MINIMISING THE ENVIRONMENTAL EFFECTS OF DREDGING – WHAREMAUKU STREAM

Kyle Christensen – Christensen Consulting Limited
Disna Pathirage – Kapiti Coast District Council
Paul Halliday – Kapiti Coast District Council
Rita O'Brien – Kapiti Coast District Council
Guy Forrest – Goodman Contracting Limited

ABSTRACT

The regular removal of sediment that builds up in natural waterways is a vital part of ensuring that the capacity of the channel is maintained so the agreed level of service is provided. This also applies to the stormwater networks that discharge into the natural waterway which can be significantly affected by elevated tailwater conditions or in worst case scenarios completely buried outlets. Cross section survey of the Wharemauku Stream in Paraparaumu (Kapiti) revealed that bed levels had built up by up to 800 mm above the 1994 design baseline. This degree of build-up was affecting the capacity of the main channel but also drowning a number of stormwater outlets that serve residential and commercial areas as well as creating backwater effects up tributary drains. The removal of sediment from within waterways has the potential to have adverse environmental effects, particularly on fish which can be excavated with the material being taken out of the stream. This was recognised as a significant risk and a methodology was developed that involved deploying fish proof nets at the upstream and downstream extent of a reach and electric fishing and relocating fish before any excavation was undertaken. Using this methodology resulted in the safe relocation of many hundreds of eels as well as numerous Red Fin Bullies, Banded Kokopu, Bluegill Bullies & Koura. The project successfully excavated over 3000 m^3 of sediment from the waterway to achieve the required design standard whilst minimising environmental effects using a best practice methodology that went beyond resource consent requirements.

KEYWORDS

Sediment, dredging, stormwater, fish, waterway capacity, consent conditions.

PRESENTER PROFILE

Kyle Christensen is an independent consultant with over 17 years' experience in the analysis, design, consenting and construction of river, stream and stormwater works. Kyle is a Chartered Professional Engineer and has a Master of Engineering specialising in the interaction of river control works and natural processes in rivers and streams. Kyle is also the Chairman of the IPENZ/Water NZ Rivers Group.

1 INTRODUCTION

The dredging or extraction of gravel, silt and sand from waterways has long been used as a mechanism for maintaining waterway capacity to reduce the effects of flooding. The areas where sediment is most likely to deposit in fluvial systems is where the gradient begins to flatten as the river/stream approaches a downstream control, most commonly the ocean. As the gradient flattens the ability of the stream to keep incoming sediment entrained reduces and a depositional regime will dominate.

The flatter areas adjacent to rivers and streams were often where communities established as the river or stream provided and important source of food, water and transport. Over time, as development intensified in these areas, stopbanks and stormwater networks were constructed to manage the risks of flooding. The design of this infrastructure was often based on the particular river bed levels evident at the time the design was undertaken.

The issue then arises when sediment builds up in the main channel which reduces its capacity resulting in an increased likelihood of stopbanks overtopping as well as non-performance of the stormwater network due to high tailwater levels or in the worst case buried outlets. The sediment build up can be managed by building higher stopbanks and with pumping stations for stormwater outlets but the solution that is often considered the most cost effective is physical excavation or dredging of the deposited material.

The two primary issues with physical excavation of the deposited material are the high cost, due to the often difficult working conditions within active waterways and the potential for significant environmental impact, particularly on the freshwater ecology. The cost of extraction can be highly variable relating to the type of material being excavated, whether it is contaminated and the constraints with working around the site. In some instances, contractors will pay a royalty or concession to extract gravel as it can be used as a resource. In other instances, particularly where contamination is an issue, costs can be as high as $500/m^3 (Hutt City Council, 2010).

The impacts on freshwater ecology are particularly relevant during the physical works with habitat disturbance, physical removal (and subsequent fatality), sediment smothering and as well as the possibility of ongoing effects with habitat destruction.

