarse substrate in the stream such as rocks and logs, overhanging vegetation, eel holes along the bank, low overhanging vegetation, and trees to provide shade) in and along the stream.

In general the results of the ecological investigations indicate that the ecological values of the stream are poor in relation to sediment quality and aquatic invertebrates, but moderate in relation to the fish community. On this basis there is great potential to improve these values (especially for fish) through improving habitat quality with some of the proposed options.

Further details of the fish surveys and existing ecological condition are provided in the Ecology Report in Appendix C.

5 Consent Strategy & High Level Risks

5.1 Consent Strategy

A Statutory Approvals Strategy has been developed for the project to detail the consenting process including approvals required and to assess existing global consents and their appropriateness for this project.

The Council holds a number of 'global' consents which authorise earthquake related / remediation activities and maintenance activities across the city. These consents provide for certain activities within the beds of waterways in Christchurch and associated activities to facilitate those activities. The scope of the existing consents and their applicability to the options is currently being determined with both Environment Canterbury and Christchurch City Council planners. While some instream works may be covered by the existing consents, the diversion and discharge of floodwater through the bypass, requires new resource consents regardless of the preferred option. Consenting and consultation requirements for removal of trees varies, depending on the nature of the trees and whether they are protected by the City Plan.

Where required, resource consent applications will be supported by an assessment of the actual and potential environmental effects of the proposal, together with any proposed mitigation or conditions under which the works will be completed. Throughout the design process, the environmental technical experts including ecologists, landscape architects, arborists and archaeologists will work alongside the designers to ensure that environmental requirements have been included and proper mitigation of likely effects is in place. Throughout this process, the consenting requirements will be refined and confirmed to address all aspects of the proposal.

5.2 Risks and Opportunities

Project risks and opportunities will be managed through the project lifecycle using risk workshops and risk mitigation plans. The following key risks have been identified for this project to date:

- The project programme is tight
- A number of resource consents are required
- Agreements are required with landowners
- Some options involve infrastructure in the Residential Red Zone
- It is important that the community understands there will still be flood risk after the project is completed (the project only returns the area to pre-earthquake levels of flood risk)
- There are construction risks associated with all options, including deep trenching, dewatering and poor ground.

Risks specific to each option are discussed in Section 8 Options Analysis.

6 Options

6.1 Option Identification

The Council's brief was to refine the previously preferred option (referred to as Optimised Option 2 in previous Jacobs work) and develop an alternative bypass option along Warden Street, through Shirley Intermediate School, Marian College, Richmond Park and the Residential Red Zone, which was expected to be approximately $5m more expensive.

The Council also requested cost estimates for two other options previously identified but not costed (a bypass along Averill Street / Poulton Street and a bypass along Petrie Street, Randall Street and Medway Street) to close out peer reviews on these options. Both options involve similar Dudley Creek channel widening along Stapletons Road. Of the two options the Randall Street / Medway Street bypass was found to be the shorter bypass with lower cost and the least impact on landscape values.

Based on the above work, the Council agreed that three options should be developed for public consultation and assessment through the Multi Criteria Analysis to identify a recommended option. The three route options are shown on Figure 6-1 below.

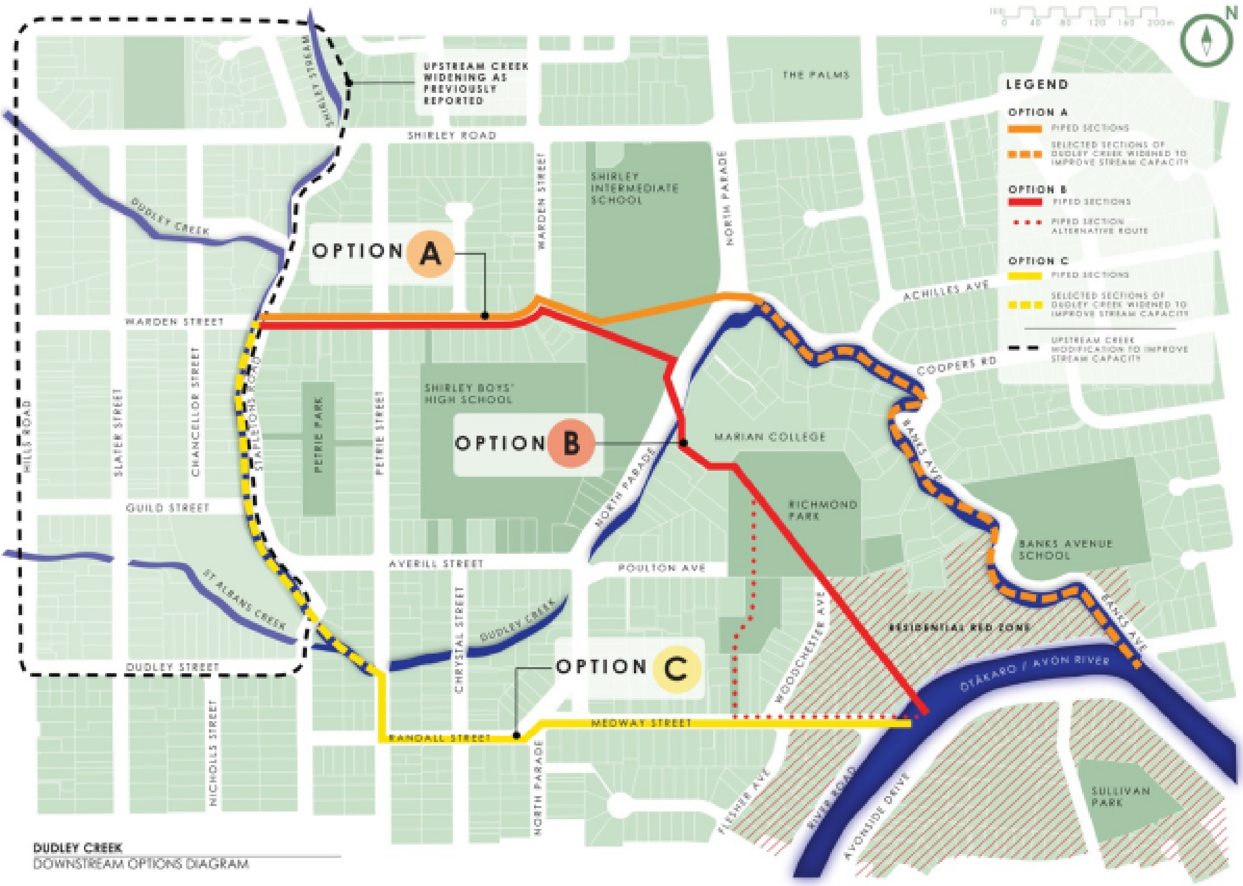
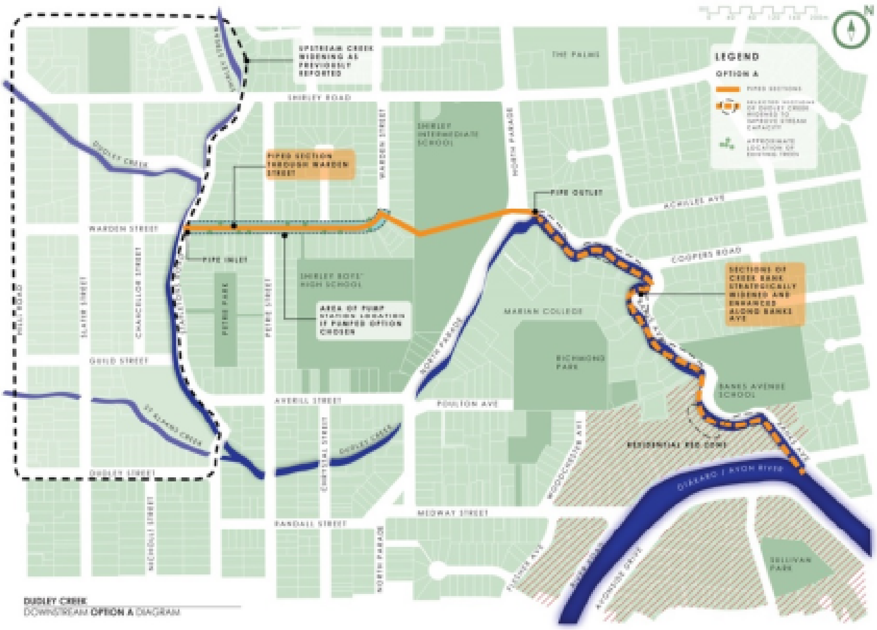
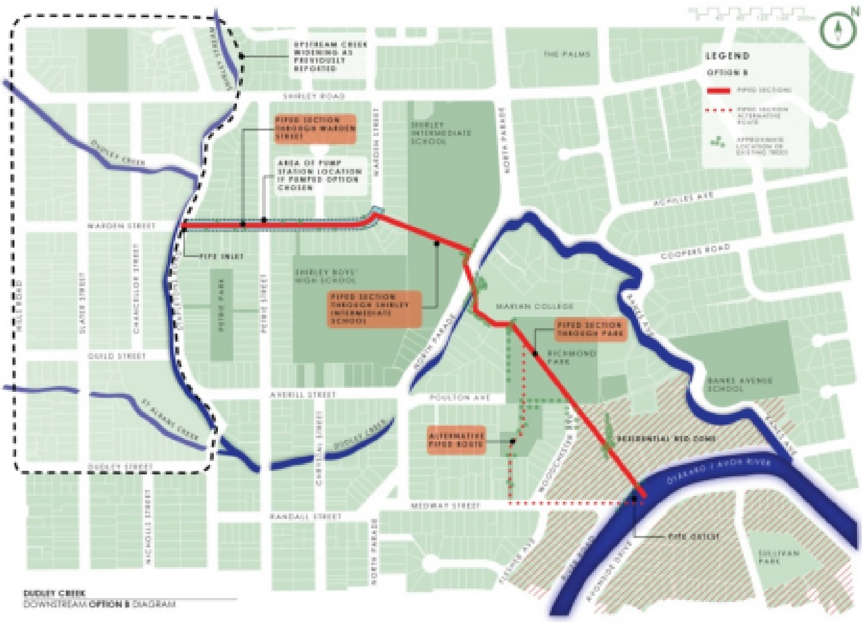


