Heathcote River Floodplain Management Plan

Christchurch City Council

Dredging Feasibility Report

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Contents

Abbreviations

Abbreviation	Definition
ARI	Annual Recurrence Interval
CCL	City Care Ltd
CDB	Christchurch Drainage Board
ECan	Environment Canterbury
HAIL	Hazardous Activities and Industrial Land
LDRP	Land Drainage Recovery Programme
LLUR	Listed Land Use Register
LWRP	Land and Water Regional Plan
NES	National Environmental Standard
OCP	Organochlorine Pesticides
TPH	Total Petroleum Hydrocarbons

Executive Summary

This report has investigated the feasibility of dredging reaches of the Heathcote River upstream of the Woolston Cut, as one of a number of possible flood management options being considered by Christchurch City Council ('the Council'). This report does not cover dredging of the Woolston Cut which is being considered separately by the Council. The wider context for investigating dredging, is that it is an option in addition to the planned upstream storage basins. Upstream storage is considered to be the foundation of all other options (including dredging) as it lowers water levels such that the benefits of other options are increased, and the costs are lower.

Hydraulic modelling has demonstrated that flooding upstream of Radley Street is caused in part by the inadequate capacity of the channel to convey flood flows to the Woolston Cut and out to the estuary. Dredging can increase channel conveyance, reduce water levels and frequent floods. Dredging can also reduce the length of time water occupies the floodplain, which has relevance where flooding displaces people from their homes or forces road closure and access restrictions. However, there are important environmental, social and financial implications.

Based on analysis of past channel profiles, the reach with the greatest raising of the bed (through sedimentation and earthquake impacts) and overall loss in cross-sectional area through sediment deposition and possibly earthquake effects, is between Hansen Park and the Woolston Cut. No hydraulic benefit of dredging any further upstream of Hansen Park is anticipated. Compared with the latest full river cross section survey in 2011, a lowered and widened channel profile is proposed which reduces bed elevation and increases cross-sectional area uniformly from the existing level and cross-section at Hansen Park to a proposed bed level of RL 7.5 m at the Woolston Cut. It is estimated that a volume of approx. 60,000 m^3 of material needs to be removed to achieve the proposed design channel. As far as possible from the available information, the design channel does not exceed the deepened and widened channel profile maintained historically until dredging of the Heathcote ceased in 1986.

The proposed channel was represented by modified cross sections in the Heathcote hydraulic model, which includes the planned upstream storage. Comparing the maximum water levels and flooded properties and roads in the basecase and post-dredging scenarios (both of which include the benefits of the planned upstream storage) indicated that it achieves benefits including:

- A maximum water level reduction of approximately 300 mm, around Hansen Park, reducing to less than 100 mm reduction around Ensors Road in an upstream direction and Radley Street in a downstream direction. A similar pattern of water level reduction is predicted for both 10 year and 50 year existing development scenarios;
- In the 10 year ARI event, dredging protects 10 of the 14 (~70%) properties at risk of overfloor flooding upstream of Radley Street, removing all overfloor at risk properties upstream to Ensors Road. In the 50 year ARI event, the water level reduction protects a higher number of properties (46 out of 118), although this is a lower proportion (~40%) of the properties at risk of overfloor flooding upstream of Radley Street;
- In a future scenario +0.25 m sea level rise from its current level, more properties are at risk of overfloor flooding in the basecase and more are protected by the proposed dredging. In the 10 year ARI event, 23 out of 36 are protected, which is a drop in the relative number protected from 70% to 65%;
- In the +1 m sea level rise 10 year ARI event, the proposed dredging protects 10 properties out of 97 which is a significant drop in relative properties protected from 70% to 10%; and
- In terms of road flooding in the 10 year ARI event, dredging in addition to the planned upstream storage provides a reduction in road/access flooding compared with the base case, and returns the whole reach between Colombo and Radley Streets largely to pre-earthquake levels of road and access flooding. This reduction in length of flooded road and number of properties with restricted access is accompanied by a reduction in the typical duration of flooding by up to 7 hours between Brougham and Hansen Park.

It is suggested that the most effective method for dredging between Hansen Park and the Woolston Cut is to use a long reach digger. Machines are available with a 20 m reach, which can therefore span the anticipated 36 m channel by working from both banks. Where direct access to the waterway is impeded by obstacles, temporary working areas can be constructed into the channel for the digger to work from, as well as from a barge tethered to the banks.

The key potential cultural, environmental, geotechnical and other issues are likely to be:

- Cultural effects: Good sediment management is of the upmost importance - disturbed sediment should be captured and removed as close to source as possible;
- Ecological effects: Fish management - fish populations were observed which included species with a conservation status of "at risk/declining". Inanga spawning area is between Hansen Park and Radley Street bridge, where between 1 January and 1 May every year no works are allowed unless an ecologist indicates that there are no spawning sites present that would be adversely affected by the works. The dredged channel profile should seek to create channel form variations suitable for ecological habitat;
- Effects on water quality as a result of undertaking works in and around streams: Consider a two stage methodology using instream silt curtains and working from upstream to downstream, and operating the Woolston Cut to capture sediment and clear this location last;
- Effects on bank stability: The excavation of the river bed has the potential to de-stabilise river banks and cause banks to erode, both as an ongoing process and through earthquake-induced lateral spread. Hansen Park to the Woolston Cut already exhibits undercutting and scouring and requires an assessment for bank instability prior to any works. Mitigation measures could also be designed to increase channel roughness following construction prior to vegetation establishment to improve stability while the channel consolidates;
- Contaminated discharges from extracted sediment: Based on high level results, the excavated material may be within recreational thresholds suitable for disposal at Burwood Landfill or, more economically, be reused elsewhere if suitable opportunities could be identified. Dewatering in stockpiles could be considered in the public areas of Hansen Park and Radley Park at the extreme ends of the reach being dredged. However, further consideration needs to be given to the cost of treatment and disposal of this material following in situ testing, particularly if any asbestos is identified; and
- Stakeholder engagement: The Heathcote River/Ōpāwaho is of high interest to the community and early identification of all stakeholders and engagement will be required to understand and, where possible, address concerns with dredging during the planning and consenting of the operations.

A high level review of the Land and Water Regional Plan indicates that dredging requires consent as a discretionary activity. The Council is currently investigating with ECan whether proposed dredging works could be authorised by, and undertaken under, one of the existing dredging consents held by the Council (CRC146620 and CRC121582).

Based on unit costs established from previous similar work (dredging, disposal, bank stabilisation etc.), the total capital cost of removing 60,000 m^3 of material between Hansen Park and the Woolston Cut, and undertaking a degree of bank stabilisation has been estimated at $14.2M. This includes high level estimates for design and project management, consenting and risk (totalling 35% of construction costs). This does not include separate costs of dredging the Woolston Cut, but efficiencies may be achieved through combining these works as soon as possible.

Depending on survey to monitor the response of the channel, maintenance dredging undertaken every 10 years may be required to remove approximately 7,000 m^3, which could cost in the order of $1.3M every 10 years (including the 35% overheads).

The programme to remove 60,000 m^3 of material will be challenging, and focussed on the 8 month window between May and December which is outside the Inanga spawning season. However, the Inanga / whitebait season between 15 August and 30 November may pose additional constraints, as will high water levels during the winter and spring season. Therefore, it may be more feasible to consider the initial dredging, as well as maintenance dredging, being undertaken in successive reaches over a longer period of time. However, this would delay achieving the full hydraulic benefits until the completion of all works, although works could be prioritised.

It is recommended that the Council continues development of this option to dredge the reach between Hansen Park and the Cut to manage flooding, and makes decisions on implementation within the context of other options to manage flooding in the catchment. Whilst this report has recognised the work being undertaken in parallel to consider dredging of earthquake liquefaction material from the Woolston Cut, it does not make any recommendations about this reach. If dredging is pursued, the following tasks are recommended:

- As far as possible, unify all work towards dredging the channel between Hansen Park and the Woolston Cut, including the Woolston Cut. This could include programming works so that the Woolston Cut is used to capture residual sediment transported downstream and cleared last, although this will depend on operation of the tidal gates;
- Undertake channel survey and revised modelling to more accurately determine the channel profile to be achieved, the volume of material to be removed and to provide a baseline against which future deposition can be measured;
- Detailed design should include channel modelling to show how proposed cross sections remain stable by assessing stream power, bed shear stress and velocity against expected stable cross section profiles;
- Engage specialist ecological input to assess the effects of any bank reconstructions, changed water depths and to determine if any spawning sites are located within the proposed dredging locations;
- Develop a fish management and relocation plan;
- Undertake *in-situ* sediment sampling to confirm absence of material above recreational levels of contamination, and in particular absence of asbestos;
- Identify all stakeholders as early as possible and develop a consenting and engagement strategy; and
- On the basis of the above, refine cost estimates for the work and seek efficiencies through reuse of excavated material and other opportunities.

Further work is required to better understand the morphology of the Heathcote River/Ōpāwaho and, in particular (i) how channel morphology will change as a result of desilting which may require mitigation measures such as batter treatment and (ii) how the river may respond to climate change and a rise in sea levels. Modelling is likely to be required to predict how the river may respond to future changes in estuary levels, which will inform the effectiveness of future dredging operations.

Important note about your report

The sole purpose of this report and the associated services performed by Jacobs is to describe information relevant to the feasibility of dredging the Heathcote River upstream of the Woolston Cut, in accordance with the scope of services set out in the contract between Jacobs and Christchurch City Council (the Client). That scope of services, as described in this report, was developed with the Client.

In preparing this report, Jacobs 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 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 derived the data in this report from information sourced from the Client 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. This report contains analysis of the flood risk to individual buildings which is based on data received from the following key sources: (i) Council floor level database (latest version issued August 2017) (ii) Rateable Value database (2016 valuations) (iii) RiskScape building depth-damages (2016 delivery of 2011 data). Together, these data provide the best available snapshot of property information across the city at a point in time and are updated at different intervals, including within the timescales of this project and report. Reasonable effort has been made to report property metrics using the latest available data and on-site observation has been used in some situations to clarify uncertainties in the data. However, these data are liable to change in the future. Jacobs 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.

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1. Introduction

The Heathcote River/Ōpāwaho catchment has a significant flood risk and the wider Land Drainage Recovery Programme (LDRP) Heathcote River Floodplain Management Plan project is developing local and catchment-wide floodplain management plans. These plans will incorporate engineering and policy options and take into account other natural hazards, to address fluvial, pluvial and tidal flood risk. The wider study will focus on achieving flood management benefits in the catchment between Halswell Road and Radley Street, although options outside of this area will be considered.

This report provides information to inform dredging of the Heathcote River/Ōpāwaho, which is only one possible flood management option being considered by Christchurch City Council ('the Council'). The report provides information to further understanding on the:

- Effectiveness of dredging for both routine river management and also floodplain management;
- Feasibility, benefits, costs and risks of dredging at different locations along the Heathcote River/Ōpāwaho including:
    - Whole reach dredging;
    - Selective dredging and/or sediment traps upstream of Woolston Cut; and
    - Use of the Woolston Cut as a sediment trap.
- Recommendations for future dredging options.

The findings of this report will be used to inform the wider options assessment for managing flooding in the catchment.

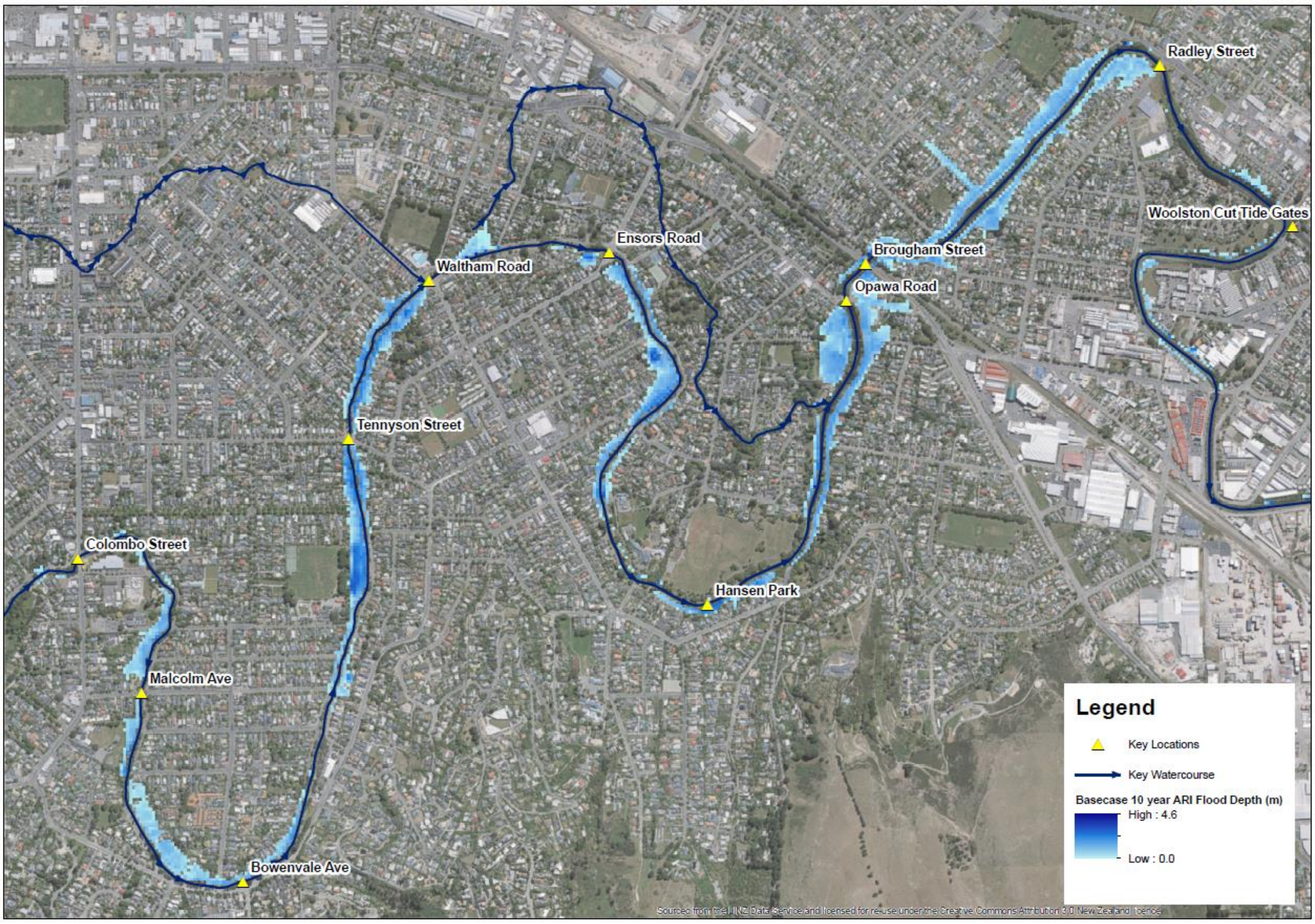


Figure 1.1 : Location map showing key locations along the River Heathcote

2. Motivation for Dredging the Heathcote River/Ōpāwaho

2.1 Floodplain Management

In general, dredging of a channel results in an increase in the cross sectional area and a reduction in the roughness of the channel. Dredging can increase channel conveyance, reducing water levels and frequent floods. Dredging can also reduce the length of time water occupies the floodplain, which has relevance where flooding displaces people from their homes or forces road closure and access restrictions. However the following are important considerations:

- As dredging can speed up flow, it can potentially increase the risk of flooding downstream;
- Dredging is unlikely to make substantial difference in rare events once flows exceed the capacity of the river channel; and
- When the downstream channel flow is impeded by a bridge or high downstream water levels (e.g. from the estuary in the lower Heathcote River/Ōpāwaho), dredging may provide limited benefit. Dredging of rivers in a coastal environment could modify the risk of coastal flooding and tsunami.

With respect to the lower Heathcote River/Ōpāwaho, in frequent fluvial floods the Radley Street bridge is not predicted to impede the downstream flow. Whilst any changed risk of coastal flooding and tsunami through dredging the lower Heathcote should be understood through specific investigation, it is noted that (i) the Loop and the channel between the Cut and the estuary provides a degree of separation from the estuary and is not anticipated to be modified through dredging and (ii) the Woolston Barrage operates to minimise the upstream propagation of flows from the estuary.

Specifically in the Heathcote River/Ōpāwaho, there are two key reasons why dredging may offer hydraulic benefits:

- The Canterbury Earthquake Sequence has reduced channel capacity through uplift, lateral spread and liquefaction deposits. Removing the earthquake deposits could assist in returning the channel to its pre-earthquake capacity, although will not offer any remediation due to uplift of the bedrock which has not scoured; and
- The Heathcote River/Ōpāwaho channel capacity is understood to limit flood discharge through its lower reaches, and this was one of the primary motivations for the Woolston Cut. Increasing the channel capacity could enable high flows to discharge more rapidly into the estuary if (i) discharge is not impeded by downstream estuary levels and (ii) major structures (e.g. the Woolston Barrage) do not then become the constraints.

2.2 Routine River Management

Two typical reasons to undertake routine river management are for navigation and gravel extraction. However, in the Heathcote River/Ōpāwaho, neither of these applies beyond recreational use, due to limited channel capacity.

Environmental enhancement (e.g. restoring fish habitat through removal of liquefaction) could be a motivation, given the high sediment loads in the river and the contaminated nature of sediment in certain reaches. As highlighted in the 2015 Sediment Quality Survey[1], if sediment is a major factor in limiting in-stream biota, dredging to remove the contaminated sediment could reduce the metal concentrations. However, the long-term sustainability of this approach requires identification and management of the contaminant sources.

There is also a motivation to keep stormwater outfalls from blocking.

[1] NIWA (2015) Sediment Quality Survey for Heathcote River Catchment, City Outfall Drain and Estuary Drain. Prepared for Christchurch City Council. September 2015

2.3 History of Dredging in the Heathcote River/Ōpāwaho

Until approximately 1986, dredging had been undertaken along the Heathcote River/Ōpāwaho, managed by the Christchurch Drainage Board (CDB; see Figure 2.1). The CDB viewed silt dredging and aquatic weed removal as the main method for improving drainage, with the outcomes focussed on drainage. Based on records between late 1920's and 1989, regular dredging was carried out downstream from Colombo Street, as well as two in-stream silt traps at Aynsley Terrace and below the Radley Street bridge[2]. The reach between Radley Street and Brougham Street was dredged frequently.

Responsibilities for any further dredging passed to the Council in 1989 following abolition of the CDB. It was suggested that dredging may have caused local bank erosion and further sedimentation arising from over deepening of the channel. No dredging was undertaken upstream of Aynsley Terrace after sand bearing springs were exposed adjacent to Riverlaw and Fifield Terraces in 1975. In 1989, further dredging was deferred to determine whether the channel at the time would adjust itself to a reasonably stable profile. No systematic dredging has been undertaken since 1989, although a number of waterways (e.g. Truscott's Road Drain in Heathcote Valley) have been cleared of liquefaction silt following the Canterbury Earthquake Sequence.

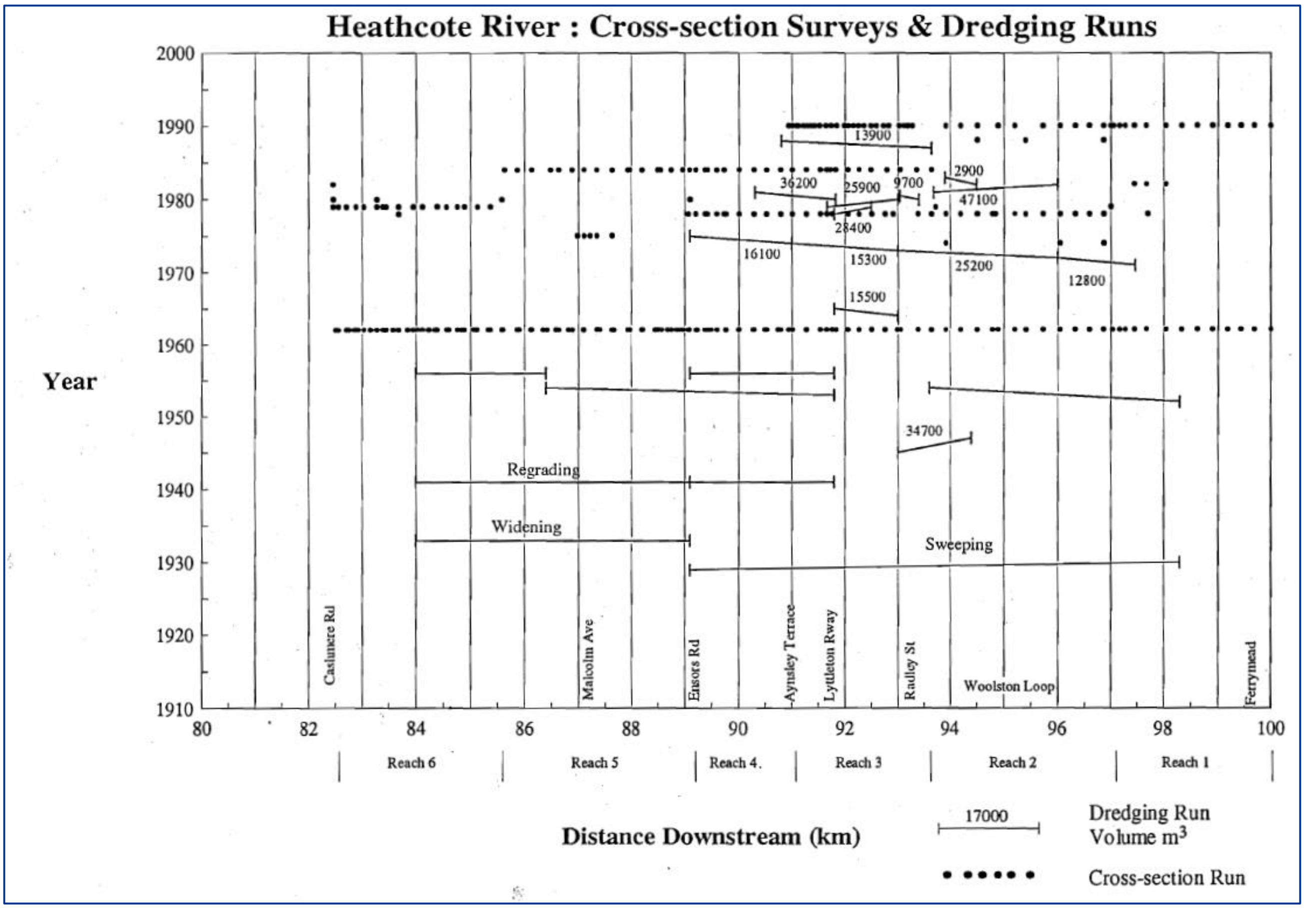


Figure 2.1 : Dredging operations through time, and estimates of material removed (taken from Hicks, 1993)

2.4 River Profile Changes

2.4.1 Main Channel Between Colombo Street and The Woolston Cut

The Council supplied cross-section data from the Heathcote River/Ōpāwaho and some tributaries which have been surveyed over time. This data has been analysed to aid understanding of how the main channel has

[2] Hicks, M. D. (1993) Sedimentation and Erosion in the Avon-Heathcote Catchment and Estuary. Report to the Canterbury Regional Council and the Christchurch City Council. March 1993

changed[3]. The primary datasets used in this analysis were cross sections and chainages[4] for various sections from 1962, 1990, 2009 and 2011. Maps were supplied showing the location of various sections. The data, supplied in Excel and text format, was collated into a spreadsheet and only sections with valid chainages along the main Heathcote River/Ōpāwaho downstream from Colombo Street were retained. All data are in Christchurch Drainage Datum.

Figure 2.2 plots the minimum elevation in each section (i.e. thalweg) against the chainage, where key locations along the river are identified as per Figure 1.1.