The above generelisations can apply to any community established next to a river or stream but for the purposes of this paper the particular issues presented by the Wharemauku Stream and the community of Paraparaumu on the Kapiti Coast will be examined with discussion of how a dredging programme can be undertaken with less than minor adverse environmental effects to achieve the agreed level of service for the flood protection assets as well as the stormwater network.

2 BACKGROUND

2.1 THE WHAREMAUKU CATCHMENT

The Wharemauku Stream catchment (see Figure 1.) is approximately 15km^2 with a mixed landuse of residential and the commercial centre of Paraparaumu on the lower plains with rural farmland and pine forest in the steep hills east of State Highway 1. The main channel of the Wharemauku Stream has multiple rural drains and tributaries that feed into it along with the entire stormwater network for the area.

It is the key floodwater/stormwater conveyance asset for Paraparaumu and Raumati and also provides habitat for nationally threatened indigenous fish including the Banded Kokopu and Redfinned Bully.

The Wharemauku stream is of spiritual significance to local iwi Te Ati Awa Ki Whakarongotai as a source of physical and spiritual sustenance and there are remnants of a large pa at the stream mouth (Greater Wellington Regional Council, 2005).

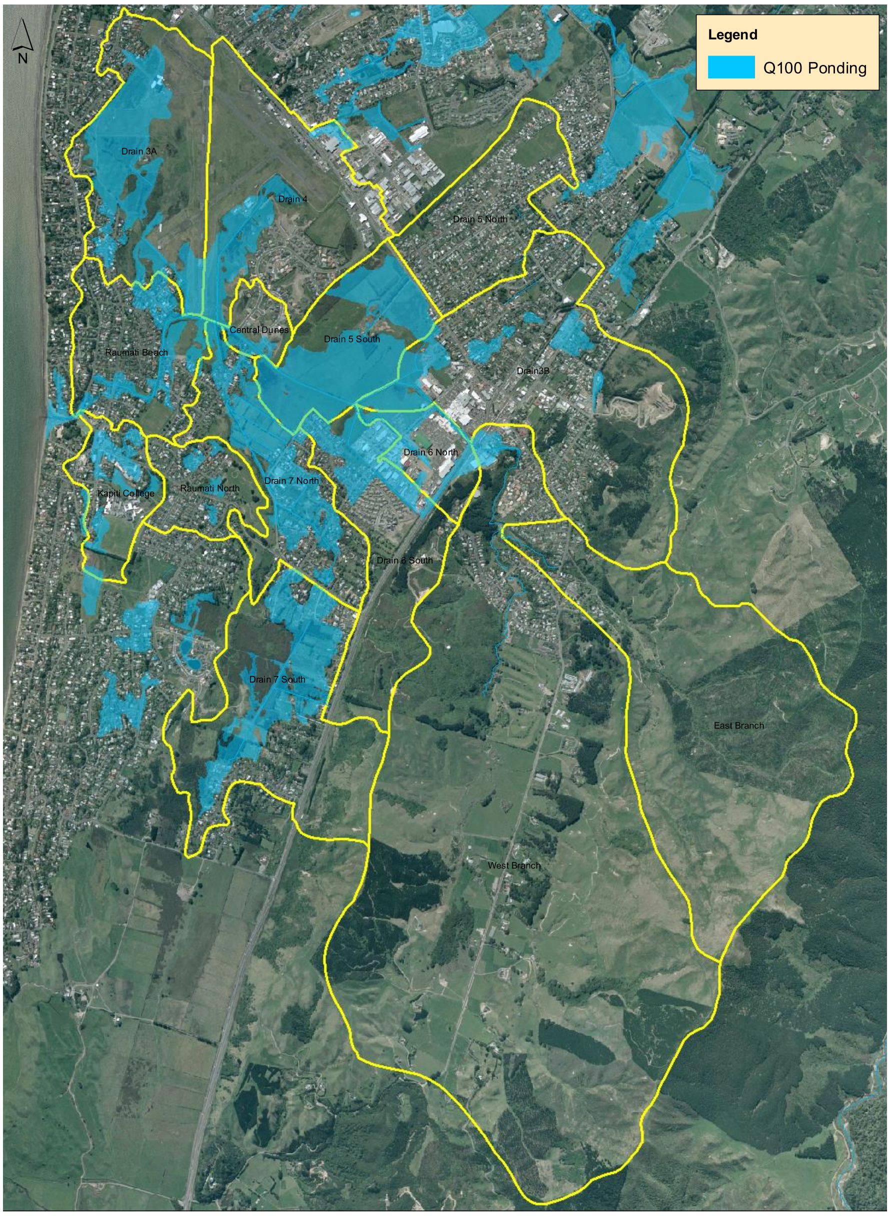

Figure 1: Wharemauku Catchment (Source SKM, 2006)

2.2 DREDGING CASE STUDIES (NEW ZEALAND)

2.2.1 LARGE GRAVEL BED RIVERS

Most large gravel bed rivers in close proximity to urban populations across New Zealand are frequently monitored to check for changes in their bed levels. Increasing bed levels (aggradation) generally results in higher flood levels whereas decreasing bed levels (degradation) can cause issues with bank erosion and undermining around structures such as bridge piers. The monitoring of bed levels is often closely linked with the management of commercial gravel extraction with contractors encouraged to extract in areas that are building up and restrictions placed in areas that are degrading. The practice often involves setting a sustainable yield from a particular reach or river or operating a "bed level envelope" that bed levels are managed within.

A summary of gravel bed river monitoring around New Zealand is summarised in the Envirolink Report – Monitoring of riverbed stability and morphology by regional councils in New Zealand (Basher, 2006).

It should be noted that gravel is being extracted as a resource for the construction industry so the costs of extraction are recovered through the sale of the product. This is different from the excavation of silt, especially when it is contaminated, which has no commercial use and will attract further costs for disposal.

