Dudley Creek

CHRISTCHURCH CITY COUNCIL

Upgrade Options Feasibility Assessment Report

Rev A

Land Drainage Recovery Programme: Investigation into Desired Profile for Upstream Rivers and Tributaries

26 March 2014

Christchurch City Council

JACOBS SKM

Dudley Creek Options Feasibility Assessment

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Contents

Executive summary

Following the Christchurch earthquakes, the drainage network in the Dudley Creek catchment has suffered a considerable loss in capacity. This has increased the frequency and severity of flooding particularly in the Flockton Street area, Hills Road Shopping Centre, Slater Street and Stapletons Road.

The primary cause of the reduced capacity is the loss of ground elevation through land settlement. Other contributing effects include the narrowing of watercourses from lateral spread of stream banks, bed heave and sedimentation of the stream bed.

In parallel to earthquake recovery waterway maintenance work Council has been investigating capacity upgrade options. In 2013, two preferred options were identified for feasibility design and assessment:

Option 1 - Major upgrading of the existing waterway capacity

Option 2 - Pump station, gravity piped diversion and lessor upgrading of the waterway capacity

The feasibility design and assessment process was in progress when the major flood of March 2014 occurred. In order to assist Council to make early decisions on a preferred capacity upgrade approach, the feasibility design was accelerated with this report and its appendices summarising the feasibility design and assessment process.

In summary the feasibility design and assessment process has determined that:

1. Option 1 and Option 2 both achieve restoration of pre-earthquake flooding risks to much of the catchment, however for both options, there will be residual street and property flooding

2. Option 1 and Option 2 have comparable preliminary all-inclusive implementation budgets of $50M (with a confidence of +30% -10%) and $53M (with a confidence of +40% -20%) respectively

3. Option 1 and Option 2 have differing implementation risk and performance resilience profiles

The principle implementation and performance resilience risks for the two options are summarised as:

Option 1 – Increased Channel Capacity

- Potentially 115 property access agreements will be required to implement the watercourse upgrading works. 29 private bridge replacements are required. It will be possible to stage the construction works as access agreements are obtained but this will incur additional costs. Failure to implement small portions of the works will reduce the effectiveness of the whole scheme.
- Watercourse upgrade works are significant, with approximately 35,000m3 of earth to be excavated and removed and approximately 3.5km of watercourse affected. A considerable portion of the mature, significant and protected trees adjacent to the stream will be removed.
- Culvert replacements require consent but have no private property risks. Construction will have potential traffic, community and environmental risks that will require management through good consultation and environmental and traffic management plans.
- Option 1 provides greater resilience than Option 2 to storm events in excess of the design 50 year return rainfall event, but provides less resilience against the impacts of future earthquake activity.
- Option 1 has greater potential to implement enhancements to the landscape, ecological, recreational and community values along Dudley Creek and its tributaries through well considered urban design and landscape plantings.

This option could experience greater difficulties in gaining property access agreements and therefore has increased risk to programme delays and it is unlikely that it can be implemented within a 2-year timeframe.

Option 2 - Pump and Bypass with limited Channel upgrades

- Potentially 70 property access agreements will be required in order to implement watercourse upgrading works. 21 private bridge replacements are required. It will be possible to stage the construction works as access agreements are obtained. Failure to implement small portions of the waterway works will only have a small reduction in the effectiveness of the whole scheme, as the pump station and gravity piped diversion account for approximately 70% of the capacity improvements.
- Pump station, rising main and the piped gravity diversion will require a pump station site and access to construct the diversion across Shirley Boys High School. They will also need resource consent to construct inlet and outlet structures in Dudley Creek.
- Watercourse upgrade works are significant, however considerably less so than for Option 1, with approximately 7,500m^3 of earth to be excavated and removed (20% that of Option 1) and approximately 1.75km of watercourse affected (50% that of Option 1). Some mature, significant and protected trees will be removed but many less than Option 1.
- Culvert replacements require consent but have no private property risks. Construction of the culverts, pump station, rising main and the piped gravity diversion will be major civil engineering projects with associated potential traffic, community and environmental risks that will require management through good consultation and environmental and traffic management plans.
- Option 2 provides less resilience than Option 1 to storm events in excess of the design 50 year return rainfall event considered, but provides greater resilience against the impacts of future earthquake activity.
- Option 2 has potential to implement enhancements to the landscape, ecological, recreational and community values along Dudley Creek and its tributaries through well considered urban design and landscape plantings. This opportunity is less than for Option 1 due to less work proposed on the watercourses and a greater reliance on hard engineering components. However the potential for future improvements of the water course is not compromised.

Option 2 has fewer property access and resource consent constraints, with the pump station, gravity piped diversion and culvert replacement components requiring only 2 property access agreements and 1 or 2 consents. This option is therefore more likely to be implemented within a 2-year timeframe.

If property access for watercourse upgrade works becomes difficult, the pump station, pressure main, piped gravity bypass and culvert upgrade components of Option 2 are less susceptible to this risk and it is likely these works can be implemented within a 2-year timeframe and provide the majority of capacity upgrading sought.

Early contactor procurement will enable more rapid implementation of the Option 2 civil engineering works and increase the likelihood of completing these components within a 2-year timeframe.

The design and construction of either option is considered feasible and the scale or type of works while challenging, are not unprecedented, particularly in light of the major civil works undertaken in the City as part of the earthquake recovery to date.

The project implementation costs and cost confidence for these options is summarised below:

	Option 1	Option 2
Construction	$38 M	$43 M
Land access	$6 M	$2 M
Project implementation	$6 M	$8 M
Target cost	$50 M	$53 M
Cost confidence	-10% +30%	-20% +40%

1. Project overview

1.1 Background

The earthquakes have caused land settlement, lateral spreading, liquefaction and siltation in Dudley Creek and tributary streams. This has resulted in a large reduction in hydraulic capacity and a significant increase in the frequency and severity of flood events within the Dudley Creek catchment. There have been significant rainfall events within the catchment since the earthquakes resulting in flooding during the August 2012, June 2013 and March 2014 events particularly in the Flockton Street area, the Hills Road shopping centre, Slater Street and along Stapletons Road. This flooding highlights the change in flood risk within the catchment caused by the earthquakes.

Since the earthquakes Council has undertaken investigations into the mechanisms for flooding, post-earthquake hydraulic performance and considered options to restore and/or enhance hydraulic performance. Council engaged SKM, now Jacobs-SKM, to undertake these investigations in accordance with a project charter with main objectives as set out below:

a. Identify the earthquake damage to the waterway and the effect on hydraulic capacity and other values (ecology, landscape, recreation, heritage and culture).

b. Assess options for repairing the waterway to restore the hydraulic capacity and other values, considering the pre-earthquake condition as a baseline.

c. Assess options for providing resilience and betterment with respect to hydraulic capacity and other values.

d. Provide project outputs which can be easily integrated with Council's GIS, asset management systems and hydraulic models.

e. Provide early indication of repair costs for Council's Long Term Plan (LTP)

f. Carry out feasibility design of the preferred repair option, programme and cost estimates.

Items a. to c. have been completed and were presented in the report "*Dudley Creek Catchment: Issues and Options*", SKM, 13 November 2013.

This report was considered by Council in late 2013 and two preferred options were identified for further consideration and feasibility assessment:

1. Major upgrade of existing waterway capacity

2. Pump station, pipe diversion and lessor upgrade of waterway capacity

These options are presented in Figure 4.1 and Figure 5.1 respectively. This report documents outcomes of the feasibility assessment of these preferred options.

1.2 Feasibility report purpose

The purpose of this report is to document the feasibility assessment of the selected design options. This report outlines the performance, potential impacts, costs and risks of the selected options to a level of certainty that will provide Council with the technical information required to select a preferred option.

1.3 Feasibility assessment process

Increased certainty of performance, potential impacts, costs and risks of the selected options has been achieved during the feasibility phase by:

- Hydraulic modelling to incorporate and test feasibility designs and improve reliability (refer Appendix B)
  - Calibration of model against flooding in June 2013 and verification of design flows
  - Modelling of present-day climatic conditions as well as the predicted 2090 mid-range impacts of climate change (increased rainfall intensity and sea level rise) in accordance with Council design guidance
  - Testing of the proposed channel treatment designs developed considering site constraints
- Map flooding extents and assess hydraulic benefits of the feasibility designs
- Review of geology and geotechnical conditions within the Dudley catchment (refer Appendix C)
- Feasibility design development of stream channel profile to reflect hydraulic demand, available land, land topography and private property constraints (refer Appendix D)
- Feasibility design development of culverts with increased capacity
- Feasibility design development of pump station, intake, rising main and by-pass channel including consideration of services clashes, power supply, land availability (refer Appendix E)
- Undertaking an assessment of statutory and planning requirements (refer to Appendix F)
- Developing construction cost estimates from independent cost estimators (refer Appendix G)
- Early contractor involvement (ECI) on constructability of the feasibility designs (refer Appendix H)
- Undertaking risk workshop with designers, Council staff and City Care, updating the project risk register to identify risks associated with design, construction and operation of the options (refer Appendix I)
- Assessment of resilience of the options against natural hazards and climate change variables
- Considering potential impacts on private property and the environment
- Considering project implementation (but not including procurement which will be reported on separately)
- Refining the arrangement and description of each option to reflect the feasibility design development
- Testing the options against the established assessment criteria (Section 1.4)
- Interfacing with Council representatives to inform of progress and to update their understanding of performance, potential impacts, costs and risks of the preferred options

The outcomes of these assessments have been incorporated into the feasibility designs, summarised in the body of the report where relevant. Where noted, more detailed reports are attached in the Appendices.

1.4 Feasibility assessment criteria

The following criteria have been agreed with Council to assess and compare performance of the options:

1. Hydraulic performance against the two objectives:
   a. Match pre-EQ level of flood risk to floor levels without climate change (minimum requirement)
   b. Protect floor levels to the 50 year level of protection including climate change impacts and 400mm freeboard (desired betterment target)

2. Resilience against failure and over-design hydraulic events

   a. Risks of failure in events such as further earthquakes, power failure, etc

    b. Risks in over-design or non-standard design flooding such as higher tailwater levels

3. Impacts private property owners, the community and environment
4. Statutory and planning requirements
5. Costs
6. Implementation programme

Risk has been considered within each of these criteria and a summary of overall project risks is included in Section 7. The current project risk register is attached in Appendix I.

The options are designed to mitigate floor level flooding as a priority and to reduce the extent of flooding to private property and streets where feasible. It is acknowledged that some flooding of these areas will still occur during extreme weather events and that this is anticipated and accepted by Council design standards.