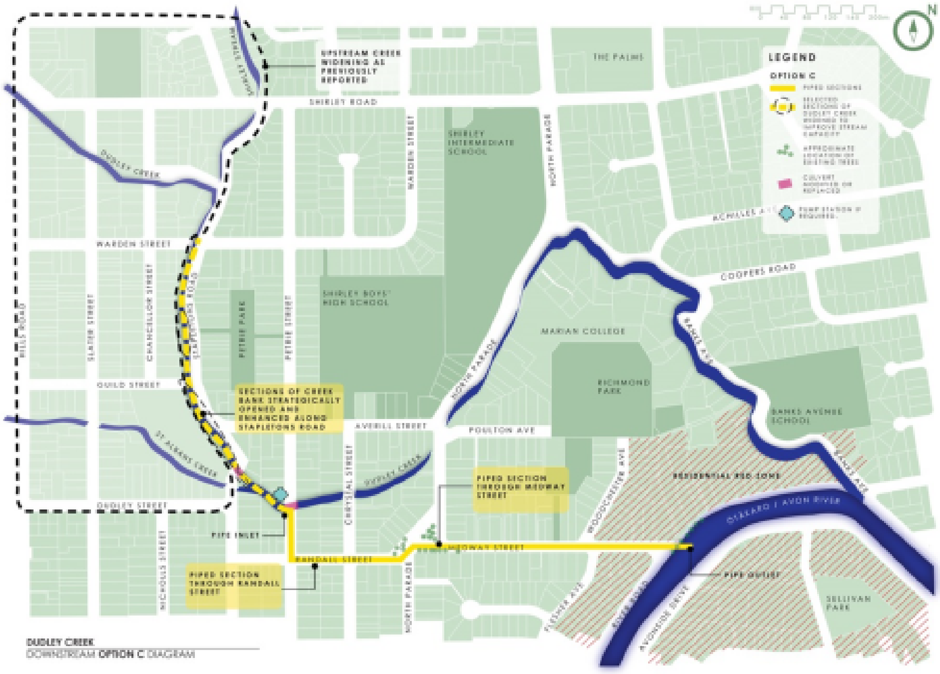
Figure 6-1 Option Overview

A summary of the options being assessed is presented in Table 6-1 below.

Table 6-1 Description of Options

<table>
<tr><th>Option</th><th>Description and Figures</th></tr>
<tr><td>Route Option A</td><td>Piped bypass route along Warden Street and through Shirley Intermediate School, re-joining Dudley Creek at the intersection of North Parade and Banks Avenue, with localised channel works in the waterway adjacent to Banks Avenue.

</td></tr>
<tr><td>Route Option B</td><td>Piped bypass route along Warden Street, through Shirley Intermediate School, Marian College, Richmond Park and through Residential Red Zone (solid line).
An alternate Option B route connects from Richmond Park south to Medway Street, travelling east to the Avon River to avoid the Residential Red Zone (dotted line).

</td></tr>
</table>

Option	Description and Figures
<u>Route Option C</u>	Channel widening works to the waterway adjacent Stapletons Road, with a piped route south along Petrie Street and east along Randall Street and Medway Street, to the Avon River.



7 Option Design Development

7.1 Civil Engineering Design

7.1.1 Level of Design

Concept civil engineering designs have been developed for each option sufficient for consultation regarding the routes and comparative costing (refer drawings contained in Appendix D). The options have been investigated, designed and costed to the same concept level of detail for the purpose of comparing the options. Following Council consideration of the options in August 2015, the preferred route option will be developed further to inform more refined cost estimates, consenting and property negotiations.

A significant amount of additional information regarding constraints such as landform and landscape features has been collected to inform the concept design. The concept design has also been taken to a higher level of detail than the 2014 work, including multiple iterations of the channel design. This process has refined the design and identified areas where the scope of work can be reduced from what was originally proposed in 2014, while still achieving the primary objective of returning the flood risk to pre-earthquake levels.

The key design considerations and elements are described in the following sections.

7.1.2 Gravity or Pumped Bypass

For each route option the bypass pipe could either be a gravity pipeline or a pump station and pressure main. Concept designs for both approaches have been prepared. The capital and operating costs, risks and benefits are significantly different for each option and it is recommended that a final decision as to whether the bypass is gravity or pumped is made once a route is chosen and the designs are further developed, tested and costed, with contractor involvement.

It is recommended that the Council selects a route option following consultation with the community and stakeholders, and that the final decision (gravity or pumped) is made by the project team later in conjunction with the Council and the contractor.

7.1.3 Gravity Pipeline Design (refer Drawing CE-060 Appendix D)

The following gravity pipeline design philosophy was used in the concept level options design:

- **Pipeline Material:** Precast concrete box culverts – 3m wide by 1.5m deep (Options A and B) and 4m wide by 1.5m deep (Option C – refer further discussion in Table 8-8 in Section 8.3)

- **Pipeline Jointing:** Standard box culvert 'shear key' butt joint with mastic sealant and external geotextile wrap

  Consideration was given to mechanical jointing (ties across the joints or concrete stitch joints) to reduce the risk of joint displacement in seismic events. However given the significant ground movement that may occur in significant seismic events, mechanical joints will likely fail resulting in joint displacement and structural damage to the culverts. It is therefore recommended that butt joints be adopted, and that a heavy geotextile joint wrap is used to reduce the risk of fines washing in through displaced joints. The MCA will consider the risks associated with this approach

- **Pipeline Cover and Depth:** The design has been based on a nominal minimum 1.2m cover over the pipeline to allow most utility and Council services to cross the culvert. The typical pipeline depth is therefore 3 to 4m to invert

- **Pipeline Buoyancy:** Calculations indicate the pipeline would experience buoyancy uplift in significant seismic events. The concept design includes 400mm wide cast insitu footings along each side of the culvert to reduce the risk of floatation

- **Pipeline Construction:** It is likely that both sides of the trench will be sheet-piled and de-watered. The pipeline will be bedded on granular bedding or geogrid wrapped granular bedding if required in difficult ground conditions.

7.1.4 Pressure Pipeline Design

The following pressure pipeline design philosophy was used in the concept level options design:

- **Pipeline Material:** Solid wall polyethylene (PE100 PN6.3) pipe – 1.8m outside diameter (Option A) and 2m outside diameter (Options B and C)

  A range of other materials could be considered including profiled wall polyethylene, fibreglass (FRP / GRP) or reinforced culvert. While these materials are potentially cheaper they are considered less resilient. The balance between cost and long term risk requires further consideration as part of design development

- **Pipeline Jointing:** Butt fusion or electrofusion couplers

- **Pipeline Cover and Depth:** The design has been based on a nominal minimum 1.2m cover over the pipeline to allow most utility and Council services to cross the culvert. The typical pipeline depth is therefore 3 to 4m to invert

- **Pipeline Buoyancy:** Initial calculations indicate the pipeline should not experience buoyancy uplift in significant seismic events, subject to good detailing of the trench width and backfill

- **Pipeline Construction:** It is likely that both sides of the trench will be sheet-piled and de-watered. The pipeline will be bedded on granular bedding or geogrid wrapped granular bedding if required in difficult ground conditions.

7.1.5 Pipeline Outlet Conditions and Design

All outlets will need to be carefully designed considering safety (limiting entry to the pipeline), hydraulic efficiency, maintenance and reliability. Given that the pipeline will operate infrequently and the discharge environment (especially the Avon) often carries silt and debris, there is a high potential for the outlet to become blocked. A range of options will be considered during the detailed design phase once the option (and therefore discharge location) is known.

7.1.6 Bypass Maintenance Considerations

The primary maintenance activities associated with the gravity bypass options will be keeping the inlet and outlet clear, ensuring the outlet backflow device is functioning and cleaning the pipe of silt. Further discussion is planned with the Council staff who maintain other such assets in the city to assess maintenance requirements.

For the pumped option, the primary maintenance activities will be keeping the inlet and outlet clear, ensuring the outlet backflow device is functioning and normal on-going maintenance of the pump station an associated equipment. The pressure pipeline should require less cleaning as it will operate at a self-flushing velocity.

7.1.7 Trenchless Pipeline Construction

Trenchless pipeline construction has been considered at a high level and will be considered further once a contractor is selected. However at this time it is considered that trenchless pipeline construction is unlikely to be the recommended approach for the entire route, based on the following considerations.

- The pipelines can be installed in relatively shallow trenches and trenchless installation is likely to be more expensive
- Ground and groundwater conditions are expected to be highly variable along the route making trenchless construction difficult and risky
- Trenchless installation typically requires adequate overburden pressure above the drilling face to mitigate the risk of ground heave and fracking of drilling fluids to the surface. The pipelines would need to be laid deep (approximately 4-5m cover) to achieve this which increases the costs of drilling pits and makes access for future maintenance difficult.

However there are local areas, such as where Option B crosses North Parade and Dudley Creek, where trenchless technology may offer advantages.

7.1.8 Services

A high level assessment of services clashes and required relocation works has been undertaken for each option and this is further discussed under the options analysis.

7.1.9 Pump Station

A high level assessment of possible pumping station arrangements has been undertaken to inform the cost estimates for the pump sub-options. The concept design and cost estimate is based on the recently constructed Kensington Street Pump Station (PS202), factored up to meet the required bypass flows.

The concept level cost estimates are based on PS202 with four larger pumps in a below ground wet well, a free standing control building and a containerised standby generator, all of which need to be confirmed during design development.

7.1.10 Waterway Design

The waterway design has been carried out in 3d design software (12d) and tested in hydraulic design software (MIKE 11). The channel design has been developed progressively through iterations – progressively increasing the extent of widening until the required hydraulic design outcomes were reached. The widening shown in the concept design (Appendix D) is considered the practical minimum to achieve the flood risk reduction target. There is flexibility however to alter where the widening occurs if that is required, for example as a result of consultation.

The widening has been targeted for public land in areas of lower landscape value, however access to some private land is still required for bridge replacement works and the like. The property requirements are described in the options analysis sections.

An example design cross section for the bank widening is shown in Figure 7-1 below.