2.2.2 LOWER WAIRAU RIVER (MARLBOROUGH)

Historic flood control works led to the deposition of 2M m^3 of sediment in the Lower Wairau River. This sediment was affecting flood capacity, drainage effectiveness, ecological values and recreational opportunities (Christensen & Doscher, 2010). A remediation option was developed that utilised an erodible embankment which diverts flood waters down the channel to flush the deposited sediment out. The erodible embankment has been in operation since 2009 and has successfully flushed out in excess of 450,000 m^3 of sediment from the Lower Wairau River. This highlights the potential for manipulating flows in as an alternative to mechanical removal.

2.2.3 PORIRUA STREAM (WELLINGTON)

During the large flood event in May 2015 a number of the stormwater outlets from the Porirua Central Business District that discharged into Porirua Stream were completely buried by gravel. This resulted in water ponding in the CBD as there was effectively no outlets. Emergency works were undertaken to pump away flood waters and clear around the immediate vicinity of the outlets. Following the event, a cross section survey was undertaken that confirmed that approximately 4,300 m^3 of gravel needed to be removed from the lower reaches of the stream. This was completed at a cost of approximately $180,000. This highlights the need to understand the interface with the stormwater network especially where there is the potential for outlets to be completely buried.

2.2.4 PORIRUA HARBOUR (WELLINGTON)

A numerical model was used to test whether an 800,000 m^3 dredged channel could flush out deposited sediment in Porirua Harbour. The outputs from the numerical model suggested it was unlikely to work and the $5M project did not proceed (DHI, 2011). This highlights the value of using numerical models to understand and test the morphological response of a system under modified conditions.

2.3 DREDGING CASE STUDIES (USA & UK)

The Environment Agency in the United Kingdom released a report in 2011 that summarised key learnings from case studies of six dredged rivers across England. The key learnings from this study that are relevant to the Heathcote River study are –

- Dredging can have notable effect on low flows but limited at 50 – 100-year event when wide floodplains come into effect;
- Costs of dredging can be higher than the economic benefit;
- Structures in the channel can control bed levels;
- Environmental compliance can be challenging.