1.5 Waterway capacity upgrade requirements

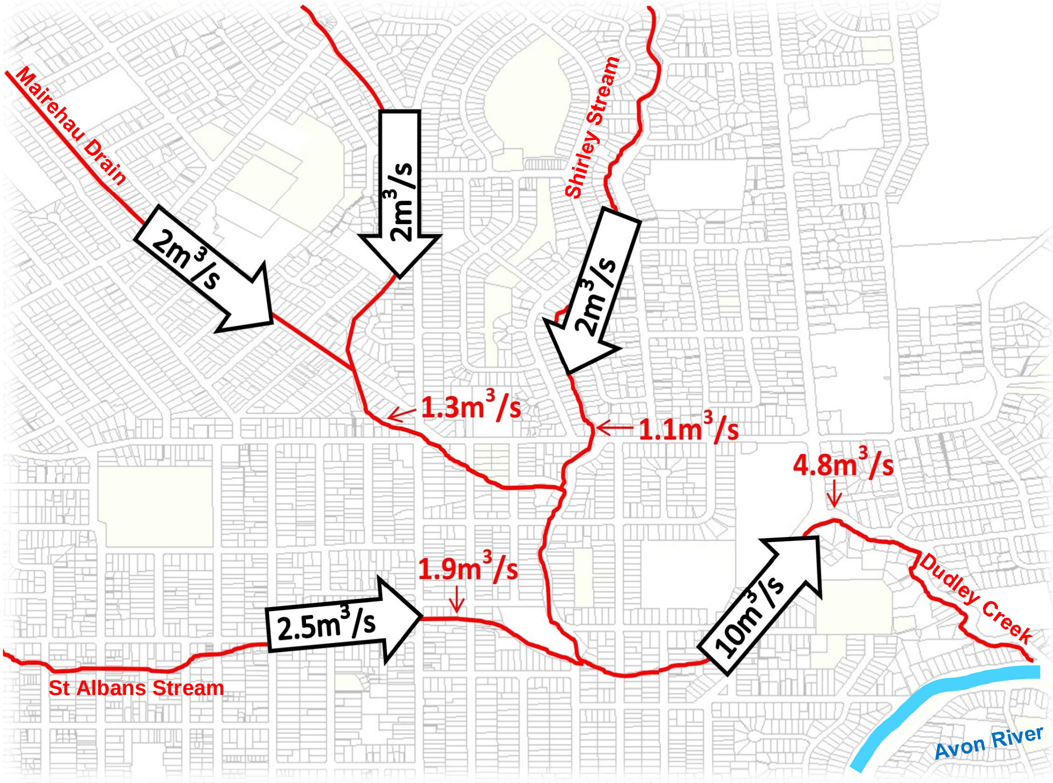
Hydraulic modelling has been undertaken to understand the impacts of the earthquakes in the Dudley Catchment, develop and assess options and to inform the feasibility design. The hydraulic modelling is discussed in detail in the *Dudley Creek Catchment: Issues and Options* Report, SKM, 13 November 2013. The recent updates to the model and additional work undertaken to refine the feasibility designs are included in Appendix B.

The earthquake impacts on the hydraulics of the drainage network in the Dudley Creek Catchment can be summarised as follows:

- Earthquake induced land settlement has resulted in the low lying areas in the catchment being 200-500mm lower than pre-earthquake levels
- The streams have lost capacity due to the lateral spreading of the banks and bed heave
- The many bridges and culverts crossing the streams are now greater restrictions to the flow due to the raised bed levels and the land settlement
- The stormwater pipe network has been damaged in some areas

The main channel of Dudley Creek between Aylesford Street and the Avon River is over 2.5km in length. Over this distance it has very little gradient. The lower reaches of the creek are also affected by tides or high flows in the Avon River. This combined with a well-developed catchment means that the stream struggles to convey the flows it receives during heavy rainfall. This is illustrated in Figure 1.1 where the hydraulic modelling has identified the design flows anticipated in a 50 year Average Recurrence Interval (ARI) rainfall event across the Dudley Creek catchment and the current channel capacities. Figures SK-10 and SK-11 in the plan set compare the extent of flooding pre and post-earthquakes.

Figure 1.1 : Indicative design flows during a 50 yr ARI event (in black arrows) and current channel capacities (in red)



The significant difference in design flows and existing watercourse capacity demonstrates that significant upgrading would be required across all of the watercourses to reduce flooding.

2. Feasibility design methodology

2.1 Watercourse upgrading

To increase the hydraulic capacity of the watercourses, they can be deepened and widened. This requires excavation and reconstruction of watercourse bed and banks, while:

- Retaining bank stability
- Resisting erosion
- Providing a sustainable aquatic habitat
- Promoting the improvement of recreational and aesthetic values where possible

The shape of the proposed bank profile and the method of bank protection varies along the watercourse. This depends upon the depth of stream bed relative to surrounding ground and availability of accessible land beside the existing stream to enable stream channel widening and transition back to natural ground level.

In order to assess the spatial extent and construction work effort required under this option, we have characterised the watercourse bank treatment profiles into 4 generic types:

Type 1 – Fully Retained

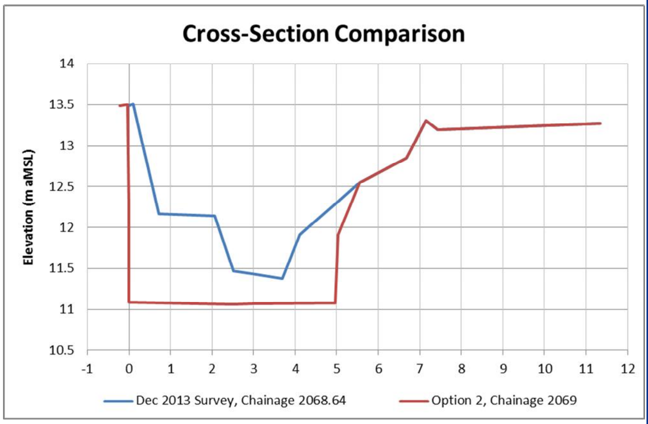
Type 2 – Natural Grade

Type 3 – Two Stage

Type 4 – Minor Works

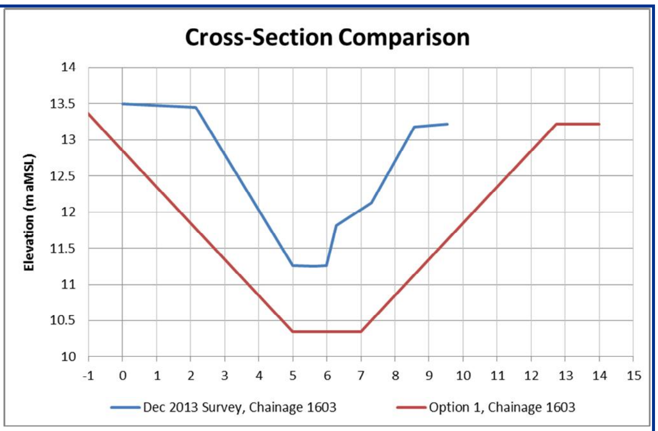
Four types are required for the conditions found in this catchment and to achieve the necessary capacity upgrade. The appearance and characteristics of these bank profiles is presented in Table 2.1.

Table 2.1 : Watercourse Bank Profile Types

Characteristics
Type 1 – Fully Retained This profile establishes a deep vertical bank profile and is required where there is limited space to construct a Type 2 or Type 3 profile. This type is typically applied when works are required adjacent to private property, in heavily constrained reaches or areas with limited access. It is also required where a transition is required from structures such as culverts or bridges to a different treatment type. This type of construction requires large civil construction equipment and when it is retaining slopes greater than 1m (as typically the case) will generally be more expensive to install than a Type 2 or Type 3 profile. Options to achieve Type 1 walls, in increasing cost order, include: timber post and plank, steel pile and concrete panel and concrete retaining wall with foundation. The steep facings of the retaining walls also reduce the potential to soften the appearance. Fencing may be required in some situations to restrict access. Exit points may be needed to permit egress from the waterway. 

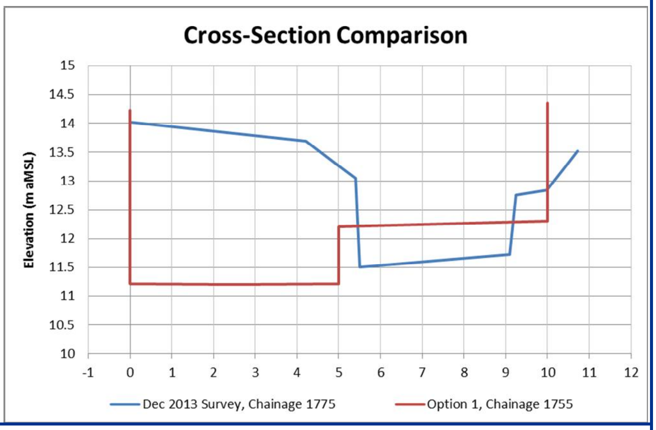
Type 2 - Natural Grade

This profile is appropriate where there is sufficient width available to utilise a graded transition from the stream channel or top of a Type 1 or Type 3 profile, back to natural ground. Batter slopes of 1:4 are preferred but slopes as steep as 1:2 are possible (shown).



Type 3 – Two Stage

This profile establishes a two stage flow channel and is the preferred option where space exists, as it provides a confined stream channel to convey normal flows and a larger secondary channel to convey flood flows. The secondary channel is typically planted with grass or other low-bulk plant species that provide protection against erosion during flood conditions. An operational maintenance programme will be required. Opportunities to improve amenity and recreation values include placement of walkways, cycle tracks or public spaces. Erosion resistant construction of the near-vertical sections is required and material will vary depending upon the flow velocity as well as visibility and amenity value. Options to achieve the near vertical component of the Type 3 walls, in order of increasing cost, include low timber post and plank, precast concrete retaining blocks, stacked stone works and low concrete retaining wall with shallow foundation.



Type 4 – Minor Works

Minor works are considered to include minor widening or deepening where these works are not expected to require additional bank retaining or extend beyond the existing watercourse.

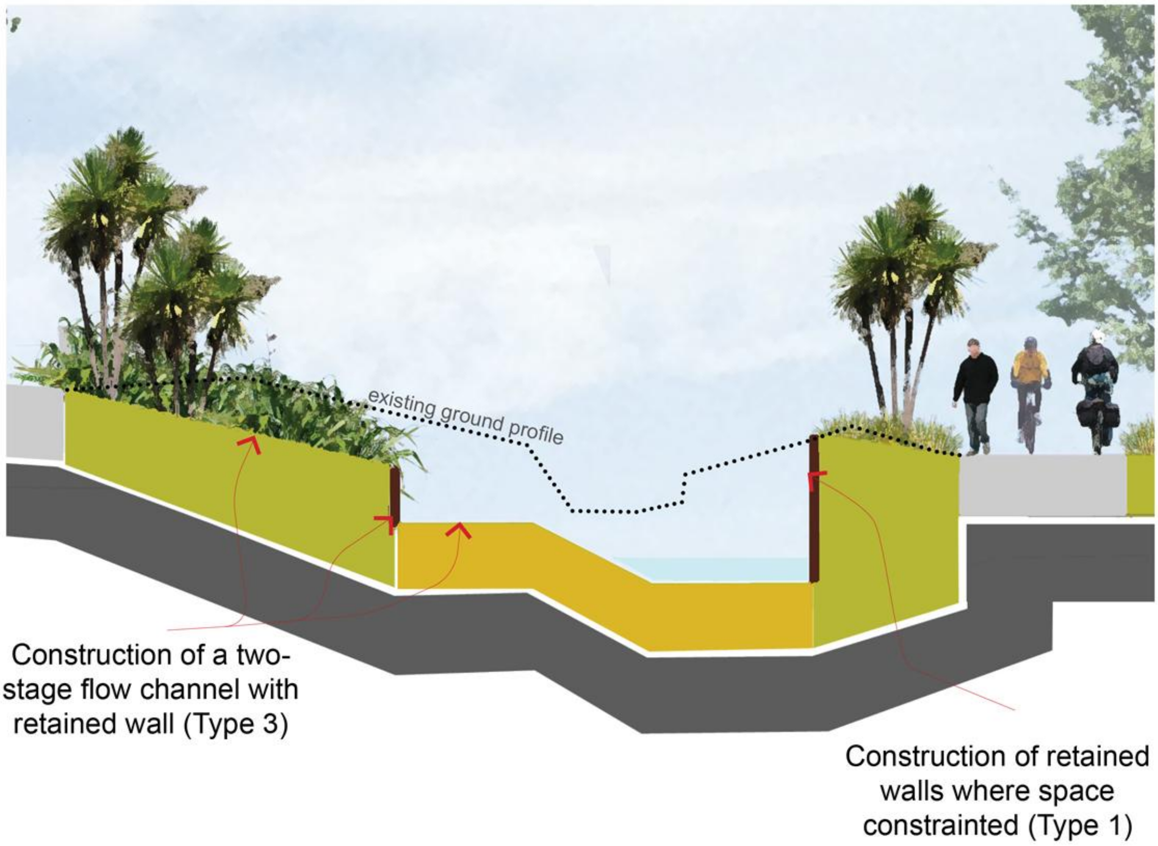
The specific materials used for the construction of retaining walls used within these bank profiles will be developed during detailed design to reflect the conditions. Key design criteria will include flow velocity and scour potential, retained height, construction access, ground conditions, public visibility and amenity, community desires and economics.