Figure 2.3 plots the cross-sectional of the channel, calculated below the 10 year ARI water level[5] at the location of that section, against the chainage. The flood level varies downstream and so the full channel cross-section may not be included in some instances, depending on the predicted water level at that location. However, the analysis provides a consistent comparison in cross-sectional area between surveys of the same section undertaken in different years, as suggested in Hicks (1993[6], Section 4.2).

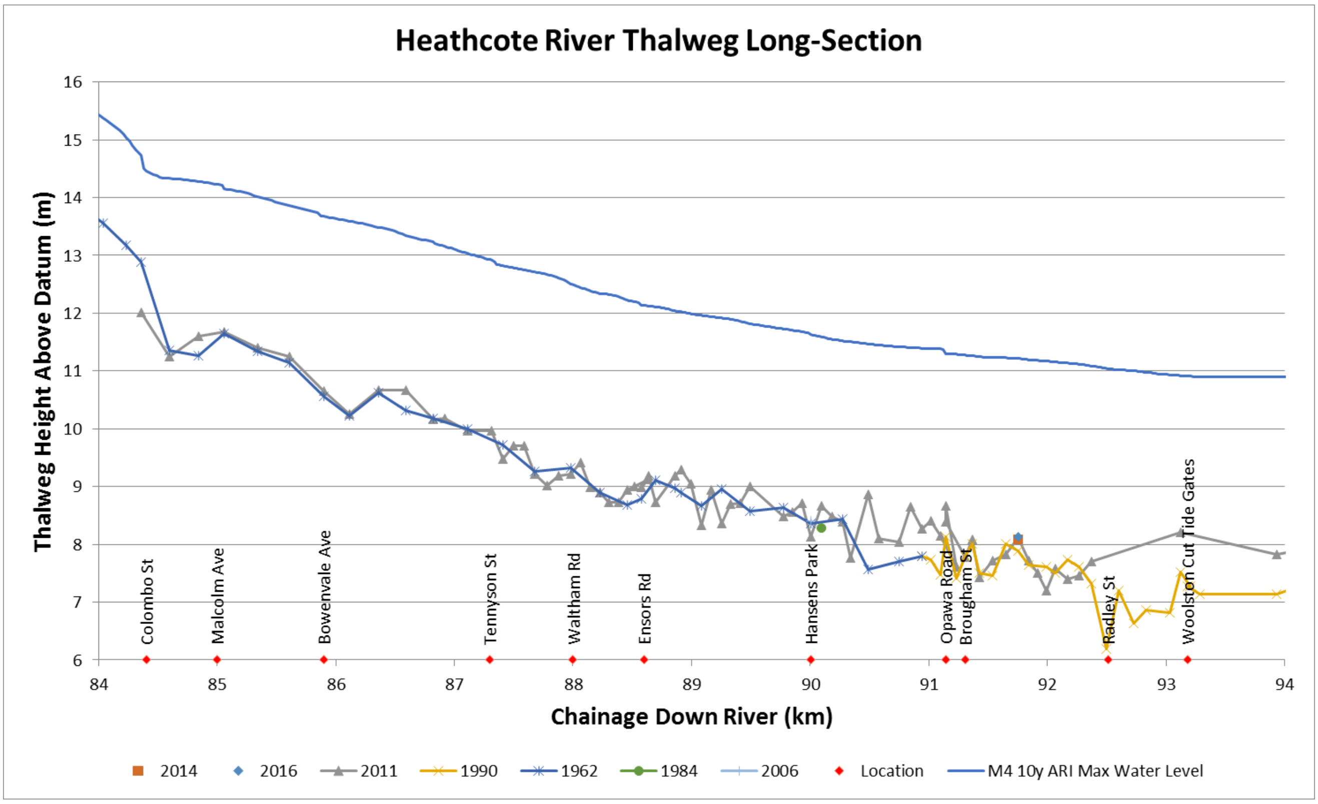


Figure 2.2 : Long section plot of thalweg from different surveys between Colombo Street and the tidal gates at the upstream extent of the Woolston Cut

[3] Cross-section survey data was supplied for the Cashmere Brook, Jacksons Creek and Milnes Drain which has not been analysed here since no dredging of these tributaries is envisaged.
[4] Chainages along the river are as used in the hydraulic model, which increase downstream to 100 km at Ferrymead Bridge
[5] The M4 model depicts the impacts of the Canterbury Earthquake Sequence on flooding, prior to any schemes being implemented post earthquake to mitigate this flood risk. The nominal date for this scenario is 2014.
[6] Hicks, M. D. (1993) Sedimentation and Erosion in the Avon-Heathcote Catchment and Estuary. Report to the Canterbury Regional Council and the Christchurch City Council. March 1993

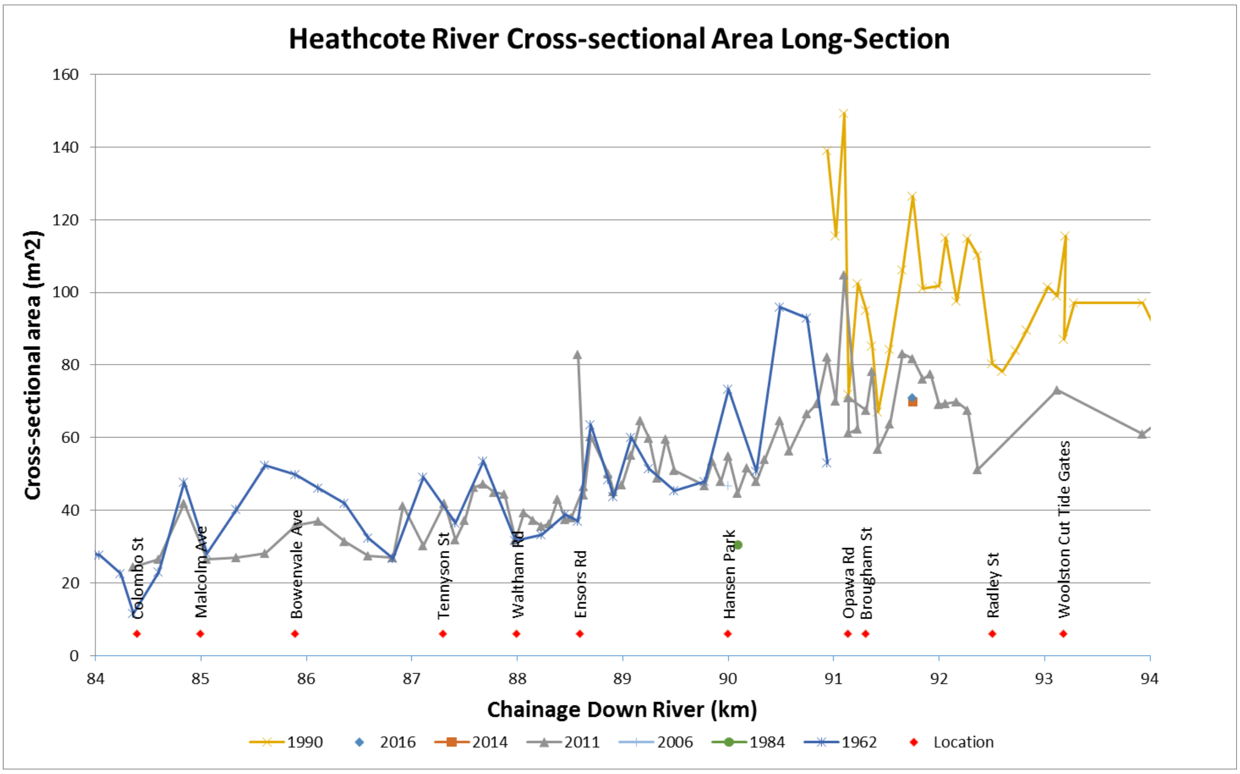


Figure 2.3 : Long section plot of cross sectional area from different surveys between Colombo Street and the tidal gates at the upstream extent of the Woolston Cut

The following observations can be made from the results downstream of Colombo Street:

- With respect to the channel thalweg:
  - Upstream of Ensors Road, the minimum channel depth is largely unchanged between 1962 and 2011;
  - Between Ensors Road and Hansen Park, the 2011 minimum levels are more variable than 1962, with no systematic change evident;
  - Between Hansen Park and Opawa Road (the downstream limit of the 1962 survey), the 2011 levels are typically higher than those in 1962, particularly towards Opawa Road;
  - Between Opawa Road and Radley Street, the 1990 and 2011 levels broadly match;
  - Downstream of Radley Street, through the Woolston Cut and around the Woolston Loop, 2011 levels are up to 1 m higher than 1990 levels (see Figure 2.5, Figure 2.6 and Figure 2.7). It is noted that the Canterbury Earthquake Sequence raised the bedrock (along with the Cut structure) by about 400 mm such that some of the raised bed elevations in this lower section may partially reflect this impact; and
  - Levels upstream, downstream and through the Woolston Cut suggest similar minimum levels in 2014/16 to those in 2011 (see Figure 2.5, Figure 2.6 and Figure 2.7).

It is clear from cross section 29 (Figure 2.5; upstream of Radley Street at MacKenzie Ave / Richardson Terrace) that thalweg alone does not show the full hydraulic change which has occurred.

- Therefore, in terms of cross-sectional area:
  - Upstream of Ensors Road, cross-sectional area is largely unchanged between 1962 and 2011, with the exception of the reach between Malcolm Ave and Tennyson Street where cross sectional area was higher in 1962 than in 2011;
  - Between Ensors Road and Hansen Park, the 2011 areas are typically higher than in 1962 and therefore no further increase is justified;

- Between Hansen Park and Opawa Road, and then between Opawa Road and Radley Street, the 1962 and 1990 cross-sectional areas are consistently higher than in 2011;
- Downstream of Radley Street, through the Woolston Cut and around the Woolston Loop, 1990 areas are consistently higher than in 2011 until just upstream of Ferrymead Bridge; and
- Cross-sectional areas surveyed in 2014/16 upstream, downstream and through the Woolston Cut are similar to 2011.

2.4.2 The Woolston Cut

The Woolston Cut (opened in 1986) is a 500 m long 36 m wide concrete-sided channel allowing flood flows to bypass the long narrow meander in the natural river channel (the Loop) by opening the gates of the Woolston Tidal Barrage (constructed in 1992-1993). Under normal operation[7], the barrage is shut to prevent saline tidal flows propagating upstream. Although saline water can bypass the barrage via the Loop, this does not happen during typical tides. The barrage consists of four radially hinged steel gates supported on concrete piers. The barrage is opened when a signal to open comes from the NIWA rain gauge on Sparks Road. The barrage is then opened manually, with further alarms suggesting the remaining 3 gates are opened. The gates then remain open until alarms are sent for the gates to be closed. The Council is considering changing the procedure to manually close the barrage no sooner than 24 hours after the rain has stopped.

The Council supplied analysis of bed levels at three cross sections in the centre of the Woolston Cut (Section 11c; Figure 2.6), as well as upstream of Radley Street (Section 29; Figure 2.5) and downstream of Tunnel Road (Section 6; Figure 2.7). The University of Canterbury (2015)[8] analysed sedimentation in the Woolston Cut, and the Council are currently planning to remove some of the estimated 30,000 m^3 of material which has settled since 1986 and which occupies about 52% of the original channel capacity. The University of Canterbury estimate of the background sedimentation rate (i.e. outside of specific storm and other events) is 5.3 cm/year, as measured between 1990 and 2012. This is equivalent to approximately 1000 m^3 / year within the 500 m long 36 m wide structure.

The original design of the Woolston Cut is shown in Figure 2.4. The Council is separately deciding on the design profile to be achieved in the Woolston Cut through removal of sediment. However, with ~400 mm uplift of the main structure by the Canterbury Earthquake Sequence, it is noted that a return to the original RL 7.1 m may encounter uplifted bedrock if this has not scoured down. Therefore, achieving a minimum level of RL 7.5 m through the Woolston Cut is assumed here as the most likely. It is noted that this planned removal of sediment from the Woolston Cut is effectively implementing the pilot study proposed in the Mayoral Taskforce Dredging Feasibility Report[9]. We understand that the dredged channel will be designed to avoid areas of sediment known to be contaminated by asbestos.

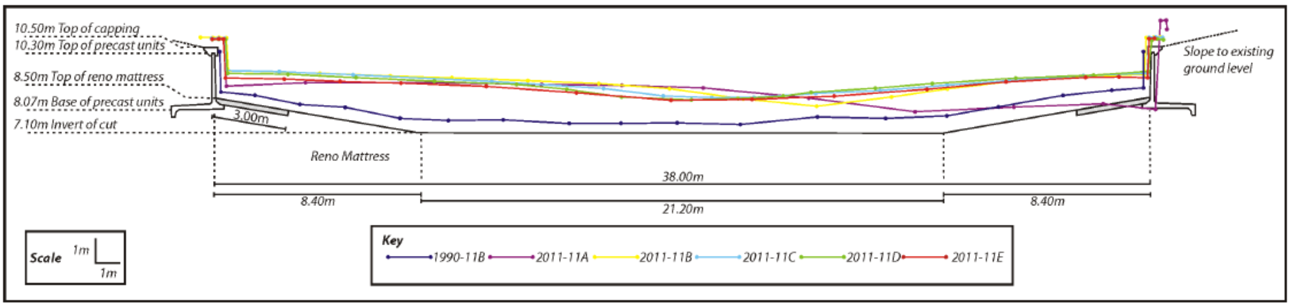


Figure 2.4 : Initial design cross section of typical channel dimensions of the Woolston Cut, with the Council survey data overlaid (taken from University of Canterbury, 2015)

It is highlighted that the Woolston Cut performs as an effective sediment trap for the lower to mid Heathcote River/Ōpāwaho. The effect of the tide together with the normal closed position of the barrage gates promotes

[7] Operation based on consultation with Chris Mance, Christchurch City Council.
[8] Sam Hampton and Francisco Perez (2012) Sedimentation within the Woolston Cut and Associated Flood Risk. University of Canterbury.
[9] Christchurch City Council (2014) Mayoral Task Force Temporary Flood Defence Measures. Draft Lower Heathcote River Dredging Feasibility Study. September 2014.

deposition of sediment mobilised both from upstream and from the estuary, although the majority is anticipated to come from upstream. Whilst not designed as a sediment trap, the Woolston Cut was constructed as a 36 m wide structure (wider than originally designed) which has resulted in it having typically low velocities (except in flood conditions) which promotes deposition[10]. Once deposited evidence suggests that movement of sediment within the Woolston Cut is highly limited, even under high flow regimes. In other words, even in flood conditions, little scour is observed. It is noted that the Woolston Cut is an engineered structure with limited natural environmental value and therefore could be routinely cleared with lower environmental and ecological impacts than dredging of the more natural upstream reach.

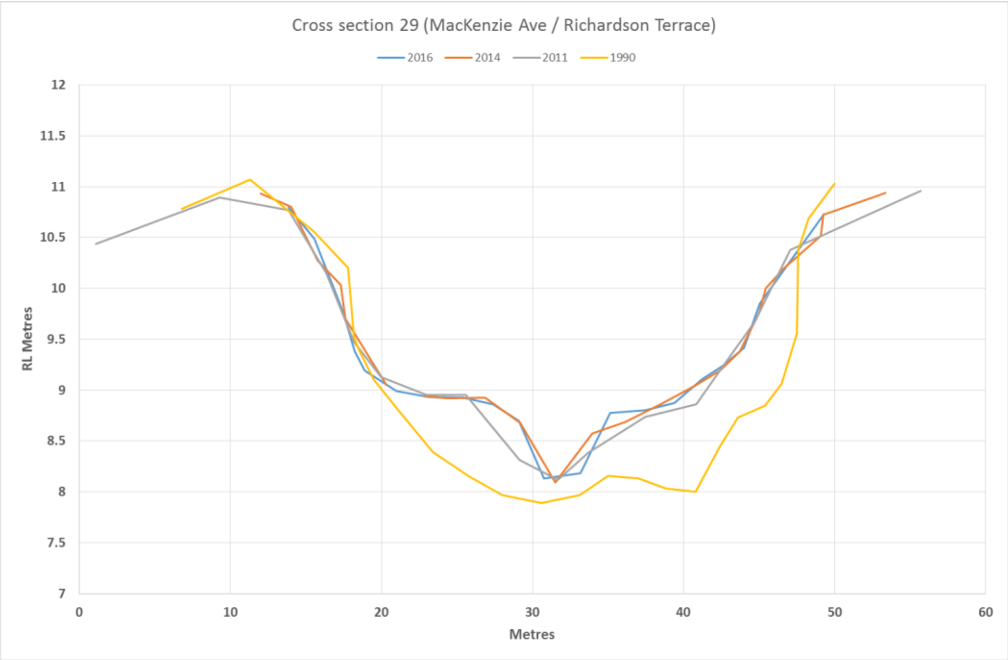


Figure 2.5 : Bed elevations at MacKenzie Ave / Richardson Terrace

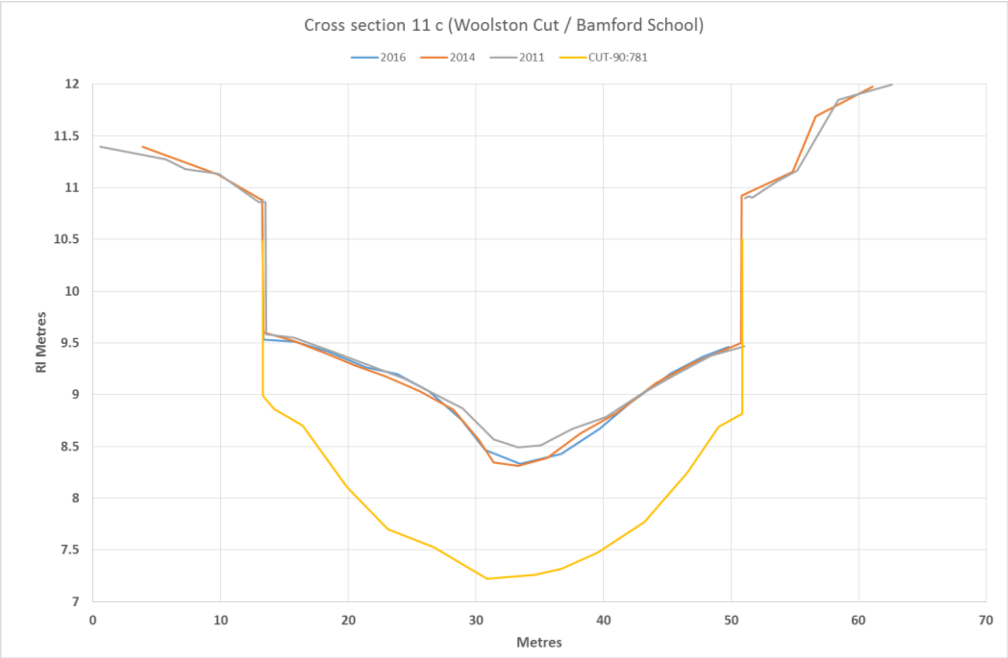


Figure 2.6 : Bed elevations in the Woolston Cut at Bamford School

10 John Walter Email 12 December 2016.

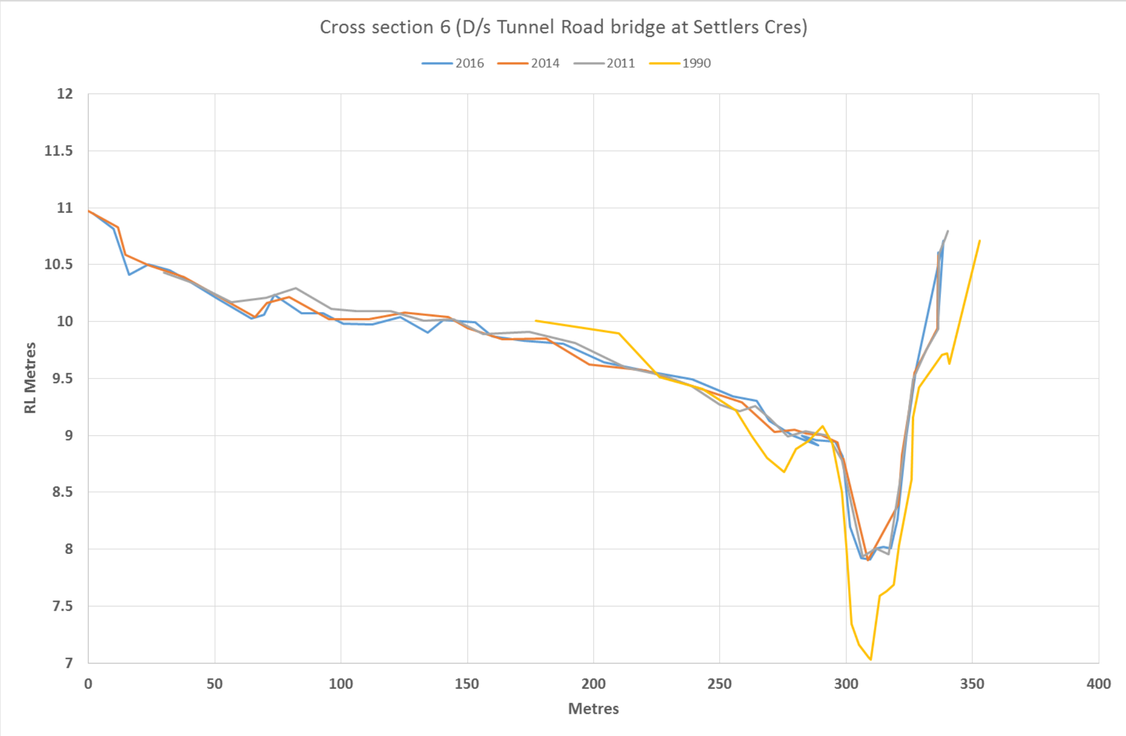


Figure 2.7 : Bed elevations downstream of Tunnel Road Bridge adjacent to Settlers Crescent

2.4.3 Rate of Deposition

Upstream of Ensors Road, Hicks (1993) estimated deposition between 1962 and 1984/1990 was negligible.

Based on observations between 1962 and 1990, Hicks (1993) estimated that deposition in the Terraces reach, between Aynsley Terrace and the Cut, was the equivalent of 6.4 cm/y (~10,000 m^3/y). Opening the Woolston Cut in 1986 led to significantly less deposition than occurred previously. After opening the Woolston Cut, deposition in the Terraces reach (~2 km long) was estimated by Hicks (1993) at around 700 m^3/y. The ongoing nature of this relatively low rate of deposition is evidenced by similarity of the few 2014/2016 survey data compared with 2011. However, the channel has been observed to respond relatively quickly to past dredging by smoothing out local high and low points which remain.

This relatively low rate of deposition (occurring over approximately 2 km in the Hicks study) is in contrast to the deposition rate of ~1000 m^3/y within the Woolston Cut (500 m long) which was estimated by the University of Canterbury (2015) based on observations between 1990 and 2011 (Section 2.4.2).

Although no geochemical analysis has been undertaken, it has been noted[11] that sediments around the Woolston Cut could be sourced more from loess soils travelling downstream than estuary sediments travelling upstream. Further, the sediments are deposited more on the sides of channels, and in locations which further suggest down current deposition. These indications support the earlier conclusions of Hicks (1993) that sediment from erosion in the Port Hills is the major source.

Prior to any further dredging, a baseline survey should be undertaken and monitored to more accurately understand the current rate of deposition. Modelling would be required to develop any improved understanding of how the movement of sediment and rate of deposition could change with climate, sea levels and sediment loading.

[11] Email from Samuel Hampton, dated 2 August 2017

2.5 Future Geomorphic Change

Further work is required to better understand the morphology of the Heathcote River/Ōpāwaho and, in particular (i) how channel morphology will change as a result of desilting which may require mitigation measures such as batter treatment and (ii) how the river may respond to climate change and a rise in sea levels. The large temporal gap in cross section surveys to date means that it is difficult to know with certainty whether the rate of aggradation is changing over time and whether the system has adjusted to the effects of the Woolston Cut and the subsequent tidal barrage as well as the earthquake induced effects. Modelling is likely to be required to predict how the river may respond to future changes in estuary levels, which will inform the effectiveness of future dredging operations. Some initial suggestions on modelling are provided in Appendix H.