The Army Corps of Engineers dredge vast quantities of sediment from rivers across the USA for the primary purpose of maintaining navigability. The annual volume of sediment being dredged has dropped by 30% since 2001 reducing from 268 million m^3 to 205 million m^3 but the cost has increased 25% from $US1.16B to $US1.44B (accessed from http://www.navigationdatacenter.us/dredge/ddcosts.htm). The dredging is generally viewed as problematic due to the high cost and negative environmental impacts (Pintera et al, 2002).

3 RECENT FLOOD EVENTS

"Heavy rain started to fall in the early hours of 14 May 2015 on the Kapiti Coast with a total of 145 mm recorded in 24 hours at McKay's Crossing. A rainfall total of this magnitude is expected once in every 40 years at this location. To the north, Waikanae received 102 mm of rain in 24 hours which is expected once every 6 years. An intense burst of rain was recorded at Te Hapua Rd, south of Te Horo Beach, where 27 mm fell in just one hour. This is equivalent to a 10-year event.

The Waikanae River peaked at a flow 270 cubic metres per second above SH1. This was the 3rd largest flow recorded since 1975 – only January 2005 and October 1998 were larger. A flow in the river of this size is expected once every 13 years.

The Wharemauku Stream turned into a raging torrent as it passed under SH1, and the recorded flow was only slightly less than that recorded during the October 1998 flood. Provisional data indicates this is likely to be in excess of a one in 20 year flood." (Greater Wellington Regional Council, 2015).

Figure 2: Residential Flooding Lower Wharemauku (Photo source – www.stuff.co.nz)

This May 2015 event caused widespread flooding across the Kapiti Coast including within the Wharemauku Catchment (See Figure 2.) which triggered a review of proposed stormwater capital works and further investigations into stormwater and open channel capital works across the entire district. During this period of further investigations there has been a number of smaller flood events (See Figure 3. which have caused notable damage and disruption with a total of 833 flood related complaints received by the Kapiti Coast District Council between June 2015 and December 2016.

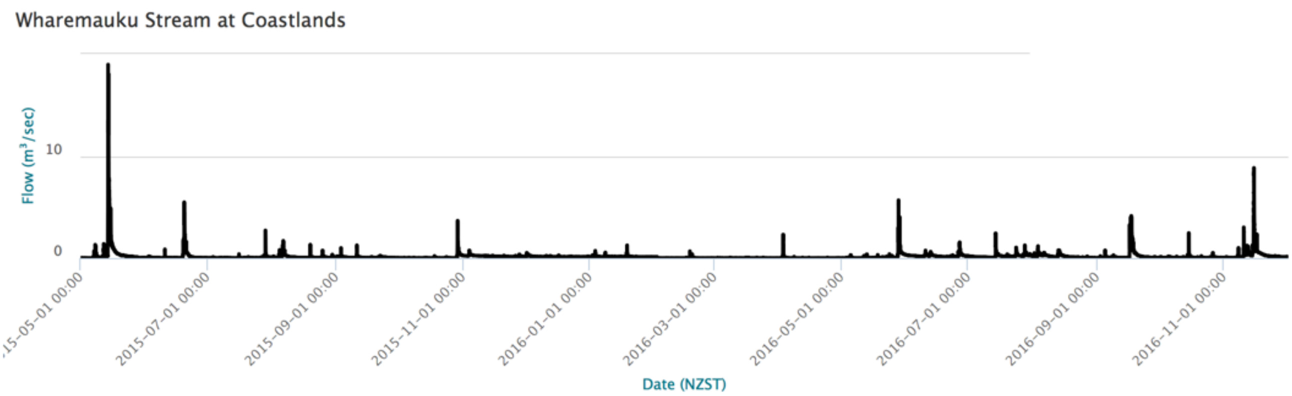

Figure 3: Wharemauku Stream flow May 2015 to December 2016 (Source – GWRC)

The May 2015 event also transported a significant volume of sediment down the Wharemauku catchment. The small sediment trap at the upstream end of the constrained Coastlands reach was completely overwhelmed and several thousand cubic metres of sand and gravel deposited in the 1.5 km reach downstream. This was quantified by cross section surveys that were undertaken from previous reference points.