For the purposes of economic assessment of options, we have assumed the following:

- Retaining >1.5m – majority being driven timber post and plank with some reinforced concrete sections
- Retained banks 0.5m - 1.5m – combination of timber post and plank and pre-cast retaining blocks

A schematic example of the application of a Type 1 and Type 3 bank profiles is provided in Figure 2.1.

Figure 2.1 : Example of Application of Type 1 and Type 3 Bank Profiles



2.2 Culvert upgrades

The majority of road culverts on Dudley Creek need to be replaced by significantly larger culverts to pass the design flow in all options. To enable an efficient and consistent construction approach and appearance, it is proposed that a standard design using pre-cast concrete culverts is adopted, with project specific aesthetics as well as functional safety aspects incorporated into headwall and culvert balustrade designs. The specific details would be developed during detailed design; however, for the purpose of this assessment we have assumed use of an inverted “U” channel placed on a cast in-situ base.

Culvert width and height are selected to achieve the design hydraulic area, with additional depth below design bed level to allow a silt/gravel bed to form which offers a natural ecological setting. A typical culvert cross section is presented in drawing SK-86 in appendix A, complete with a schedule of replacement culverts and their sizes, lengths, headwall types and the known service crossings.

Ground conditions close to the locations of each of the culverts have been considered (Appendix C Geotechnical Overview). Relatively soft ground has been identified that is at risk of liquefaction and lateral spread. Specific geotechnical testing would be required prior to confirming foundation method and design, however based on the information available, the foundation methodology proposed is a shallow gravel bed incorporating geogrid reinforcing.

The monolithic nature of a culvert structure offers good stability against lateral spreading forces that might eventuate during seismic activity and the broad base spreads construction loads and reduces bearing pressure on the supporting ground. These attributes are highly beneficial in this application.

Culvert headwalls will be required and it is proposed that balustrade type protection is adopted to improve stream visibility, rather than parapet walls. Railings are required to act as pedestrian edge protection as a minimum and further consideration is required at the detailed design phase as to whether vehicle restraint is required. The low speed nature of the roads at the majority of the culverts and the set-back achieved by footpaths may provide sufficient vehicle crash risk mitigation. This approach is consistent with current Council guidance but would not comply with the New Zealand Transport Agency (NZTA) requirements as outlined in the Bridge Manual, which form the default guidelines for bridges in New Zealand.

There is an opportunity for head walls and balustrades to be designed to provide an attractive and consistent aesthetic across the culverts in this area. The design and appearance could be influenced the local environment and community. Similar recent examples adopted by Council as well as SCIRT's Bridge Design Guidelines would form the basis of development of project specific arrangements.

For culverts being replaced on low traffic volume roads such as Slater Street, there is an opportunity to locally narrow the road carriageway by removing parking lanes to enable a narrower culvert. During detailed design this could realise cost savings and increase visibility of the watercourses.

Support or re-laying of buried utility services that cross the existing culverts will be a considerable component of the costs and risk associated with several of the culvert replacements, particularly as the culverts will be enlarged. Existing as-built information provides a good understanding of the number of services to be encountered and their relative location; however, detailed field investigations will be required during the detailed design phase in order to gain the certainty necessary to manage the cost risk associated with unexpected services clashes. This is particularly so for high-value services such as fibre-optics and high voltage buried power and also for gravity sewer services that are difficult to re-align. As the culverts already exist, in most situations replacing them is not expected to involve significant service relocation.

2.3 Private bridges

Feasibility design of private bridges has not been undertaken due to the possible range of differing situations. It is anticipated that bridges would be single lane, pre-cast concrete deck supported on intermediate bank-edge columns and with pedestrian and vehicle restraints. A nominal sum has been included in the cost estimates to allow for private bridge modifications.

The ownership of replacement bridges will require consideration, particularly if their replacement is funded through this project. Present Council policy leaves ownership and maintenance of private access bridges with the property owner. Where Council are altering a drain to an extent that new bridges are required, past practice has been to renew the bridge at Council's cost. As a consequence Council accepts liability for future maintenance. In this circumstance, a number of the bridges are subject to private insurance claims. A Council policy will be required to inform cost sharing and recovery, if desired.

2.4 Cost estimating and project budgeting

Costs estimates for construction, property access and project implementation have been assessed as described below.

- Construction costs

  Estimates have been developed using available data for similar recent works within the Christchurch area where available or otherwise based upon industry market rates for comparable works. Where there are no applicable similar work costs or where it has not been possible to define the scope of an element of the work, provisional sums have been incorporated to provide an allowance for these uncertain/undefined costs.

  It is noted that due to the tight delivery programme of this report there has been insufficient time to robustly test the cost estimates by further consultation with the construction industry. Accordingly, the estimates have additional risk built in. This results in increased total cost estimates and reduced accuracy. The degree of conservatism in the pricing is considered to be appropriate and consistent with the feasibility design of the options.

- Cost allowance for property access

  An allowance has been made for obtaining property access agreements. Individual property owners will need to be consulted to inform this portion of the cost estimate.

- Project implementation costs

  A cost allowance of 15% of construction budget has been allowed for associated with project implementation including site investigations, consultation, design, construction management and Council costs.

Detailed cost schedules and costing methodology are presented in Appendix G.

3. Statutory considerations and planning assessment

An assessment of statutory considerations and planning requirements has been undertaken (Appendix F). Some form of statutory approval is required to undertake the works proposed under either option. The methods of gaining approval to undertake the necessary works include:

- Use of relevant existing global consents held by Council, if applicable
- Seek project specific RMA consents
- Seek a Notice of Requirement (NOR) to designate the public works
- Use of the Canterbury Earthquake (Resource Management Act) Order 2011 (SR 2011/34)

Various consents are held by Council in order to undertake post-earthquake and routine maintenance and upgrade works within watercourses. These consents do not currently provide for the construction of new structures such as retaining walls, culverts, bridges, intake structures and outlet structures and as a minimum, consent approval of some form will be required to construct these items.

It is considered that only some of the works within watercourses will be covered by the global consents held by Council. All options will therefore require a due process to be followed in order to gain the necessary statutory approvals and an indicative programme is presented in Table 3.1.

Some of the works proposed for this project regarding the beds and margins of waterways will be covered by the global waterways consent so long as certain conditions and legal requirements are met. However, some major works are excluded (or not specifically included) in this global consent. The following activities have been identified as likely to need additional resource consents for both options:

- if major stream channel works and culvert upgrades cannot be provided under the global consents held by Council the following Section 13 (RMA) consents will be required
  - Erection or placement of new culverts (Rule BLR4: which could require a consent for discretionary activity)
  - Earthworks within a riparian zone (Rule WQL30)

Consents may also be required if works are required if contaminated material is to be disturbed or removed above what is allowed for in the Global Consent held for removing liquefaction material.

In terms of Council approvals, earthworks land use consents for both option 1 and 2 where property access is required and where designed access to houses needs to be reformed or fencing modified is an example.

For option 2, land use consent may be required for:

- The proposed pump station off Warrington Street
- Earthworks for the diversion structure which will cross Shirley Boys High School

Table 3.1 : Indicative Consenting Programme using the Canterbury Earthquake Order 2011 (in months from commencement)

Informed Approach using the Order in Council (SR 2011/34)	1	2	3	4	5	6	7	8	9
Property negotiation to obtain access to sites to enable works									
Engagement letter to affected landowners and initial education of the affected landowners[1] testing landowners desires. (Letter and collaboration meeting)									
Consent Authorities S10[2] OIC requirement to consult									
Land investigations and Survey (access agreements and tasks)									
Development of the application (assessments, consultation[3], engagement/pre app meeting with Councils)									
Lodge statutory applications (ECan/Council)									
Decision on application made (non-notified)									
Design to inform consents									
Detailed design									
Property acquisition if necessary									
Construction activity in areas which do not require statutory approvals									

Option 2 has significantly less major channel works in comparison to Option 1, which results in less impact on private properties. This becomes a balance between the consenting requirements and the implication of property needs and lesser environmental effects.

The key differences and RMA Planning implications between the two options are outlined in Table 3.2.

[1] Should include land entry for investigations, survey and delivery through construction.
[2] The Consent Authority is required (s.10(1) Canterbury Earthquake (Resource Management Act) Order 2011) to consult any person that the consent authority considers will be, or is likely to be, or whose property will be, or is likely to be, adversely affected by the activity to which the application relates.
[3] Assumes consultation engagement continuing as outlined in a consultation and engagement plan.

Table 3.2 : Comparison of Consent Requirements for Option 1 and Option 2

Consent Requirement	Option 1	Option 2	Implications
National Environmental Standard (NES) for Contaminated Land Land Use consent	Major channel profiling required around the former Churchill Hospital site	Possible if HAIL sites are identified. Research is required.	An NES application would be required from Council.
Floodwater diversion (Rule WQN24: consent for discretionary activity) Erection of a new outlet structure into Dudley Creek (Rule BLR4).	-	Bypass construction to divert water and building a new outflow pipe to Dudley Creek	A new consent application will be required in addition to global consents and will require additional assessments, particularly around the outlet structure.
Sign off from Ministry of Education to enable Council to undertake the works through the Ministry of Education designation for Shirley Boys or Shirley Intermediate School under Section 177(1)(a) of the RMA.		Bypass construction through the school could potentially impact on the usability of sports fields at the school. These impacts can be addressed through the design of the culvert or open channel.	Early engagement is required with the Ministry of Education to ensure that the potential construction over their designation is acceptable, including what the final design form of the bypass will be. e.g open channel may not be acceptable to the school if they want to retain usability of the sports fields.
Land use consents or additional scope in the NoR		Construction of a pump station in residential neighbourhood	Additional assessments such as noise and landscape required to support a statutory application.

Consents gained under the RMA will not provide the rights of access necessary to give effect to the consents.

Due to the importance of the property access and consenting to Council and the community, property access and consenting strategies be given further consideration. Options for property access could include a Notice of Requirement or Use of the Canterbury Earthquake Order. Due to the greater power of these approvals, they would provide greater certainty for moving the project ahead however risk upsetting those adversely affected.

The following would help to inform the development of such strategies:

- Consultation with Environment Canterbury to explore the applicability of existing consents to this project, giving due consideration to the urgency and the compatibility of existing consents
- Undertake consultation with directly affected property owners to gauge their views and position with regards to granting Council access for the proposed works
- Undertake consultation with key stakeholder groups to seek their views

Council will then be in a position to better understand the risks associated with each consenting and property access approach, which will directly influence the ability to deliver the upgrade options proposed.

Council may also give consideration of how the options can be implemented in stages should property access and gaining of consents become an impediment to commencing the project. Some parts of the watercourse upgrading will comply with existing consents or may be able to gain consent in a reasonable timeframe where not impacted by private property access issues. Likewise, the pump station and diversion can be constructed primarily on publicly owned land and consents may have a lower risk to the implementation programme.