3. Scenarios for Dredged Channel Profiles

3.1 Framework for Developing the Scenarios

Channel widening and deepening has been considered at locations along the approximately 9 km reach of the main Heathcote River/Ōpāwaho between Colombo Street and the Woolston Cut, to improve hydraulic capacity of the channel to convey high flows. The concept has been guided by the following principles:

- Surveyed sections from 1962 and 1990 (Figure 2.2 and Figure 2.3) have been used to guide the maximum amount of deepening and widening; the channel when dredging ceased before 1990 was thought to be over-excavated;
- The most recent full survey from 2011 indicates varying bed levels and cross-sectional areas along the profile; this concept aims for a smoothly-varying channel form focussing on removing constrictions. It is noted that 7 additional years of deposition (to 2018 when dredging could potentially be commenced) is likely to have occurred since this 2011 survey;
- The lateral extent of the channel (as defined by the top of bank markers in the 2011 survey used in the postEQ hydraulic model) is not changed; all works are considered within the current understanding of the channel extent;
- The upstream extent of channel considered is Colombo Street bridge. There is currently up to a 500 mm head difference across the bridge in the 50 year ARI basecase water levels. However, smoothing the bed profile is not likely to provide any upstream benefit due to the low risk of flooding upstream of Colombo Street, and instead could increase flow into the mid Heathcote River/Ōpāwaho reaches which are more at risk of flooding;
- The downstream extent of channel works is the Woolston Barrage Gates at the upstream limit of the Woolston Cut. Sediment is being removed from the Woolston Cut separately by the Council. Downstream of this point, including around the Woolston Loop, water levels are influenced more strongly by tidal levels which will nullify any channel modifications; and
- A condition assessment report[12] (Figure 3.1) indicates non-earthquake faults upstream of Waltham Road are predominantly due to bank instability, whereas downstream they are predominantly a result of undercutting/scouring. These faults indicate that dredging upstream of Waltham Road may further exacerbate the instability, despite the Council's proposed bank stabilisation works, and would result in significant additional remediation cost.

[12] Opus (2016) LDRP 098 Open Channel Condition Assessment Condition Assessment Report for Heathcote River downstream of Colombo Street

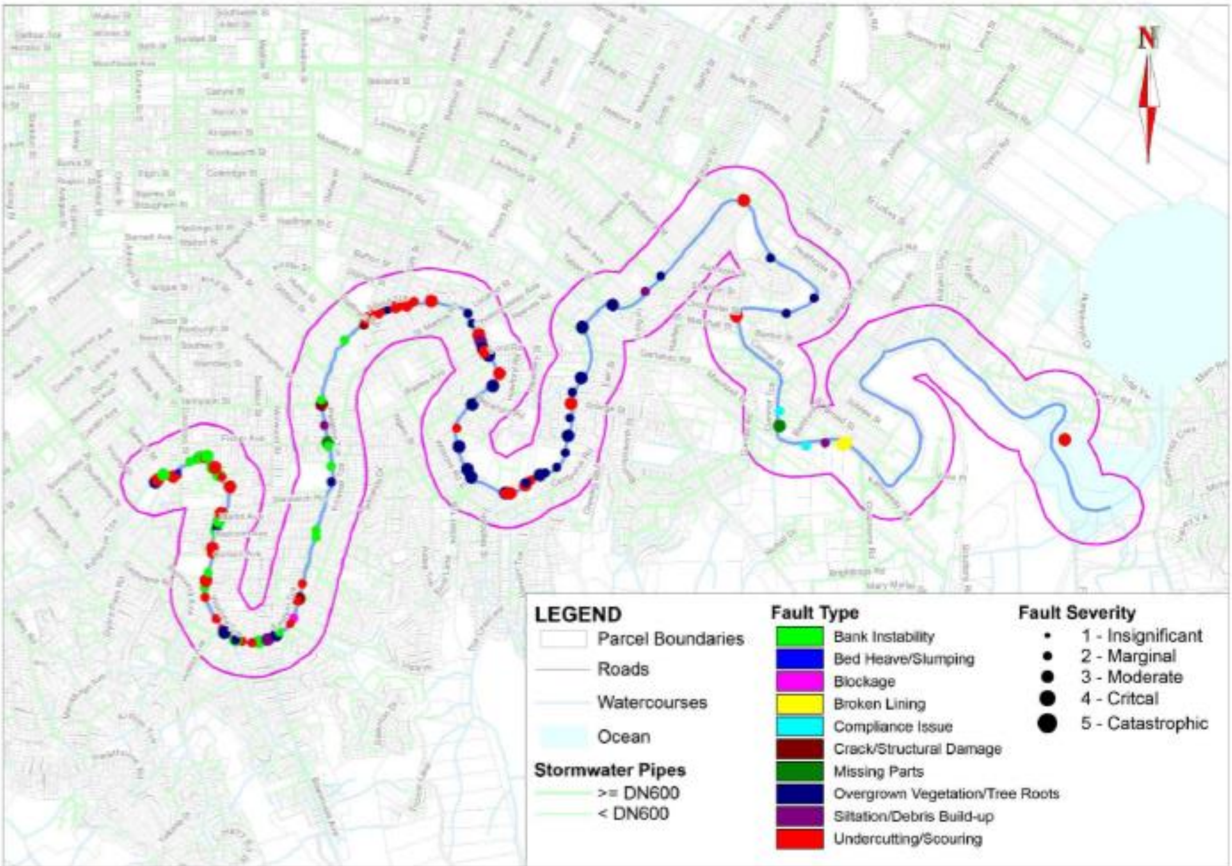


Figure 3.1 : Fault type and severity, taken from Opus (2016)

3.2 Whole Reach Dredging

Analysis of historic data in Section 2.4 has demonstrated that:

- Upstream of Hansen Park, thalweg and cross-sectional area is largely unchanged or has not systematically changed between 1962 and 2011. Therefore, there is unlikely to be substantial benefit in channel widening and deepening;
- Between Hansen Park and the Woolston Cut, the thalweg has largely increased and cross sectional area largely decreased between 1962/1990 and 2011. This reach could benefit from an increase in flood conveyance;
- Through the Woolston Cut and around the Woolston Loop, 2011 and subsequent bed levels are up to 1 m higher than 1990 levels, and cross sectional areas below the 10 year ARI event are substantially reduced. However, there is unlikely to be any substantial additional benefit from works in these reaches since:
  - Compared with through the Woolston Cut, minimal flood flow is conveyed around the Loop; and
  - These reaches are tidal dominated and therefore modifying channel form will have limited impact on flood conveyance.

  It is also noted that the Council is separately planning to remove sediment from the Woolston Cut, possibly to RL 7.5 m minimum level or lower.

In summary, the 3.1 km reach between Hansen Park (at the junction of Riverlaw Terrace and Centaurus Road) and the Woolston Barrage gates exhibits the largest and most consistent rise in minimum bed elevation and reduction in cross-sectional area between the 1962/1990 and 2011 surveys. Therefore, channel reprofiling along this reach could provide significant hydraulic benefit. This independent analysis and recommendation is consistent with that made by the Mayoral Flood Taskforce following the March 2014 floods, given that the Woolston Cut is being dredged separately by the Council.

3.3 Selective Reach Dredging

Figure 3.2 shows the proposed bed profile (red line) from Hansen Park to the Woolston Cut, relative to 1962/1990 and 2011 survey. The minimum channel levels between these points broadly follows – but does not go deeper than – the 1962/1990 values. Because the Woolston Cut is anticipated to be lowered to a minimum level of RL 7.5 m, this is the level which has been adopted at the Woolston Barrage. It is recognised that this conceptual 'smooth' channel bed profile is used at this stage to understand the hydraulic benefits, whereas through further design the profile should allow for variations to encourage ecological habitat.

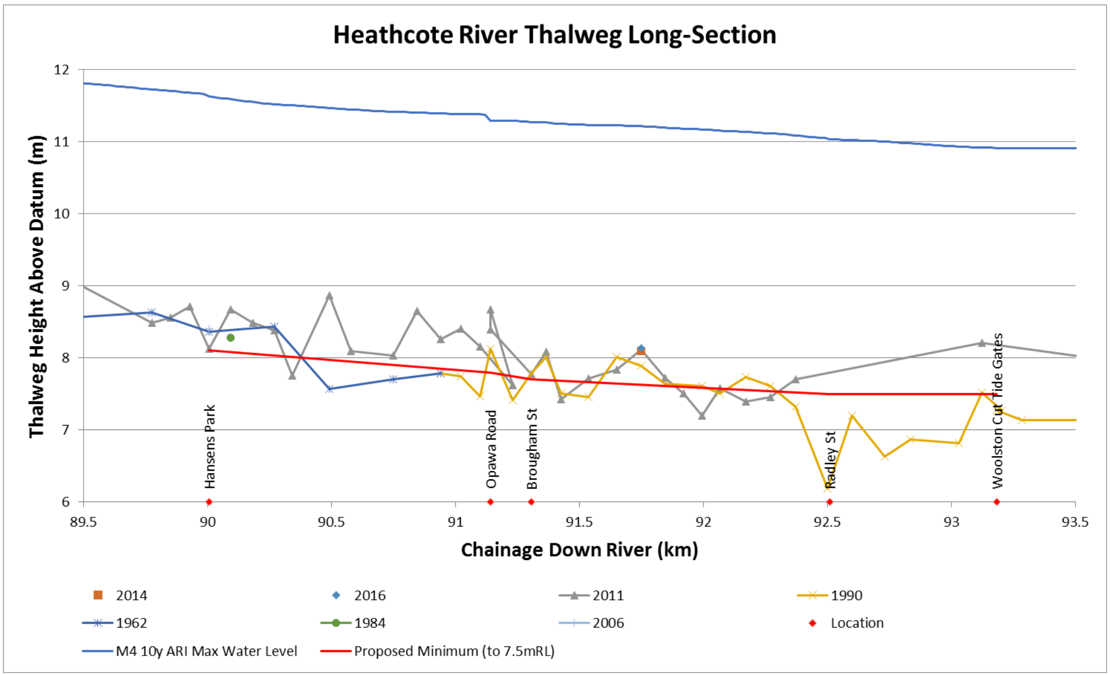
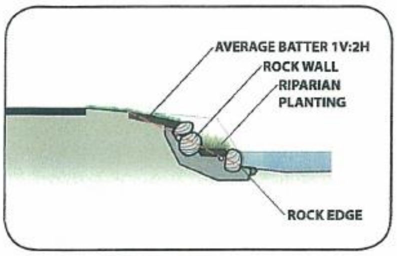


Figure 3.2 : Long section plot of thalweg from different surveys between Hansen Park and the Cut, showing possible lowered bed profile tying into level of RL 7.5 m at the Woolston Barrage Tide Gates

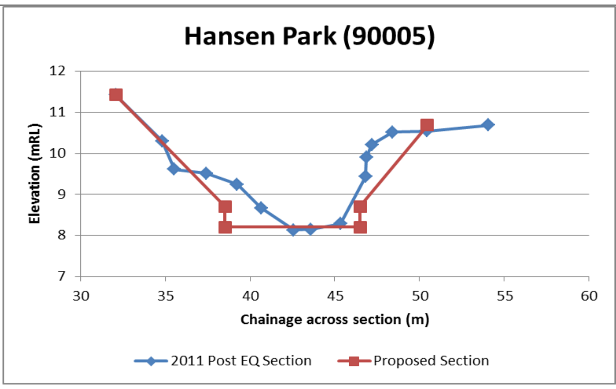
The 2011 cross sections in the postEQ model, which includes planned upstream storage[13], were modified to achieve these bed level targets, as shown in Figure 3.4. Only cross sections at notable landmarks[14] (e.g. bridges) were modified and the model allowed to interpolate sections between these. Proposed channel sections were based on the concept reproduced in Figure 3.3 from the Bank Stabilisation Draft. This involves a 0.5 m high rock edge above the minimum bed level and a 1V:2H bank sloping from the top of this up to the top of bank. The 1V:2H bank slope provides a good balance between stability and widening. As far as possible from the available information, the banks were not widened so as to minimise the impact on adjacent trees which the community will likely want to retain, and in recognition that the river banks are where crayfish and mussels burrow. Any bank stabilisation works undertaken to repair and/or further protect the bank as part of the channel works should be designed to protect this environment (see Section 6.6).



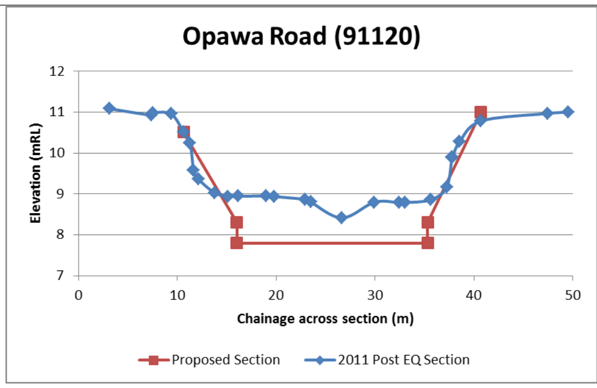
[13] The Heathcote MIKE FLOOD M5 (2018) model represents the already planned LDRP schemes (increased storage in Cashmere-Worsley, Hendersons South and Sutherlands, Wigram Wetpond, adjacent to Curletts Stream, Halswell Common and storage/pumping at Bells Creek) which are anticipated to be constructed within 2018.

[14] Hansen Park, Opawa Road bridge, Brougham Street bridge, Radley Street bridge and the Woolston Cut

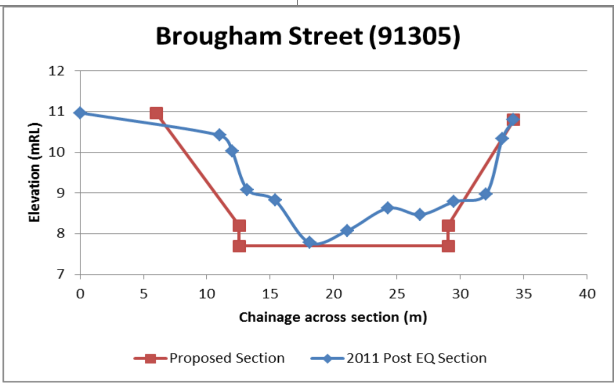
Figure 3.3 : Conceptual design profile taken from AECOM (2016) used as a basis for proposed channel profiles



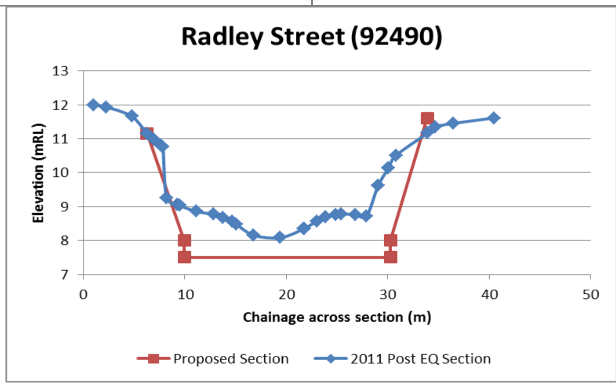
Minimum elevation:	Cross sectional area:
• 2011: RL 8.1 m	• 2011: 42 m²
• Proposed: Rl 8.1 m	• Proposed: 44 m²



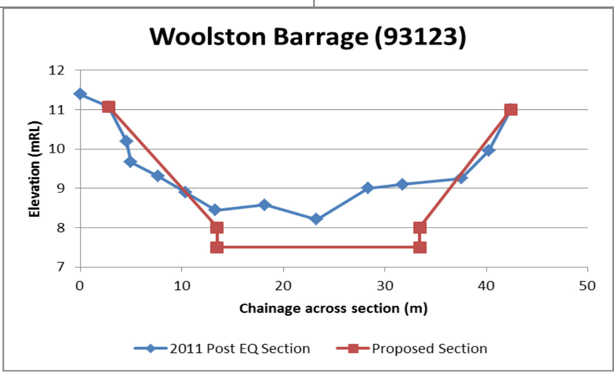
Minimum elevation:	Cross sectional area:
• 2011: RL 8.4 m	• 2011: 78 m²
• Proposed: RL 7.8 m	• Proposed: 90 m²



Minimum elevation:	Cross sectional area:
• 2011: RL 7.8 m	• 2011: 66 m²
• Proposed: RL 7.7 m	• Proposed: 80 m²



Minimum elevation:	Cross sectional area:
• 2011: RL 8.1 m	• 2011: 53 m²
• Proposed: RL 7.5 m	• Proposed: 82 m²



Minimum elevation:	Cross sectional area:
• 2011: RL 8.2 m	• 2011: 73 m²
• Proposed: RL 7.5 m	• Proposed: 96 m²

Figure 3.4 : 2011 PostEQ sections (blue) and proposed lowered and widened sections (red) between Hansen Park and the Woolston Cut. Minimum elevations and cross-sectional area below the 10y ARI water levels show anticipated difference.

Importantly, detailed design based on these high level cross sections should assess the longitudinal profile of the channel to limit the development of headcuts. The channel should also be modelled to show how proposed cross sections would remain stable by assessing stream power, bed shear stress and velocity against expected stable cross section profiles.

The volume of material to be removed to achieve the proposed channel profile was calculated using three separate methods based on the best available information. The three methods used to calculate the material to be removed from the 2011 channel were:

1. Using an end-area technique as per Hicks (1993), the average area to be removed at two adjacent cross sections in Figure 3.4 was multiplied by the length of channel between, and the values summed along all reaches between Hansen Park and the Cut;

2. In the hydraulic model, the volume of water below a static water level (RL 11.0 m) was calculated between Hansen Park and the Woolston Cut in the base and dredged scenarios; and

3. The 2011 channel profile and the dredged channel profile were imported into 12d as surfaces, and the cut/fill balance between the surfaces calculated between Hansen Park and the Woolston Cut.

These methods produced total estimates between 52,000 m^3 and 59,000 m^3, with the middle estimates from the hydraulic model being rounded upwards and summarised in Table 3.1. Added to these 2011 values, is the likely volume of deposition since 2011. The best available estimate of deposition between Hansen Park and the Woolston Cut is that provided by Hicks (1993) as ~700 m^3/y. In the 7 years between 2011 and 2018, this would suggest an additional 5,000 m^3 of material. This suggests a total of 60,000 m^3 to be removed from the channel in 2018 to achieve the channel profile proposed.

It is noted that the Mayoral Taskforce Dredging Feasibility Report estimated in 2014 that 94,000 m^3 of material must be removed between Waltham Road and the Heathcote Towpath to achieve a 1990 bed profile. Of this, approximately 50,000 m^3 was estimated between Hansen Park and the Woolston Cut, which could be 55,000 m^3 with the additional 7 years of accumulation between 2011 and 2018. This independent analysis is therefore consistent with the earlier analysis based on the same data.

Table 3.1 : Rounded estimate of sediment volume to be removed from 2011 sections to achieve proposed channel profile (taken from the hydraulic model). Sedimentation between 2011 and 2018 is added in the penultimate row.

Reach	Length (m)	Volume to be Removed (m^3)
Hansen Park – Opawa Road (90005 – 91120)	1,100	12,000
Opawa Road – Brougham Street (91120 – 91305)	190	3,000
Brougham Street – Radley Street (91305 – 92490)	1,190	23,000
Radley Street – Woolston Barrage (92490 – 93123)	630	17,000
Additional 7 years of sedimentation between 2011 and 2018		5,000
TOTAL (Hansen Park – Woolston Barrage)	**3,110**	**60,000**

3.4 Sediment Traps

The Christchurch Drainage Board operated two in-stream silt traps at Aynsley Terrace and one below the Radley Street bridge. These were cleared regularly. However, following recognised over-excavation of the channel between Clarendon and Aynsley Terrace, this reach was observed to be acting as a large silt trap, as has the Woolston Cut following installation of the tidal barrage.

Based on available information, the Woolston Cut has exhibited the greatest rate of deposition in the channel, accumulating sediment, most likely from both upstream and downstream. Given the artificial nature of the Woolston Cut compared with the more natural channel upstream, the Woolston Cut should be considered as a sediment trap. However, this would require the gates to be opened on a tidal cycle so that normal fluvial flows pass through the Cut, rather than around the Loop. The Cut would, therefore, require more frequent maintenance dredging in the future.

Alternative options include siting a silt trap between the tidal gates and Radley Street bridge, although this could require minimising onward sediment movement down the Loop through a silt curtain or similar, which would have to be designed not to impede recreational use of the channel. The Loop itself acts as natural silt trap but the existing sediment would need to be tested for contamination.

4. Hydraulic Benefits of Dredging

4.1 Approach

The modified channel profile was tested in the postEQ model, which includes planned upstream storage, to determine the hydraulic benefits. Since this model represents the already planned upstream storage (increased storage in Cashmere-Worsley, Hendersons South and Sutherlands, Wigram Wetpond, adjacent to Curletts Stream, Halswell Common and storage/pumping at Bells Creek) which are anticipated to be constructed within 2018, this is taken as the baseline. These schemes have the effect of lowering the water level through the Heathcote River/Ōpāwaho (downstream to Radley Street) compared with the existing post earthquake situation prior to the upstream storage. Therefore the further hydraulic benefits offered by dredging are relevant to this anticipated future scenario rather than directly relevant to the existing situation. Completing dredging as proposed would approximately coincide with the completion of these other schemes such that the comparison is valid.

4.2 Model Results

Figure 4.2 compares long sections of water levels in the channel between the basecase and with the proposed dredged scenario, in the existing development (i.e. no climate change) 10 year ARI and 50 year ARI events. The difference in floodplain water levels are shown in the maps provided in Appendix A. The numbers of properties at risk of overfloor flooding (water level within 100 mm of floor level) in the basecase and with the option are tabulated in Table 4.1[15]. In the same events, Table 4.2 reports the difference in numbers of properties flooding underfloor (i.e. flood touching the building footprint). The following subsections provide key observations from (firstly) the 10 year ARI event and then the 50 year ARI events, with and without climate change.

4.2.1 10 year ARI Events

In the existing development scenario:

- The maximum water level reduction is approximately 300 mm, around Hansen Park;
- The water level reduction resulting from the channel enlargement reduces to less than 100 mm around Ensors Road in an upstream direction and Radley Street in a downstream direction; and
- The proposed dredging protects 10 of the 14 (~70%) properties at risk of overfloor flooding upstream of Radley Street, removing all overfloor at risk properties upstream to Ensors Road. As noted on the map in Appendix A, these 10 properties are also eligible for consideration under the Council's Flood Intervention Policy[16].

Overfloor flooding is defined as the flood level being within 100 mm of the floor level. Figure 4.1 illustrates how the water level reduction predicted with the proposed dredging protects those at risk of overfloor flooding up to Ensors Road. Given the inherent uncertainties in the modelling and survey of floor levels over such a wide area, If the freeboard allowance was increased to 200 mm (i.e. overfloor flooding was defined as flood level within 200 mm of floor level), then 15 additional properties would be classified at risk of overfloor flooding and therefore *may* be protected by the proposed dredging as they are downstream of Ensors Road.