The build-up of gravel had raised stream bed levels by up to 700 mm, which generated significant backwater effects up the very flat gradient stormwater networks and urban, open channel drainage systems servicing the area. During periods of "normal flow", when there had been no rain for several weeks, a number of key stormwater outlets were completely drowned with the upstream pipe network full of water.

This highlighted the need for a significant dredging programme to be investigated.

4 DREDGING PROGRAMME

A number of key parameters need to be considered to develop a successful dredging programme. This section describes each of the parameters considered for the Wharemauku Stream dredging programme. Figures 4 and 5 show the extent of the stream channel and key reference points referred to in more detail.

Figure 4: Upper Reach of Wharemauku Stream (Source SKM, 2006)

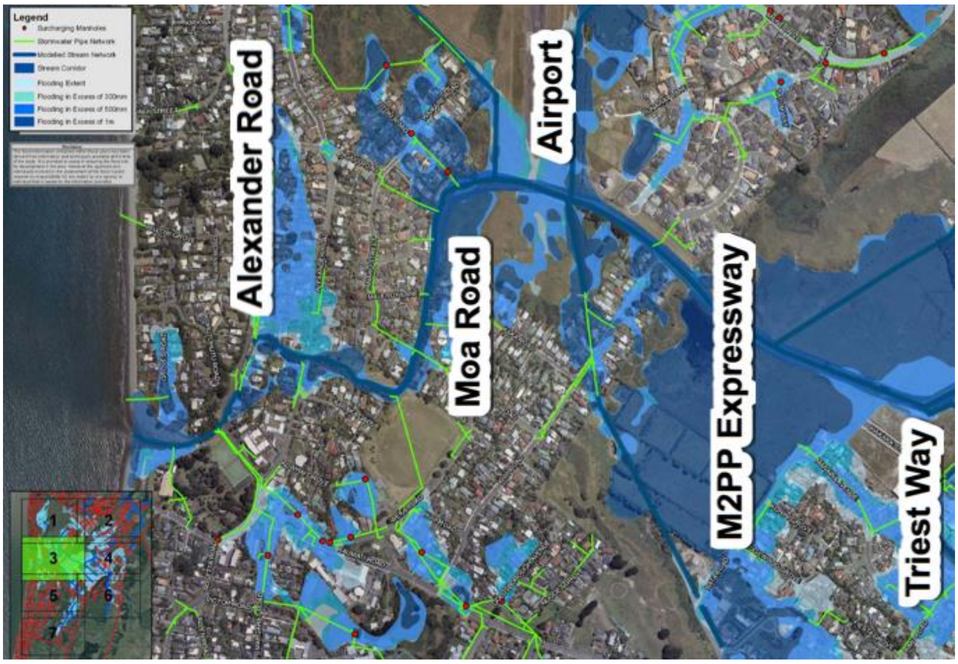

Figure 5: Lower Reach of Wharemauku Stream (Source SKM, 2006)

4.1 DESIGN PROFILE

The most important consideration when developing a dredging profile is what depth of material is going to be removed. The factors that need to be considered are often linked with a historic reference survey or bed level envelope that provides the required floodway conveyance and provides tailwater levels that allow the stormwater network to perform as designed. Care must be taken not to over extract material as this can result in undermining and erosion of stream banks which will add to future channel build up as well as threaten assets in close proximity to the stream. Over extraction can also result in undermining of bridge piers and abutments and previously constructed rock rip-rap or other protection measures. Large scale and sustained over extraction can also reduce adjacent groundwater levels which is of particular importance where there are wetlands close to the channel or shallow water supply bores.