4. Option 1 – major upgrade of watercourse

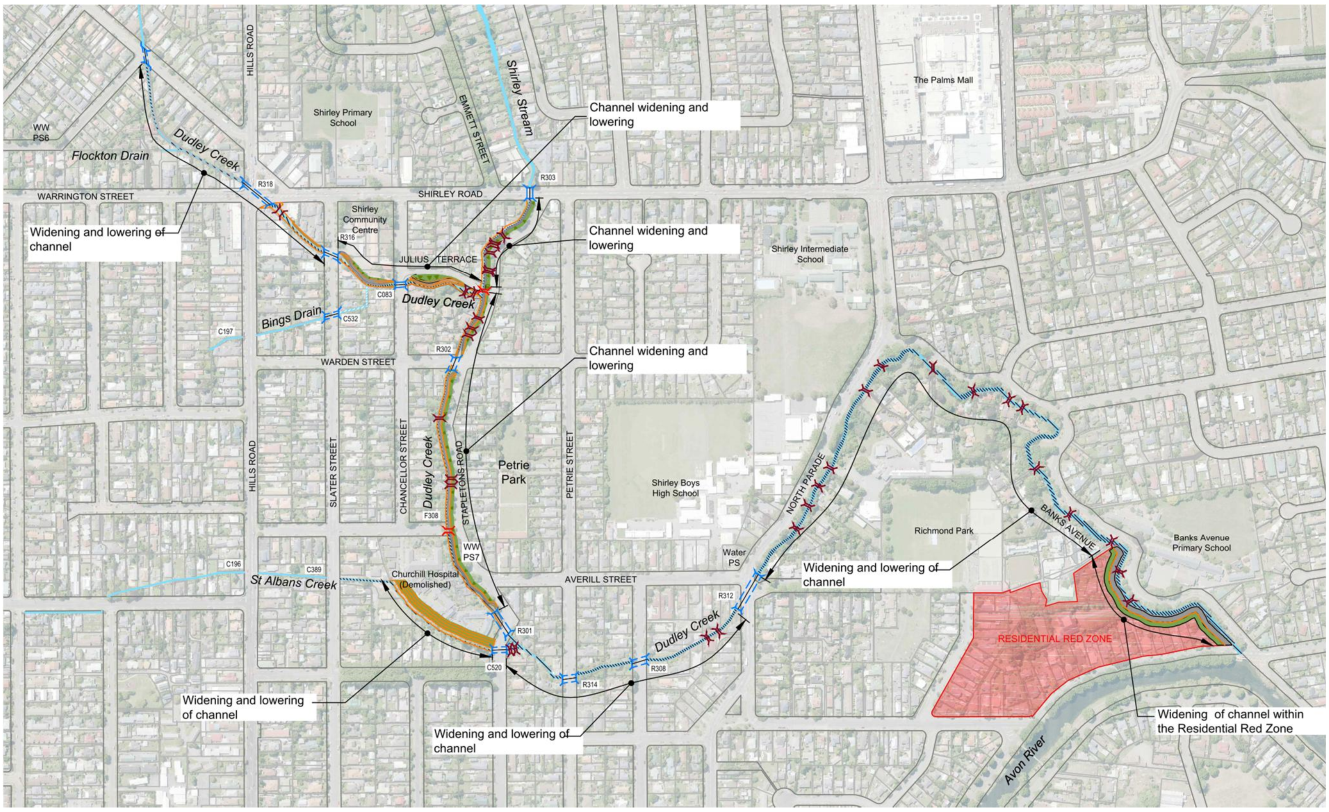
4.1 Extent and appearance of upgrade work

Option 1 seeks to increase conveyance capacity by increasing the width and depth of watercourses and to replace culverts at road crossings and bridges at private properties. This option is based on enhancing the existing drainage systems in the catchment.

4.1.1 Watercourse upgrade work

All of Dudley Creek downstream of the Aylesford culvert to the Avon River, plus short section of Shirley Stream, Bings Drain and St Albans Creek require major capacity upgrading. These watercourses have been assessed to determine the type, location and extent of widening and bank profile treatment required to achieve the design capacity. The outcome of this assessment is presented in Figure 4.1 and provided in detail in drawings SK-40 to SK-52 in the plans in Appendix A.

Figure 4.1 : Option 1 Extent of Works for Watercourse Upgrading



Overall, the extent of channel widening and deepening proposed is considerable and the physical works required to achieve this will be significant (Table 4.1).

Table 4.1 : Option 1 Summary of Work Quantities for Watercourse Upgrading

Item	Quantity
Bulk excavation	35,000 m^3
Bank profile Type 1 – Fully Retained	4900 m
Bank profile Type 2 – Natural Grade	550 m
Bank profile Type 3 – Two Stage	700 m

The bank profile upgrade quantities for Type 1, Type 2 and Type 3 refer to bank length as opposed to watercourse length.

In the absence of full coverage of detailed topographical survey of the watercourses this assessment remains relatively subjective. The current survey data is sufficiently accurate to enable determination of the overall scope and spatial extent of anticipated watercourse upgrade works, to enable assessment of interface with private property, community and environmental impacts and implementation costs. The extent of the works proposed at the individual property level will need to proceed in negotiation with the property owners.

4.1.2 Culvert replacement

Twelve road crossings and two public foot bridges (at Guild Street and Julius Terrace) require replacement to achieve the full benefit of capacity upgrading of the water courses. The location of these are indicated in Figure 4.1 and provided in drawing SK-40 (Appendix A). The width and length of each culvert is presented in Table 4.2.

Table 4.2 : Option 1 Required Culvert Replacements Dimension

Culvert	Width	Length
Aylesford Street – Dudley Creek	5m	22m
Shirley Road / Warrington Street – Dudley Creek	5m	51m
Slater Street – Dudley Creek	5m	22m
Chancellor Street – Dudley Creek	5m	14m
Warden Street – Dudley Creek	10m	20m
Stapletons Road – Dudley Creek	10m	37m
Stapletons Road – St Albans Creek	5m	21m
Petrie Street - Dudley Creek	10m	20m
Chrystal Street - Dudley Creek	10m	22m
North Parade - Dudley Creek	10m	57m
Shirley Road – Shirley Stream	4m	21m
Slater Street – Bings Drain	2m	22m

Of note:

- The Dudley Creek culverts at Shirley Road / Warrington Street, Stapletons Road and North Parade cross at an angle, thus represent significantly more work
- The will be some significant traffic management requirements to enable construction of some of these culverts which has been factored into cost estimates
- The design and construction of the Shirley Road culvert is being progressed by SCIRT, however, remains incorporated in this assessment at this stage

Feasibility design of the footbridges has not been progressed as part of this assessment but will require consideration and potentially community input during detailed design.

4.1.3 Private access bridge replacement

There are a total of 29 private vehicle crossings that require upsizing to achieve the full benefit of capacity upgrading of the water courses. These are in a variety of conditions, with most being in serviceable condition.

The location of these are indicated in Figure 4.1 and provided in drawing SK-40 (Appendix A).

4.2 Hydraulic performance

Option 1 significantly reduces flooding in the key target areas of the upgrades including the Flockton area, Hills Road Shopping Centre and the Slater Street area. While the more frequent rain events modelled show almost no flooding in these areas there is still areas of flooding predicted in a 50 year ARI flood event. In all scenarios modelled the Option 1 upgrades reduce flooding in these target areas to below pre-earthquake levels. These are presented in drawing SK-13 and SK-14 in Appendix A.

There are 550 properties predicted to be benefited by a reduction in peak flooding levels of100 mm or more in a 50 year ARI rainfall event. These are highlighted in drawings SK-12 in Appendix A. Within these benefited areas the number of at-risk residential floor levels has reduced from 80 to 15 for the 50 year ARI design storm. This is also lower than the 32 at-risk residential floor levels for the pre-earthquake scenario.

The increased capacity gained via channel widening and deepening and culvert upgrades results in Dudley Creek being capable of conveying higher flow rates. Significantly, it also lowers the water level at Flockton stormwater outlet allowing better drainage for the Flockton area.

Flooding will still occur in the upper catchment and this flooding contributes to overland flows which can eventually reach the Flockton area. Other flood prone areas that are unaffected by these works include St Albans Creek along Edgeware Road between Champion Street and Slater Street, and Shirley Stream flooding near Orontes Street. Some further opportunities to address these problem areas are outlined in Section 7.

In Option 1 there is approximately 2m fall along 2,500m of watercourse, nominally at a gradient of 1:1250. This fall drives the flow along the watercourse. The hydraulic performance of the system is therefore dependent on maintaining the available elevation and watercourse hydraulic area. Gaining additional hydraulic performance in the future will be relatively difficult as the proposed upgrading will be to a fixed design flow rate (i.e. all the culverts will be designed to the same scenario) and will remove all individual and specific hydraulic constraints. Gaining additional capacity would require increasing the hydraulic area along the entire watercourse. It is recommended therefore that if major works are to be undertaken, a conservative approach be adopted in setting the design flows.

Key mitigation strategies to manage potential hydraulic performance risks are:

- Adoption of sufficiently conservative design flows
- Establish clear design parameters and ongoing operational requirements for watercourse flood channel plantings and incorporate these into watercourse maintenance plans
- Establish guidelines for the construction of culverts and private bridges within this catchment

4.3 Long term performance resilience

There a range of natural hazards and environmental climate changes that may impact the hydraulic performance of the watercourse over time. Some of the more foreseeable risks and their possible impact are discussed in Table 4.3.

Table 4.3 : Long Term Performance Resilience Risks and Impacts

Risk	Impact	Potential Remedies
Earthquake – lateral spread	Channel constriction and watercourse bank damage, possibly along a significant length of watercourse, potential moderate to major impact on watercourse capacity	Design to restrain banks, will be prohibitively expensive. Civil works after an event, possibly of similar scale to watercourse upgrade work currently proposed, capacity likely to be recoverable at high cost.
Earthquake – land settlement	Reduction in available elevation as downstream tailwater conditions remain constant, potential moderate to major impact on watercourse capacity	Design for possible land settlement by increasing capacity, likely to significantly increases costs and face major private property access constraints. Civil works after an event, possibly of similar scale to watercourse upgrade work currently proposed, capacity likely to be recoverable at high cost. Supplementary capacity likely to be more cost effective option, achievable by pumping, storage or flow diversion out of catchment, will be comparable cost as Option 2.
Earthquake – liquefaction and sedimentation	Channel sedimentation, possibly along a significant length of watercourse, potential minor to moderate impact on watercourse capacity	Design for possible sedimentation, likely to have minor to moderate cost impact on upgrade project. Civil works after an event, possibly of similar scale to watercourse emergency recovery works undertaken after recent earthquakes, capacity likely to be recoverable at minor to moderate cost.
Increased rainfall intensity associated with climate change	Greater flow volumes and faster concentration, will result in watercourse network have slightly lower level of protection	Given the constraints in this catchment it will be difficult to extract further capacity from the Open Channels in the future particularly if sea levels increase the tail-water conditions in the Avon River. The two most likely options to increase protection in this catchment in the future are house raising or pump stations to divert flows out of the catchment.
Increased tail water levels resulting from sea-level rise	Reduces available elevation and therefore reduces system capacity	Option 1 has demonstrated acceptable resilience to midrange predictions of increased sea levels in the modelled resilience scenarios.
Extreme flooding events	Channel design capacity is overwhelmed resulting in flooding on the floodplain.	In the modelled scenario of the 200 year flood event Option 1 demonstrated the ability to offer a much higher level of protection to the properties in this area than in either the pre or post-earthquake catchment.

Of the risks discussed above, climate change factors are able to be accommodated to some extent during design at a relatively moderate cost increase.

The impacts as described resulting from an earthquake are significantly more difficult and costly to design out and may require slope reinforcement or additional structural retaining to mitigate risks sufficiently. A decision will be required as to what extent and where this is done due to the high cost of mitigating this risk across the entire work area.

In the event of significant land damage, the most likely response to restore capacity will require a combination of watercourse restoration and construction of supplementary capacity to regain overall hydraulic capacity. In this regard, increasing the capacity contribution of pumping and piped diversion will increase resilience.

4.4 Potential community and environmental impacts

The construction of major watercourse upgrades will pose a range of adverse impacts on the community and the environment during construction, however in the longer term the upgrades will also provide opportunity for a range of positive impacts to occur. The key short and long term community and environmental impacts are summarised in Table 4.4.

Table 4.4 : Option 1 Key Community and Environmental Impacts

Aspect	Construction Phase Impact	Long Term Impact
Private property	Private property access for new channel extents and construction access agreements across properties adjacent to the watercourses are required to enable works to be implemented. There are 115 properties adjacent to the stream. Many would be impacted in this option. Private bridges will be temporarily decommissioned. Traffic management may impact access to properties.	Permanent infringement of the creek extent on some private property between Aylesford Street and Banks Avenue. Replacement of 29 private bridges.
Ecology	Complete removal of existing in-stream and riparian habitat along the entire extent of watercourse upgrade works. May require fish and flow by-pass during construction.	Creation of a stable and viable habitat with native local species, likely to result in overall beneficial ecological impact. Removal of historical stream sediment contaminants.
Landscape	Complete change to existing landscape, including removal of mature trees, some of which are significant or protected. Refer drawing SK-40 to SK-52 for significant or protected trees that will be removed.	Master planned landscape design that is informed by and meets community and environmental setting, likely to result in overall beneficial landscape amenity impact.
Recreation	Limited recreational opportunities at present. Temporary restriction on access during	Potential to incorporate recreational amenity via walkways and resting areas, likely to result in overall beneficial recreation impact.

	construction and plant establishment.	
Heritage	Limited existing heritage features so minimal impact.	Potential to incorporate heritage values into design of structures and landscaping and these elements have potential to be of future heritage value, opportunity to result in overall beneficial heritage impact.
Cultural	Limited existing cultural interaction apart from a general interest. Ability to accommodate cultural requirements as part of construction process.	Potential to incorporate cultural values into design of structures and landscaping, opportunity to result in overall beneficial cultural impact.