[15] Results are tabulated in terms of Flood Risk Areas which are individual areas of similar flood risk used within the wider LDRP110 project
[16] https://www.ccc.govt.nz/the-council/plans-strategies-policies-and-bylaws/policies/sustainability-policies/flooding-intervention-policy/

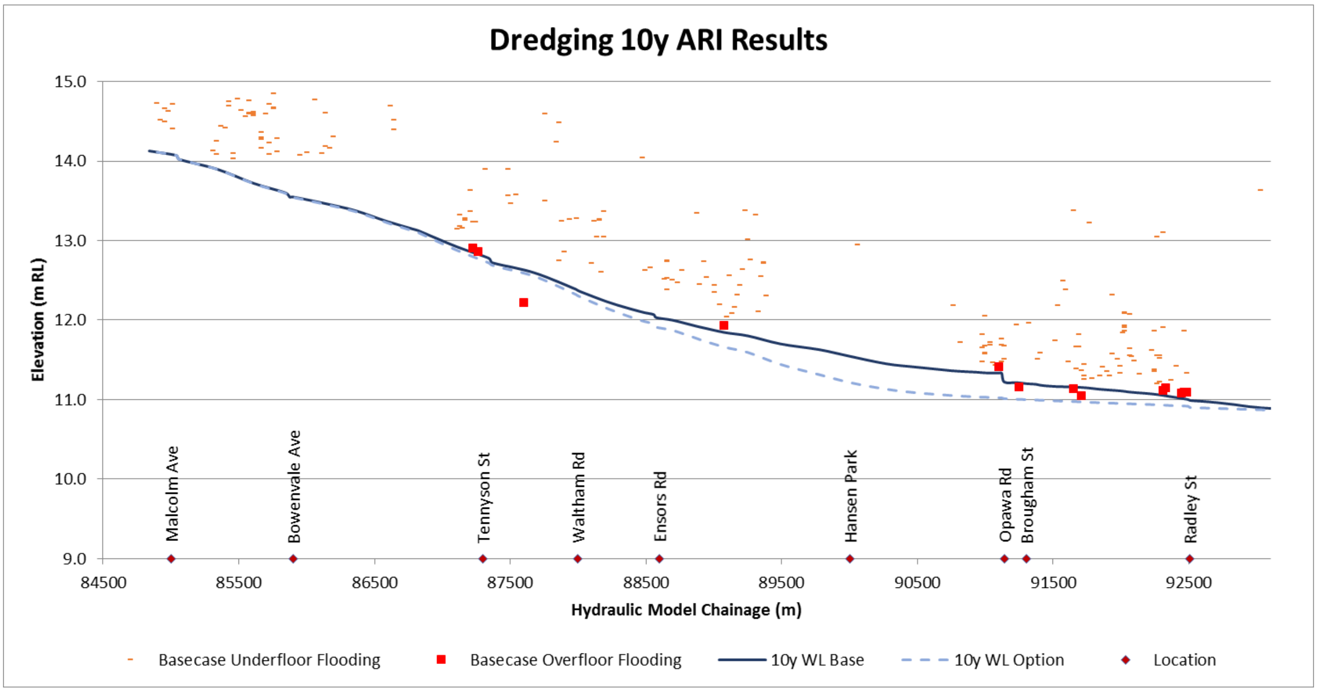


Figure 4.1 : Long section plot showing water level reduction achieved by proposed dredging, together with the properties at risk of overfloor flooding in the basecase which benefit

In future scenarios considering (i) a sea level rise of +0.25 m from its current level (and rainfall increases by +5.8%) and (ii) a sea level rise of +1 m matched with a rainfall increase of 16%[17]:

- The maximum water level reduction in the +0.25m sea level rise scenario is up to 250 mm around and just upstream of Hansen Park, and up to 150 mm elsewhere between Radley Street and Ensors Road. In the +1 m scenario, the reduction is up to 200 mm around and just upstream of Hansen Park, and up to 100 mm elsewhere;
- In the +0.25 m sea level rise scenario, more properties are at risk of overfloor flooding in the basecase and more are protected by the proposed dredging (23 out of 36 protected), which is a drop in the relative number protected from 70% to 65%; and
- In the +1 m sea level rise 10 year ARI event, the proposed dredging profile protects 10 properties out of 97 which would otherwise flood. This is a significant drop in relative properties protected (70% to 10%), and these are a different set of properties than are protected in the existing 10 year ARI event. Those remaining at risk are concentrated downstream of Hansen Park where the influence of the sea level rise is greatest.

These future scenarios indicate that, if the proposed channel was maintained for approximately the next 100 years, the benefits (i.e. reduction in overfloor flooding) provided currently in the 10 year ARI event would diminish with rising sea level but would diminish more gradually for the next 30 or so years until the sea level rises by up to +0.25 m, and then more rapidly.

In terms of underfloor flooding, Table 4.2 reports that 32 properties out of 97 (~30%) at risk between Hansen Park and Radley Street are protected by the proposed dredging in the 10 year ARI event. These 32 may include some of the same properties identified as being protected from overfloor flooding. With climate change, the relative number of underfloor flooded properties protected by dredging reduces slightly to under 30% (35 out of 127) with +0.25 m sea level rise and to under 10% (15 out of 212) with +1 m sea level rise.

[17] Under the International Panel on Climate Change RCP4.5 stabilisation pathway projection, temperature increase and climate change leading to a +0.25m rise in sea level and associated 5.8% rise in rainfall, could occur in 2050. The +1m sea level rise matched with the 16% increase in rainfall is the New Zealand standard for considering impacts of climate change, which could be reached within 100 years from now.

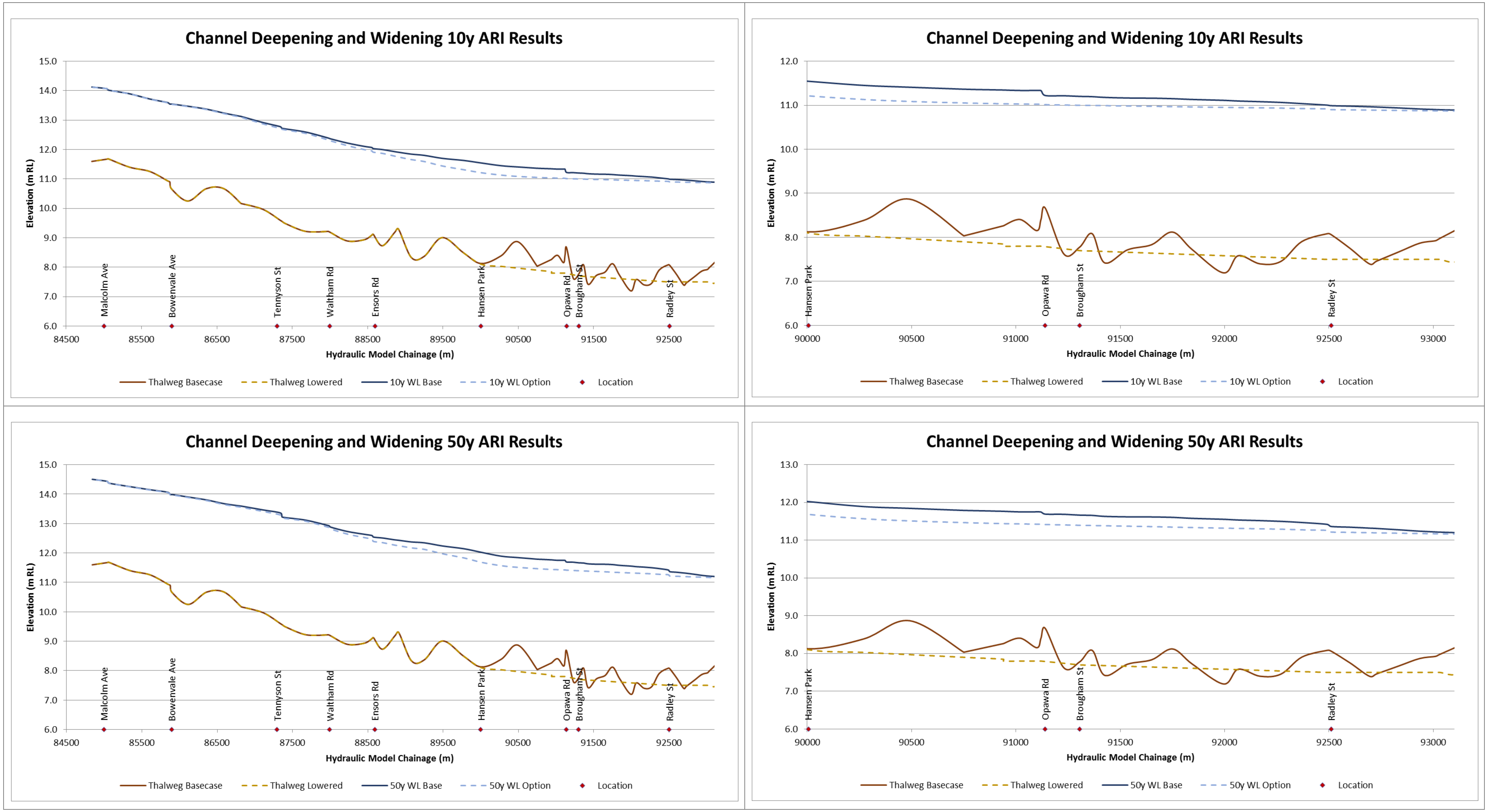


Figure 4.2 : Long sections of bed and maximum water levels in the 10 year and 50 year ARI events

Table 4.1 : Summary of properties at risk of overfloor flooding (flood level within 100 mm of floor level)

Flood Risk Area	Number of Overfloor Flooded Buildings														
	10 year ARI (existing development)			10 year ARI (climate change; +0.25m SLR, +5.8% Rainfall)			10 year ARI (climate change; +1m SLR, +16% Rainfall)			50 year ARI (existing development)			50 year ARI (climate change; +1m SLR, +16% Rainfall)		
	Basecase	Option	Protected	Basecase	Option	Protected	Basecase	Option	Protected	Basecase	Option	Protected	Basecase	Option	Protected
Clarendon Terrace	5	0	**5**	9	5	**4**	20	20	**0**	15	10	**5**	26	24	**2**
Richardson Terrace	0	0	**0**	7	0	**7**	23	19	**4**	19	9	**10**	26	26	**0**
Opawa to Sheldon Street	2	0	**2**	6	2	**4**	13	13	**0**	11	7	**4**	27	23	**4**
Aynsley Terrace	1	0	**1**	2	1	**1**	15	11	**4**	10	2	**8**	19	17	**2**
Fifield to Richardson Terrace	1	0	**1**	5	0	**5**	9	9	**0**	9	5	**4**	10	9	**1**
Centaurus Road	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
Ford to Ombersely Road	0	0	**0**	0	0	**0**	0	0	**0**	1	0	**1**	6	3	**3**
St Martins to Armstrong Ave	1	0	**1**	2	0	**2**	6	6	**0**	15	7	**8**	30	21	**9**
Ensors to Ford Road	0	0	**0**	0	0	**0**	0	0	**0**	3	0	**3**	4	4	**0**
Riverlaw to St Martins Road	0	0	**0**	0	0	**0**	0	0	**0**	3	1	**2**	14	8	**6**
Fifield Terrace	0	0	**0**	0	0	**0**	1	0	**1**	1	1	**0**	3	1	**2**
Buxton to Riverlaw Terrace	1	1	**0**	1	1	**0**	3	2	**1**	5	5	**0**	15	14	**1**
Eastern Terrace	3	3	**0**	4	4	**0**	6	6	**0**	11	11	**0**	13	13	**0**
Palatine Terrace	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	3	1	**2**
Waimea to Eastern Terrace	0	0	**0**	0	0	**0**	1	1	**0**	12	11	**1**	23	23	**0**
Hunter Terrace	0	0	**0**	0	0	**0**	0	0	**0**	3	3	**0**	8	8	**0**
TOTALS	**14**	**4**	**10**	**36**	**13**	**23**	**97**	**87**	**10**	**118**	**72**	**46**	**227**	**195**	**32**

Table 4.2 : Summary of properties at risk of underfloor flooding (flood level touching building footprint)

Flood Risk Area	Number of Underfloor Flooded Buildings														
	10 year ARI (existing development)			10 year ARI (climate change; +0.25m SLR, +5.8% Rainfall)			10 year ARI (climate change; +1m SLR, +16% Rainfall)			50 year ARI (existing development)			50 year ARI (climate change; +1m SLR, +16% Rainfall)		
	Basecase	Option	Protected	Basecase	Option	Protected	Basecase	Option	Protected	Basecase	Option	Protected	Basecase	Option	Protected
Radley Street to Hansen Park	97	65	**32**	127	92	**35**	212	197	**15**	178	136	**42**	267	240	**27**
Hansen Park to Colombo Street	148	139	**9**	167	155	**12**	204	195	**9**	303	283	**20**	605	577	**28**
Outside Flood Risk Areas	318	318	**0**	420	415	**5**	1693	1604	**89**	920	896	**24**	3035	2800	**235**
TOTALS	**563**	**522**	**41**	**714**	**662**	**52**	**2109**	**1996**	**113**	**1401**	**1315**	**86**	**3907**	**3617**	**290**

In terms of road flooding, information from the UK[18] and New Zealand[19], for example, indicates that 0.15 m depth of water will stall / strand a car and cars will start to float and lose control in 0.3 m depth of water. No specific guidance was identified about using velocity or duration of flooding to classify flooded roads. Road centrelines were used to identify segments of roads (within the modelled flood extent) where depths exceed 0.15 m and 0.3 m at some point along the road. The rating units adjacent to these sections of flooded roads were used to identify those with restricted access. Table 4.3 summarises the length of flooded roads and number of rating units with restricted access in the area between the Woolston Cut and Colombo Street, but excluding the Bells Creek area. It is noted that this initial analysis could be refined based on location-specific understanding of access routes and that some rating units represent open space (e.g. Hansen Park) rather than residential dwellings. However, the following observations provide further insight into the hydraulic benefits of dredging:

- The length of road flooded and number of rating units with restricted access increases with the earthquakes and prior to the upstream storage. The greatest increase is seen in the reach downstream of Hansen Park;
- There is a reduction in length of road flooded and number of rating units with restricted access as a result of the upstream storage. This decrease is greatest upstream of Hansen Park, since the benefit of upstream storage diminishes as you move downstream. The already planned upstream storage, therefore, has not fully returned the road/access flooding issues to pre-earthquake levels; and
- Proposed dredging in the 10y ARI event provides a further reduction in road/access flooding compared with upstream storage, and returns the whole reach between Colombo and Radley Streets largely to pre-earthquake levels of road and access flooding.

Table 4.3 : Summary of lengths of road flooded and number of rating units adjacent to flooded roads with restricted access. Total length is along the Heathcote from Radley Street to Colombo Street.

Flooded Road Event (all 10 year ARI events)	Max depth > 0.15 m						Max depth > 0.3 m					
	Downstream of Hansen Park (m)		Upstream of Hansen Park (m)		Total		Downstream of Hansen Park (m)		Upstream of Hansen Park (m)		Total	
	Length (m)	Rating Units	Length (m)	Rating Units	Length (m)	Rating Units	Length (m)	Rating Units	Length (m)	Rating Units	Length (m)	Rating Units
Pre-earthquake	2,800	200	3,600	320	**6,400**	**520**	2,300	170	3,300	280	**5,600**	**450**
Post earthquake before upstream storage	4,400	250	4,700	490	**9,100**	**740**	4,400	250	4,500	470	**8,900**	**720**
Post earthquake after upstream storage	4,300	250	4,200	360	**8,500**	**610**	4,100	240	3,600	300	**7,700**	**540**
After dredging and upstream storage	3,100	200	3,800	320	**6,900**	**520**	2,800	180	3,300	280	**6,100**	**460**

Finally, modelling suggests that the duration of flooding will be reduced through dredging. Between Radley Street and Brougham Street, flooding is predicted to be reduced by up to 6 hours in a 10 year ARI event, between Brougham and Hansen Park by around 7 hours and by up to 3 hours upstream to Ensor's Road. These reductions are relative to a baseline flood duration of approximately 16 hours.

[18] https://smartdriving.co.uk/Driving/Driving_emergencies/Floods.htm
[19] https://www.drivingtests.co.nz/resources/how-to-drive-through-a-flood/

4.2.2 50 year ARI Events

The water level reduction in the 50 year ARI event in the existing development scenario is similar to that for the 10 year ARI event. However, the water level reduction protects a higher number of properties (46 out of 118), although this is a lower proportion (~40%) of the properties at risk of overfloor flooding upstream of Radley Street. In the +1 m sea level rise 50 year ARI event (no +0.25m scenario has been run at this stage), the proposed dredging protects 32 out of 227 properties (~15%) which would otherwise flood, with protected properties extending as far upstream as Palatine Terrace. Those remaining at risk are concentrated downstream of Hansen Park where the influence of the sea level rise is greatest. Table 4.2 shows that the number of underfloor flooded properties protected in the 50 year ARI events follows the same broad pattern as for overfloor flooding, with a lower proportion of properties protected by dredging with climate change.

4.3 Alternative Dredged Profile to RL 7.1 m

The alternative dredged profile excavated to RL 7.1 m at the Woolston Barrage, as represented by the cross-sections in Appendix B, has been tested in the same 10 year ARI hydraulic model. However, this model did not represent the RL 7.1 m continuing through the Woolston Cut. The model predicted the same water level reductions as for the 10 year ARI model down to RL 7.5 m, as well as the same 10 properties protected in this event.

Although not conclusive, this alternative model run indicates that there is limited additional hydraulic benefit offered in the existing development 10 year ARI event by dredging to the lower depth of RL 7.1 m and continuing this through the Woolston Cut. However, for completeness, Table 4.4 provides the approximate volumes of material to be removed between the Cut and Hansen Park to achieve this alternate channel profile.

Table 4.4 : Rounded estimate of sediment volume to be removed from 2011 sections to achieve the alternative channel profile. Sedimentation between 2011 and 2018 is added in the penultimate row.

Reach	Length (m)	Volume to be Removed (m^3)
Hansen Park – Opawa Road (90005 – 91120)	1,100	13,000
Opawa Road – Brougham Street (91120 – 91305)	190	4,000
Brougham Street – Radley Street (91305 – 92490)	1,190	27,000
Radley Street – Woolston Barrage (92490 – 93123)	630	21,000
Additional 7 years of sedimentation between 2011 and 2018		5,000
TOTAL (Hansen Park – Woolston Barrage)	**3,110**	**70,000**

4.4 Comparison with Previous Analysis

The Mayoral Taskforce Dredging Feasibility Report modelled a similar modification of cross sections between Aynsley Terrace and the Heathcote Tow Path to that proposed here. The modified cross sections were used in an earlier version of the Heathcote model to that used here, and used to represent the 5 March 2014 flood. This March 2014 flood event is understood to have had an Annual Return Interval of less than 10 years, but is likely to be similar to the 10 year than the 50 year ARI design events modelled here. As reproduced in Figure 4.3, the modelling predicted up to a 0.33 m reduction in water level between Radley Street and Ensors Road, with the maximum benefit occurring around Hansen Park. These results are very similar to those reported in Section 4.2.

The Taskforce modelling predicted that 13 properties which flooded twice above floor since the Canterbury Earthquake Sequence were protected, and that the number of properties flooding underfloor was reduced by over 50%, from 127 to 53. Although the building stock and the floor level database has changed substantially since this analysis, the 10 overfloor flooded properties and 30% of underfloor flooded properties predicted to be protected in this study show a similar level of benefit.

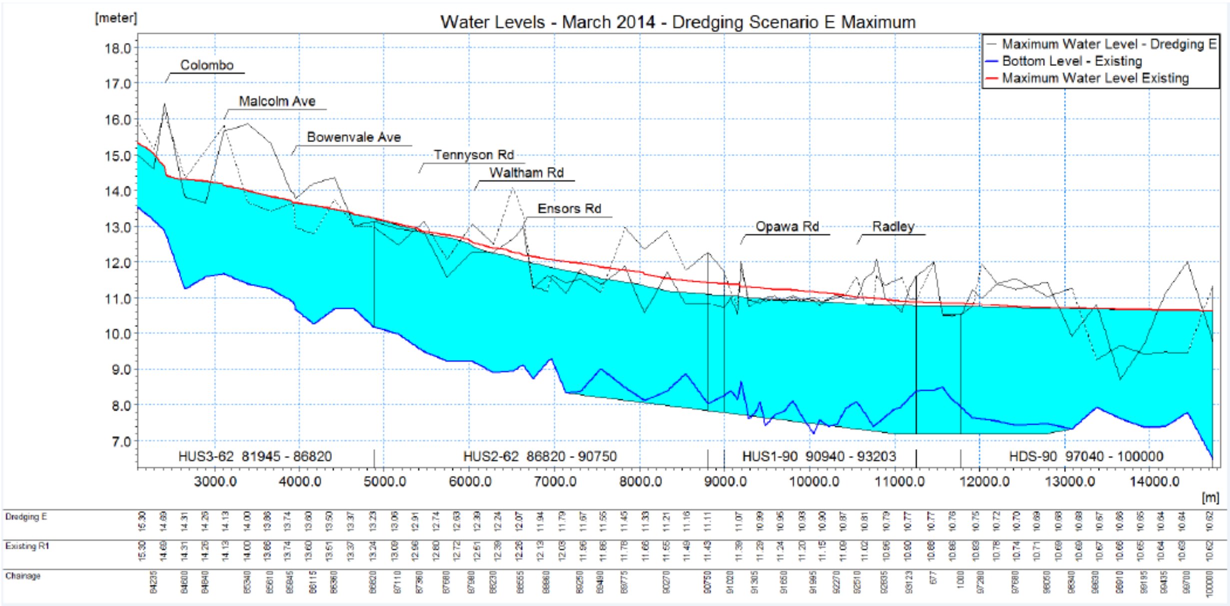


Figure 4.3 : Mayoral Taskforce Dredging scenario modelling showing up to a 0.33 m drop in water level between Radley Street and Ensors Road (taken from Christchurch City Council, 2014)

5. Approaches to Dredging

Appendix C summarises approaches to dredging which have previously been used in the waterways around Christchurch, and which have been considered in this study to achieve the proposed profile between Hansen Park and the Woolston Cut.

Channel width varies in the 3.1 km reach between 12 m at Hansen Park and 36 m at the Woolston Cut. The depth of the channel (below bank) varies between 2 m and 4 m. There are several road bridges, footbridges, a rail bridge and an overpass located along the reach. In addition to these obstructions sections of the river bank are densely vegetated or located adjacent to private properties.

Consultation with a contractor with long-term and recent experience in dredging the Heathcote River/Ōpāwaho (as well as other Christchurch waterways) suggested that the most effective method for dredging this reach is to use a long reach excavator. Machines are available with a 20 m reach, which can therefore span the anticipated 36 m channel by working from both banks. Where direct access to the waterway is impeded by obstacles (including trees), temporary working areas could be constructed into the channel for the excavator to work from, or alternatively from a barge tethered to the banks.

Although other methods (e.g. suction dredge) may provide a ‘smoother’ channel finish, these are likely to be significantly more expensive. In addition, it has been observed that the channel rapidly adjusts after dredging to naturally ‘smooth’ out any local high or low points. As noted in Section 6.3, obtaining a ‘smooth’ bed profile is not ideal for encouraging ecological diversity.

6. Environmental, Geotechnical and other Considerations

6.1 Overview of Key Issues

This high level assessment of the proposed activity indicates that the key potential environmental issues are likely to be:

- Cultural effects: Good sediment management is of the upmost importance - disturbed sediment should be captured and removed as close to source as possible;
- Ecological effects: Fish management - fish populations were observed which included species with a conservation status of "at risk/declining". Inanga spawning area is between Hansen Park and Radley Street bridge, where between 1 January and 1 May every year no works are allowed unless an ecologist indicates that there are no spawning sites present that would be adversely affected by the works. The dredged channel profile should seek to create channel form variations suitable for ecological habitat;
- Contaminated discharges from extracted sediment: Based on high level results, the excavated material may be within recreational thresholds suitable for disposal at Burwood Landfill or, more economically, be reused elsewhere if suitable opportunities could be identified. Dewatering in stockpiles could be considered in the public areas of Hansen Park and Radley Park at the extreme ends of the reach being dredged. However, further consideration needs to be given to the cost of treatment and disposal of this material following in situ testing, particularly if any asbestos is identified;
- Effects on water quality as a result of undertaking works in and around streams: Consider a two stage methodology using instream silt curtains and working from upstream to downstream, and operating the Woolston Cut to capture sediment and clear this location last;
- Effects on bank stability: The excavation of the river bed has the potential to de-stabilise river banks and cause banks to erode, both as an ongoing process and through earthquake-induced lateral spread. Hansen Park to the Woolston Cut already exhibits undercutting and scouring and requires an assessment for bank instability prior to any works. Mitigation measures could also be designed to increase channel roughness following construction prior to vegetation establishment to improve stability while the channel consolidates;
- Stakeholder engagement: The Heathcote River/Ōpāwaho is of high interest to the community and early identification of all stakeholders and engagement will be required to understand and, where possible, address concerns with dredging during the planning and consenting of the operations.