For the Wharemauku Stream there is a historic reference survey (1994) which serves as the desired design profile which provides a lower limit to have no more than minor effects on the risks highlighted above. The 2015 survey showed significant channel build up, particularly at the upstream end of the system. The upper end of the system from Coastlands Weir to Triest Way is characterised by a relatively steep slope of 1 in 200 which reduces to 1 in 450 through the Mackay's to Peka Peka (M2PP) Expressway alignment. Further downstream the channel transitions into a tidal reach with a slope reducing to less the 1 in 1000. The channel profile, with key reference points is shown in Figure 6 below.

The deposited material is predominantly medium size gravel (D_{50} ~ 30 mm) which is unable to be easily transported once the slope of the stream flattens to less than 1 in 200. Some finer material is transported further downstream but the downstream limit of any change from the 1994 survey is Moa Road. This is the upstream extent of the tidal influence so that flood levels will largely be determined by the downstream water level and not the bed level of the stream. This was problematic from a public relations point of view in that the properties on Moa Road were some of the worst affected during the May 2015 and subsequent floods and that there was a perception that "that stream needed to be dug out" even though this would not provide any hydraulic benefit due to the downstream tidal control. A separate floodwall project to manage the effects of flooding in this reach is proposed and this was communicated with affected property owners who were upset about the dredging not extending into the reach adjacent to their properties.