The range of construction phase impacts discussed above reflects the major civil works that are required. Overall however there is a good opportunity to enable positive long term effects for most of these community and environment aspects.

4.5 Costs

Preliminary estimates of the cost to construct Option 1 as discussed above and more fully presented in the referenced drawings have been assessed based on the cost estimating approach outlined in Section 2.4.

The combined project budget range is summarised in Table 4.5 and presented in detail in Appendix G.

Table 4.5 : Option 1 Project Implementation Cost Estimates and Cost Confidence

Component	Target Cost (excl GST)
Construction	$38 M
Property access	$6 M
Project implementation	$6 M
Target cost	**$50 M**
Cost confidence	-10% +30%

This total project budget equates to approximately $90,000 / property benefited.

4.6 Project implementation

Project components that need to be achieved or completed in order to implement the works and achieve the capacity increase sought include:

- Property access
- Resource consents
- Site investigations

- Detailed design
- Procure Contractor

Implementation of the entire Option 1 is required to achieve the desired capacity improvements, with upgrading of the watercourse providing the greatest capacity benefit but neither the watercourse or culvert upgrade component providing sufficient increase capacity on their own.

Construction of the works can however be staged on the basis of ease of ability to gain the necessary approvals and on work type and location, provided the over-arching need to increase capacity from the downstream end first is observed, or that modelling if undertaken to assess the impacts of any other work staging considered.

Construction of watercourse upgrading components cannot commence until access rights to the many potentially affected properties as well as resource consent for the works have been gained and design completed. As discussed in Section 3 this is anticipated to be difficult and take time. Some areas will not be constrained by the property access requirements however it is expected that partial works would not be undertaken due to the risk that if property access cannot be gained in a timely manner, additional mobilisation and construction costs will be incurred and possibly, sections of the upgrading will not be completed for some time and the overall capacity upgrade objectives will not be met.

Construction of culvert replacements cannot commence until resource consents are gained and design completed however there are unlikely to be any significant private property access constraints.

Gaining of consents for the proposed upgrade works will likely required comprehensive community and stakeholder consultation, particularly considering the significant ecological and visual changes that will result and the need to interface with many residents adjacent the works areas.

Detailed design of Option 1 requires specific geotechnical investigations and detailed topographical survey of the entire watercourse network ahead of design. Detailed design will commence from when property access is gained, or from the time Council agrees to proceed if property access cannot be timeously achieved or design is to be progressed at risk.

Procurement of a Contractor to undertake these works is the subject of a separate report to Council. For the purposes of this assessment, we assume a fast-track process run in parallel to design.

Assuming that unimpeded access and consents are gained, construction of the works is in principle relatively simple and there are several competent Contractors experienced in these works. Key risks are discussed in Table 4.7.

Due to the scale of the proposed works it is expected that a Contractor would apply multiple crews over a number of work sites. Culvert construction is logically separated from watercourse construction due to the different work type and specific locations. Several culverts could be constructed concurrently. Waterway construction would likely be undertaken with several crews, working on specific work sections generally in the same area. Again, it is likely there would be specialty crews for specialty works such retaining walls.

In order to develop a preliminary implementation programme, the following assumptions have been adopted:

- Gaining of property access agreements takes a nominal period of 9-months. There is no formal basis for this assumption other than there are many access agreements required and there are likely to be difficulties. In reality some access agreements may not be gained by mutual agreement and this process could take longer
- Resource consents are sought under the under in Council, and the relevant statutory agencies meet prescribed timeframes for assessment and notification
- Investigation and design is run concurrently to the property access and resource consent process
- Contractor procurement process is run concurrently to Investigation and design
- The basis for these assumptions is that there is urgency to implement the project.

The resulting preliminary programme is provided in Table 4.6, which indicates the general interaction between project components.

Table 4.6 : Option 1 Preliminary Implementation Programme (in months from commencement)

Component	1	2	3	4	5	6	7	8	9	10	11	12
Site access agreements												
Resource consents												
Site investigations												
Detailed design - culverts												
Detailed design - watercourse												
Construction documentation												
Contactor procurement												
Construction												

A nominal construction period of 18-months is considered achievable however considering the works are within an active watercourse network that is susceptible to flooding, contains poor ground and with significant public interface, a longer construction programme would reduce delivery pressures and risks.

The overall implementation programme including the nominal 9-month period to gain property access and an 18-month construction programme is therefore likely to extend out to 27-months, with incumbent delay risks as outlined and discussed further in Section 4.7.

4.7 Project implementation risks

A risk register has been established for the project and the results of a risk workshop undertaken during the feasibility design phase have been incorporated (refer Appendix I).

Key risks that may affect project implementation are summarised below.

Table 4.7 : Option 1 Implementation risks

Component	Risk	Potential Impact
Site access agreements	Access approval for site investigations not gained Access approval for construction not gained	Design delayed, additional costs incurred Construction delayed, incomplete works
Resource consents	Strong community views Processing delays	Need additional consultation which delays process Approvals delayed, construction start date pushed back
Site investigations	Delay, considered low risk due capacity in the market	Delay in design
Detailed design	Property access not confirmed results in redesign Deign delays	Delays construction, increases design cost Delays construction
Construction documentation	Low risk	
Contactor procurement	Early Contractor engagement then Project delayed	Contractor standing costs
Construction	Environmental spill or siltation Wet weather or major storm event Location and supporting of utility service crossings Poor ground conditions result in bank instability or poor bearing	Environmental damage, enforcement action Erosion of works, environmental damage, lost time, rework Construction cost, programme, public disruption if broken Rework, design changes, delay, increased cost

5. Option 2 - Pump station, flow diversion and lesser upgrade of watercourse

5.1 Extent and appearance of upgrade work

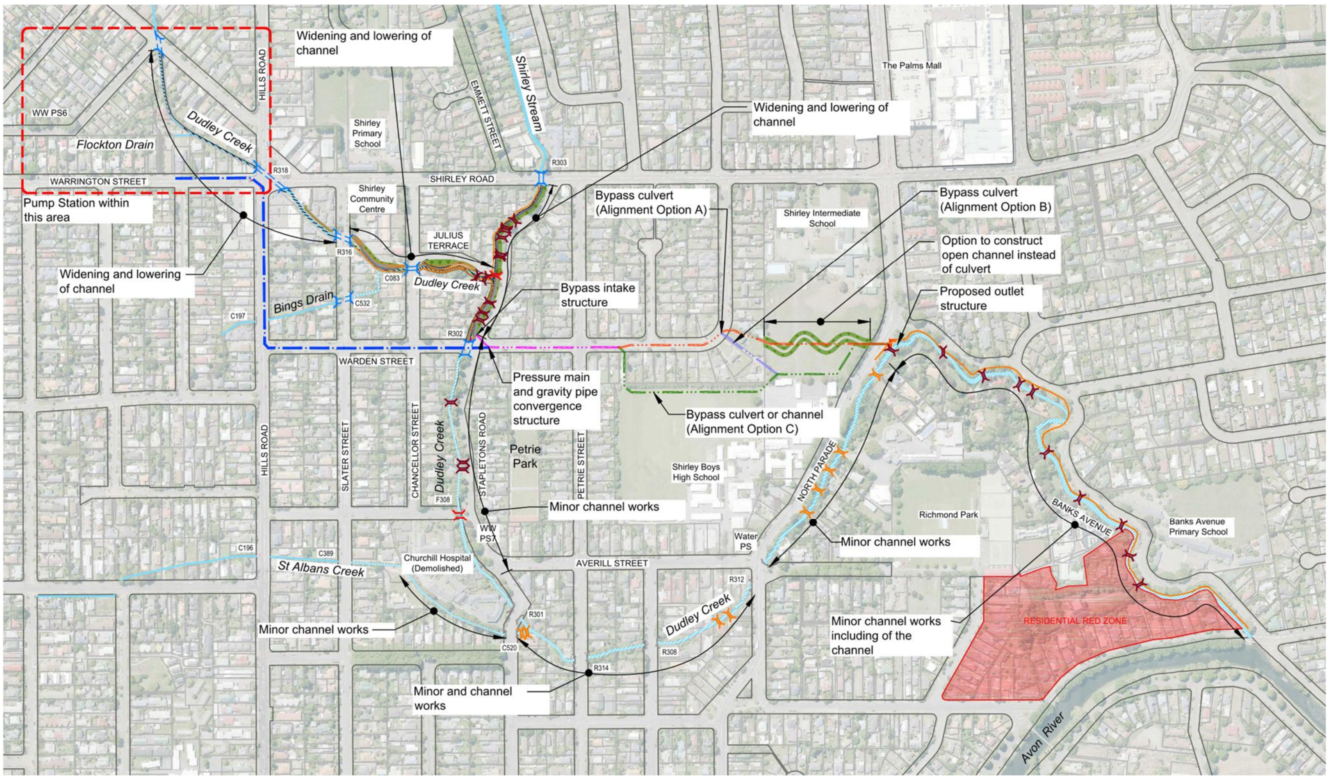
Option 2 seeks to increase conveyance capacity to meet design flows by a combination of increasing the width and depth of a portion of the catchments watercourses, replacement of culverts at road crossings and bridges at private properties and providing supplementary capacity via pumping and a piped diversion.

This supplementary capacity reduces the extent of watercourse capacity upgrading by 3 m^3/s from the pump station to Warden Street and by 4.4 m^3/s from Warden Street to the outfall.

5.1.1 Watercourse upgrade work

All of Dudley Creek downstream of the Aylesford culvert to Warden Street and the section adjacent Banks Avenue require significant capacity upgrading. The section of Dudley Creek between Warden Street and the Stapletons Road crossing, plus short sections of Shirley Stream, Bings Drain and St Albans Creek also require minor capacity upgrading. These watercourses have been assessed to determine the type, location and extent of widening and bank profile treatment required to achieve the design capacity. The outcome of this assessment is presented in Figure 5.1 and in drawing SK-60 (Appendix A).

Figure 5.1 : Option 2 Extent of Works for Watercourse Upgrading



Overall, the extent of channel widening and deepening proposed is significant. A summary of the key work quantities anticipated is summarised in Table 5.1. The total watercourse length and work quantities are considerably less than Option 1 (Table 4.1).

Table 5.1 : Option 2 Summary of Work Quantities for Watercourse Upgrading

Item	Quantity
Bulk excavation from watercourse	8000 m^3
Bank profile Type 1 – Fully Retained	2600 m
Bank profile Type 2 – Natural Grade	550 m
Bank profile Type 3 – Two Stage	250 m
Bank profile Type 4 – Minor upgrading	1000 m

The bank profile upgrade quantities for Type 1, Type 2 and Type 3 refer to bank length as opposed to watercourse length, whereas quantities for Type 4 refer to watercourse length.

In the absence of full coverage of detailed topographical survey of the watercourses this assessment remains relatively subjective; however, it is sufficiently accurate to enable determination of the overall scope and spatial extent of anticipated watercourse upgrade works, to enable assessment of interface with private property, community and environmental impacts and implementation costs.