Further information on these is provided in the following sections. Additional issues could include noise and vibration and loss of amenity. In preparing this section, we have consulted with environmental representatives from Christchurch City Council and Environment Canterbury.

6.2 Cultural Considerations

Discharging contaminants such as sediment to water is culturally unacceptable to Ngāi Tahu[20]. Therefore, appropriate sediment management during dredging is of the upmost importance. Encouraging onwards discharge of excessive sediment to the estuary will not be acceptable, and disturbed sediment should instead be captured and removed as close to its source as possible. The mauri of a waterway is degraded if it no longer has the capacity to support traditional uses and values such as food gathering (mahinga kai).Therefore, timing of works to avoid spawning or fishing seasons will be important (see Section 6.3).

6.3 Ecological Considerations

There is the potential for more than minor environmental effects from a large scale dredging operation. Due to the urban constraints adjacent to the river, the tidal nature of sediment transport and the need to balance timing of environmentally sensitive and flood seasons, river mitigation options will be difficult to implement. The key environmental effects to be considered are those on fish and the management of sediment that is activated.

[20] http://esccanterbury.co.nz/project/ngai-tahu-voice/

A report prepared by Boffa Miskell in 2015[21] includes ecological information at two sites within the proposed dredging reach (Aynsley Terrace and Catherine Street). At these sites fish populations of 20-25 /100 m^2 (Catch Per Unit Effort) were observed which included species with a conservation status of “at risk/declining”. The species found included Giant Bully, Common Bully, Longfin Eel, Shortfin Eel, Inanga and Yellow Eye Mullet. Boffa Miskell (2015) noted that overall the lower Heathcote River/Ōpāwaho had poor ecological health but did provide habitat for ecologically important native macro-invertebrate and fish species. With dredging not having occurred since approximately 1989, the ecology has had approximately 30 years to develop, although the earthquakes and liquefaction will have recently disturbed this. As noted in Section 3.3, implementation of the ‘smooth’ design bed profile used here for testing hydraulic benefit should seek to create an ecologically acceptable habitat and not an ‘ecological desert’.

It is noted that kōura (freshwater crayfish) and kākahi (freshwater mussel) shells, are known to be present in some areas of the Heathcote River / Ōpāwaho and Cashmere Stream. In the 2015 survey, these species were found upstream of Colombo Street and outside the reach proposed for dredging but it is possible to have presence within the dredging area. To mitigate the effects of aquatic species mortality, a fish management and relocation plan is expected to be developed and implemented for these works. The plan should seek to remove as many individuals as possible prior to dredging, exclude fish during works and provide for any incidentally caught individuals found within the removed soils. There are difficulties with removing fish species even with these measures so it is expected that some mortality will occur during dredging.

The generally accepted best practice to minimise the impact on fish is to isolate a reach with fish proof nets and deploy electric fishing teams to catch and relocate fish out of the reach being dredged. This is relatively straightforward and practical in small waterways that are less than 3 m wide. However, in a system such as the Heathcote River/Ōpāwaho this would be a significant undertaking, although it may be feasible to install silt controls (Section 6.5) and provide for fish passage at the same time.

As shown in Figure 6.1, there are reaches that are Inanga or trout spawning areas. However, it is difficult to determine where the sensitive areas are, due to the challenges of surveying in deep waters. During spawning periods, no works (including sediment disturbing works) are allowed in the waterway unless a qualified ecologist indicates that there are no spawning sites present that would be adversely affected by the works:

- Between 1 May to 31 October every year for Trout
- Between 1 January and 1 May every year for Inanga

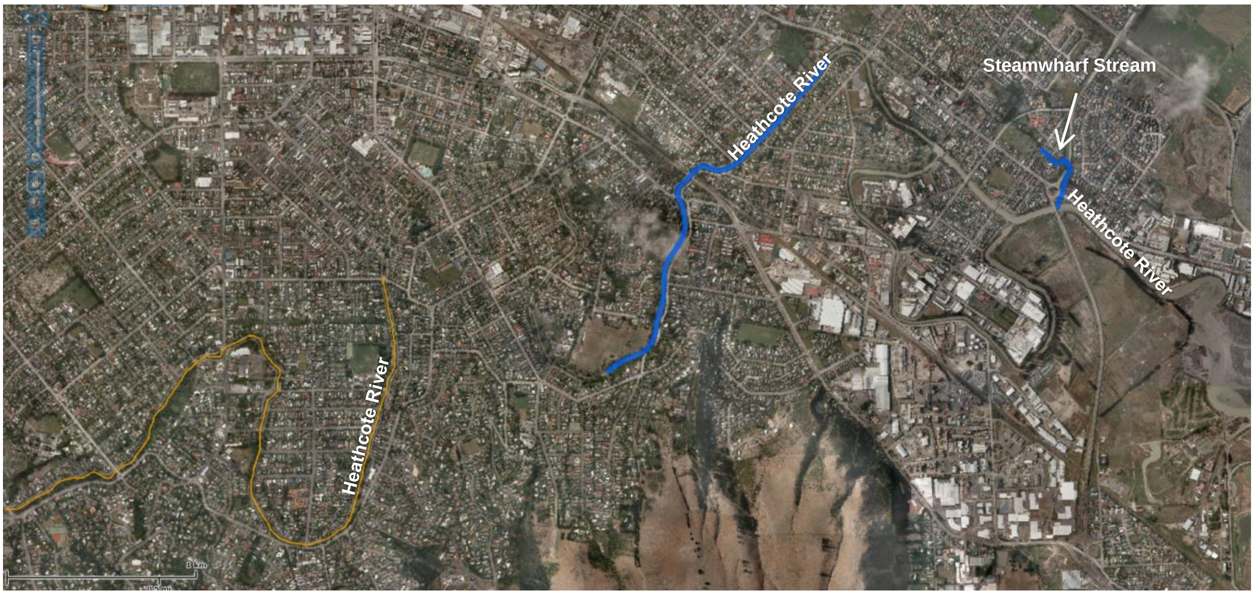


Figure 6.1 : Inanga spawning on the Heathcote River/Ōpāwaho and Steamwharf Stream (blue line). Trout Spawning on the Heathcote River/Ōpāwaho is shown in orange.

[21] Boffa Miskell (2015) Aquatic Ecology of sites within the Heathcote, Estuary & Coastal and Avon SMP catchments Informing the Comprehensive Discharge Consent. Prepared for Christchurch City Council. 25 August 2015

Dredging between Hansen Park and the Woolston Cut therefore requires likely avoidance of the Inanga spawning seasons between 1 January and 1 May. This suggests works will be limited to the 8 month period May through December, which includes winter when water levels will typically be high. Furthermore the Inanga / whitebait season is open between 15 August and 30 November each year. This is an important fishery in New Zealand from a commercial and cultural perspective. Whilst there are no restrictions on in-stream works during this period due to ecological reasons, it is likely that some stakeholders will require restrictions in place during this period to reduce interference with whitebait fishing. These stakeholders will need to be considered during a resource consent process.

Given the various constraints, it is recommended that specialist ecological input is obtained at an early stage to assess the effects of any bank reconstructions and/or changed water depths. The ecologist will also be able to determine if any spawning sites are located within the proposed dredging locations.

Mussels, freshwater crayfish etc., if present, will establish themselves following dredging. Maintenance dredging may therefore be best undertaken in successive reaches, thereby allowing migration and settlement in areas which are less disturbed.

6.4 Managing Potentially Contaminated Material

6.4.1 HAIL Sites

Land can become contaminated through a variety of means including the repeated application of pesticides or herbicides, deliberate disposal of unwanted products by burial or accidental spillage of solids or liquids, and run off from contaminated land and roofing over time. Sites known to be contaminated or that may be contaminated because of past land use are listed in the Listed Land Use Register (LLUR) maintained by Environment Canterbury (ECan). It records where hazardous activities and industrial land (HAIL) has been, or are thought to have been carried out. Many of these sites have not been investigated and the level of contamination (if any) cannot be confirmed without further investigation. It is possible that activities on these sites may have caused contaminants to leach into the adjacent Heathcote River/Ōpāwaho. Therefore an assessment of HAIL sites adjacent to the Heathcote River/Ōpāwaho has been carried out. Details of all HAIL sites within 10 m of the banks of the Heathcote River/Ōpāwaho and downstream of Colombo Street are provided in Appendix D. This list shows several former landfills and sites where pesticides were used and/or stored were located on the banks of the Heathcote River/Ōpāwaho.

6.4.2 Sediment Quality

Based on the Council's resource consent CRC121582 (Appendix E) used to undertake post-earthquake dredging operations, removed sediment must be tested for contaminants prior to permanent disposal, at a sampling rate of one sample per 250 m^3 of sediment. Testing shall include as a minimum heavy metals (arsenic, cadmium, chromium, copper, lead, nickel and zinc), total petroleum hydrocarbons (TPH) and organochlorine pesticides (OCP). Unit costs for metals, TPH and OCP testing (screen level) are in the order of $150 per sample.

It is highlighted that asbestos has been found in sediments in the Cut but no evidence of testing further upstream of the Cut was available at this stage. The absence or presence of asbestos in the natural channel between Hansen Park and the Cut should be confirmed as a priority as this will heavily influence project costs if identified in sediments to be removed.

Table 6.1 provides values from the most recent NIWA (2015) [22] sediment quality report for the Heathcote. Sample location 12 is at Aynsley Terrace upstream of Louisson Place and 13 is at Catherine Street upstream of the Woolston Barrage. Comparison with the Canterbury Background Soil Levels for Recent soils suggests that the tested sediment is largely in line with background levels. The National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health (Soil NES[23]) provide guideline values for various land uses. For disposal of soils at Burwood Landfill, the contaminant concentrations must be at or below the Recreational Guideline Values. Table 6.1 demonstrates that sediment tested by NIWA does not

[22] NIWA (2015) Sediment Quality Survey for Heathcote River Catchment, City Outfall Drain and Estuary Drain. Prepared for Christchurch City Council. September 2015

[23] http://www.mfe.govt.nz/publications/rma-land-hazards/users-guide-national-environmental-standard-assessing-and-managing

exceed the levels set for metals. Environmental Guideline Values for nickel and zinc have been used in the absence of Soil NES values for these elements (Guideline on the Investigation Levels for Soil and Groundwater[24]), and the measurements for sites 12 and 13 are within the thresholds.

Based on these high level results, and subject to further testing – particularly for asbestos, the excavated material may be suitable for disposal at Burwood Landfill or, more economically, be reused elsewhere if suitable opportunities could be identified.

Table 6.1 : Sediment quality measurements in the Hansen Park to Woolston Cut reach taken from NIWA (2015)

Measurement	Value at Site Number		Soil NES Recreational Contaminant Standards (mg / kg)	Environmental Guideline Values (Recreational)	Canterbury Background Soil Levels (Trace Elements Level 2)
	12	13			
Mud (%)	68	41	N/A		
TOC (%)	2.9	2.5	N/A		
Phosphorus (mg/kg)	570	520	N/A		
Arsenic (mg/kg)	6.7	4.6	80		16.3
Cadmium (mg/kg)	0.39	0.3	400		0.2
Chromium (mg/kg)	22	25	2700		20.1
Copper (mg/kg)	24	19	> 10000		19.5
Lead (mg/kg)	45	64	880		128.8
Nickel (mg/kg)	11	12	N/A	600	18
Zinc (mg/kg)	340	300	N/A	1400	166.8
Total PAHs	8.1	77	N/A		

6.4.3 Stockpiles

Recently removed sediment will ideally be temporarily stockpiled to dewater prior to permanent disposal. This dewatering achieves an approximate 25% reduction in weight of excavated material which must be dumped[25]. This also results in lower weight of material to transport and avoids the need for sealed trucks. The previous consent authorised sediment to be stored in public areas subject to specific requirements as follows.

All sediments and weeds removed from the bed of a water body shall not be placed or stored where it may enter a surface water body, and shall be removed from site as soon as is practical. Stockpiles of sediment in public areas shall be demarcated or fenced, kept damp or covered, and a sign shall be displayed informing the public of a health risk resulting from contact with stockpiled sediment.

Note that the stockpiling sediment in public places carries additional risk. Dredged sediment may contain organic material at varying degrees of decay which could lead to odour issues and potential complaints from the public. Any material with an identified asbestos content could not be stockpiled on the banks due to the potential for air pollution. The silt fences forming the sides of the stockpile would need to be dug into the ground.

Stockpiles could be considered in the public areas of Hansen Park and Radley Park at the upstream and downstream extents of the reach, if the material could be transported. Each of these areas could store approximately 5,000 m^3 of excavated sediment if piles of 500 m long x 5 m wide x 2 m high were developed. However, the volume of material stored for dewatering at any one time is likely to be less than this maximum available.

As an alternative to stockpiles, sediment tanks could be used and flocculant added to encourage the deposition of suspended sediment. If these could be developed within containers which can then be

[24] http://www.nepc.gov.au/system/files/resources/93ae0e77-e697-e494-656f-afaaf9fb4277/files/schedule-b1-guideline-investigation-levels-soil-and-groundwater-sep10.pdf
[25] Approximate conversion rate is 1 m^3 : 1.6 T dewatered sediment, 1 m^3 : 2.1 T not dewatered

transported to landfill, the need for double handling of material could be avoided. Standard containers have a 39 m^3 storage capacity.

Figure 6.2 : Example stockpile of dredged material

6.4.4 Permanent Disposal

Ideally, reuse of the dredged material which meets the recreational contamination levels will keep disposal costs to a minimum, and opportunities should be explored as a priority. Burwood and Kate Valley are options for landfill disposal. It is noted that Burwood has zero tolerance for asbestos which was found within sediment in the Woolston Cut. Kate Valley can accept material which does not satisfy recreational standards, with acceptance depending on the results of testing.

6.5 Managing Sediment Plumes

A key consideration will be the management of a sediment plume created by a dredging operation, which has the potential to travel both upstream and downstream due to the tidal nature of the river between Hansen Park and the Woolston Cut. The methods listed in Appendix E may be used in combination, although will need to consider the width of flow of the river. All the identified methods require careful installation to trap as much silt as possible, and need to be regularly inspected and maintained to prevent failure. Material that has accumulated upstream of a filter or barrier should be carefully removed and properly disposed of with the dredged material.

ECan has recently updated the sediment and control guidance[26] which contains the following advice for sediment removal and dredging:

- Isolate the area to be dredged from flowing water, if possible. Silt curtains and coffer dams are options to keep flowing water away from the dredging area;
- Use a suitably qualified or experienced person to remove all fish and eels from the work area. Transfer these animals to suitable habitat;
- Dredging without isolating the work area will create a sediment plume well downstream, so use (and enhance) natural features such as pools downstream as areas where sediment lost during the dredging can be collected and then removed later;
- If you are using an excavator to remove sediment, a toothed bucket may cause less sediment disturbance than a straight-edged bucket;

[26] http://esccanterbury.co.nz/project/other-waterway-tasks/

- Place dredgings straight into a truck for transport from the site. If this is not possible, put them well away from the water edge or bank edge. Protect the stream from additional sediment from the stockpiled dredgings by using filter socks or silt fences; and
- Dredgings may contain fish and eels. Use suitably qualified or experienced people to remove any fish from the dredged material and return them to suitable habitat.

Figure 6.3 : A typical sediment curtain. Photo courtesy of City Care Ltd.

For the reach of the Heathcote River/Ōpāwaho under consideration, a two stage methodology could be considered:

1. Use instream silt curtains (Figure 6.3) and work from upstream to downstream. This should prevent the bulk of mobilised sediment from entering the main channel, which may be acceptable given the relatively low degree of likely contamination; and

2. Isolate the Woolston Loop adjacent to the barrage so the natural channel does not act as a sediment trap, and operate the Woolston Cut to capture sediment and clear this location last. The Woolston Cut will act as a sediment trap to minimise residual sediment from travelling out to the estuary. If tides allow, timing any major disturbances to occur on an incoming tide will provide maximum chance for settlement in the cut on the outgoing tide. However, it is recognised that this could be highly limiting.

6.6 Geotechnical and Channel Form Considerations

The excavation of the river bed has the potential to de-stabilise river banks and cause banks to erode. Bank instability is both an ongoing process and, potentially, an earthquake-induced process of lateral spread. Anecdotal evidence indicates that attempts were made to stabilise the bank toes at Richardson and Clarendon Terrace following previous dredging operations, by placing gravel. The lower Heathcote exhibited lateral spread during the Canterbury Earthquake Sequence.

Not only does bank erosion add more sediment to the system but it also reduces the ability of the channel to move sediment as the wider eroded channel will generally have lower velocities, and therefore lower sediment transport capacity, than a narrower channel. Mitigating the effects of both ongoing and earthquake-induced bank erosion could significantly increase the cost of the project.

A condition assessment undertaken by Opus in 2016[27] highlighted 119 faults in the Heathcote River downstream of Colombo St and of those 21 were bank instability and 41 were bank undercutting/scouring. The

[27] Opus (2016) LDRP 098 Open Channel Condition Assessment Condition Assessment Report for Heathcote River downstream of Colombo Street

reach between Hansen Park and the Woolston Cut was rated "good" although Figure 3.1 highlights a number of existing faults due to undercutting/scouring and bed heave/slumping. An assessment of bank instability faults between Colombo Street and Radley Street in June 2016[28] made the following recommendations for the reach proposed for dredging:

- Armstrong Avenue to Louisson Place (~1.2 km): Majority of faults are medium size and do not require urgent attention. Stabilisation options were recommended to be developed for implementation in the medium term; and
- Opawa Road to Radley Street (~1.4km): Considerable number of medium sized slumps but none required urgent attention. This area was assigned a lower priority than Armstrong Avenue to Louisson Place although it was recommended that stabilisation options are developed for implementation in the medium term.

The proposed dredging operation has the potential to worsen these already undercut/scouring sections, as well as the risk of lateral spread, and should therefore be assessed for bank instability prior to any works. AECOM (2016b)[29] and Beca (2017)[30] are currently designing bank stabilisation works for the channel between Colombo Street and Waltham Road. Initial unit rates for mitigation works range widely depending on site constraints and the type of mitigation option being used, although suggests a high level rate of $2,000 / m of riverbank excluding overheads. Mitigation measures could also be designed to increase channel roughness following construction prior to vegetation establishment to improve stability while the channel consolidates.

Figure 6.4 shows the information in the SCIRT viewer for the only potentially buried services crossing the channel between Hansen Park and the Woolston Cut. The available information suggests that other services cross under bridge platforms. There is no information on invert for the 315 mm Rock Gas pipeline, and survey would be required to verify its location and level. The 280 mm waste water pipe crosses downstream of Brougham Street at a stated level of between RL 7.96 m and RL 7.10 m. This is near to model cross section 91365 which has a 2011 channel invert of RL 8.1 m. This could pose a constraint to the lowered profile proposed in Figure 3.4, which should be confirmed by survey at an early stage.

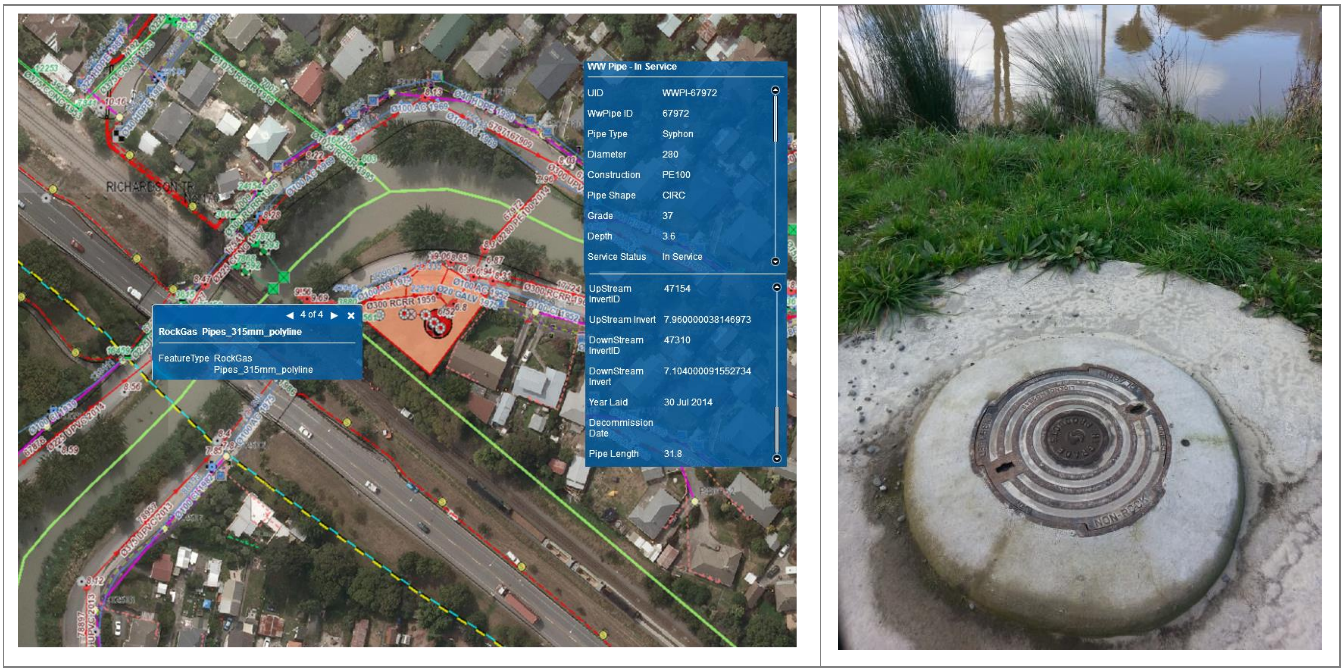


Figure 6.4 : Potentially buried services cross the channel between Hansen Park and Radley Street. Photo of service cover on the right hand bank downstream of the railway bridge

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28 AECOM (2016) Mid-Heathcote/Opawaho Fault Inspection Report, Draft 17 June 2016

29 AECOM (2016b) Upper and Mid-Heathcote River / Opawaho Design Packages. LDRP15 – Upper and Mid Heathcote. 11 October 2016

30 Draft report provided by Council by email 28 June 2017

6.7 Consenting Considerations

A high level review of the Land and Water Regional Plan (LWRP) in Appendix G indicates that dredging in the Heathcote River/Ōpāwaho would require consent as a discretionary activity. This confirms the earlier findings of the 2014 Mayoral Task Force[31].

The Council currently hold two consents for excavation of waterways which are:

- The general consent CRC146620 to 'Disturb or Excavate Bed, Structure' which addresses minor re-grading and bank work; and
- Consent CRC121582 'To Remove Earthquake Derived Sediments from Christchurch's Surface Water Bodies' which covers remedying bed level changes and removing liquefaction silt deposited as a result of earthquakes. This consent expires in 2022.

The Council is currently investigating with ECan whether proposed dredging works could be authorised by, and undertaken under, one of these existing dredging consents held by the Council. If so, no further consent would be required for the dredging activity.

If the existing consents could not be used and a new consent is required, then there are a number of key issues that would require comprehensive specialist assessment to support any future resource consent application:

- Detailed design drawings of proposed works;
- Construction methodology for undertaking works in and around a stream, for undertaking works within the road reserve, for undertaking works within a river;
- Ecological Assessment for undertaking works within a Site of Special Wildlife Interest or Significant Ecological Area (terrestrial/freshwater/marine);
- Geomorphic (bank) stability assessment; and
- Cultural assessment.

6.8 Stakeholder Engagement

The Heathcote River/Ōpāwaho is of high interest to the community. This includes residents who live or travel near to it, those who use the banks for recreation and a wider community interest in the water quality and ecological health of the river and estuary. In addition, many of these values and uses also overlap with the cultural values and uses of the waterbody.