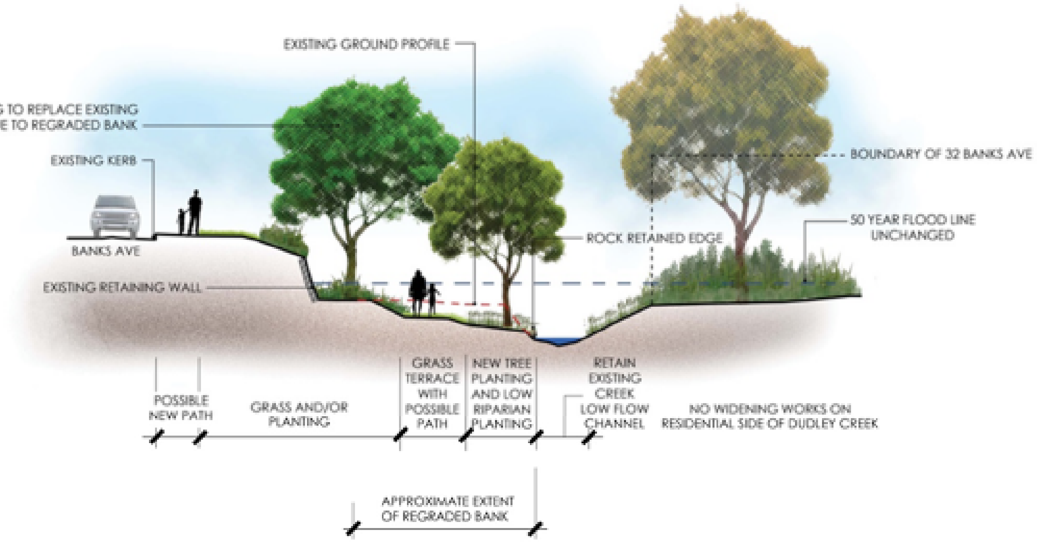


Figure 7-1 Example Design Cross Section

The design section is designed to:

- Avoid deepening the existing channel
- Narrow the low flow channel to enhance ecological outcomes
- Create a low bank along the waters edges to allow plants to overhang to create habitat
- Create a floodway not subject to tidal inundation (the channel along Banks Ave is tidal)
- Incorporate paths where possible (as this was identified as important to the community in earlier consultation) at an elevation not subject to regular inundation (the frequency of inundation requires further discussion with the Council in subsequent design phases and has not been specifically modelled at this time)
- Avoid retaining walls where possible for cost and aesthetic reasons.

7.1.11 Culverts / bridges

The concept design has considered which of the existing bridges and culverts across the waterways need to be replaced and this is discussed under the options analysis sections.

7.1.12 Geotechnical Design & Resilience

A geotechnical assessment was carried out to identify project risks, consider anticipated resilience associated with static and seismic performance, and recommend potential mitigation measures for incorporation into the concept option cost assessment. The assessment considered information collected from the Canterbury Geotechnical Database to develop soil profiles, seismic performance during the Canterbury Earthquake Sequence (CES) and empirical formulae and back calculations against the CES to verify these formulae.

The Concept Geotechnical Report for this downstream section is presented in Appendix E. The report presents and assesses the types of work associated with the downstream options, including waterway modification, pipelines, pump stations and bridge structures.

All the options involving gravity bypass pipelines may be affected by post construction static settlement, and in significant seismic events they will be affected by joint displacement caused by ground settlement and lateral spreading. There is also a risk of seismically induced floatation. To a degree the seismic risks can be mitigated (but not removed) by geogrid wrapped bedding, geotextile wrapping around the pipe joints and extended footings. There will however be joint displacement and damage in large seismic events and repair will most likely be required.

Pressure pipelines are expected to be more resilient, particularly if constructed from polyethylene. The main risk is seismically induced floatation which can be managed through appropriate trench detailing. Pump stations would be at risk of seismic damage (settlement, lateral spreading, floatation, structural damage), however these risks can be reduced through appropriate design.

The effect of widening Dudley Creek on the seismic performance of the adjacent land and buildings has been assessed. The effect of the widening was assessed to be very minor such that no mitigation work is required, providing the widening is further than 15m from such land or buildings and the creek bed is not lowered (removing competent material). In areas where widening is required within 15m of private land or buildings a site specific assessment needs to be made and some form of mitigation work (such as a retaining wall or mass stabilisation) might be required.

7.2 Landscape and Ecology Design

7.2.1 Design Philosophy

A landscape and ecology design philosophy has been developed and incorporated into the design. The philosophy considers the Council's 'Six Values' design approach and recognises the works as an opportunity to improve the landscape and ecological values of the waterways and their riparian zone. This will have long-lasting benefits to the stream and wider environment. The following attributes have been considered for enhancing the existing waterway wherever possible, and will be further incorporated during further design stages.

Soft Landscape and Trees

- Replacement tree planting so that the existing diverse character of native and exotic trees is retained and where possible enhanced
- Additional waters' edge and steeper bank mass planting areas to enhance ecological, landscape and cultural values
  Appropriate planting that does not compromise the long-term drainage function of Dudely Creek
- Protection, wherever possible, of existing trees of high value

- Planting of appropriate tree species on the lower banks suited to periodic flooding and tidal influences, and able to provide important shade, erosion control, mahinga kai and habitat values to the waterway
- Potential opportunities to extend the proposed tree replacements to areas outside of the direct areas of bank modification by removing trees identified as having a short-term life expectancy, and replacing them with semi-advanced tree specimens more suited to the new (post-earthquake) ground conditions
- Retaining key areas of native tree clusters that are utilised by resident native birds will also help to retain the existing habitat and food resources for native birds in the area; and
- Provision of overhanging cover in the form of soft native groundcover plants along the stream edge.

Stream Design

- Protection and enhancement of areas of higher value in-stream habitats
- Removal of fine sediment and addition of clean gravels
- Incorporation of low-flow planted flood plains for improved ecological and mahinga kai values
- Provision of instream and bank cover in the form of larger rocks and logs; and
- Protect and enhance those areas of the stream that have existing faster flow and a coarser substrate as a result of a narrow low flow channel and steeper gradient than other sections of stream.

Paths and Walkways

- Establishing safer and improved pedestrian access both along the creek and to the waters' edge to improve recreational values; and
- Maintained or enhanced visibility from the street and adjacent properties, of both the waterway and the bank, to ensure Crime Prevention Through Environmental Design (CPTED) principles are followed.

Structures

- Intake and outlet structures designed to consider and mitigate, where possible, effects on aquatic ecology; and
- Bypass pipeline design to reduce the risk of providing a suitable habitat for mosquito breeding if there are areas of isolated ponded water which remain in the structure for prolonged periods after flood flows have receded.

7.3 Hydraulic Design

7.3.1 Design Philosophy

The design philosophy established for the project by the Council has been used, in particular:

- The design seeks to return the flood risk in the Flockton Street area to pre-earthquake levels
- The scheme has not be designed to account for the effects of climate change, however the design will be tested for sensitivity and adaptability to climate change and this will be one of the issues considered in the MCA.

To reduce the flood risk Jacobs identified a scheme that widens Dudley Creek significantly, allowing significantly more flow out of the Flockton Street area and lowering water levels in the upstream reaches. This requires significant increases in flow capacity in the downstream system without increasing water levels above current levels. This design philosophy has been adopted and used for the downstream options development.

Even though the philosophy of the scheme has not changed, the concept design has been developed further than is was in 2014 based on additional information regarding constraints, such as land form and landscape values, and an iterative design process. This process has refined the design and identified areas where the scope of work is less than was originally proposed in 2014 while still achieving the same outcome.

7.3.2 Design Process

The hydraulic design process for the downstream options built on the previous peer reviewed modelling and design work carried out by Jacobs.

To achieve the desired outcomes in the upstream catchment, target water levels equivalent to those achieved in the Jacobs Optimised Option 2B model (50-year event) were targeted. To define the target water levels and flows for downstream options, results from Jacobs Optimised Option 2B hydraulic model (hydrographs, water level time series, and flood depth and extent maps) were analysed.

Existing channel cross-sections and alignments, and culvert and bridge dimensions, were refined in the 12d survey model and the hydraulic model to achieve a more detailed and representative hydraulic model. This refinement was achieved through the collation of the Jacobs “current” hydraulics model, existing survey, LiDAR, use of additional topographic survey, and site measurements and investigations.

Concept design was carried out for each of the downstream options for the Dudley Creek channel, bypass culverts, pipes, bridges and other structures using Colebrook-White and Manning’s calculations (in spreadsheets). These designs were then tested in the hydraulic model. Results from the hydraulic modelling were analysed, the design refined, and then retested in the model. This iterative approach was repeated until the desired levels were achieved and the concept designs were finalised.

7.3.3 Model Adaptation

The existing hydraulic model is a coupled DHI MIKE 2D model with three software components:

- MIKE Urban – used for modelling the pipe system (in 1D) and associated hydrology;
- MIKE 11 – used for modelling the waterways (in 1D) and associated hydrology; and
- MIKE FLOOD – used for coupling of 1D elements (MIKE Urban and MIKE 11) to the 2D surface to model overland flow and ponding.

Due to its complexity and the long run times, it was not practicable to use the 1D/2D coupled MIKE hydraulic model to design the downstream options within the required timeframe. Therefore a trimmed 1D model using MIKE 11 was developed using the most recent Jacobs model (Optimised Option 2B), additional survey data and the proposed concept designs. The Jacobs model was trimmed to cover the area affected by downstream options works (Dudley Creek from immediately downstream of the Shirley Stream confluence through to the Avon River), with inflows and boundary conditions from the Jacobs Optimised Option 2B model. In this affected area there is very little overland flow or interaction with the MIKE FLOOD model and therefore this is an appropriate approach at this stage of design.

Inflow hydrographs from the Jacobs MIKE 11 and MIKE Urban models were inserted into the trimmed model, and water level time series at the Avon River discharge points were attached as downstream boundary conditions (these vary with discharge location).

The trimmed model was run and downstream hydrographs and water level time series were compared with the Jacobs full 1D/2D coupled MIKE Optimised Option 2B model. This comparison demonstrated that the trimmed 1D model was of sufficient accuracy for comparison of downstream options. The final design will need to be tested in the coupled 1D/2D hydraulic model.

7.3.4 Option Modelling

To refine the model of the existing Dudley Creek downstream area:

- Channel cross-sections were imported into MIKE 11 from 12d. These 12d cross-sections used all available survey and other ground level data, and were imported at intervals (approximately 10 m) to capture any changes in existing channel shape.
- Private bridges were added to the model, and road culvert and bridge dimensions were checked against site measurements and some recent survey. The channel roughness (Mannings n) was modified in these sections to accommodate this discretisation of the roughness components (previously the private bridges and other local restrictions were allowed for in the model by using a higher overall roughness).
- The downstream end of the existing Dudley Creek was modified to more accurately reflect the hydraulic interaction of Dudley Creek and the Avon River through the residential Red Zone and the existing Avon River stopbank.

For each option, channel widening design was carried out in 12d. The extent of widening was based on a desired cross-section established from capacity calculations (carried out in spreadsheets, using Manning's equation), and considered factors such as cadastral boundaries, road corridors, existing trees (including information from arborist assessments), civil, geotechnical (including slope stability), structural, landscaping, and ecological design. The existing low flow channel was left mostly unmodified, and the design of the low flow channel can be further refined at detailed design to enhance the ecological value. Channel roughness was varied for different reaches in the hydraulic model to reflect the changed design channel cross-sections, hydraulic grade, and proposed landscape design.

Initial pipe and culvert design was also completed using spreadsheet calculations. Where an option includes a pipe bypass, low flow will be maintained through the Dudley Creek channel, with spill into the bypass only during storm events. Suitable hydraulic head loss has been allowed for in the concept design for a spill structure from the channel into the pipe bypass. However, this will require further design at the detailed design stage.