5.1.2 Culvert replacement

Six road crossings and two public foot bridges (at Guild Street and Julius Terrace) require replacement to achieve the full benefit of capacity upgrading of the water courses. The location of these culverts is provided in drawing SK-60 (Appendix A). The size and required capacity of culverts are presented in Table 4.2

Table 5.2 : Option 2 Culvert Replacements

Culvert	Width	Length
Aylesford Street – Dudley Creek	5m	22m
Shirley Road / Warrington Street – Dudley Creek	5m	51m
Slater Street – Dudley Creek	5m	22m
Chancellor Street – Dudley Creek	5m	14m
Shirley Road – Shirley Stream	4m	21m
Slater Street – Bings Drain	2m	22m

Of note:

- The Dudley Creek culverts on Shirley Road / Warrington Street, Stapletons Road and North Parade cross the roads on an angle, resulting in significantly more work
- The will be some relatively significant traffic management requirements to enable construction of some of these culverts which has been factored into cost estimates
- The design and construction of the Shirley Road culvert is being progressed by SCIRT however remains incorporated in this assessment at this stage

Feasibility design of the footbridges has not been progressed as part of this assessment but will require consideration and potentially community input during detailed design.

5.1.3 Private access bridge replacement

There are a total of 21 private vehicle crossings that require upsizing to achieve the full benefit of capacity upgrading of the water courses. These are in a variety of conditions, with most being in serviceable condition.

The location of these private access bridges are indicated in drawing SK-60 (Appendix A).

5.1.4 Pump station and rising main

A pump station within the Flockton area will convey the design flows via a pressure main and the piped diversion to Dudley Creek at the intersection of North Avon Road and Banks Avenue.

Hydraulic modelling has indicated a pumped flow of approximately 3 m^3/s is required in combination with the proposed watercourse upgrades and piped diversion.

The pump station should be located so that it can pump flows from both Dudley Creek and from the Flockton catchment and positioning it on the existing piped discharge from the Flockton catchment to Dudley Creek (known as the Flockton Invert) is ideal.

In conjunction, installing flow control gates to isolate Dudley Creek from the Flockton catchment enables the pump station to operate both as a pumped diversion and a flood pump station as required. The ability to commence pumping before the on-set of flooding provides additional storage within the stream network and will assist to reduce the on-set of flooding under extreme weather events.

Feasibility design of the pump station has been developed in accordance with the internationally adopted American Institute of Hydraulics design guidelines, which has determined the following:

- Use of submersible axial or mixed flow propeller pumps is proposed, nominally 2 x 1500 L/s pumps @ 10m head for axial flow pumps or 2 x 1500 L/s pumps @ 20m head for mixed flow pumps
- Use of variable frequency drives on the pumps, possibly in combination with increasing the static lift at the discharge column will be required to achieve sufficient minimum head for the selected pumps
- Intake structure to enable pump station to be isolated and drained when not in use
- Formed suction intakes proposed to reduce footprint and depth of pump station and minimise risk of development of vortices
- Overall pump station dimensions of approximately 6 m wide by 8m long by 5 m deep, excluding the intake structure, with grating cover rather than concrete lid of building
- Electrical hut to house main switchboard and motor control centre rather than a building
- Connection to 11kV power supply in Warrington Street is feasible and a 750kVA to 1MVA transformer is required on-site, with transformer sizing dependent on final design pump capacity and pump start method adopted
- Site raised to approximate RL14.0 (0.5m above existing ground level) and electrical installations raised to RL14.5 (1.0m above existing ground level); these levels to be confirmed during detailed design

The resulting pump station feasibility design is presented drawings SK-79 and SK-80 in Appendix A.

Feasibility design of the pressure main has been developed in accordance with conventional hydraulic assessment of pumps and pipes and with consideration of existing services and other site constraints, which has determined the following:

- A 650m long (approximate) by 1.0m diameter rising main along Warrington Street, Hills Road then down Warden Street and discharging to the piped diversion at Warden Street on the east side of Dudley Creek is proposed
- A pressure main material has not been selected as the difficult and expensive installation means that the pipe supply cost differences between the various pipe materials has a minor impact on overall costs

- The pressure main will require specific assessment of pressure transients due to the significant momentum of the pumped water column in the pressure main

The resulting pressure main feasibility design is presented in drawings SK-81 and SK-82 in Appendix A.

The feasibility design development of the pump station is reported in detail in Appendix E.

5.1.5 Piped diversion

A piped diversion is proposed in this option along Warden Street, across the Shirley Boys High School ground and discharging to Dudley Creek adjacent Banks Avenue. The diversion would convey the design flows from the pump station and some flows from the creek. It would reduce the watercourse capacity required between Warden Street and the discharge location by a comparable amount, significantly reducing the physical works required in this reach.

Hydraulic modelling has indicated a diversion flow of 4.4 m^3/s is required in combination with the proposed watercourse upgrades and pump station.

Feasibility design of the piped diversion has been developed in accordance with conventional hydraulic assessment of pipes and with consideration of existing services and other site constraints, which has determined the following:

- A screened intake, with tapered sides and sloped to minimise hydraulic losses, is proposed upstream of the Warden Street road crossing, to enable this structure to control flows in the downstream section of Dudley Creek
- A 715m long by 3.0m X 1.5m box culvert diversion along Warden Street from Dudley Creek and across the Shirley Boys High School ground, placed to grade as determined by inlet and outlet arrangements. This can be reduced to 630m if private property access can be achieved.
- Some service relocations are anticipated

The resulting pipe diversion feasibility design plans, long sections, intake structure and outlet structure is presented in drawings SK-77 to SK-78 in Appendix A.

An open channel across the open ground of Shirley Boys High School has been considered in principle and remains an option if acceptable to the Ministry of Education. This should be assessed during detailed design if Option 2 is preferred.

5.2 Hydraulic performance

The key target areas of this upgrade include the Flockton area, Hills Road Shopping Centre and the Slater Street area. Option 2 significantly reduces flooding in these areas (drawings SK-16 and SK-17 in Appendix A). The modelled option reduces flooding to below pre-earthquake levels in rainfall up to the 50 year ARI event. For the 10 year ARI design flood, the channel and culvert upgrades result in almost no significant flooding around the lower Flockton area.

The number of at-risk residential floor levels has reduced from 80 to 19 for the 50 year ARI design storm in this option (Drawing SK-15 in Appendix A). This is also lower than the 32 at-risk residential floor levels for the pre-earthquake scenario. 490 properties are predicted to benefit in the form of reduced flooding as a result of this option.

The Dudley Creek bypass allows approximately 4.4 m^3/s peak flow to be diverted directly to the lower reaches of the creek thus reducing the need to upgrade the channel between Warden Street and Banks Avenue. The pump station drains Flockton area and also reduces the peaks flows downstream of the Flockton Invert outlet. Channel and culvert upgrades from Aylesford Street to Warden Street are still necessary but the bed does not need to be lowered as much as in Option 1 for this reach.

As with Option 1, flooding may still occur in the upper catchment and contributes to overland flooding which eventually ends in the Flockton area. Option 2 was found to be less effective than Option 1 at reducing the flooding in St Albans Stream or in rare flooding events in Slater Street. Similar to Option 1, areas of flooding that are not benefited by this option include the St Albans Stream along Edgeware Road between Champion Street and Slater Street, and Shirley Stream flooding near Orontes Street. Some further opportunities to address these problem areas are outlined in Section 7.

5.3 Long term performance resilience

There a range of natural hazards and environmental climate changes that may impact the hydraulic performance of the watercourse over time. Some of the more foreseeable risks and their possible impact are discussed in Table 5.3.

Table 5.3 : Option 2 Long Term Performance Resilience Risks and Impacts

Risk	Impact	Potential Remedies
Earthquake – lateral spread	Channel constriction and watercourse bank damage, possibly along a significant length of watercourse, potential moderate to major impact on watercourse capacity. Overall impact reduced compared to Option 1 due to reduce reliance on watercourse capacity. Minimal structural impact on pump station or diversion.	Design to restrain banks, will be prohibitively expensive. Civil works after an event, possibly of similar scale to watercourse upgrade work currently proposed, capacity likely to be recoverable at high cost. Design retaining walls at critical areas to resist lateral spread, with moderate cost impact.
Earthquake – land settlement	Reduction in available elevation as downstream tailwater conditions remain constant, potential moderate to major impact on watercourse capacity. Overall impact reduced compared to Option 1 due to reduced reliance on watercourse capacity. Possible settlement of pump station and rising main but negligible impact on performance. Reduced grade available for diversion with some flow capacity reduction.	Design for possible land settlement by increasing watercourse capacity, likely to significantly increases costs and face major private property access constraints. Civil works after an event, possibly of similar scale to watercourse upgrade work currently proposed, capacity likely to be recoverable at high cost. Increase supplementary capacity likely to be more cost effective option, achievable by pumping, storage or flow diversion out of catchment. Design diversion conservatively to allow for some land settlement, likely to provide reasonable mitigation at moderate cost impact
Earthquake – liquefaction and sedimentation	Channel sedimentation, possibly along a significant length of watercourse, potential minor to moderate impact on watercourse capacity. Overall impact reduced compared to Option 1	Design watercourse upgrade for possible sedimentation, likely to have minor to moderate cost impact on upgrade project. Civil works after an event, possibly of similar scale to watercourse emergency recovery works undertaken after recent earthquakes, capacity

Risk	Impact	Potential Remedies
	due to reduced reliance on watercourse capacity. Minor sedimentation impact on pump station, pressure main or diversion.	likely to be recoverable at minor to moderate cost.
Increased rainfall intensity associated with climate change	This option showed a lower resilience to the impacts of climate change than Option 1. Up to 24 floor level in the Flockton Cluster and Slater Street would be at risk in the 50 year flood event should the predicted 2090 mid-range impacts of climate change be realised.	Management of this risk could be undertaken through house raising as required or through increasing the capacity of the pump station. Increasing the capacity of the pump station will increasing the capacity of the bypass.
Increased tail water levels resulting from sea-level rise	Reduces available elevation and therefore reduces system capacity. No impact on the pump station and pressure main and therefore no impact on the Flockton area.	Design for possible sea level rise – likely to have moderate cost impact on upgrade project. To gain additional capacity if required in future, a general watercourse or Bypass duplication upgrade will be required or supplementary capacity provided.
Extreme flooding events	This option did not perform as well as Option 1 in the modelling of a 200 year flood event. The fixed capacity of the pumpstation and bypass resulted in flooding in many areas of the catchment.	Increasing the capacity of the main channel downstream of the Warden Bypass as in Option 1 could provide increased resilience to extreme flooding events.

Option 2 demonstrated lower resilience than Option 1 to the potential impacts of climate change and extreme flooding, however it may be possible in the future to gain some additional capacity in the bypass by boost pumping.

The impacts as described resulting from an earthquake are significantly more difficult and costly to design out and may require slope reinforcement or additional structural retaining to mitigate risks sufficiently. A decision will be required as to what extent and where this is done due to the high cost of mitigating this risk across the entire work area.

In the event of significant land damage, the most likely response to restore capacity will require a combination of watercourse restoration and construction of supplementary capacity to regain overall hydraulic capacity. In this regard, increasing the capacity contribution of pumping and piped diversion will increase resilience.

5.4 Potential community and environmental impacts

The construction of major watercourse upgrades will pose a range of adverse impacts on the community and the environment during construction, however in the longer term the upgrades will also provide opportunity for a range of positive impacts to occur. The key short and long term community and environmental impacts are summarised in Table 4.4.

Table 5.4 : Option 2 Key Community and Environmental Impacts

Aspect	Construction Phase Impact	Long Term Impact
Private property	Private property access for new channel extents and construction access agreements across properties adjacent to the watercourses are required to enable works to be implemented. There are 72 properties adjacent to the stream. Many would be impacted in this option. Property access required to construct pump station. Property access required across Shirley Boys High School. Private bridges will be temporarily decommissioned. Traffic management may impact access to properties.	Permanent infringement of the creek extent on some private property between Aylesford Street and North Parade. Replacement of 21 private bridges. Easement or open drain across the Shirley Boys High School property.
Ecology	Complete removal of existing in-stream and riparian habitat along the extent of major watercourse upgrade works. Some disturbance between Warden Street and North Parade. May require fish and flow by-pass during construction.	Creation of a stable and viable habitat with native local species, likely to result in overall beneficial ecological impact. Removal of historical stream sediment contaminants.
Landscape	Complete change to existing landscape, including removal of mature trees, some of which are significant or protected. Refer drawing SK-60 to SK-72 for significant or protected trees that will be removed. Those between Warden Street and North Parade can mostly be retained.	Master planned landscape design that is informed by and meets community and environmental setting, likely to result in overall beneficial landscape amenity impact. Existing landscape retained between Warden Street and North Parade.
Recreation	Limited recreational opportunities at present. Temporary restriction on access during construction and plant establishment.	Potential to incorporate recreational amenity via walkways and resting areas, likely to result in overall beneficial recreation impact.