These parties are likely to be interested in, and potentially affected by, any proposed dredging and as such could be a key factor in the consenting process. The development of consent applications will take time and the application process itself will also present a timeline risk, especially if an application was notified and had public submission. No works can start until the required resource consents have been obtained.

Early identification of all stakeholders and engagement will be required to understand and, where possible, address concerns with dredging during the planning and consenting of the operations. A stakeholder engagement plan should be developed and implemented early in any planning phase.

7. Summary of Benefits, Costs, Risks and Next Steps

7.1 Hydraulic Benefits

Hydraulic modelling of the proposed dredged scenario has demonstrated that:

- Dredging achieves a maximum water level reduction of approximately 300 mm, around Hansen Park, reducing to less than 100 mm reduction around Ensors Road in an upstream direction and Radley Street in a downstream direction. A similar pattern of water level reduction is predicted for both 10 year and 50 year existing development scenarios;
- In the 10 year ARI event, dredging protects 10 of the 14 (~70%) properties at risk of overfloor flooding upstream of Radley Street, removing all overfloor at risk properties upstream to Ensors Road. In the 50 year ARI event, the water level reduction protects a higher number of properties (46 out of 118), although this is a lower proportion (~40%) of the properties at risk of overfloor flooding upstream of Radley Street;
- In a future scenario +0.25 m sea level rise from its current level, more properties are at risk of overfloor flooding in the basecase and more are protected by the proposed dredging. In the 10 year ARI event, 23 out of 36 are protected, which is a drop in the relative number protected from 70% to 65%;
- In the +1 m sea level rise 10 year ARI event, the proposed dredging protects 10 properties out of 97 which is a significant drop in relative properties protected from 70% to 10%; and
- In terms of road flooding in the 10 year ARI event, dredging provides a reduction in road/access flooding compared with the base case, and returns the whole reach between Colombo and Radley Streets largely to pre-earthquake levels of road and access flooding. This reduction in length of flooded road and number of properties with restricted access is accompanied by a reduction in the typical duration of flooding by up to 7 hours between Brougham and Hansen Park.

7.2 Estimated Costs

A number of cost estimates for removing a cubic metre of sediment were reviewed, largely from local experience in the Heathcote and Avon Rivers (Table 7.1). The costs varied between approximately \$100 / m^3 to \$130 / m^3, with most costs explicitly including the costs of dumping the excavated material at landfill. Based on these past unit costs, a unit rate of \$135 / m^3 is used here, which is a slight increase on the available rate for work in the Heathcote.

In the absence of more detailed survey and assessment, an allowance for bank stabilisation works is included here assuming 50% of the total left and right hand bank length (50% of 2.4 km = 1.2 km) of the highest priority section between Hansen Park and Opawa Road bridge (see Section 6.6) and high level unit costs (\$2,000 per metre, excluding overheads) developed for similar works further upstream. Sediment testing has been included at a rate of \$300 per 250 m^3 sample of material (Section 6.4).

Table 7.2adds in high level estimates for design and project management, consenting and risk (totalling 35% of construction costs) which indicate an overall capital budget requirement of \$14.2M. This excludes separate costs of dredging the Woolston Cut, but efficiencies may be achieved through combining these works. Re-use of "clean" excavated material through landscaping adjacent to river may reduce disposal costs.

If maintenance dredging is undertaken along the reach on average once every 10 years, assuming an annual deposition rate of 700 m^3, there is likely to be an ongoing cost implication of \$1.3M every 10 years (including the 35% overheads applied below). Again, this does not include dredging of the Woolston Cut.

Table 7.1 : Unit costs of previous dredging operations in Christchurch, ordered by decreasing cost

Study or Source	Unit Rate (per m^3 material removed)	Notes
Heathcote bank slump removal (provided by email from the Council 31.07.2017)	\$130 / m^3 (\$205,000 for 1,600 m^3 material removed)	460 linear metres from the Heathcote. Material could be stockpiled nearby and dumped at Burwood. There was no asbestos found in the sediment

Study or Source	Unit Rate (per m^3 material removed)	Notes
Styx (Council Review of Dredging, 2016)	$125 / m^3 ($349,500 for 2,812 m^3 material removed)	Reach between Spencerville and the Spencerville Road bridge. Total project cost comprised $282,000 dredging and $67,500 dumping at Burwood.
Avon River Loop silt removal (provided by email from the Council 31.07.2017)	$120 / m^3 ($357,000 for 3,000 m^3 material removed)	840 linear metres from the Avon. Material could be stockpiled nearby and dumped at Burwood. There was no asbestos found in the sediment
Avon (Council Review of Dredging, 2016)	$100 / m^3 ($1,035,000 for 10,000 m^3 material removed)	Total project cost comprised $795,000 dredging and $240,000 dumping at Burwood.

Table 7.2 : High level cost estimate for proposed dredging of the Heathcote between Hansen Park and the Woolston Cut

Cost Item	Unit	Rate	Total
Excavation and dumping of material	60,000 m^3	$135 / m^3	$8,100,000
Bank stabilisation (assumed 50% of total left and right hand bank length in highest priority section)	1,200 m	$2,000 / m	$2,400,000
Sediment testing (assumed 1 sample per 250 m^3 excavated)	240 samples	$150 / sample	$36,000
SUBTOTAL CONSTRUCTION			**$10.5M (rounded)**
Design and Project Management	Each	10%	$1.1M (rounded)
Consenting	Each	5%	$0.5M (rounded)
Risk	Each	20%	$2.1M (rounded)
TOTAL			**$14.2M (rounded)**

7.3 Programme

If a long reach excavator is used, its productivity depends on the size of bucket, difficulty of access etc. Based on a recent dredging operation in the Avon River, an extraction rate of approximately 240 t per day was achieved using an excavator bucket size of 0.4 m^3. This wet weight of 240 t is equivalent to approximately 115 m^3 wet sediment or 150 m^3 dewatered sediment[32].

At this rate, one excavator would take approximately 18 months to remove 60,000 m^3 of material from the Heathcote River/Ōpāwaho. If 2 or more excavators were used in parallel, the work could be more realistically accomplished within the 8 month window between May and December, depending on many factors.

One important factor is the Inanga / whitebait season between 15 August and 30 November each year. Whilst there are no restrictions on in-stream works during this period due to ecological reasons, it is likely that some stakeholders will want restrictions in place during this period. This also excludes any channel stabilisation rehabilitation works.

Therefore, it may be more feasible to consider the initial dredging, as well as maintenance dredging, being undertaken in successive reaches over a longer period of time. This would spread the expenditure over a number of years and could allow migration and settlement of species in areas which are less disturbed.

[32] Approximate conversion rate is 1 m^3 : 1.6 T dewatered sediment, 1 m^3 : 2.1 T not dewatered.

However, it would also delay achieving the full hydraulic benefits until the completion of all works, although works could be prioritised.

7.4 Risks

Risk has been considered throughout the feasibility assessment. See Table 7.3 for a summary of identified risks.

Table 7.3 : Risk Register

Risk	Impact	Potential Mitigation
Existing services	Line and level of existing services may restrict depth of achievable dredging	There are known service crossings of the river downstream of Brougham Street. Further work should be undertaken to confirm their depth during design phase. Early engagement with utility companies to identify services during design phase.
Existing structures	There are a number of bridge and rail crossings of the river within the proposed dredging reach. Dredging at or near foundations may destabilise the structures.	Further work should be undertaken to confirm depth of existing foundations and extent of scour protection. In addition, proposed dredged depth is not to exceed that of previous dredging, reducing likelihood of destabilising structures.
Existing outfalls	Potential to undermine existing outfall structures into the river	Location and level of existing outfalls to be identified during design phase. New dredged profile to minimise impact of outfalls.
Rock level	Proposed dredged profile is not able to be achieved due to high rock levels as a result of uplift in the Canterbury Earthquake Sequence	Depth to rock to be confirmed during design phase
Increased channel conveyance	Dredging of the channel may increase flow velocity and increase risk of flooding downstream	Likelihood of increasing flood risk downstream is minimal as the hydraulic modelling has indicated that flood risk downstream is not increased as a result of dredging
Sediment build-up	Increased frequency of dredging to achieve dredged profile, resulting in increased maintenance costs	Long term strategy adopted by the Council
Reduction in water quality	Release of silt into the river as a result of dredging	Appropriate sediment management procedures to be followed
Channel excavation – ecology	Damage to established ecosystems and potential release of contaminants into the river	Dredged profile to minimise excavation of river bank. Material testing to be undertaken of proposed dredged material to identify any contaminants.
Channel excavation stability	Unstable batters following excavation	Design a stable channel cross section which is suitably wide with flat vegetated batters or provides batter stabilisation using measures such as rock. Design mitigation measures to increase channel roughness following construction and prior to vegetation establishment to improve stability while the channel consolidates.
Contaminated material	Disposal of contaminated material (particularly asbestos), increased cost of disposal	Material testing to be undertaken of proposed dredged material to identify any contaminants
Earthquake – lateral	Slope failure of dredged banks	Mitigation measures to be confirmed during design phase but likely to include (and not be limited to) shallow

Risk	Impact	Potential Mitigation
spread		gradation of the dredged banks, rock edge to channel profile and ground improvement works. Proposed dredged depth is not to exceed that of previous dredging.
Earthquake – liquefaction ejecta	Reduced capacity of the channel following a liquefaction event	Excavate and dispose of ejecta silt to an approved receiving area
Resource Consents	A new resource consent may be required to undertake the dredging activities. Developing applications for resource consents and then going through the application process will take time that limits when works can start.	Consultation with ECan and the Council to explore the applicability of existing consents and any new consenting requirements
Resource Consents	Strong community views requiring additional engagement which delays process	Early engagement with community
Social disruption	Disruption to public, including road closures, noise, vibration etc	Undertake dredging works only following engagement and implementing mitigations, and also outside whitebait and spawning seasons

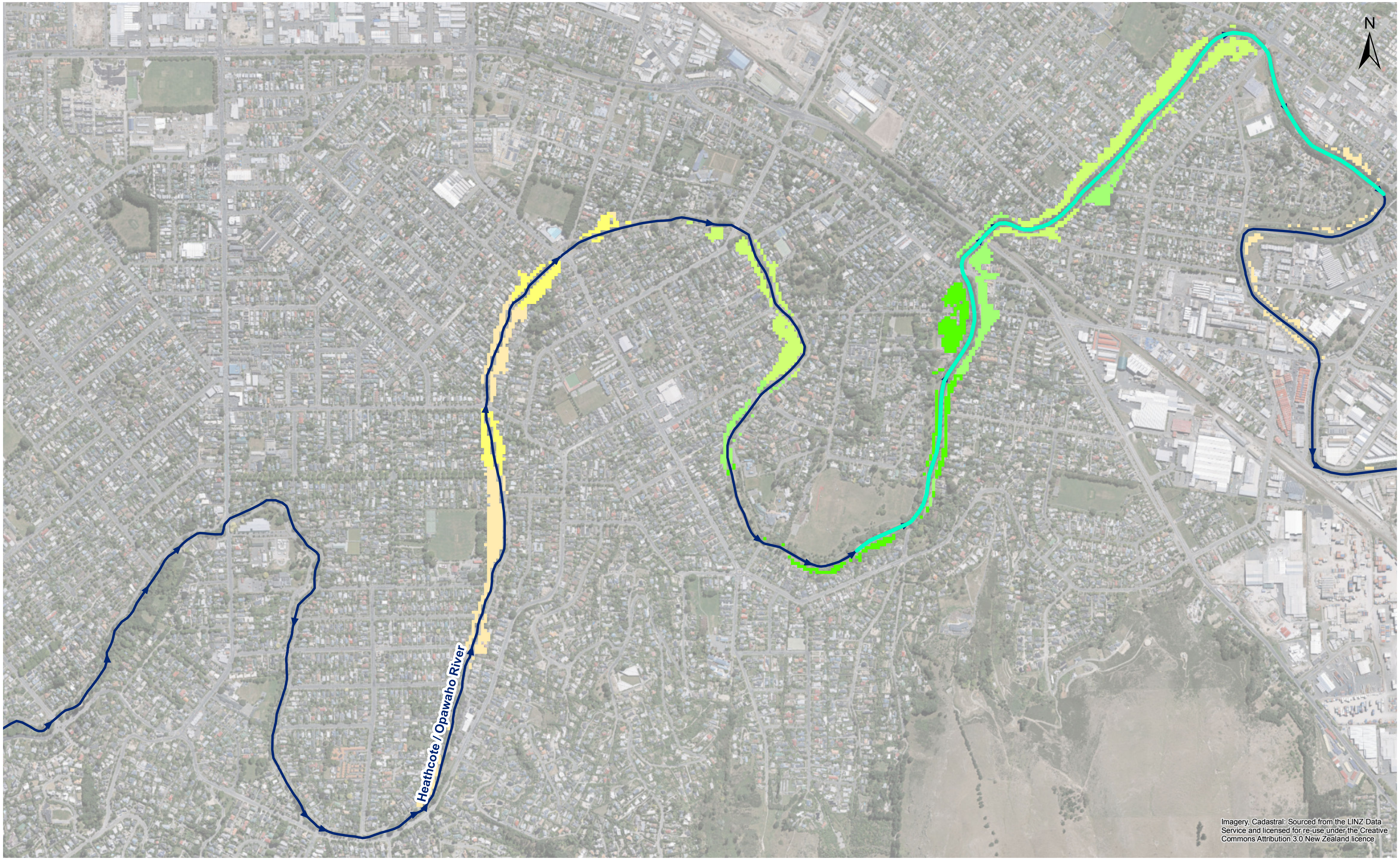
7.5 Next Steps

It is recommended that the Council continues development of this option to dredge the reach between Hansen Park and the Cut to manage flooding, and makes decisions on implementation within the context of other options to manage flooding in the catchment. Whilst this report has recognised the work being undertaken in parallel to consider dredging of earthquake liquefaction material from the Woolston Cut, it does not make any recommendations about this reach. If dredging is pursued, the following tasks are recommended:

- As far as possible, unify all work towards dredging the channel between Hansen Park and the Woolston Cut, including the Woolston Cut. This could include programming works so that the Woolston Cut is used to capture residual sediment transported downstream and cleared last, although this will depend on operation of the tidal gates;
- Undertake channel survey and revised hydraulic modelling to accurately determine the channel profile to be achieved, the volume of material to be removed and to provide a baseline against which future deposition can be measured;
- Detailed design needs to assess the longitudinal profile to limit the development of headcuts. The channel should be modelled to show how proposed cross sections would remain stable by assessing stream power, bed shear stress and velocity against expected stable cross section profiles;
- Engage specialist ecological input to assess the effects of any bank reconstructions, changed water depths and to determine if any spawning sites are located within the proposed dredging locations;
- Develop a fish management and relocation plan;
- Undertake *in-situ* sediment sampling to confirm absence of material above recreational levels of contamination, and in particular absence of asbestos;
- Identify all stakeholders as early as possible and develop a consenting and engagement strategy; and
- On the basis of the above, refine cost estimates for the work and seek efficiencies through reuse of excavated material and other opportunities.

Further work is required to better understand the morphology of the Heathcote River/Ōpāwaho and, in particular (i) how channel morphology will change as a result of desilting which may require mitigation measures such as batter treatment and (ii) how the river may respond to climate change and a rise in sea levels. The large temporal gap in cross section surveys to date means that it is difficult to know with certainty whether the rate of aggradation is changing over time and whether the system has adjusted to the effects of the Woolston Cut and the subsequent tidal barrage as well as the earthquake induced effects. Modelling is likely to be required to predict how the river may respond to future changes in estuary levels, which will inform the effectiveness of future dredging operations. Some initial suggestions on modelling are provided in Appendix H.

Appendix A. Maps



CLIENT	
Christchurch City Council	
PROJECT	
Heathcote Floodplain Management Plan	
SCALE	PROJECT CODE
1:11,500 @ A3	IZ076600
PROJECT MANAGER	DRAWN
IW	DC
PROJECT DIRECTOR	DATE
VVB	16/10/2017

10y ED Water Level Reduction (m)

- < 0
- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- > 0.5
- Proposed Dredging
- Heathcote River

0 0.25 0.5 1 Kilometres

Heathcote Floodplain Management Plan

Proposed Dredging (10 year ARI ED)

JACOBS
Wynn Williams Building
47 Hereford Street
Christchurch, 8013
Tel +64 3 940 4900

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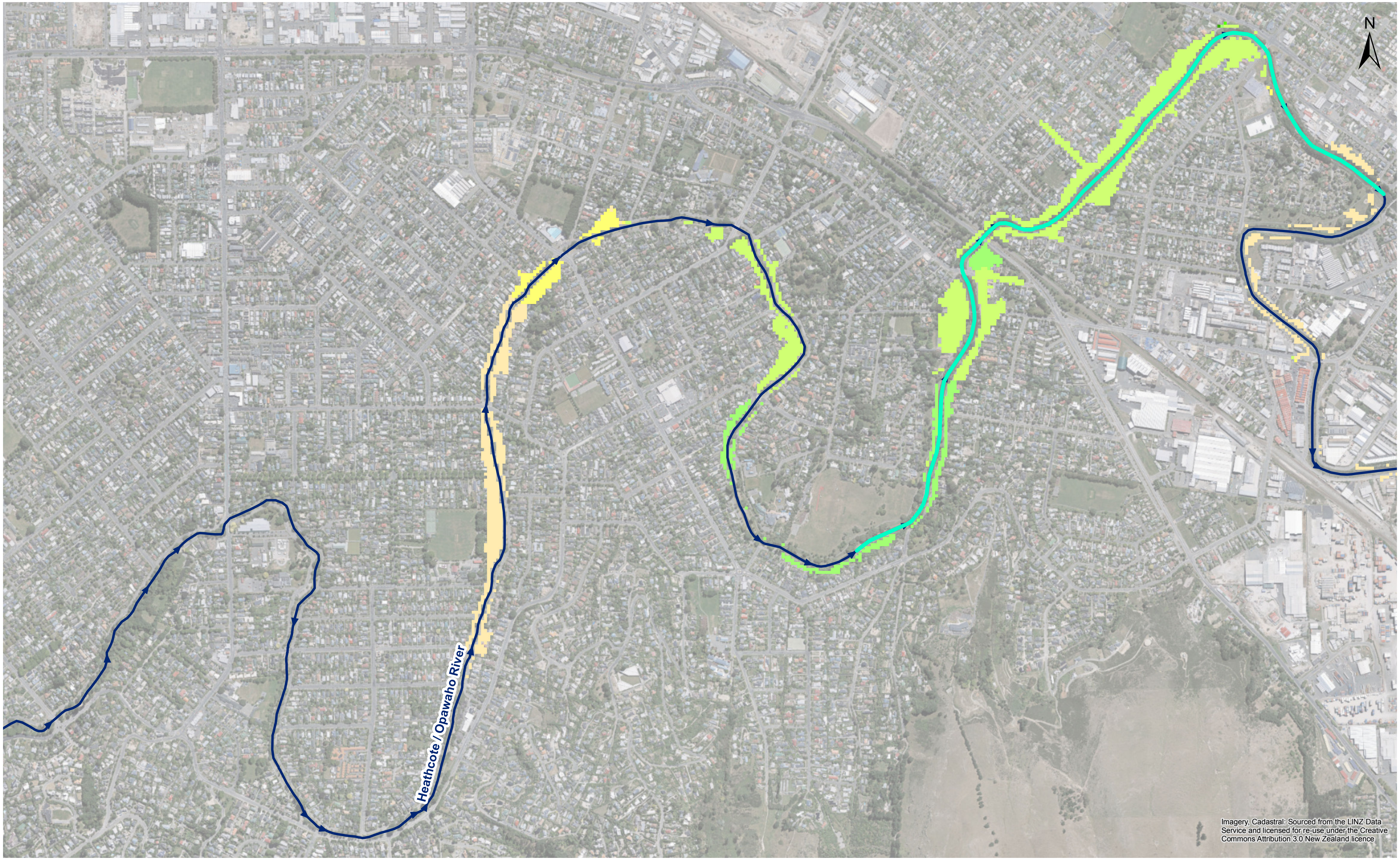

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CLIENT Christchurch City Council	
PROJECT Heathcote Floodplain Management Plan	
SCALE 1:11,500 @ A3	PROJECT CODE IZ076600
PROJECT MANAGER IW	DRAWN DC
PROJECT DIRECTOR VVB	DATE 17/10/2017

10y CC (+0.25m) Water Level Reduction (m)

- < 0
- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- > 0.5

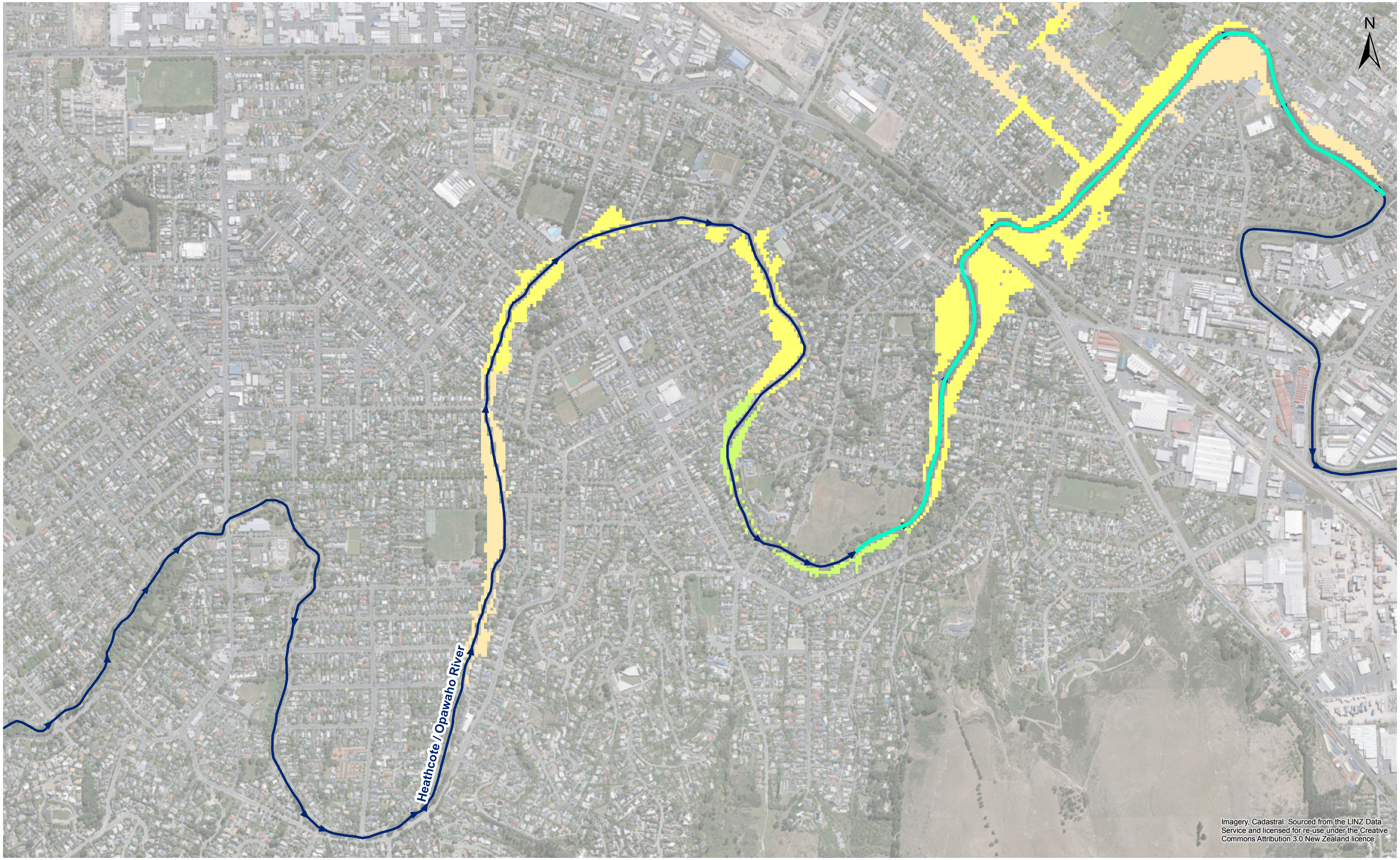
- Proposed Dredging
- Heathcote River

Heathcote Floodplain Management Plan

Proposed Dredging (10 year ARI CC +0.25m)