Cross-sections were exported from 12d to MIKE 11, and along with the pipe, culvert and bridge designs these were tested in the trimmed model. Results were then analysed to see if the designs achieved the target water levels. If required, channel and pipe modifications were made and remodelled until design targets were achieved.

7.3.5 Sensitivity Testing & Future Proofing

The Council has requested hydraulic sensitivity testing of the scheme to understand how each option might be affected by climate change (increased rainfall and increase tide levels) and how readily each option can be upgraded to provide a higher future level of service (if required) or modified to respond to climate change. This work is on-going and will be available as an input to the MCA scoring workshop.

8 Options Analysis

8.1 Route Option A

8.1.1 Overview

Option A comprises either a gravity bypass (Option A1) or a pumped bypass (Option A2), both following the same route. In the previous work by Jacobs, Option A1 was referred to as Optimised Option 2.

8.1.2 Option A1 Gravity Bypass

Option A1 comprises a gravity bypass pipe along Warden Street and Shirley Intermediate School re-joining Dudley Creek at the intersection of North Parade and Banks Avenue, and localised bank widening works along Dudley Creek from North Parade to the Avon River.

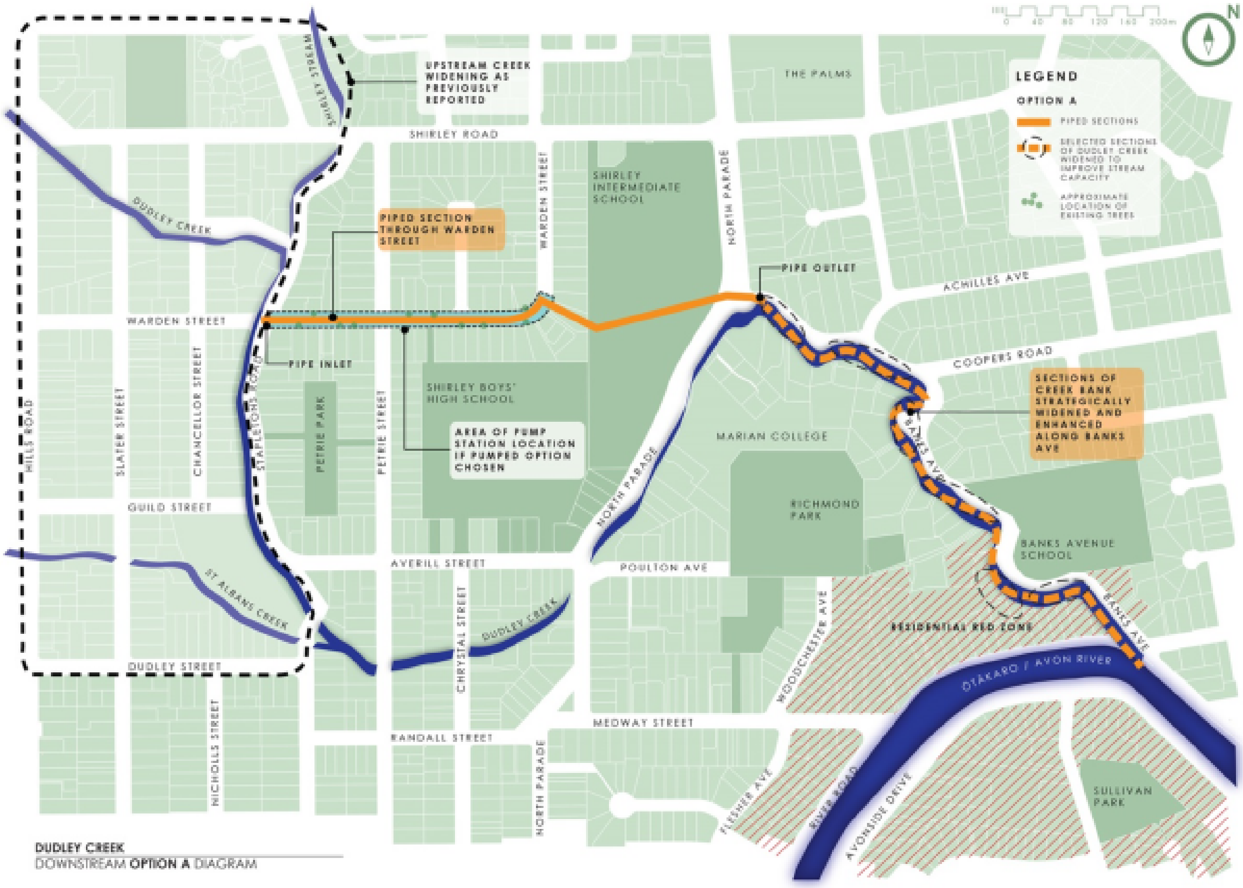


Figure 8-1 Option A Overview

Table 8-1 Option A1 Elements and Description

Element	Description
Gravity Bypass Pipe	■ Inlet structure with bar screen located on Dudley Creek upstream of Warden Street ■ 680m long, 3m wide by 1.5m deep concrete box culvert along Warden Street through the Housing New Zealand property at 98 Warden Street, through Shirley Intermediate School and across North Parade, re-joining Dudley Creek at the intersection of North Parade and Banks Avenue ■ Some tree removal and replacement along Warden Street and in Shirley Intermediate ■ Outlet structure located in Dudley Creek
Bank Widening and Other Works	■ Sections of bank widening to remove 'pinch points' in the channel, targeting public land on the true left bank (left bank looking downstream) in areas of lower landscape value ■ Tree removal and appropriate tree replacement in areas of bank widening ■ New gravel paths in areas of bank widening, ideally extended to meet existing paths where possible ■ Removal and replacement of all nine private bridges with longer and higher structures (all existing bridges create channel restrictions) ■ Possible stopbank along true right side along Residential Red Zone ** ■ Possible replacement of the River Road Bridge at the Dudley Creek confluence with the Avon River **

** Potential works to offset scheme impacts on Residential Red Zone land (refer further discussion below)

8.1.3 Option A2 Pumped Bypass

Option A2 follows the same route, but comprises a pump station with a pressure main bypass pipe along Warden Street and Shirley Intermediate School re-joining Dudley Creek at the intersection of North Parade and Banks Avenue. This options also involves the same localised bank widening works as Option 1 along Dudley Creek from North Parade to the Avon River.

Table 8-2 Option A2 Elements and Description

Element	Description
Pump Station and Intake Structure	■ Inlet structure with bar screen located on Dudley Creek upstream of Warden Street ■ Pump station located along Warden Street (between Dudley Creek and 98 Warden Street)
Pressure Bypass Pipe	■ Up to 680m long, 1.8m outside diameter pipeline along Warden Street through the Housing New Zealand property at 98 Warden Street, through Shirley Intermediate School and across North Parade, re-joining Dudley Creek at the intersection of North Parade and Banks Avenue ■ Some tree removal and replacement along Warden Street and in Shirley Intermediate ■ Outlet structure located in Dudley Creek
Bank Widening and Other Works	■ Same as proposed in Option A1 above

8.1.4 Option A1 and A2 Analysis

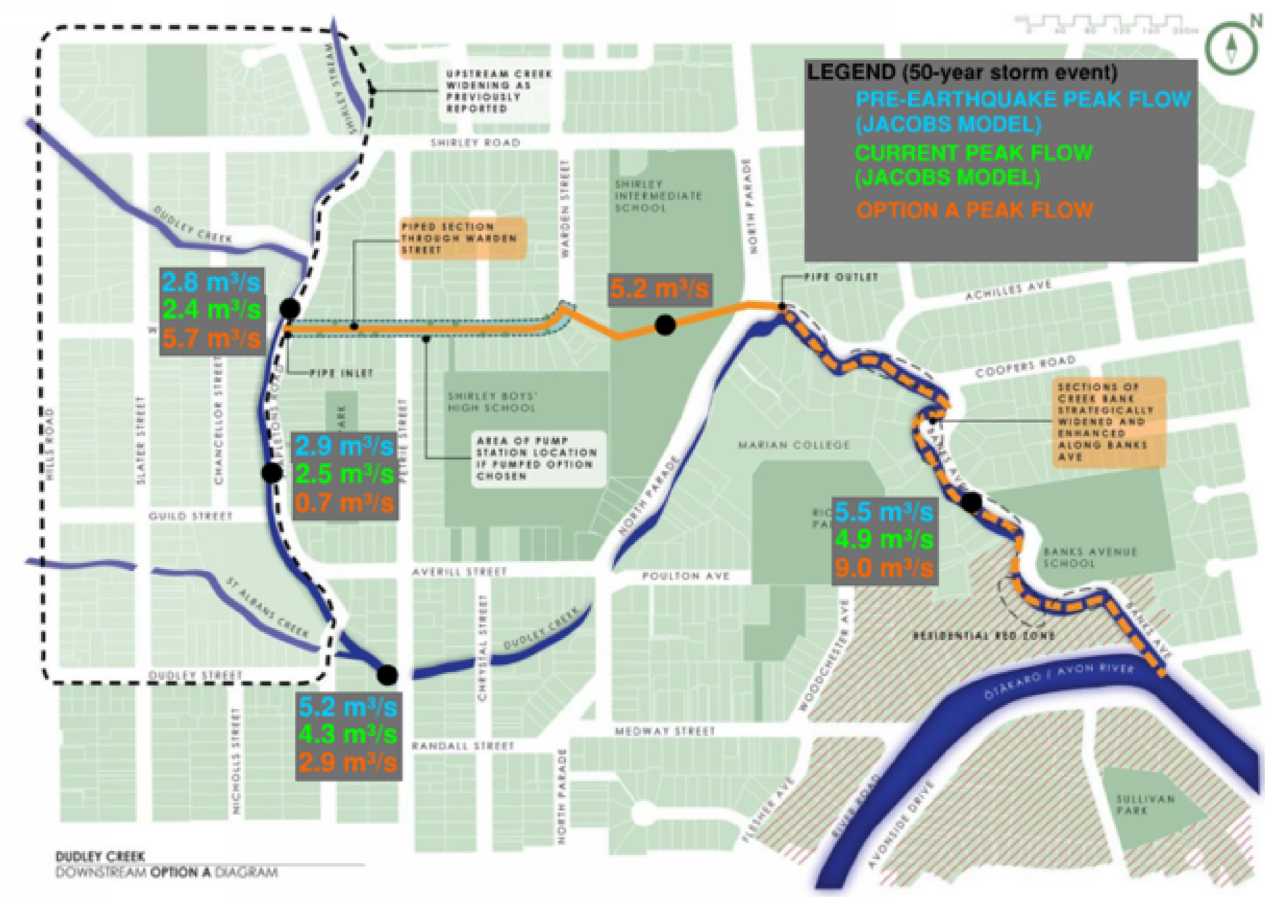
Hydraulic Performance

The desired upstream water levels (consistent with the previous SKM/Jacobs Optimised Option 2 water levels) were achieved. Figure 8-3 shows the upstream peak water levels and peak flow rates at key points along the route for this option, the pre-earthquake case, and the current day case.