Heritage	Limited existing heritage features so minimal impact.	Potential to incorporate heritage values into design of structures and landscaping and these elements have potential to be of future heritage value, opportunity to result in overall beneficial heritage impact.
Cultural	Limited existing cultural interaction apart from a general interest. Ability to accommodate cultural requirements as part of construction process.	Potential to incorporate cultural values into design of structures and landscaping, opportunity to result in overall beneficial cultural impact.

The range of construction phase impacts discussed above reflects that major civil works are required and that these works will have a major short-term impact. Overall however there is a good opportunity to enable positive long term effects for most of these community and environment aspects. These impacts and benefits are however over a considerably smaller area than Option 1 due to the reduced extent of work within the watercourses.

5.5 Costs

Preliminary estimates of the cost to construct Option 2 as discussed above and more fully presented in the referenced drawings have been assessed based on the cost estimating approach outlined in Section 2.4.

The combined project budget range is summarised in Table 5.5 and presented in detail in Appendix G.

Table 5.5 : Option 2 Project Implementation Cost Estimates and Cost Confidence

Component	Target Cost (excl GST)
Construction	$43 M
Property access	$2 M
Project implementation	$8 M
Target cost	**$53 M**
Cost confidence	-20% +40%

This total project budget equates to approximately $110,000 / property benefited.

5.6 Project implementation

Project components that need to be achieved or completed in order to implement the works and achieve the capacity increase sought include:

- Property access
- Resource consents
- Site investigations
- Detailed design

- Procure Contractor

Implementation of the entire Option 2 is required to achieve the desired capacity improvements, however delivery of the pump station and bypass accounts for approximately 70% of the benefit achieve by Option 2.

Gaining of the necessary approvals for the pump station and bypass components is considered likely to be easier than for the culvert and watercourse works and construction staging of these components ahead of these works is logical and feasible if required, since the discharge is located at the lower end of Dudley Creek, it is less critical to undertake works from the downstream up.

Construction of watercourse upgrading components cannot commence until access rights to the many potentially affected properties as well as resource consent for the works have been gained and design completed. As discussed in Section 3 this is anticipated to take time. Some areas will not be constrained by the property access requirements however it is expected that partial works would not be undertaken due to the risk that if property access cannot be gained in a timely manner, additional mobilisation and construction costs will be incurred and possibly, sections of the upgrading will not be completed for some time and the overall capacity upgrade objectives will not be met.

Gaining of consents for the proposed watercourse upgrade works will most likely require comprehensive community and stakeholder consultation, particularly considering the significant ecological and visual changes that will result and the need to interface with many residents adjacent the works areas. The smaller extent of works will reduce the potentially affected community however other stakeholders will remain interested.

Detailed design of Option 2 requires specific geotechnical investigations and detailed topographical survey of the pump station site, pressure main route, piped gravity diversion and inlet and outlet structure locations, as well as for the portions of the watercourse where work will occur. Detailed design will commence from when property access is gained, or from the time Council agrees to proceed if property access cannot be timeously achieved or design is to be progressed at risk.

Procurement of a Contractor to undertake these works is the subject of a separate report to Council. For the purposes of this assessment, we assume a fast-track process run in parallel to design.

Assuming that unimpeded access and consents are gained, construction of the works is in principle relatively simple and there are several competent Contractors experienced in these works. Key risks are discussed in Table 5.7.

Due to the scale of the proposed works it is expected that a Contractor would apply multiple crews over a number of work sites. Culvert construction is logically separated from the pump station and associated pressure main, piped gravity diversion, inlet and outlet and from the watercourse construction, due to the different work type and specific locations. Several culverts could be constructed concurrently and pump station and pipe mains could be constructed concurrently. Waterway construction would likely be undertaken with several crews, working on specific work sections generally in the same area. Again, it is likely there would be specialty crews for specialty works such retaining walls.

In order to develop a preliminary implementation programme, the following assumptions have been adopted:

- Gaining of property access agreements takes a nominal period of 6-months. There is no formal basis for this assumption other than there are many access agreements required and there are likely to be difficulties. In reality some access agreements may not be gained by mutual agreement and this process could take longer. A lessor figure is assumed compared with Option 1due to there being considerably fewer agreements to obtain.
- Resource consents are sought under the under in Council, and the relevant statutory agencies meet prescribed timeframes for assessment and notification, with consents required to effect the pump station, pressure main, piped gravity diversion and inlet and outlet structures separated from watercourse works consents to enable more rapid assessment and approval.
- Investigation and design is run concurrently to the property access and resource consent process

- Contractor procurement process is run concurrently to Investigation and design

The basis for these assumptions is that there is urgency to implement the project.

The resulting preliminary programme is provided in Table 5.6, which indicates the general interaction between project components.

Table 5.6 : Option 2 Preliminary Implementation Programme (in months from commencement)

Component	1	2	3	4	5	6	7	8	9	10	11	12
Site access agreements												
Resource consents												
Site investigations												
Detailed design - culverts												
Detailed design - watercourse												
Construction documentation												
Contactor procurement												
Construction												

A nominal construction period of 18-months is considered achievable however considering the extent of large and deep civil work as well as works within an active watercourse network that is susceptible to flooding, contains poor ground and with significant public interface; a longer construction programme would reduce delivery pressures and risks.

The overall implementation programme including the nominal 8-month period to gain property access and an 18-month construction programme is therefore likely to extend out to 24-months, with delay risks as outlined and discussed further in Section 5.7.

5.7 Project implementation risks

A risk register has been established for the project and the results of a risk workshop undertaken during the feasibility design phase have been incorporated (refer Appendix I).

Key risks that may affect implementation of the watercourse work component are the same as for Option 1, albeit at a reduced risk level due to the smaller extent of watercourse and private property. Refer to Table 4.7 for those and to Table 5.7 for risks associated with the pump station, pressure main, gravity diversion and inlet and outlet structures.

Table 5.7 : Option 2 Implementation Risks

Component	Risk	Potential Impact
Site access agreements	Access approval for site investigations not gained Access approval for construction not gained Low risk as 2 properties	Design delayed, additional costs incurred Construction delayed, incomplete works
Resource consents	Strong community views, low risk due to small area of potential effects Processing delays	Need additional consultation which delays process Approvals delayed, construction start date pushed back
Site investigations	Delay, considered low risk due capacity in the market	Delay in design
Detailed design	Insufficient flows reach pump station	Pump station not as effective as designed
Construction documentation	Low risk	
Contactor procurement	Early Contractor engagement then Project delayed	Contractor standing costs
Construction	Environmental spill or siltation Wet weather or major storm event Location and supporting of utility service crossings Poor ground conditions during pipe laying	Environmental damage, enforcement action Erosion of works, environmental damage, lost time, rework Construction cost, programme, public disruption if broken Rework, design changes, delay, increased cost

6. Opportunities to provide additional flood protection

Any undertaking of flood mitigation works provides opportunities to enhance aspects of the Council's Six Values outlined in the Christchurch City Council *Waterways, Wetlands and Drainage Guide*. These values include drainage, ecology, landscape, recreation, cultural/ heritage values and land stability. The opportunities presented here will focus on enhancement of drainage and have not been considered in detail.

6.1 Shirley Stream

While there are few floor levels at risk upstream of Shirley Road on Shirley Stream there is significant flooding predicted by the model on the floodplain and within streets. Flooding within streets and private property is permitted within Council design standards and none of the options considered include significantly reducing this flooding. However all options have made capacity allowance to accommodate increased flows from Shirley Stream in case future or additional works are undertaken in Shirley Stream to reduce the flooding upstream of Shirley Road. Channel upgrades could be extended upstream from Shirley Road to Orontes Street (including the enlarging of the culvert under Orontes Street). This will help alleviate some of the drainage problems along Emmett Street and Jebson Street.

6.2 Upper Mairehau Catchment

Option 1 and Option 2 also allow for further upgrades in the upper catchment including Mairehau Drain, Tay Street Drain and the connected stormwater pipe network. During a heavy rainfall the pipe network under Innes Road and Malvern Street just upstream of the Mairehau Drain open channel are unable to convey the flows resulting in surface flooding. In addition to flooding the local properties in this area, the floodwaters flow overland in a south-easterly direction and cross Westminster Street and add to the flooding in the Flockton area. There is the opportunity to upgrade the stormwater network in this area including potentially pumping floodwaters to the Dudley Diversion Drain to the north. This may be a viable alternative to downstream upgrades to address future increases in flood risk within the Flockton area resulting from climate change.

6.3 Floor raising

The opportunity to raise individual residential floor levels is also present for both options. Based on the 50 year ARI design flood, 15 dwellings in Option 1 and 19 dwellings in Option 2 would need to be raised to provide 50 year level of protection to all residential properties within the area benefited by the options. This is expected to cost between $2 M to $3 M. However some of these properties may be already be scheduled for raising as part of the rebuild relating to earthquake damage. This approach may be advantageous for localised areas of flooding which will be difficult or costly to reduce water levels. This should be assessed and advanced in conjunction with project works if funding and property access requirements allow.

6.4 St Albans creek upgrades

The opportunity exists to extend channel upgrades upstream in St Albans Creek to Hills Road with culvert upgrades to both Slater Street and Hills Road crossings. This opportunity is most effective for Option 1 which includes reduced bed levels in Dudley Creek at the St Albans Creek confluence with Dudley Creek. This would significantly reduce flooding along Edgeware Road between Champion Street and Slater Street. The modelling predicts three properties in this area to have at risk floor levels in a 50 year flood event.

6.5 Increase pump station capacity (Option 2 only)

When designing the pump station for Option 2, there is the opportunity to allow for future increased pump capacity. This may be beneficial in larger magnitude events (i.e. larger flooding than 50 year ARI) or to accommodate future upgrades to the pipe networks in the Flockton area. This would be particularly beneficial to the properties around the Slater Street crossing.

A variant to Option 2 is replacing the gravity bypass with a pressurised rising main the discharges into the lower Dudley Creek. This would require an increased pump station capacity (4-5 m^3/s) but would also result in a smaller pipe than the large bypass. This option is heavily dependent on the pump station operating effectively in a flood.

6.6 Combined option (Option 3)

Options 1 and 2 both meet the objective of the restoration of pre-earthquake flooding hazard to much of the catchment; however the hydraulic modelling predicts surface flooding in a number of locations in the 50 year rainfall event. For comparative purposes a third option was considered to identify the benefits of further work that could be undertaken in the catchment possibly as a second stage to the initial project or undertaken when the predicted impacts of climate change are realised. To model this Option 1 and Option 2 were combined. That is Option 3 includes include the full channel and culvert upgrades between Aylesford Street and the Avon River as well as a pump station and the Warden Street Bypass, as per plan SK-85 (Appendix A). In addition to these upgrades the stormwater pipe network within the Flockton area was also upgraded in the model.

Plan SK-18 in Appendix A illustrates a schematic of this option and compares the flooding extents with the pre-earthquake flooding in the 50 year rainfall event including the predicted impacts of climate change. The model results show that this option offers a high level of protection from flooding in Dudley Creek. Flooding in the upper catchment remains and is almost unaffected by Option 3. However where this flooding flows overland and into the low lying Flockton area Option 3 offers an increased level of protection due to the upgraded stormwater pipe network being able to convey this flooding to the pump station.