0 0.25 0.5 1 Kilometres

JACOBS
Wynn Williams Building
47 Hereford Street
Christchurch, 8013
Tel +64 3 940 4900



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CLIENT Christchurch City Council	
PROJECT Heathcote Floodplain Management Plan	
SCALE 1:11,500 @ A3	PROJECT CODE IZ076600
PROJECT MANAGER IW	DRAWN DC
PROJECT DIRECTOR VVB	DATE 16/10/2017

10y CC Water Level Reduction (m)

- < 0
- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- > 0.5
- Proposed Dredging
- Heathcote River

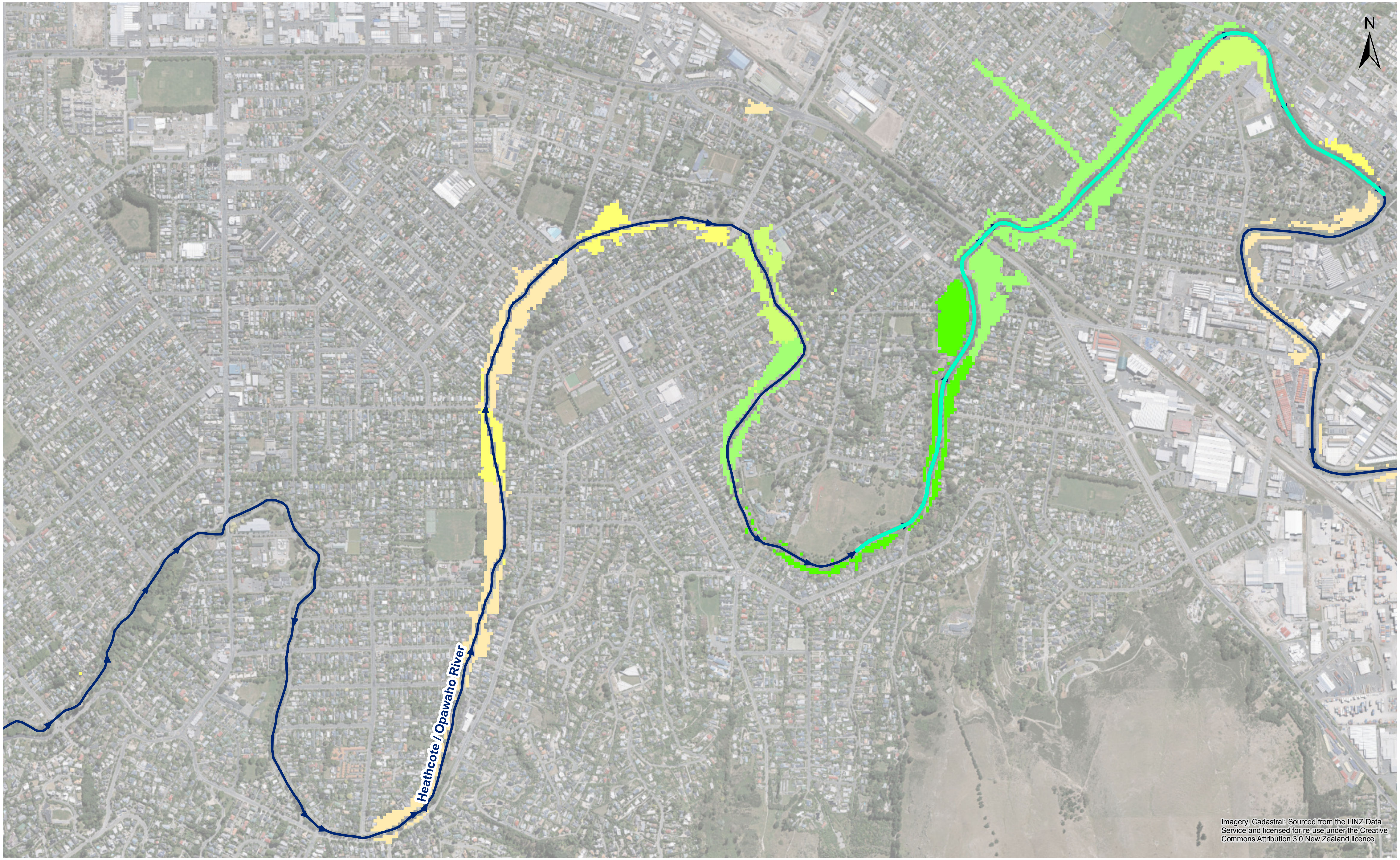
Heathcote Floodplain Management Plan

Proposed Dredging (10 year ARI CC +1m)

0 0.25 0.5 1 Kilometres

JACOBS

Wynn Williams Building
47 Hereford Street
Christchurch, 8013
Tel +64 3 940 4900



Heathcote Floodplain Management Plan

Proposed Dredging (50 year ARI ED)

CLIENT Christchurch City Council	
PROJECT Heathcote Floodplain Management Plan	
SCALE 1:11,500 @ A3	PROJECT CODE IZ076600
PROJECT MANAGER IW	DRAWN DC
PROJECT DIRECTOR VVB	DATE 16/10/2017

JACOBS
Wynn Williams Building
47 Hereford Street
Christchurch, 8013
Tel +64 3 940 4900

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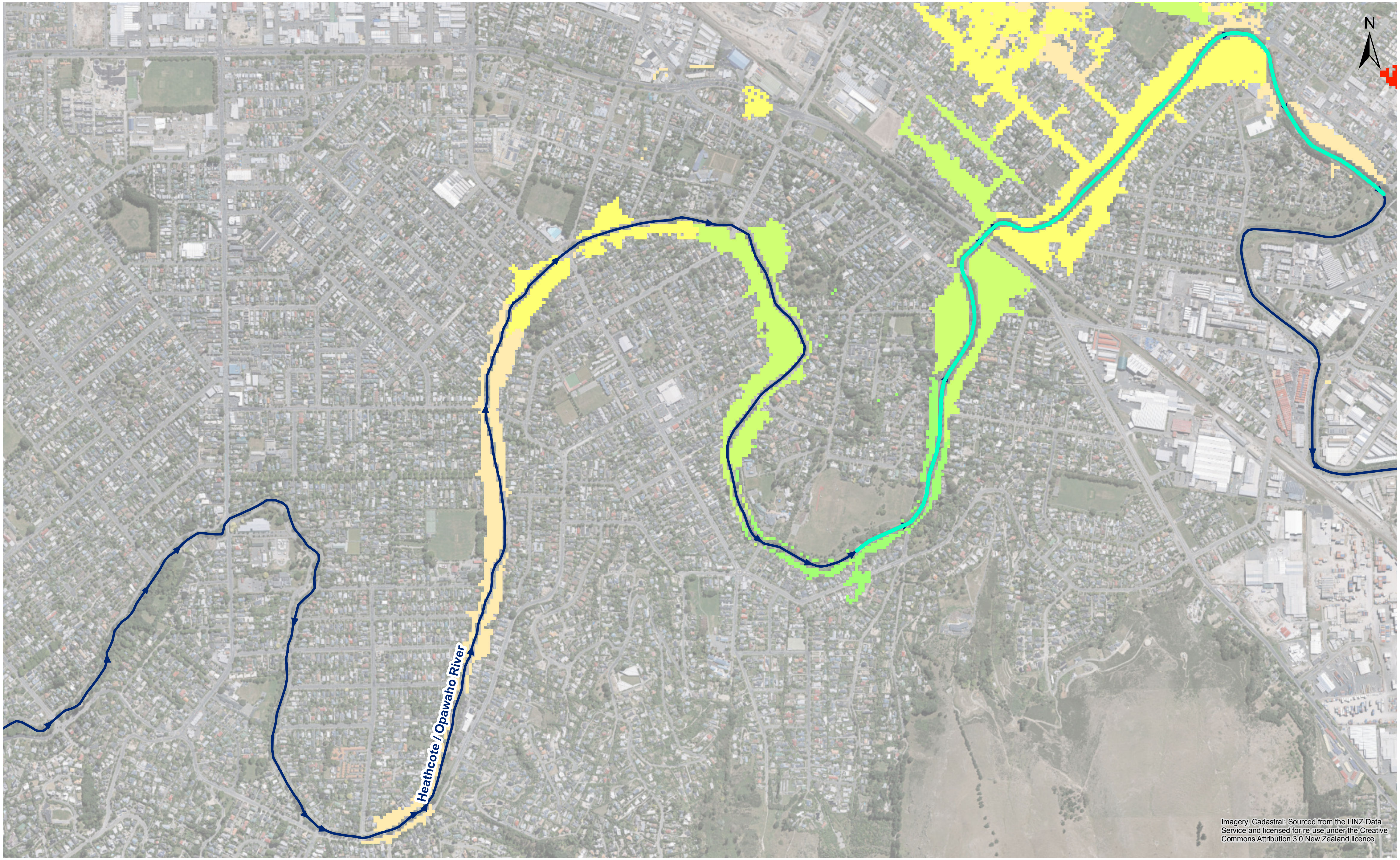

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CLIENT Christchurch City Council	
PROJECT Heathcote Floodplain Management Plan	
SCALE 1:11,500 @ A3	PROJECT CODE IZ076600
PROJECT MANAGER IW	DRAWN DC
PROJECT DIRECTOR VVB	DATE 16/10/2017

50y CC Water Level Reduction (m)

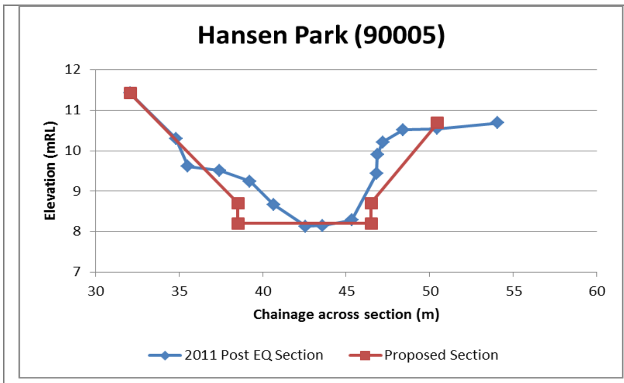
- < 0
- 0 - 0.05
- 0.05 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- > 0.5
- Proposed Dredging
- Heathcote River

0 0.25 0.5 1 Kilometres

Heathcote Floodplain Management Plan
Proposed Dredging (50 year ARI CC +1m)

JACOBS
Wynn Williams Building
47 Hereford Street
Christchurch, 8013
Tel +64 3 940 4900

Appendix B. Alternative Channel Profile to RL 7.1 m

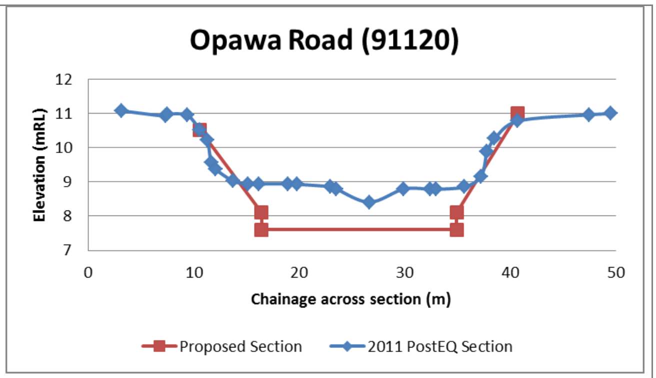


Minimum elevation:

- 2011: RL 8.1 m
- Proposed: RL 8.1 m

Cross sectional area:

- 2011: 42 m^2
- Proposed: 44 m^2

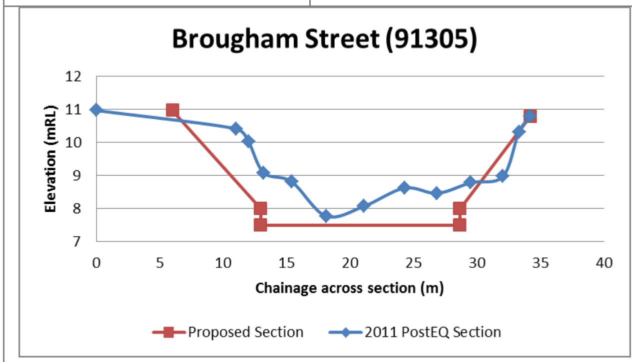


Minimum elevation:

- 2011: RL 8.4 m
- Proposed: RL 7.6 m

Cross sectional area:

- 2011: 78 m^2
- Proposed: 93 m^2

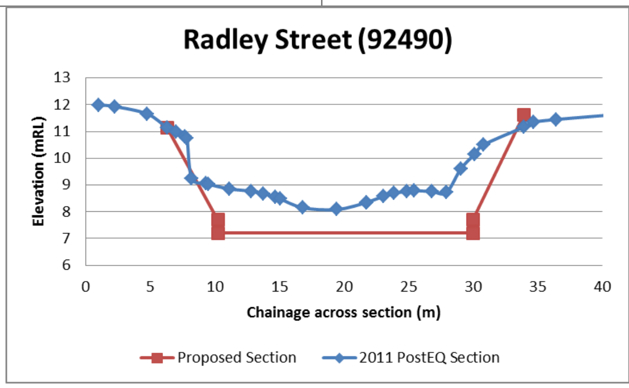


Minimum elevation:

- 2011: RL 7.8 m
- Proposed: RL 7.5 m

Cross sectional area:

- 2011: 66 m^2
- Proposed: 83 m^2

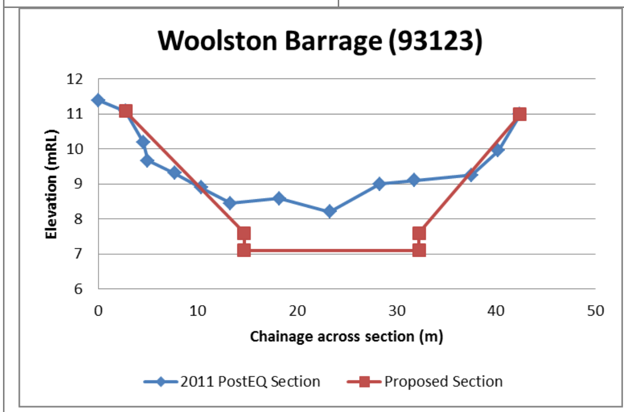


Minimum elevation:

- 2011: RL 8.1 m
- Proposed: RL 7.2 m

Cross sectional area:

- 2011: 53 m^2
- Proposed: 88 m^2



Minimum elevation:

- 2011: RL 8.2 m
- Proposed: RL 7.1 m

Cross sectional area:

- 2011: 73 m^2
- Proposed: 103 m^2

Figure B.1 : 2011 PostEQ sections (blue) and alternative lowered and widened sections (red) between Hansen Park and the Woolston Cut. Minimum elevations and cross-sectional area below the 10y ARI water levels show anticipated difference.

Appendix C. Dredging Methods Used Previously

C.1 Dragline Dredge

Early dredging operations used a pneumatic sweeper. This disturbed silt on the bed of the river and the flow of water would then carry the sediment downstream. The CDB also owned and operated dragline dredges which were rotated around the main rivers. These were in used up until 1989.

The dragline (Figure C.1) is a versatile machine that has the longest reach of any member of the crane-shovel family. It can dig in soft to medium-hard material. The bucket teeth and weight of the bucket produce the digging action as the drag cable pulls the bucket across the river bottom.

Issues with the drag line include lack of lateral control and it does not have a positive digging action. As a result the bucket may bounce or move sideways during dredging. Also the bucket is more likely to spill material and create larger sediment plumes.

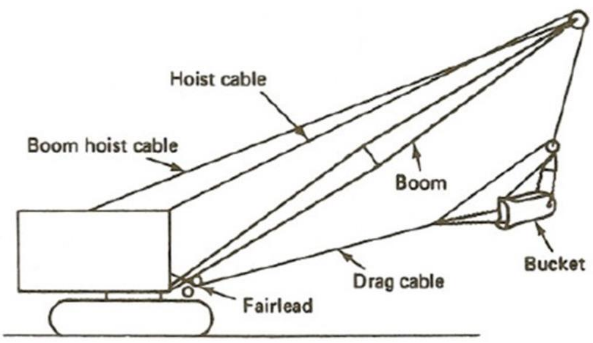


Figure C.1 : Schematic of a dragline dredge

C.2 Long Reach Excavator

Small backhoe dredgers can be track-mounted and work from the banks of rivers and streams or can be used in combination with small barges (Figure C.2). The backhoe dredger is equipped with a half-open shell. The shell can be filled by moving the bucket either towards or away from the machine. This dredging technique is mainly used in shallow water.

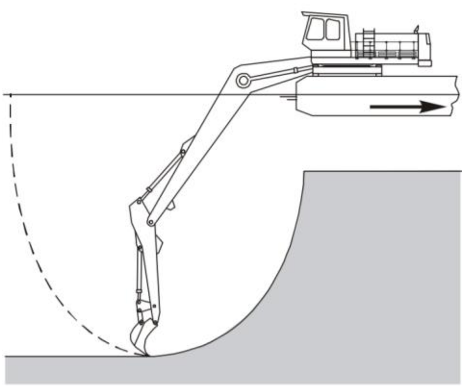


Figure C.2 : Schematic of a digger dredge

C.3 Cutterhead Suction Dredge

The cutter head dredge (Figure C.3) is a hydraulic suction pipeline with a rotating cutter head attached to the suction intake to mechanically assist in the excavation of consolidated material. Cutter head blades are designed to direct loosened material efficiently toward the suction intake. Efficient operation of a cutter head dredge and minimisation of sediment resuspension can be achieved by proper dredge design and operation. The intake velocity of the suction mouth must be sufficient to remove all of the material excavated by the cutter head blades, or the excess material will enter the water column.

The issue with this type of dredging is that the rotating cutter head re-suspends sediment which can be an issue when dredging contaminated sediment. Further, it increases the amount of dewatering of extracted sediment required, when compared with other methods. Cutterhead suction dredges can be expensive to operate and are mainly used in areas when large quantities of sediment need to be dredged.

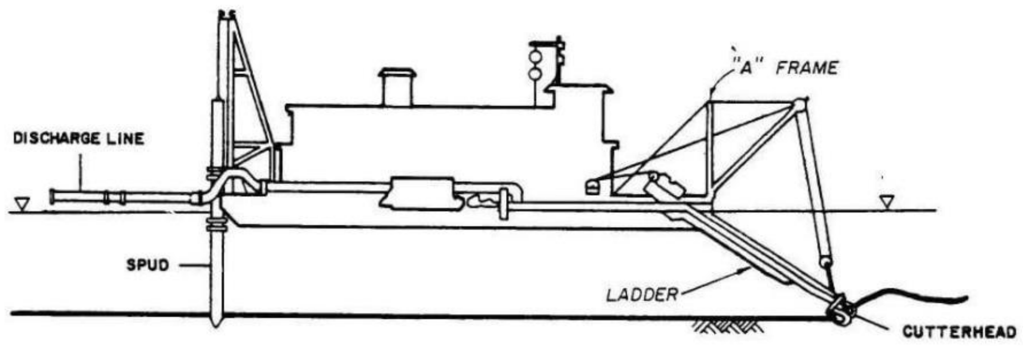


Figure C.3 : Schematic of a cutterhead suction dredge

C.4 Clamshell Dredge

A clamshell dredge (Figure C.4) is a mechanical device that is operated by either crane or digger. A clamshell dredge is similar to a backhow dredger except that the digger bucket is shaped like a shell. Sediment re-suspension from a clamshell dredge can be controlled by reducing the speed at which the crane or digger moves the (empty or full) bucket through the water column. High suspended sediment concentrations will be unavoidable in the immediate vicinity of the bucket as it is lifted to the surface.

Bucket penetration will depend on the bucket weight for crane operated clamshells. More control can be obtained with a clamshell on the end of the hydraulic arm of an excavator. However, clamshells on the end of a crane will have a greater reach.

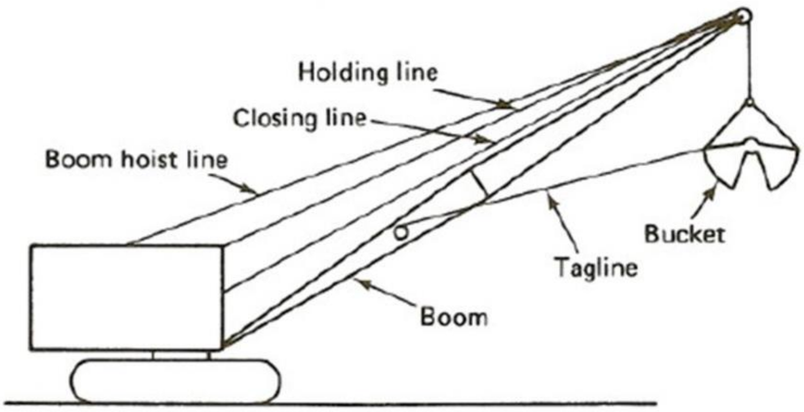


Figure C.4 : Schematic of a clamshell dredge

Appendix D. List of HAIL Sites that Border the Heathcote River/Ōpāwaho

Hail Sites that occur within 10 m of the banks of the Heathcote River/Ōpāwaho.

HAIL No	Title/Location	HAIL
26614	Mount Pleasant	F6 -Railway yards
10764	66 & 70 Colombo Street Landfill, northern portion of Christchurch Landfill #51	G3 - Landfill sites
11018	Brickworks Landfill, Christchurch Landfill Map #84, Centaurus Road, Huntsbury, Christchurch	G3 - Landfill sites
11171	Beckford Road - Riverlaw Terrace - Derrett Place, Historic Horticultural Sites, Saint Martins, Christchurch	A10 - Persistent pesticide bulk storage or use
1536	G.L. Bowron & Co. Ltd., 2-12 Long Street, Woolston, Christchurch	A17 - Storage tanks or drums for fuel, chemicals or liquid waste
962	G.L. Bowron & Co. Ltd., 2-12 Long Street, Woolston, Christchurch	A16 - Skin or wool processing
4794	G.L. Bowron & Co. Ltd., 2-12 Long Street, Woolston, Christchurch	G3 - Landfill sites
10746	Ferry Road Landfill, CCC Landfill #67, Woolston, Christchurch	G3 - Landfill sites
10749	Ombersley Terrace Landfill#30, Butler Street Landfill#35, Old Christchurch Landfills, Opawa, Christchurch	G3 - Landfill sites
10753	Riverlaw Terrace Landfill, Old Christchurch Landfill #41, St Martins, Christchurch	G3 - Landfill sites
26658	Laura Kent Place, Woolston	A10 - Persistent pesticide bulk storage or use
408	Acme Engineering Ltd, 30 Broad Street, Woolston, Christchurch	A17 - Storage tanks or drums for fuel, chemicals or liquid waste
27984	20 Broad Street	A17 - Storage tanks or drums for fuel, chemicals or liquid waste
34980	Thorrington Primary School, Hunter Terrace, Cashmere	A10 - Persistent pesticide bulk storage or use
3232	Former West Truscotts Landfill, 140 Ferrymead Park Drive, Ferrymead, Christchurch	G3 - Landfill sites
25183	Woolston	A10 - Persistent pesticide bulk storage or use
4226	42 Bamford Street, Woolston, Christchurch	A10 - Persistent pesticide bulk storage or use
111922	16 Riverlaw Terrace, St Martins, Christchurch	G3 - Landfill sites
122823	Kennaway Farm, Tunnel Road	A10 - Persistent pesticide bulk storage or use
122824	Kennaway Farm, Tunnel Road	G3 - Landfill sites

Appendix E. Sediment Plume Management

Some methods will only work in shallow, low flow sections:

- Sedi-mats: These are products that can be placed on the bed of a river downstream of works to trap sediment as water flows over them. They may be suitable for small and shallow burns or where a barrier has been placed downstream to slow the flow;
- Straw bales: Placing a barrier of straw bales downstream of works may help trap suspended sediment while allowing the water through the bales. Careful anchoring and regular checking of the bales will be needed. This method may be enhanced by materials such as sedi-mats being placed upstream to trap settled sediment;
- Straw bale cages: Bales can be placed into a cage or net to keep them together and then placed downstream of works to act as a filter for suspended sediment. This method may be enhanced by having materials such as sedi-mats placed up stream to trap settled sediment; and
- Rock filter dams: temporary barriers placed downstream of works, made from rock and geotextile, which allow water to filter through them, trapping sediment in the process.