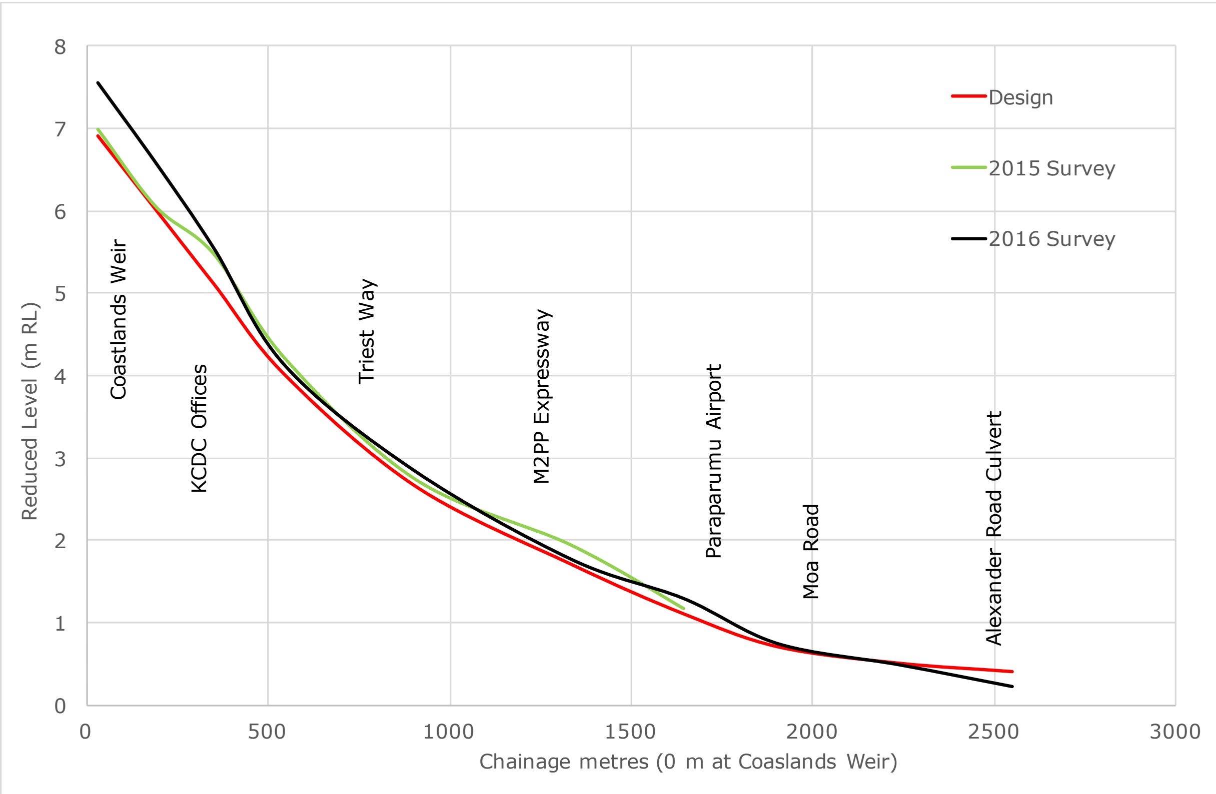

Figure 6: Wharemauku Stream Longsection

4.2 DESIGN CROSS SECTION

With the depth and extent of dredging determined the proposed cross section now how to be determined. The original 1994 design level provided for a uniform flat based channel (See Figure 7.). The project team, including Greater Wellington Regional Council decided that this lacked habitat diversity and that a profiled channel with a deeper side that alternated from the left bank to the right bank would provide a better solution. In addition to this, pool-riffle-run sequences were incorporated into the long section profile to mimic the existing habitat.