Option A reduces the peak flows along Stapletons Road (by diverting flow to the pipe bypass) and lowers the upstream peak water level. The peak flows increase along the Banks Avenue reach however water levels do not increase due to the channel widening.

Note that the peak flows in each portion of the waterway occur at different times during the peak storm event and additional flows come into the network between flow locations shown. For this reason the flows cannot simply be added together to calculate the peak flow when waterways meet.

Figure 8-3 Option A Summary of Hydraulic Results – 50-Year Event



Property Requirements

The property requirements associated with this option are described in Table 8-4.

Table 8-4 Summary of Option A Property Discussions

Property	Owner	Requirements and Status of Discussions
98 Warden Street	Housing New Zealand (HNZ)	The Council would need to purchase this property The Council has been in discussion with HNZ about this property
Shirley Intermediate School	Crown (Ministry of Education)	Access required for construction and 10m wide (to be confirmed) easement required for ongoing operations and maintenance MOE has been approached and has given agreement in principle
Owners / Part Owners of Private Bridges Along Banks Avenue	Multiple owners (and potential multiple owners for each bridge)	Agreements and access to replace private bridges The Council has not yet formally approached any owner regarding bridge replacement
Residential Red Zone on Banks Avenue	Crown (Canterbury Earthquake Recovery Authority)	Agreements for access and on-going use of red zone for Dudley Creek widening (true right bank) and for additional flood flow across low lying red zone land The Council is in on-going discussion with CERA

Works in Residential Red Zone

The concept design includes work in the Residential Red Zone. Firstly it requires bank widening in the residential red zone on the true right of Dudley Creek.

It also impacts on the low-lying red zone land on the west side of Dudley Creek close to the Avon River, currently subject to flooding from Dudley Creek and the Avon River. The construction of the bypass and widening of Dudley Creek significantly increases storm flows along lower Dudley Creek, resulting in more frequent flooding and increased flow onto red zoned land. CERA has indicated that this may compromise future use of the land, noting future use of all red zoned land is subject to public consultation. Assuming the project needs to avoid adverse impact on the land, the concept design estimates include stop banking along the true right bank and enlargement of the River Road Bridge to enable the full flow to pass through Dudley Creek without increasing the current water levels in Dudley Creek.

Council and Utility Services

A number of services need to be temporarily or permanently relocated to construct the bypass pipeline. The major works for this option are:

- The pipeline clashes with an existing 450mm gravity wastewater line running south along Petrie Street. There are a number of options for this crossing, and the cost estimate is based on re-laying the wastewater main as a siphon below the new pipeline with a drop and a riser manhole either side
- The pipeline clashes with multiple services where is crosses North Parade. It is likely the pipeline can be trenched across North Parade and allowance for additional traffic management and services relocations are included in the estimates. An alternative option is to thrust the pipeline across North Parade.

Long Term Sustainability

Future proofing: Hydraulic sensitivity testing (refer Section 7.3.5) is still to be undertaken to assess whether this option could be upgraded to provide a greater level of service in the future, if that is ever necessary. This work will be available before the MCA workshop.

Climate change: Hydraulic sensitivity testing will also assess how resilient this option is with respect to climate change.

Seismic resilience: Refer section 7.1.12.

Maintenance

The primary maintenance activity associated with the Option A1 gravity pipeline is keeping the inlet and outlet clear and cleaning the pipe of silt. Option A is the shortest of the three bypasses so maintenance requirements are anticipated to be somewhat lower.

For Option A2 less pipeline maintenance will be required as the pipeline will operate at a self-flushing velocity. However the pump station will require normal regular maintenance.

Ecology

This option provides the opportunity to improve the condition of Dudley Creek and its riparian zone along Banks Avenue, which will have a long-lasting ecological benefit to the stream and wider environment.

The loss of trees as part of flood channel widening along Banks Ave will have a temporary impact on terrestrial ecology. This will be rectified in the long-term with the establishment of new trees, and with additional groundcover planting along the stream edge. Retaining key areas of native tree clusters, wherever possible, that are utilised by resident native birds will also help to retain some of the existing habitat and food resources for native birds in the area.

Landscape

The proposed bank widening along Banks Avenue has been targeted for areas of public land where existing tree health is the most compromised, and any required removal of healthy, long-life trees is minimised.

Approximately 108 trees and shrub groups will need to be removed along the Banks Avenue bank due to the required widening. Of these 41 have a short-term life expectancy, 33 have a medium-term life expectancy, and 34 have a long-term life expectancy.

The work proposed along Warden Street has the potential to impact on 10 existing flowering cherries and kowhai street trees. These trees have been assessed as being in poor condition with a short-term life expectancy. Any trees impacted by the works will be replaced.

The removal of any existing trees, whether they have short to long term life expectancy will have an obvious and immediate visual impact on the existing landscape on Banks Avenue in the short to medium term. The proposed tree replacement program, combined with the additional riparian and upper bank planting will provide enhanced landscape values and character in the medium to long term from that currently existing.

Where possible, a semi-mature tree will be planted for every tree that is removed. The aim is to plant the right tree in the right location – soil, moisture and tidal impacts will determine their appropriate placement on the bank. The immediate replanting with the works will ensure the current character will return in the medium term (10–20 years). The remaining trees will ensure the habitat values for bird and insect life is retained.

Refer to the Arboricultural Report in Appendix B and the Existing Tree and Ecology Plans in Appendix F for further details.

Consenting

Option A involves the following activities relating to the bypass of floodwater which have an impact on the consenting for this option:

- Permanent diversion of flood flows from Dudley Creek via a bypass and subsequent discharge to the Avon River
- Earthworks/excavation of land to construct the bypass
- Works in Dudley Creek and the Avon River to construct the inlet and outlet structures
- Temporary dewatering, damming or diverting of water and associated discharges back to the waterway during construction

Option A involves further activities in the bed and on the bank of Dudley Creek along Banks Avenue including:

- Narrowing of the low flow channel to improve habitat values
- Widening of waterways by re-grading or re-profiling the banks above waterline
- Removal of existing and erection of new retaining walls, bank protection and culverts
- Removal of existing and erection of new private access bridges
- Removal of trees and vegetation (both protected and non-protected)
- Landscaping/replanting and naturalisation of banks, and where feasible, informal or formal public paths.

The consenting impacts of Option A include bypassing floodwater and changes to the bed and banks of the waterway adjacent Banks Ave.

Risk

The key risks associated with Option A relate to delays with obtaining property agreements, CERA approval to use the red zone and requirements for removal of trees.

8.2 Route Option B

8.2.1 Overview

In 2014 the Council identified a potential alternative piped bypass route along Warden Street, through Shirley Intermediate School, Marian College, Richmond Park and the Residential Red Zone to the Avon River. An alternative alignment which avoids Residential Red Zoned land (through Richmond Park and along Medway Street to the Avon River) was also developed in case access to the red zone is not possible.

Options B1 and B2 follow the same, more direct, bypass route through the Residential Red Zone. Option B1 is a gravity bypass and Option B2 is a pumped bypass.

Options B3 and B4 follow the same, less direct, bypass route avoiding the Residential Red Zone. Option B3 is a gravity bypass and Option B4 is a pumped bypass.

8.2.2 Option B1 / B3 Gravity Bypass

Option B1 and B3 comprise a piped route along Warden Street, through Shirley Intermediate School, Marian College, Richmond Park and the Residential Red Zone (Option B1) or along Medway Street (Option B3) to the Avon River.

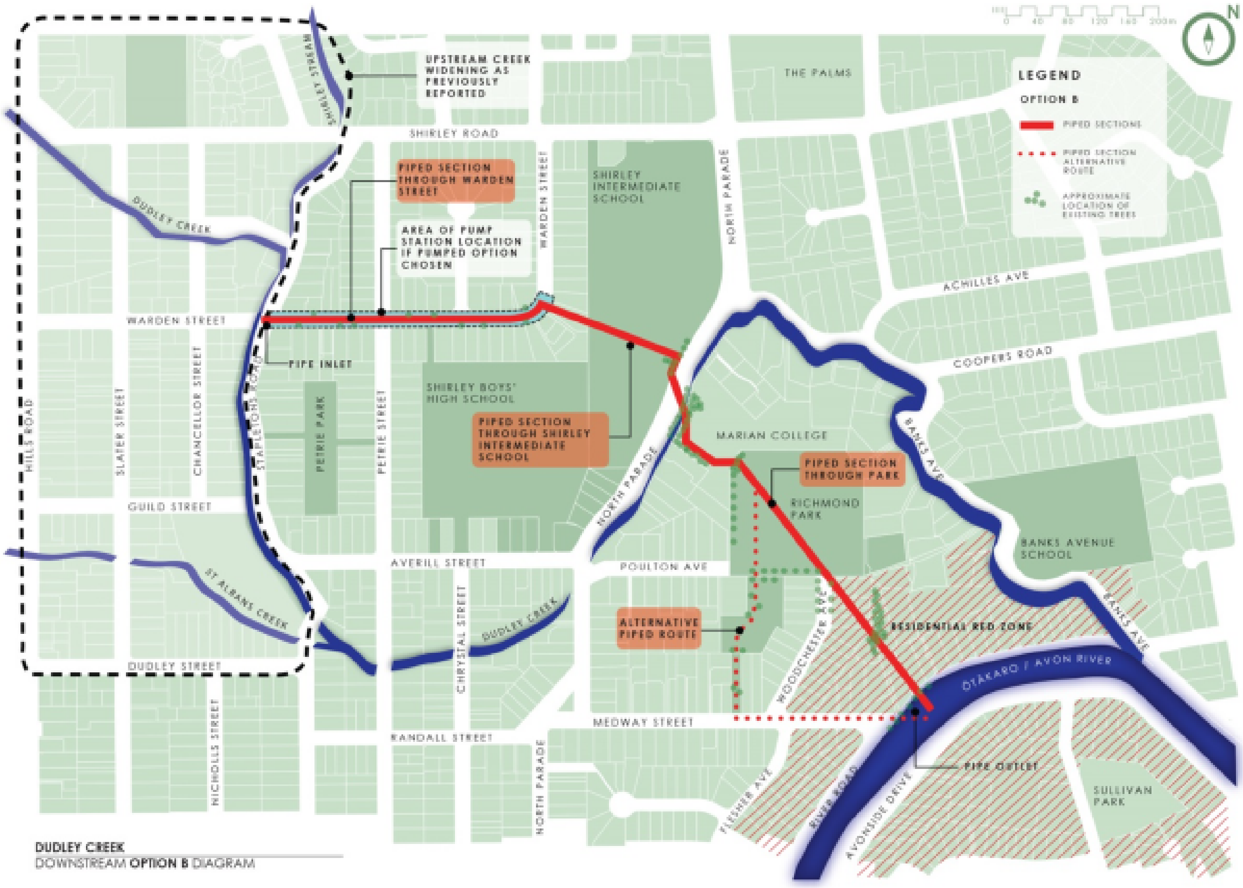


Figure 8-2 Option B Overview

Table 8-5 Option B1/B3 Elements and Description

Element	Description
Gravity Bypass Pipe	■ Inlet structure with bar screen located on Dudley Creek upstream of Warden Street ■ 1160m long, 3m wide by 1.5m deep concrete box culvert along Warden Street through the Housing New Zealand property at 98 Warden Street, through Shirley Intermediate School and across North Parade, through Marian College, Richmond Park and the residential red zone (B1) or along Medway Street (B3) to the Avon River ■ The alignment crosses Dudley Creek between Shirley Intermediate and Marian College; and there are two options for this crossing: – Constructing a siphon beneath the creek (at this stage nominally a 2.5m diameter steel pipe jacked beneath North Parade and Dudley Creek based on discussions with a specialist drilling contractor, with access points at either end), or – Breaking the bypass at the creek, with a discharge structure on the North Parade side and an intake structure on the Marian College side Both options have been modelled and can be made to work, however more design work and discussion with landowners is required to confirm the best approach. The