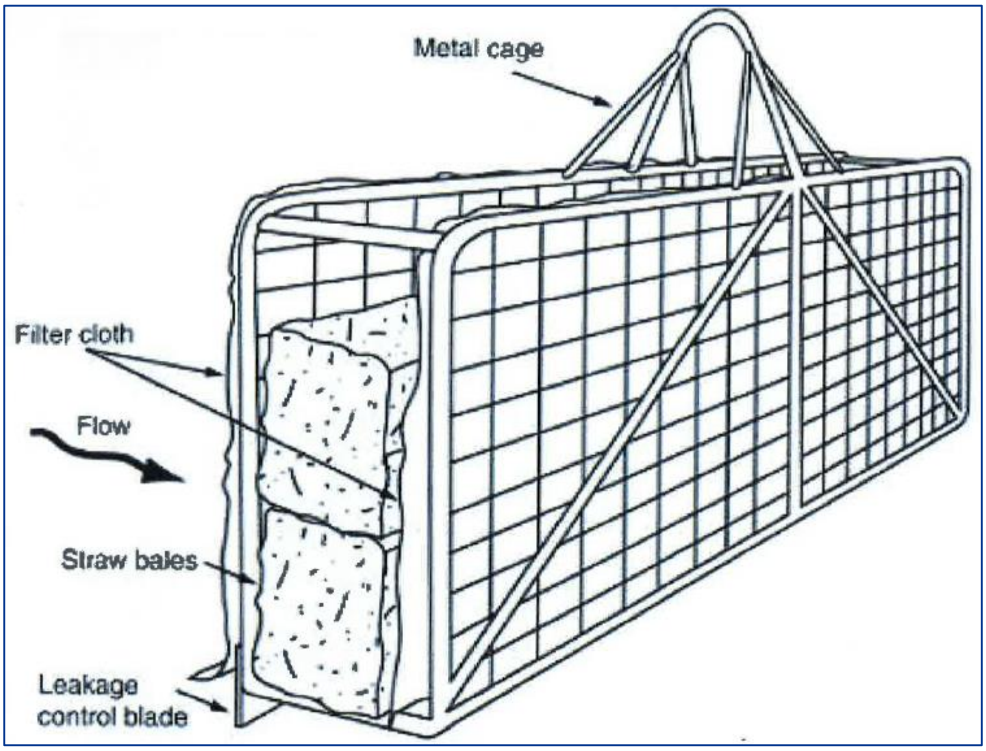


Figure E.1 : Sediment filter cage. Figure courtesy of City Care Ltd.

There are other methods available, however these are generally more expensive and take more effort to install:

- Coffer dams: temporary barriers placed around works to create a dry working area, constructed from, e.g. sand bags, sheet piling, clay/earth, wooden sheeting;
- Aqua-dams: a water filled barrier which can isolate a dry working area. These can be limited by the depth of the water above the bed, which could be greater than 2 m in this section of river;

- Flumes: river water is directed through a pipe keeping it separate from dredging works. A coffer dam is usually employed to direct water into the flume;
- Over-pumping: The area to be dredged is isolated, e.g. using a coffer dam, and dried by pumping the water downstream of the works; and
- Silt curtains: A permeable screen of fabric, e.g. hessian, vinyl or other geotextile, normally used to isolate an area. The screen is anchored and hangs within the watercourse.

Appendix F. CCC's Resource Consent CRC121582

To remove earthquake derived sediments from Christchurch's surface water bodies

1. The works authorised by this consent are:

   a) Disturbance of the bed of rivers and lakes including by dredging or any other suitable method of sediment removal; and

   b) The associated sediment discharge,

For the purpose of remedying bed level changes and removing liquefaction silt deposited as a result of earthquakes.

Advice Note: The consent holder is required to obtain permissions and easements needed from landowners and others in order to secure access to and/or undertake any works authorised by this consent on land that is not owned by the consent holder

2. Sediment may be cleared from the beds of surface water bodies including rivers (excluding the Waimakariri River mainstem, and the Otukaikino River), online retention and detention basins (excluding Wigram Retention Basin) and lakes within the area identified on plan CRC121582A, attached to and forming part of this consent. For the purposes of this consent online retention and detention basins are defined as any artificial basin or lake which is either wholly of partly within the bed of a river or bed of another lake, and has a river flowing out of it.

Advice Note: This consent does not authorise any works in the coastal marine area (such as the Avon-Heathcote Estuary).

3. Sediment shall not be removed below the pre-September 2010 natural bed level of the water body. The bed level shall be calculated and reported by the consent holder for each water body before dredging or cleaning to remediate bed level changes and/or remove liquefaction silt commences, and shall be included within the Management Plan for the Site, identified in condition 11.

4. A Schedule of Proposed Works, detailing the works to be undertaken in the following 12 month period, shall be provided to the Canterbury Regional Council: Attention RMA Compliance and Enforcement Manager, Te Ngai Tuahuriri, Te Hapu o Ngati Wheke (Rapaki) Runanga and Mahaanui Kurataiao Limited, at least 15 working days prior to the start of the 12 month period. The Schedule of Proposed Works shall list surface water bodies where sediment is to be removed or dredged, and shall identify which of these are

   a) "Rivers" as defined by the Resource Management Act (1991),

   b) online retention or detention basins and artificial lakes as defined in condition 2, or

   c) natural lakes

5. The Canterbury Regional Council: Attention RMA Compliance and Enforcement Manager, the office of the relevant Runanga, and Mahaanui Kurataiao Limited, shall be notified 12 monthly of works which have been undertaken during the previous 12 months, and any unscheduled works which have been required but were not anticipated in the previous schedule of works. For the purposes of this consent, unscheduled works are defined as works that were not anticipated at the time of the development of the Schedule of Proposed Works but which were required to protect people, property or assets, or to avoid, remedy or mitigate an adverse effect on the environment.

6. The consent holder shall erect a sign on the site for the duration of the works explaining the nature of the work, time frames expected for completion of the works, advice to local fisheries of a temporary increase in suspended sediment, and a contact name and telephone number if the period of the works is to exceed one month.

7. The Canterbury Regional Council: Attention RMA Compliance and Enforcement Manager shall be notified at least ten working days before each dredging or clearing project. The notification shall include the Management Plan required for each site as identified in condition 11 to this consent.

8. The office of the relevant Runanga and Mahaanui Kurataiao Limited shall be notified at least ten working days before each dredging or clearing project that was not included in the previous schedule of works provided in accordance with condition 4.

9. The Canterbury Regional Council, Attention: Regional Engineer, shall be notified not less than ten working days prior to the commencement of works in the Halswell, Otukaikino or Styx Catchments.

10. The consent holder shall ensure that all personnel undertaking activities authorised by this consent are made aware of, and have access to, the contents of this consent document and the Management Plan for each site identified in condition 11 prior to the commencement of the works.

11. The works shall be carried out in accordance with a Management Plan for each site. The Management Plan shall include but not be limited to:

    a) Contact details for the Contractor on site;

    b) Identification of the area to be cleared and map references;

    c) Timing of the works;

    d) Identification of any significant ecological sites as identified on Plan CRC121582B (attached to and forming part of this consent) which may be affected, including taonga species listed in Schedule CRC121582C (attached to and forming part of this consent);

    e) In consultation with the relevant Runanga, identification of any sites of significance to tangata whenua, which may be affected;

    f) Details of any sediment sampling to be undertaken;

    g) Results from any sampling for sediment contamination which has been undertaken;

    h) Methods used to clear or dredge the water body;

    i) Mitigation measures to be undertaken to avoid potential or actual adverse effects on the environment, in particular the reduction of the transport of suspended sediments, and monitoring;

    j) Procedure for dealing with the sediment once it has been removed from the water body;

    k) Location of final disposal environment for excavated sediments;

    l) Spill response plan;

    m) Whether any further consents are required;

    n) Management of effects on the stability of structures not owned by the consent holder; and

    o) Procedure for notification to any downstream surface water abstractors of increased sediment in the waterway.

Advice Note: CCC hold an Archaeological Authority for wider Christchurch (Reference Number: 2012/321eq) which may be applicable to some of the works carried out under this consent.

12. The Management Plan for a site may be amended at any time. Any amendments shall be:

    a) For the purpose of improving the efficacy of the measures in the Management Plan;

b) To include information provided in relation to cultural values and taonga species;

c) Consistent with the conditions of this resource consent; and

d) Submitted in writing to the Canterbury Regional Council, Attention: RMA Compliance and Enforcement Manager, prior to any amendment being implemented.

13. If any ecologically significant site (as identified in plan CRC121582B) or taonga species (listed in Schedule CRC121582C) are located either adjacent to or downstream of a proposed clearing or dredging site, the Christchurch City Council's Waterway Ecology Planner shall be notified and be involved in the determination of clearance methodology, mitigation and the timing of works to be included in the Management Plan. A copy of the Christchurch City Council's Waterway Ecology Planner's advice shall be provided to the Canterbury Regional Council on request.

14. The works shall not cause erosion of the banks and margins of surface water bodies.

15. All disturbance of banks and margins of water bodies caused by dredging/clearing works, shall be restored to at least its pre-works conditions as soon as practicable following completion of the works.

16. All practical measures shall be used to avoid or minimise the movement downstream of any suspended sediments. These measures:

a) shall be determined on a site by site basis and included in the Management Plan required by condition 11; and

b) may include, but shall not be limited to,

i. diversion of water around the work site;

ii. working in a upstream to downstream direction; and/or

iii. partially damming the riverbed to create a working area outside of flowing water; and

c) shall be implemented in accordance with Canterbury Regional Council's "Erosion and Sediment Control Guidelines for the Canterbury Region" Report No. CRCR06/23, February 2007.

17. All practicable measures shall be undertaken to prevent oil and fuel leaks from vehicles and machinery including but not limited to the following:

a) There shall be no storage of fuel or lubricants, refuelling, or lubrication of vehicles and machinery within 20 metres of a watercourse.

b) Fuel shall be stored securely or removed from site overnight.

18. The works shall not undermine any structure that is not owned by the consent holder.

19. All practicable measures shall be undertaken to preserve the passage of fish, and to prevent the stranding of fish in pools and channels. Stranded fish shall be relocated to a flowing reach of the stream.

20. Works shall not be undertaken in the flowing channel at the spawning sites identified on spawning map Plan CRC100750E attached to this consent and any updated spawning maps required by condition (25)(c) of consent CRC100750, during the trout spawning period of 1 May to 31 October for all waterways, and at identified inanga fish spawning sites during January 1 to May 1, unless a spawning survey by a qualified ecologist indicates that there are no spawning sites present that would be adversely affected by the works.

a) A copy of any spawning survey undertaken required by condition (19)(a) shall be supplied to the North Canterbury Fish and Game Council and the Canterbury Regional Council Attention: RMA Compliance and Enforcement Manager, prior to the commencement of works.

Advice Note: A copy of plan CRC100750E is attached to this consent. For the best resolution see Environment Canterbury electronic document number C11C/50146.

21. To prevent the spread of Didymo or any other aquatic pest, the consent holder shall ensure that activities authorised by this consent are undertaken in accordance with the Biosecurity New Zealand's hygiene procedures.

Note: You can access the most current version of these procedures from the Biosecurity New Zealand website or Environment Canterbury Customer Services.

22. Sediment removed from water bodies shall be temporarily stored at Burwood landfill at the location marked "C" on the attached plan CRC121582D, attached to and forming part of this consent. Prior to permanent disposal, sediment shall be tested for contaminants in accordance with the following criteria:

    a) One sample per 250 cubic metres of sediment shall be taken, and the minimum number of samples shall be one.

    b) The samples shall be collected by a contaminated land specialist with a tertiary qualification and at least two years experience in contamination management / site identification ("the Specialist").

    c) The Specialist shall determine what the sediment samples shall be tested for, but shall include as a minimum heavy metals (arsenic, cadmium, chromium, copper, lead, nickel and zinc), total petroleum hydrocarbons and organic chlorine pesticides.

    d) Analysis of samples shall be undertaken using the most appropriate method by a laboratory that is certified for that method of analysis by an accreditation authority such as International Accreditation NZ (IANZ).

    e) The results of the analyses undertaken in accordance with condition (21), along with the name(s) of the person(s) who collected the samples, and the date and time of sampling shall be provided to the Canterbury Regional Council, Attention: RMA Compliance and Enforcement Manage, within 14 days of the laboratory results being received.

23. All sediments and weeds removed from the bed of a water body shall not be placed or stored where it may enter a surface water body, and shall be removed from site as soon as is practical. Stockpiles of sediment in public areas shall be demarcated or fenced, kept damp or covered, and a sign shall be displayed informing the public of a health risk resulting from contact with stockpiled sediment.

24. Contaminated sediment shall be disposed of at a facility authorised to receive such material.

25. The Canterbury Regional Council may, once per year, on any of the last five working days of May or November, serve notice of its intention to review the conditions of this consent for the purposes of

    a) Dealing with any adverse effects on the environment which may arise from the exercise of this consent.

    b) Requiring the adoption of the best practicable option to remove or reduce any adverse effect on the environment.

26. The lapsing date for the purposes of section 125 shall be 30 June 2017.

Appendix G. Future Consenting Requirements

This section presents the likely consenting requirements for dredging activities within the Heathcote River/Ōpāwaho. Three possible scenarios have been considered:

1. Dredging the whole length of the channel both as a large initial activity and then as a repeat maintenance activity

2. Dredging selective reaches where the bed is high and/or width is narrow. Undertaken initially and then repeated as required.

3. Dredging sediment traps i.e. digging out designated areas of the channel where sediment collects

G.1 Planning provisions

Table G.1 below sets out the relevant rules under the Land and Water Regional Plan (LWRP) for the above dredging activities.

Table G.1 - Relevant rules of the LWRP

Activity	Ref.	Provision	Activity Status	Comment
Dredging	5.137	The installation, alteration, extension, or removal of bridges and culverts, and the consequential deposition of substances on, in or under the bed of a lake or river, the excavation or other disturbance of the bed of lake or river, and, in the case of culverts, the associated take, discharge or diversion of water is a permitted activity, provided the following conditions are met:	**Permitted**	As the works are to occur in flowing water the permitted activity conditions cannot be met. As such consent will be required under Rule 5.141B as a discretionary rule.
	1	*Any material deposited in, on, under or over the bed of a lake or river in order to construct or maintain the structure is of inert materials of colour and material type that blends with the surrounding natural environment and does not contain or is not coated with any hazardous substance; and*		Works will be occurring within flowing water.
	2	*The activity is undertaken at a distance greater than 10m from any dam, weir, bridge, or network utility [ole, pylon or flood protection vegetation, or 150m from any water level recorder, or 50m from any defence against water, or closer where there is evidence that permission has been obtained from the owner of the infrastructure or the works are being carried out by or on behalf of the owner; and*		
	3	*The works do not occur in flowing water; and*		
	4	*The activity is not undertaken in a salmon spawning site listed in Schedule 17, or in*		

Activity	Ref.	Provision	Activity Status	Comment
		any inanga spawning season of 1 March to 1 June inclusive; and		
	5	*Upon completion of the activity:* *a. Any area of the bed of a lake or river which has been disturbed is returned to as near as practicable to its original state; and* *b. Any excavated areas are left with battered slopes not steeper than 3:1 slope angle (3 horizontal to 1 vertical) and any flow channels disturbed during the activity are reinstated; and*		
	9	*The works or structures do not prevent any existing fish passage*		
	5.141B	Where not classified by any other Rule in this plan, the diversion or discharge of water and contaminants as a result of the excavation and disturbance of a river or lake bed, or the establishment of a structure or defence against water, is a discretionary activity.	**Discretionary**	As the activity cannot meet the permitted activity conditions for Rule 5.137 it will be classified as a discretionary activity.
Contaminant Discharges	5.99	Any discharge of water or contaminants into surface water or onto or into land in circumstances where it may enter surface water that is not classified by any of the above rules, is a permitted activity, provided the following conditions are met:	**Permitted**	As the permitted conditions cannot be met for Rule 5.99 the activity will require consent in accordance with Rule 5.100
	1	*The discharge is not from or into contaminated or potentially contaminated land; and*		Extracted sediment is anticipated to be contaminated.
		The discharge is not into a Natural State water body; and		
	3	*The discharge meets the water quality standards in Schedule 5 after reasonable mixing with the receiving waters, in accordance with Schedule 5; and*		
	4	*The concentration of total suspended solids in the discharge shall not exceed:* *(a) 50g/m³ where the discharge is to any Spring-fed river, Banks Peninsula river, or to a lake; or* *(b) 100g/m³ where the discharge is to any other river or to an artificial watercourse; and*		
	5	*The discharge does not result in more than 20% change in the rate of flow of the receiving surface water body; and*		
	6	*The discharge does not contain any*		

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Activity	Ref.	Provision	Activity Status	Comment
		hazardous substance, hazardous waste or added radioactive isotope.		
	5.100	Any discharge that is not permitted by either Rule 5.98 or 5.99 and is not classified by any other rule in this Plan is a discretionary activity	**Discretionary**	As the discharge is likely to be from contaminated land the activity does not meet the permitted activity conditions and therefore consent would be required as a discretionary activity under Rule 5.100.
Sediment disposal	5.168	The use of land for earthworks outside the bed of a river or lake or adjacent to a wetland boundary but within: (a) 10m of the bed of a lake or wetland boundary in Hill and High Country land or land shown as High Soil Erosion Risk on the Planning Maps; or (b) 5m of the bed of a lake or river or a wetland boundary in all other land not shown as High Soil Erosion Risk on the Planning Maps or defined as Hill and High Country is a permitted activity, provided the following conditions are met:	**Permitted**	The act of disposing of dredged material may be undertaken as a permitted activity in some instances, however as this material is likely to be contaminated Rule 5.100 above also applies to this activity.
	1	*Except in relation to recovery activities, or the establishment, maintenance or repair of network utilities and fencing, the extent of earthworks within the relevant setback distances in any property:* *(a) Does not at any time exceed:* *i. An area of 500m^2, or 10% of the area, whichever is the lesser; or* *ii. A volume of 10m^3 on land shown as High Soil Erosion Risk on the Planning Maps; or* *(b) Is undertaken in accordance with a Farm Environment Plan that has been prepared in accordance with Schedule 7 Part A; or* *(c) For plantation forestry activities is undertaken in accordance with the Environmental Code of Practice for Plantation Forestry (ECOP) 2007 and the NZ Forest Road Engineering Manual (2012); and*		
	2	*Except in relation to recovery activities or the establishment, maintenance or repair of network utilities and fencing, any discharge of sediment associated with the activity into the water in a river, lake, wetland or the Coastal marine Area does*		

Activity	Ref.	Provision	Activity Status	Comment
		not exceed 8 hours in any 24 hour period, and does not exceed 24 hours in total in any 6 month period; and		
	3	*The activity does not occur adjacent to a significant spawning reach for salmon or an inanga spawning area listed in Schedule 17; and*		
	4	*Except in relation to recovery activities or the establishment, maintenance or repair of network utilities and fencing, any earthworks or cultivation is not within 5m of any flood control structure.*		
	5.169	Vegetation clearance and earthworks outside the bed of a river or lake or adjacent to a wetland boundary but within: (a) 10m of the bed of a lake or river or a wetland boundary in Hill and High Country land and land shown as High Soil Erosion Risk on the Planning Maps; or (b) 5m of the bed of a lake or river or a wetland boundary in all other land not shown as High Soil Erosion Risk on the Planning Maps or defined as Hill and High Country that does not comply with the conditions in Rules 5.167 or 5.168 is a restricted discretionary activity.	**Restricted Discretionary**	Where permitted activity volumes of Rule 5.168 are exceeded consent as a Restrict Discretionary activity under Rule 5.169 would be required.

Overall, consent for a **discretionary activity** will be required. This activity status would apply to each of the three dredging scenarios.

G.2 Key Issues and Specialist Inputs

This high level assessment of the proposed activity indicates that the key potential environmental issues are likely to be:

- Effects on water quality as a result of undertaking works in and around streams;
- Ecological effects resulting from undertaking works in a stream;
- Cultural effects;
- Effects on bank stability;
- Contaminated discharges from extracted sediment;
- Noise and vibration; and
- Amenity.

It is considered that the following environmental information/technical reports should be prepared and incorporated into the design:

- Detailed design drawings of proposed works;

- Construction methodology for undertaking works in and around a stream, for undertaking works within the road reserve, for undertaking works within a river;
- Ecological Assessment for undertaking works within a Site of Special Wildlife Interest or Significant Ecological Area (terrestrial/freshwater/marine);
- Geomorphic (bank) stability assessment and modelling; and
- Cultural assessment.

G.3 Conclusion

This high level review of the Land and Water Regional Plan (LWRP) indicates that each of the 3 dredging scenarios in the Heathcote River/Ōpāwaho would require consent as a discretionary activity.

The Council currently holds two consents for excavation of waterways which are:

- The general consent CRC146620 to 'Disturb or Excavate Bed, Structure' which addresses minor re-grading and bank work; and
- Consent CRC121582 'To Remove Earthquake Derived Sediments from Christchurch's Surface Water Bodies' which covers remedying bed level changes and removing liquefaction silt deposited as a result of earthquakes. This consent expires in 2022.

The Council is currently investigating with ECan whether proposed dredging works could be authorised by, and undertaken under, one of these existing dredging consents held by the Council. If so, no further consent would be required for the dredging activity.

If the existing consents could not be used and a new consent is required, then there are a number of key issues that would require comprehensive specialist assessment to support any future resource consent application.

Appendix H. Morphological Modelling

As identified within this report, morphological modelling would likely be required to address the following gaps in current knowledge:

- The channel morphology has an important control on flooding and it is not known how the morphology might change with climate or future land use; and
- Whilst dredging may be needed initially, maintenance dredging could potentially be avoided/reduced by alternative sediment management techniques.

The key information required to inform both of these are (1) locations of deposition (2) estimates of deposition rates (3) how these might change with climate and (4) what scale of benefit can be expected with source control options. There are two main modelling-based approaches available:

A. Average annual models: have usefulness as a screening tool but cannot predict transport during events which is when most sediment is mobilised. Therefore, unlikely to inform (2) and (3) above.

B. Daily models: can predict event-driven sediment transport, where events (i30 maximum 30-minute rainfall intensity) could be varied with climate change. These could predict depth and extent of sediment deposition, including impacts of sea level rise. Therefore, they could achieve (1) – (4) above.

Approach (B) could be significantly more expensive than approach (A). However, undertaking either would depend on the availability of calibration data, which will require time and cost to obtain.

A further alternative is sediment transport risk modelling which uses results of hydraulic models to map locations of likely sediment deposition. This modelling would not give deposition rates but the risk zones will change with climate change (sea level rise and velocities) and therefore could address (1) and (3) above. Importantly, the method does not require any calibration data, could be achieved within relatively short timescales and will be substantially less expensive.

In summary, it appears that approach A (average annual modelling) is less useful. Approach B (daily model) would fulfil the above requirements but will be expensive and likely require time to collect calibration data. The sediment transport risk modelling would use available hydraulic modelling to map zones of deposition and how these may change with climate. It could then potentially be inferred how much deposition would occur in these zones based on available data on past deposition.