Option 3 results in the reduction of floor levels predicted to be at risk by the model in the 50 year ARI rainfall event with the predicted 2090 midrange impacts of climate change by 12 floor levels compared to Option 1 and an 20 floor levels than Option 2.

6.7 Upgrade of pipe networks and secondary flow paths

Both options have the potential to extend the benefits of the upgrades by upgrading the connected stormwater drainage. Upgrades to the pipe network and secondary flow paths that discharge to the upgraded streams may help alleviate flooding in various localised areas such as between Shirley Road and Sabina Street. This is particularly evident in Option 3 where the benefits can be seen of larger and more hydraulically efficient stormwater pipes and inlets in the Flockton area including Speight Street, Archer Street and Squire Street. Option 2 which includes a pump station would be the most easily extended to include upgrades to the pipe network in the Flockton area.

6.8 Raising of minimum floor levels over time

Design floor levels for many properties in the area are presently below the 50 year flood level plus 400mm freeboard. The District Plan suggests that for new dwellings in the catchment the design floor levels will be set at the 200 year flood level plus 400mm. Over time this planning control will help reduce the flooding risk to floor levels in the catchment.

7. Comparison of feasibility designs, principle risks and opportunities

This section provides a comparison of the options against the six evaluation criteria agreed with Council:

1. Hydraulic performance against the two objectives
2. Resilience against failure and over-design hydraulic events
3. Impacts private property owners, the community and environment
4. Statutory and planning requirements
5. Costs
6. Timing of implementation

7.1 Comparison of hydraulic performance

The results of the hydraulic modelling have been used to identify floor levels at risk in the area benefited by the two options. This provides a practical measure of the performance of the two options and a comparison of the options against the pre and post-earthquake scenarios. Figure 7.1 illustrates this comparison for the 10 and 50 year ARI rainfall events as well as for the 50 and 200 year rainfall events including the predicted 2090 midrange impacts of climate change.

Figure 7.1 : At-risk Floor Levels in Various Scenarios and Flooding Events in the Dudley Catchment

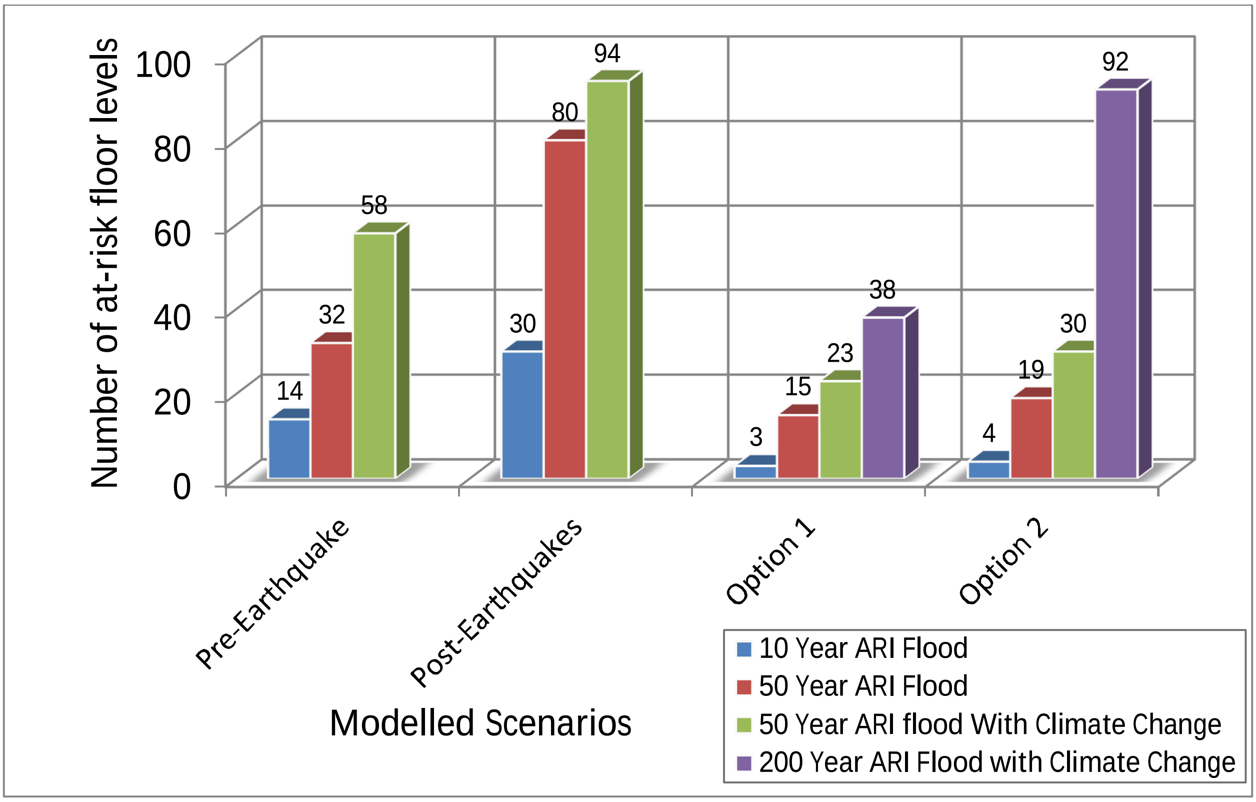


Figure 7.1 demonstrates that prior to the earthquakes there was a number of floor levels with flooding risk in the Dudley Creek Catchment. The hydraulic modelling predicts that there was flooding risk to 32 floor levels in a 50 year rainfall event. With the inclusion of the predicted 2090 midrange impacts of climate change on rainfall up to 58 floor levels could be at risk. This doubling of the at risk floor levels suggests that this area and particularly the Flockton cluster had little resilience to the potential changes in the climate.

Figure 7.1 also clearly illustrates the impact the earthquakes have had on flooding risk in the Dudley Catchment. The model results predict that the earthquakes have greatly increased the number of floor levels at risk in the 10 and 50 year rainfall scenarios.

The model results with the inclusion of the upgrades associated with Options 1 and 2 also help to quantify the benefits of the options. In flooding up to the 50 year ARI rainfall event both options show significant reduction in risk to floor levels when compared to the current (post-earthquake) flooding risk. Furthermore both options show some improvement on pre-earthquake flooding risk.

Compared to each other Option 1 shows slightly better hydraulic performance than Option 2. Hydraulically the major difference between the two options is in their resilience to extreme flooding events. Option 1 shows a greater level of protection to floor levels in the 200 year flood event than Option2 which has a fixed capacity pump station and bypass. It would be possible to design the pump station and bypass with additional capacity to help mitigate some of this residual risk if the benefits are considered appropriate against the additional cost.

7.2 Comparison of resilience against failure

For earthquakes of a large enough magnitude to induce liquefaction and lateral spread, both options are susceptible to bed heave and lateral spread of banks, with associated restriction in channel capacity. Culverts and retained sections are likely to avoid failure if designed for this purpose, however it is expected that a large portion of the watercourse length could sustain significant damage. Option 2 would be expected to suffer a similar extent of damage to watercourses as Option 1, however the engineered pump station, pressure main, bypass and culverts could be designed to limit damage and would be expected to sustain the majority of their operational performance after an earthquake, perhaps with some repair required.

Failure of the pump station during a flood event is a residual risk that will need consideration during design.

7.3 Comparison of impacts on private property owners, the community and environment

Both options being considered will affect landowners adjacent to the stream where work is undertaken. This could be to allow access for equipment or the construction work encroaching onto private property. Much of the work for both options will occur within the existing channel or on the adjacent floodplain. Wherever possible disruption to public land, such as road reserve, has been preferred to impacts on private property but in areas of channel widening the works are likely to encroach onto usable areas of private property.

Table 7.1 summarises the number of affected property owners in each option. ‘Affected’ in this instance means they are either adjacent to a section of stream that is subject to bank widening, or have a private access bridge that will require replacement as part of the project. In addition to this both options may require alterations to some residential dwellings to accommodate the channel widening.

It is important to note that no consultation with land owners has yet occurred and that the designs will be further refined once a preferred option has been selected. All affected land owners will be consulted prior to work being undertaken and it may be possible to avoid or mitigate the impacts of the works. It is recognised and included in the costing and feasibility design that quality landscaping will be an integral part of all of the options.

Table 7.1 : Private Property Access Requirements

Properties	Option 1	Option 2
Number properties where full access may be required	8	2
Number properties some access required	70	40
Number properties requiring consultation	115	72

Table 7.1 illustrates that the two options differ in that Option 1 requires engagement with a greater number of private property owners, whereas Option 2 makes greater use of the existing road corridor.

The environmental impact of the construction of the options follows the same trend; further disruption of a greater distance of stream is required for Option 1. Both options require mature tree removal along Julius Terrace, north Stapletons Road and Banks Ave, but Option 1 will also require the removal of a significant number of mature trees on south Stapletons Road and on North Parade.

7.4 Statutory and planning requirements

All options will require a due process to be followed in order to gain the necessary statutory approvals. An indicative programme based on the use of the Canterbury Earthquake (Resource Management Act) Order 2011 (SR 2011/34) suggests that a 9-12 month approval process will be required.

Some of the works proposed for this project in the beds and margins of waterways will be covered by the existing Council global waterways consent however it is likely that the culvert upgrades and earthworks within a riparian zone (Rule WQL30) will require additional consents.

This creates a significant point of difference between Option 1 and Option 2. There is little that can be done on Option 1 under the existing consents as much of this option includes work in the riparian zone, however there are portions of Option 2 that could begin within 6 months of the preferred option being selected, specifically the pump station, rising main, bypass and culvert construction as well as the watercourse improvements downstream of the bypass outlet.

Another key area of difference between Option 1 and Option 2 is the property access consultation. Option 2 which has significantly less extent of impact on private property will require less consultation with reduced risk of delays or excessive disruption. To implement the civil works identified above, there are only 2 potentially affected properties and 1 consent required.

7.5 Comparison of costs

The estimated project implementation cost estimates and cost confidence are summarised in Table 7.2.

Table 7.2 : Project Implementation Cost Estimates and Cost Confidence

	Option 1	Option 2
Construction	$38 M	$43 M
Land access	$6 M	$2 M
Project implementation	$6 M	$8 M
Target cost	$50 M	$53 M
Cost confidence	-10% +30%	-20% +40%

The target cost estimates for both options are similar, however Option 2 has lower cost estimating confidence. A significant component of the cost risk with Option 2 stems from the uncertainties surrounding the final location and design detail. Completion of ground investigations, site survey and pot-holing of services will enable refinement of buried pipeline design alignments and associated cost risk profile.

7.6 Comparison of timing of implementation

Both options have property access and resource consent requirements that will take time to achieve. Option 1 is most constrained by property access, as the option cannot be meaningfully implemented in parts and therefore construction commencement could be delayed until the necessary approval are gained. Preliminary programming indicates this could take 9-months, however due to the number of properties where access agreements would be required, there is risk that this could take considerably longer.

Works within the watercourse for Option 2 are subject to the same constraints; however, the balance of work that is anticipate to provide approximately 70% of the capacity upgrade benefit has few approval constraints. Implementation of Option 2 is therefore at lower risk of delay and if property access becomes problematic, the balance of civil engineering works are likely to be able to be completed within a 2-year timeframe.

Important note about your report

The sole purpose of this report and the associated services performed by Jacobs SKM is to develop the feasibility design of identified flow capacity improvement options, develop indicative project implementation costs and assess the performance of agreed options against a range of agreed criteria. This is in accordance with the scope of services set out in the contract between Jacobs SKM and Council. That scope of services, as described in this report, was developed with Council.

In preparing this report, Jacobs SKM has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs SKM has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

Jacobs SKM derived the data in this report from information sourced from the Council and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report.
Jacobs SKM has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by Jacobs SKM for use of any part of this report in any other context.

Specific limitations apply to the accuracy of the scope and cost of upgrade work identified, due to the limited input information including ground topography and detailed geotechnical information, and to the feasibility designs developed which reflect that this project is at feasibility stage, with further preliminary and detailed design phases to come.

This report has been prepared on behalf of, and for the exclusive use of, Council, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs SKM and the Client.
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