Element	Description
	cost estimate includes the siphon option ■ Some tree removal and replacement along Warden Street, in Shirley Intermediate, in Marian College, Richmond Park and on River Road ■ Outlet structure located in the Avon River on River Road

8.2.3 Option B2 / B4 Pumped Bypass

Options B2 and B4 follow the same route, but comprise a pump station with a pressure main bypass pipe along Warden Street, through Shirley Intermediate School, Marian College, Richmond Park and the Residential Red Zone (Option B2) or along Medway Street (Option B4) to the Avon River.

Table 8-6 Option B2/B4 Elements and Description

Element	Description
Pump Station and Intake Structure	■ Inlet structure with bar screen located on Dudley Creek upstream of Warden Street ■ Pump station located along Warden Street (between Dudley Creek and 98 Warden Street)
Pressure Bypass Pipe	■ 1340m long, 2m diameter polyethylene pressure pipeline along Warden Street through the Housing New Zealand property at 98 Warden Street, through Shirley Intermediate School and across North Parade, through Marian College, Richmond Park and the residential red zone (B2) or along Medway Street (B4) to the Avon River ■ The alignment crosses Dudley Creek between Shirley Intermediate and Marian College via a 2m diameter siphon beneath the creek (at this stage nominally a 2m diameter steel pipe jacked beneath North Parade and Dudley Creek based on discussions with a specialist drilling contractor ■ Some tree removal and replacement along Warden Street, in Shirley Intermediate, in Marian College, Richmond Park and on River Road ■ Outlet structure located in the Avon River on River Road

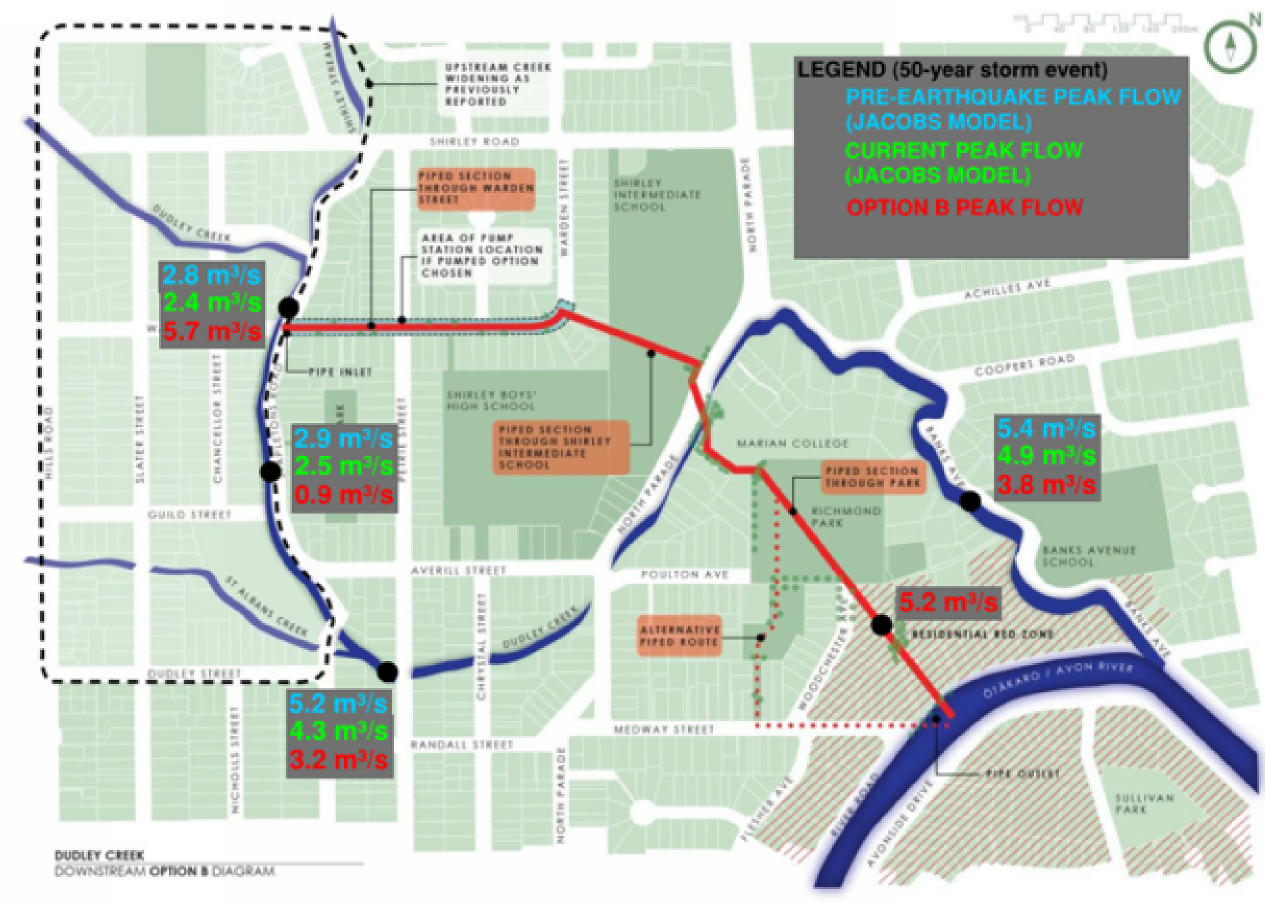
8.2.4 Option B1 to B4 Analysis

Hydraulic Performance

The desired upstream water levels (consistent with the previous SKM/Jacobs Optimised Option 2 water levels) were achieved. Figure 8-7 shows the upstream peak water levels and peak flow rates at key points along the route for this option, the pre-earthquake case, and the current day case.

Note that the peak flows in each portion of the waterway occur at different times during the peak storm event and additional flows come into the network between flow locations shown. For this reason the flows cannot simply be added together to calculate the peak flow when waterways meet.

Figure 8-3 Option B Summary of Hydraulic Results – 50-Year Event



Option B reduces the peak flow along Stapletons Road and Banks Avenue (by diverting flow into the bypass pipeline direct to the Avon River), while lowering the upstream peak water level.

Property Requirements

The property requirements associated with these options are described in Table 8-7.

Table 8-7 Summary of Option B Property Discussions

Property	Owner	Requirements and Status of Discussions
98 Warden Street	Housing New Zealand (HNZ)	The Council would need to purchase this property HNZ has been approached about this property and await further advice from the Council
Shirley Intermediate School	Crown (Ministry of Education)	Access required for construction and 10m wide (to be confirmed) easement required for ongoing operations and maintenance MOE has been approached and has given agreement in principle

Property	Owner	Requirements and Status of Discussions
Former Marian College site	Catholic Diocese of Christchurch	Access required for construction and 10m wide (to be confirmed) easement required for ongoing operations and maintenance The Council is in on-going discussion with the Catholic Diocese regarding this option
Richmond Park	Christchurch City Council	Access required for construction for ongoing operations and maintenance Council Parks and Recreation has been approached and has given approval in principle subject to understanding design and construction details and timeframes
Residential Red Zone between Richmond Park and the Avon River (Options B1 and B3 only)	Crown (Canterbury Earthquake Recovery Authority)	Agreements for access and on-going use of red zone for pipeline The Council is in on-going discussion with CERA

Works in Residential Red Zone

Option B1 and B3 involve construction of a pipeline across Residential Red Zone land. Options B2 and B4 are alternative options that avoid the need to use red zone.

At this stage the future use of the Residential Red Zone is still to be considered by CERA in discussion with other agencies and the public, and this may limit CERA's ability to consent to a pipeline across the land. The Council is in on-going discussion with CERA about these options.

Council and Utility Services

A number of services need to be temporarily or permanently relocated to construct the bypass pipeline. The major works for this option are:

- The pipeline clashes with existing the 450mm gravity wastewater line running south along Petrie Street. There are a number of options for this crossing and the estimate is based on re-laying the wastewater main as a siphon below the new pipeline with a drop manhole and a riser manhole on either side

- The pipeline clashes with multiple services where is crosses North Parade. There are numerous services here and the cost estimate allows for the pipeline to be installed by pipe jacking, deep enough to avoid services clashes and pass under Dudley Creek.

Long Term Sustainability

As with Option A, hydraulic sensitivity testing is still to be undertaken to assess whether this option could be upgraded to provide a greater level of service in the future, if that is ever necessary, and to assess how resilient this option is with respect to climate change.

Seismic Resilience: In addition to the general resilience consideration described in section 7.1.12, if the pipeline crosses under Dudley Creek via a siphon there are risks associated with lateral spreading of the creek banks damaging the siphon and siphon access points.

Maintenance

As with Option A the primary maintenance activities associated the gravity pipeline are keeping the inlet and outlet clear and cleaning the pipe of silt. The Option B bypasses are significantly longer than the other options (1160-1340m compared with 680-780m) and may also include a siphon beneath Dudley Creek / North Parade and maintenance requirements are likely to be higher.

Ecology

This option incorporates minor changes to the waterway at the location of the intake and outlet structures. As this option does not incorporate other works to the stream, it removes the opportunity to provide enhancements to the waterway and hence the option has little ecological impact, either negative or positive.

Landscape

Although the design will seek to minimise the impact on trees, some tree removal will be required.

As with Option A, the work proposed along Warden Street may impact on 10 existing flowering cherries and kowhai street trees. These trees have been assessed as being in poor condition with a short-term life expectancy and may be replaced as part of the project.

Five trees in Shirley Intermediate School beside North Parade will also need to be removed.

There are two areas where the pipe route is still being finalised through discussions with landowners and other stakeholders; the route through Marian College and Richmond Park. For that reason, the exact numbers of trees to be affected is still to be determined. However it is estimated that 22 trees will need to be removed in Marian College land, and a further 6 trees will need to be removed within Richmond Park.

One tree will need to be removed on River Road beside the Avon River.

While this option has the least impact on existing landscape values and character, it also provides no opportunity for improvements to the existing landscape values and character of Dudley Creek along either Banks Avenue or Stapletons Road.

Refer to the Arboricultural Report in Appendix B and the Existing Tree and Ecology Plans in Appendix F for further details.

Consenting

Option B involves the following activities relating to the bypass of floodwater which have an impact on the consenting for this option:

- Permanent diversion of flood flows from Dudley Creek via a bypass and subsequent discharge to the Avon River
- Earthworks/excavation of land to construct the bypass
- Works in Dudley Creek and the Avon River to construct the inlet and outlet structures
- Temporary dewatering, damming or diverting of water and associated discharges back to the waterway during construction

Overall, this option requires fewer consents than Options A or C as there are only minor works within the existing waterway.

Risk

The key risks associated with Option B relate to delays associated with property agreements, use of the Residential Red Zone (B1 / B3), the difficulty (and therefore cost risk) of crossing North Parade and Dudley Creek, and construction of a significantly longer bypass.

8.3 Route Option C

8.3.1 Overview

Option C comprises either a gravity bypass (Option C1) or a pumped bypass (Option C2), both following the same route.

8.3.2 Option C1 Gravity Bypass

Option C1 comprises sections of channel widening works to Dudley Creek adjacent to Stapletons Road between Warden Street and Petrie Street, with a piped gravity bypass running south along Petrie Street and east along Randall Street and Medway Street to the Avon River.

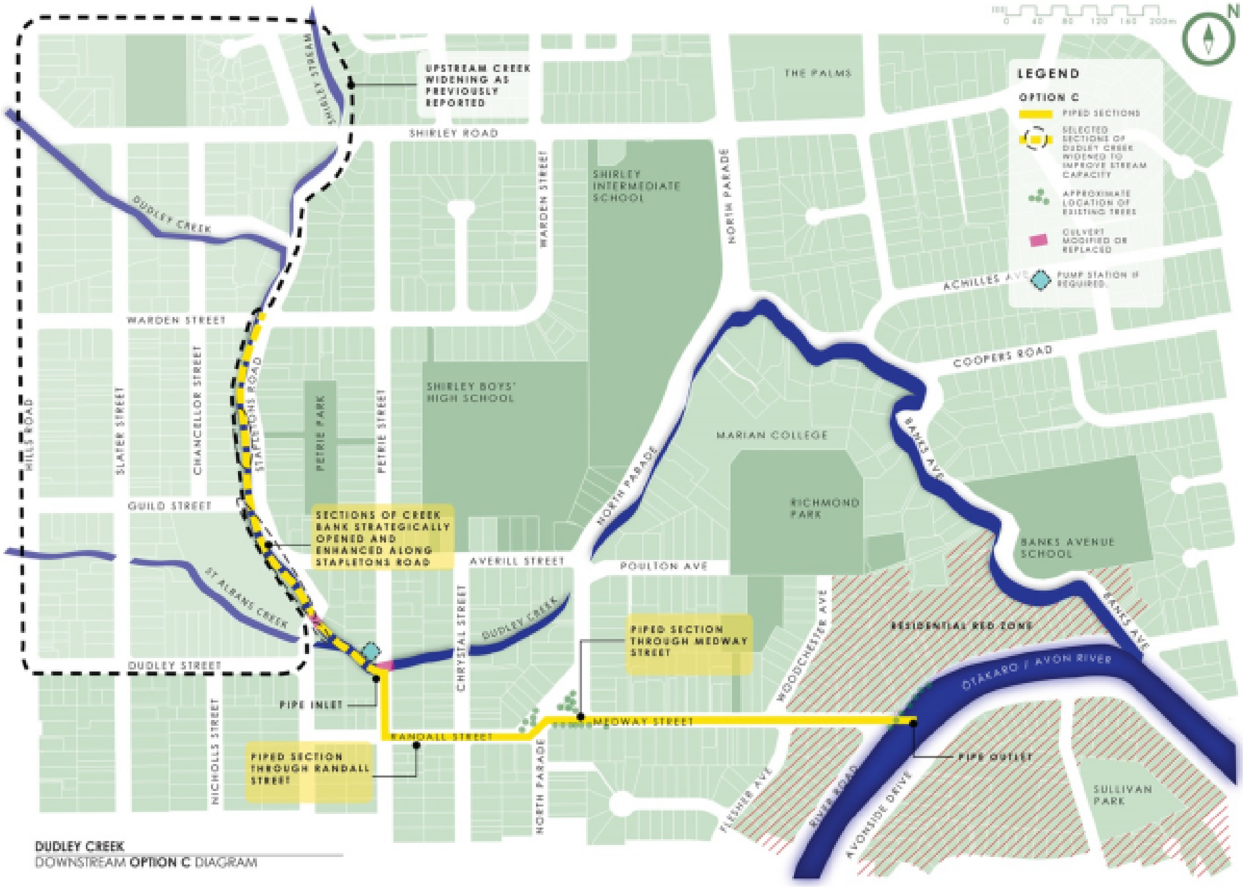


Figure 8-4 Option C Overview

Table 8-8 Option C1 Elements and Description

Element	Description
Stapletons Road Bank Widening and Other Works	■ Sections of bank widening to remove 'pinch points' in channel, generally targeted for public land on the true left bank in areas of lower landscape value. Note however that there are opportunities to reduce tree removal and improve the overall landscape outcomes, by working with landowners beside the waterway to identify areas where the stream could be widened on the true right bank in private land, rather than on the true left bank. These opportunities will be explored during the consultation period. ■ Widening the section of Dudley Creek between Stapletons Road and Petrie Street which requires access to private land ■ Tree removal and appropriate tree replacement in areas of bank widening ■ New gravel paths in areas of bank widening, ideally extended to meet existing paths where possible ■ Removal and replacement of two private bridges with longer and higher structures ■ Enlargement of the Stapletons Road culvert on Dudley Creek
Gravity Bypass Pipe	■ Inlet structure with bar screen located on Dudley Creek upstream of Petrie Street and modifications to existing Petrie Street culvert to tie in the new inlet ■ 780m long, 4m wide by 1.5m deep concrete box culvert along Petrie Street, Randall Street and Medway Street to the Avon River The culvert is larger and passes higher flows (4m wide compared to 3m wide in Options A and B) due to the need to pull Creek water levels down further at Petrie Street to achieve target water levels at Warden Street. The lower water level at Petrie Street reduces hydraulic grade (and therefore flow) in lower Dudley Creek ■ Some tree removal and replacement at the Medway Street / North Parade intersection ■ Outlet structure with bar screen located in the Avon River

8.3.3 Option C2 Pumped Bypass

Option C2 follows the same route, but comprises a pump station with a pressure main bypass pipe along Petrie, Randall and Medway Street discharging to the Avon River. This options also involves localised bank widening works along Dudley Creek on Stapletons Road from Warden Street to Petrie Street.

Table 8-9 Option C2 Elements and Description

Element	Description
Pump Station and Intake Structure	■ Inlet structure with bar screen located on Dudley Creek upstream of Petrie Street and modification of Petrie Street culvert to tie in to new inlet ■ Pump station located on Council land at 65 Petrie Street
Stapletons Road Bank Widening and Other Works	■ As described in Option C1 above

Element	Description
Pressure Bypass Pipe	■ Inlet structure with bar screen located on Dudley Creek upstream of Petrie Street and modifications to existing Petrie Street culvert to tie in the new inlet ■ Up to 780m long, 2m diameter pressure pipe along Petrie Street, Randall Street and Medway Street to the Avon River ■ Some tree removal and replacement at the Medway Street / North Parade intersection ■ Outlet structure with flap gate located in the Avon River

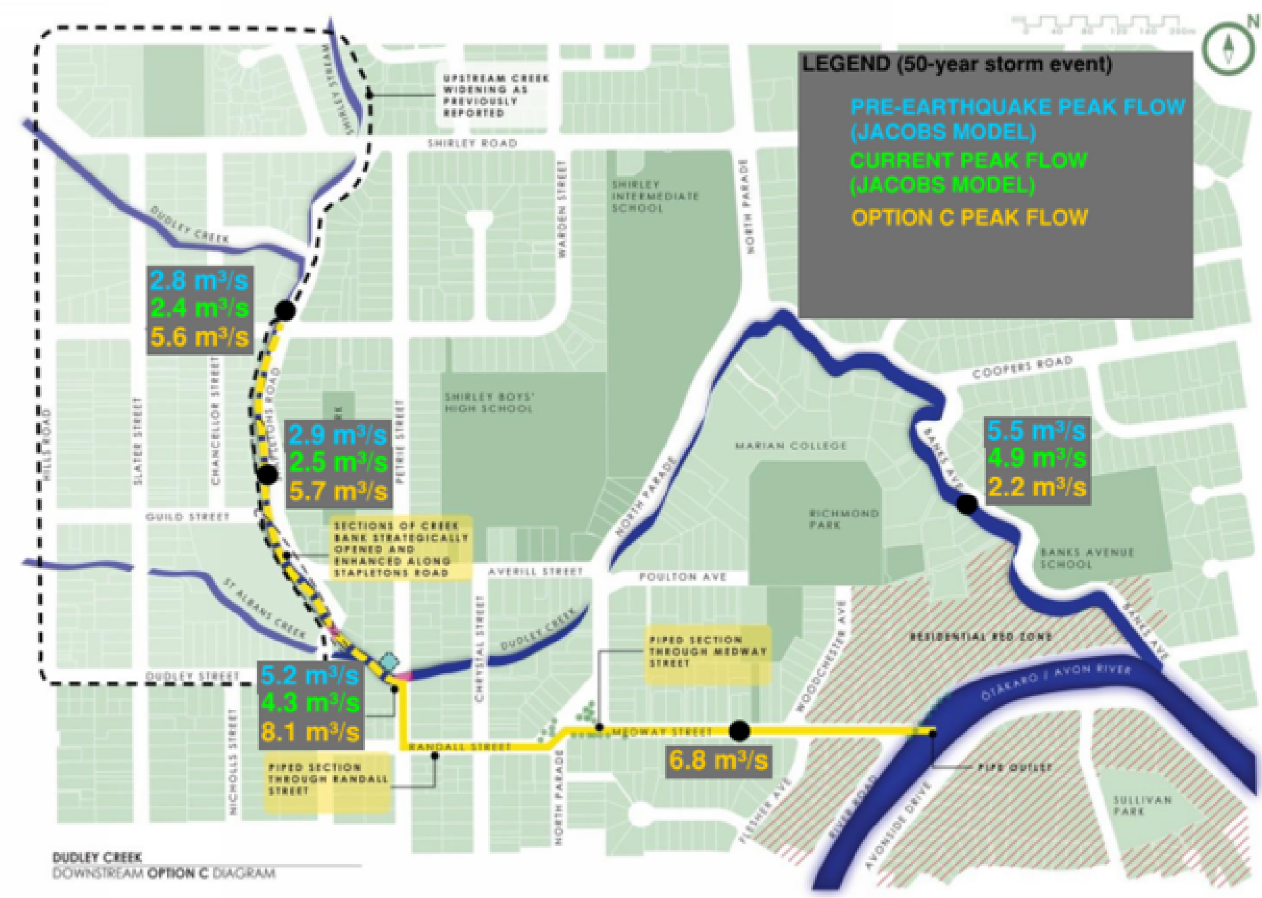
8.3.4 Option C1 and C2 Analysis

Hydraulic Performance

The desired upstream water levels (consistent with the previous SKM/Jacobs Optimised Option 2 water levels) were achieved. Figure 8-11 shows the upstream peak water levels and peak flow rates at key points along the route for this option, the pre-earthquake case, and the current day case.

Note that the peak flows in each portion of the waterway occur at different times during the peak storm event and additional flows come into the network between flow locations shown. For this reason the flows cannot simply be added together to calculate the peak flow when waterways meet.

Figure 8-10 Option C Summary of Hydraulic Results – 50-Year Event



Option C increases the peak flow (but lowers water levels as much or more than Options A and B) along Stapletons Road. The peak flow along Banks Avenue reduces (as flow is diverted into the bypass pipeline direct to the Avon River).

Property Requirements

The property requirements associated with this option are described in Table 8-11.

Table 8-11 Summary of Option C Property Discussions

Property	Owner	Requirements and Status of Discussions
Owners / Part Owners of Private Bridges Along Stapletons Road	Multiple owners	Agreements and access to replace private bridges The Council has not yet formally approached any owner regarding bridge replacement
Owners along Dudley Creek along Stapletons Road and Petrie Street	Multiple owners	Agreement for access and widened waterway within private land The Council has not yet formally approached any owner regarding access or widening

Works in Residential Red Zone

No work is required in the residential red zone for these options.

Council and Utility Services

A number of services need to be temporarily or permanently relocated to construct the bypass pipeline. The major works for this option are:

- The pipeline runs parallel to the Council's Northern Relief trunk gravity wastewater main on Randall Street between Petrie Street and North Parade. The concept design shows there is adequate room to run both services in parallel, although a number of local wastewater and water mains will need to be relocated to create a sufficient corridor. Initial discussions with the wastewater asset team indicated approval in principle with this approach, with formal approval being subject to receiving more detailed design information to review.

- The pipeline clashes with multiple services where it crosses North Parade. It is considered that the pipeline can be 'open cut' with appropriate traffic management.

Long Term Sustainability

Hydraulic sensitivity testing is still to be undertaken to assess whether this option could be upgraded to provide a greater level of service in the future, if that is ever necessary, and to assess how resilient this option is with respect to climate change.

Seismic Resilience: Refer section 7.1.12.

Maintenance

The primary maintenance activity associated with the Option C1 gravity pipeline is keeping the inlet and outlet clear and cleaning the pipe of silt. The Option C bypass is significantly shorter than the Option B bypasses (780m compared with 1160-1340m) so maintenance requirements will be lower.

For Option C2 less pipeline maintenance will be required as the pipeline will operate at a self-flushing velocity. However the pump station will require normal regular maintenance.

Ecology

The ecological impacts of Option C are similar to Option A in that it provides the opportunity to greatly improve the condition of Dudley Creek and its riparian zone, which will have a long-lasting ecological benefit to the stream and wider environment.

The loss of trees as part of flood channel widening along Stapletons Road will have less of a short term impact on terrestrial ecology as there are fewer trees overall, and specifically fewer native trees, affected by the works. Native birds in the area are likely to make use of the native trees on the west (i.e. privately owned) side of the stream which are not proposed to be affected by the works. The proposed plans will not impact on the majority of the swamp cypress trees which are used as roosting sites by overwintering monarch butterflies.

Landscape

The proposed bank widening along Stapletons Road has been targeted for areas of public land where existing tree health is the most compromised, and any required removal of healthy, long-life trees is minimised.

Approximately 63 trees and shrub groups will need to be removed along Stapletons Road. Of these, 28 have a short-term life expectancy, 18 have a medium-term life expectancy, and 17 have a long-term life expectancy.

Six trees will need to be removed at the intersection of North Parade, Medway Street and Randall Street, however the most significant trees will be retained. One tree will need to be removed on River Road close to the Avon River.

The removal of any existing trees, whether they have short to long term life expectancy will have an obvious and immediate visual impact on the existing landscape on Stapletons Road in the short to medium term. The proposed tree replacement program, combined with the additional riparian and upper bank planting will provide enhanced landscape values and character in the medium to long term from that currently existing.

Where possible, a semi-mature tree will be planted for every tree that is removed. The aim is to plant the right tree in the right location – soil, moisture and tidal impacts will determine their appropriate placement on the bank. The immediate replanting with the works will ensure the current character will return in the medium term (10–20 years). The remaining trees will ensure the habitat values for bird and insect life is retained.

Refer to the Arboricultural Report in Appendix B and the Existing Tree and Ecology Plans in Appendix F for further details.

Consenting

Option C involves the following activities relating to the bypass of floodwater which have an impact on the consenting for this option:

- Permanent diversion of flood flows from Dudley Creek via a piped bypass and subsequent discharge to Dudley Creek
- Earthworks/excavation of land to construct the bypass
- Works in Dudley Creek to construct the inlet and outlet structures
- Temporary dewatering, damming or diverting of water and any associated discharges back to the waterway during construction.

Option C involves further activities in the bed and on the bank of Dudley Creek along Stapletons Road including:

- Narrowing of the low flow channel to improve habitat values
- Widening of waterways by re-grading or re-profiling the banks above waterline
- Removal of existing and erection of new retaining walls, bank protection and culverts
- Removal of existing and erection of new private access bridges
- Removal of trees and vegetation (both protected and non-protected)
- Landscaping/replanting and naturalisation of banks, and where feasible, informal or formal public paths.

The consenting impacts of Option C are similar to those of Option A as the activities include bypassing floodwater and changes to the bed and banks of the waterway adjacent Stapletons Road.

Risk

The key risks associated with Option C relate to delays with obtaining property agreements, and requirements for removal of trees.

9 Costs

Cost estimates have been produced based on the concept level designs for the purposes of option comparison. The estimates have been built up using benchmarked rates from recent, comparable projects, together with appropriate factors to present concept design level costs for the alignments and construction methodologies.

The Council engaged Bond CM to prepare parallel cost estimates based on Beca quantity take-offs. The Council, Bond CM and Beca met to compare the Beca and Bond CM estimates, areas of differences were explored and the estimates were then adjusted.

The comparative estimated costs for the proposed alignment options are shown in Table 9-1 below, and range from $26 million for the shortest gravity bypass option (C1) to $39 million for the longest pumped option (B4).

Table 9-1 Summary of Comparative Cost Estimates

Alignment A		Alignment B1/B3 (short)		Alignment B2/4 (long)		Alignment C	
A1 Gravity	**A2 Pumped**	**B1 Gravity**	**B2 Pumped**	**B3 Gravity**	**B4 Pumped**	**C1 Gravity**	**C2 Pumped**
$27.7M	**$32.5M**	**$28.8M**	**$35.9M**	**$32M**	**$39.2M**	**$26.2M**	**$30.5M**

A further breakdown is shown in Table 9-2 below:

Table 9-2 High-level Breakdown of Costs

ITEM	Alignment A		Alignment B (short)		Alignment B (long)		Alignment C	
	Gravity	Pumped	Gravity	Pumped	Gravity	Pumped	Gravity	Pumped
TOTAL CONSTRUCTION BUDGET	$15,990,000	$20,670,000	$17,530,000	$24,245,500	$19,820,000	$26,720,000	$15,131,000	$19,370,000
RISK CONTINGENCY (incl FOREX)	$4,800,000	$4,210,000	$5,260,000	$5,020,000	$5,950,000	$5,540,000	$4,540,000	$3,960,000
CORRIDOR RISK	$3,120,000	$3,730,000	$2,280,000	$2,930,000	$2,580,000	$3,230,000	$2,950,000	$3,490,000
PROFESSIONAL FEES	$3,000,000	$3,000,000	$3,000,000	$3,000,000	$3,000,000	$3,000,000	$3,000,000	$3,000,000
PROPERTY COSTS	$820,000	$810,000	$720,000	$710,000	$720,000	$690,000	$570,000	$570,000
TOTAL COMPARATIVE COST	**$27,730,000**	**$32,420,000**	**$28,790,000**	**$35,910,000**	**$32,070,000**	**$39,180,000**	**$26,190,000**	**$30,390,000**
TOTAL ALIGNMENT COMPARATIVE RANGE	**$27.7M**	**$32.5M**	**$28.8M**	**$35.9M**	**$32M**	**$39.2M**	**$26.2M**	**$30.5M**

Design and construction contingency allowances of 20% and 30% were made to reflect current stage and nature of the design & methodologies.

Additional corridor risk allowances were made to reflect the unique challenges and risks associated with each alignment that may affect the final construction cost.

Cost risks include additional delay and cost in obtaining access from private property owners, working in residential areas and areas with high amenity values, risk of additional cost in pipe and culvert installation, trenchless pipe installation, risk of pump station design and location, additional cost in relocating or replacing existing underground services infrastructure including siphons, culverts and below-ground pump stations, additional delay and cost in stream widening works and bridge replacements.

Opportunities identified include alternative pipe/culvert materials and design, alternative trenchless installation, and possibility of increased productivities in grassland / park areas.

The following items of work or likely project costs are excluded from our estimate but should be considered when establishing the likely project budget:

- Goods and Services Tax (GST)
- Legal fees, accounting and finance costs, and cost of capital
- Construction cost escalation beyond the date of this report
- Development levies and contributions, resource consents
- Compensation for impacts upon private/other entities/business affected by the works
- The cost of the upstream works.

10 Conclusion and Recommendations

This section to be written following the MCA workshop.