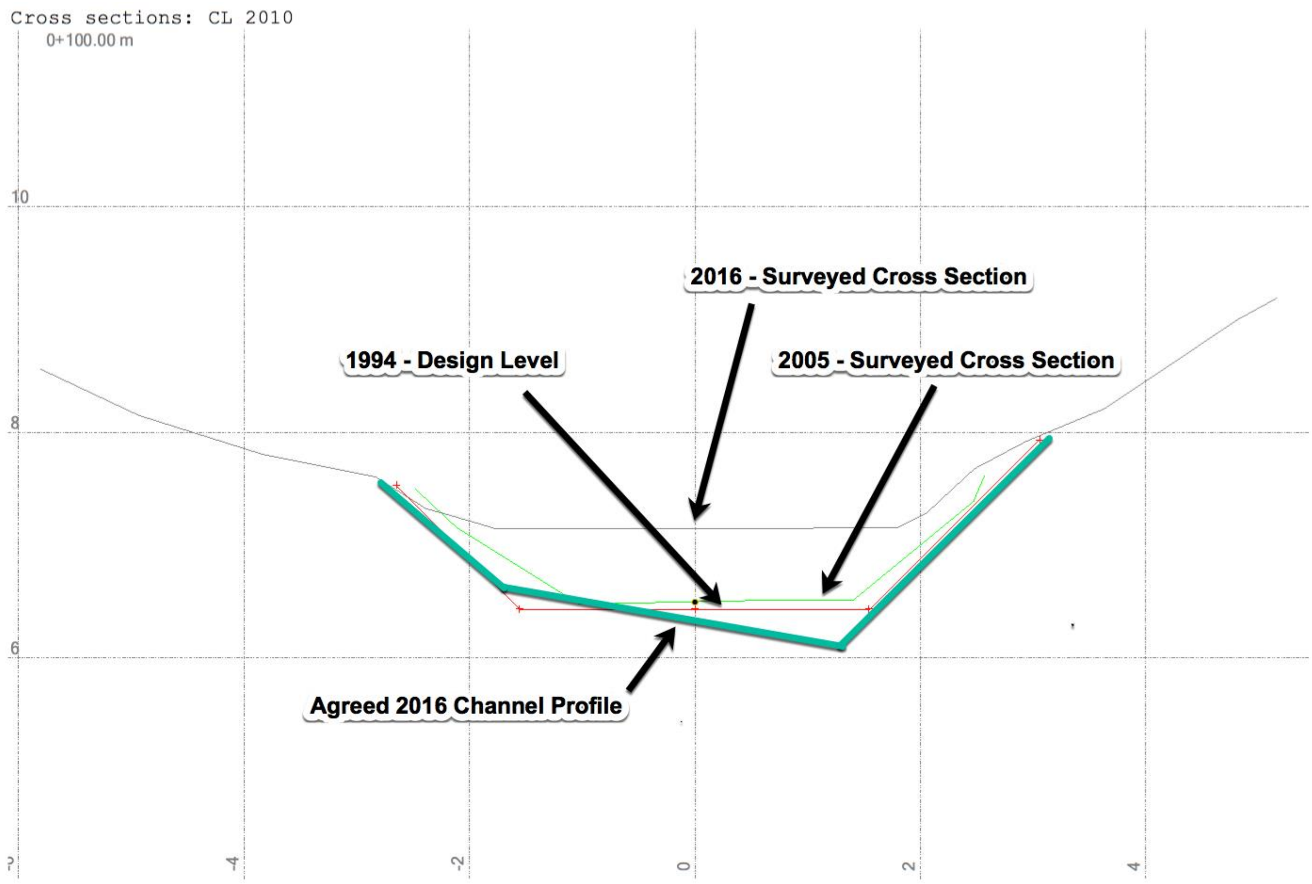

Figure 7: Wharemauku Design Cross Section (Chainage 100 m)

4.3 BANK PROTECTION WORKS

A number of sites within the dredged reach were identified as having erosion issues. With the excavation of up to 700 mm these existing erosion hot spots would only get worse. Where there was critical infrastructure in close proximity the areas of erosion were to be repaired with rock rip-rap which was trenched in to 500 mm below the invert of the dredged profile. In other areas it was proposed to flatten the vertical banks back to a 3:1 profile and in other areas fencing was proposed as mitigation for the potential for people to fall down the vertical banks.

4.4 RIPARIAN VEGETATION REFUGES

In consultation with Iwi it was agreed that no works would be done in one particular reach and that in the lower reach where the profile was only be lowered by 100 – 200 mm that riparian vegetation would be left untouched on one bank. This was generally not possible further upstream in the confined reach as the channel had to be widened as well as deepened to create the design profile.

4.5 RESOURCE CONSENT

An existing resource consent was being used for the completion of the works which had particular conditions around the timing of the works to mininise environmental effects especially on the nationally threatened native fish including the Banded Kokopu, Giant Kokopu, Koaru and Redfinned Bully that had all been previously identified as being present in the stream. To protect the key native fish spawning period no works were allowed from 1 March to 31 August and proposed works methodologies had to be approved by GWRC prior to commencement of the works.

4.6 DREDGING CONTRACT

The dredging works along with the bank protection works were packaged into a contract and invited tenders sought. Interesting points to note were the basis of payment for the dredged material, which was on a surveyed solid measure of material removed from the channel. There was a separate hourly rate item for removal of vegetation. This was considered the fairest and most accurate way to administer payments and avoided difficulties with having to survey a bulk measure of a stockpile that may include a portion of vegetation. Following the tender process, the contract was awarded to local contractor Goodmans.

5 METHODOLGY

With the design profile and contractor appointed a methodology had to be developed to satisfy the requirements of the resource consent. The key elements to consider were sedimentation and effects on fish.

There were very limited options for managing sedimentation during construction, so the best practicable solution was proposed which was using in-channel silt fences to trap as much of the finer sediment as possible. The direction of works was also agreed to commence from the upstream end so that material that did move downstream would be excavated as operations moved downstream.

The most significant concern was the potential effects on the native fish species present in the stream, noting that there was some mitigation already in place by way of no works being done during the spawning period. It was still considered likely that there would be fish physically removed as part of the sediment removal and that there was a high likelihood of fatality. Mitigation methods were discussed which included having an "eel officer" on site to help eels back into the stream but this was not considered adequate, particularly noting the numerous different species present and the potential for them to be buried under the temporary stockpiles on the banks of the stream.

It was decided that a fish relocation method would be used so that the working reaches would be isolated with fish proof nets and fish moved to the upstream reach while works were being done. A plan was developed to isolate reaches of approximately 200 m at a time with the fish proof nets being integrated with the in-stream silt curtains at both the upstream and downstream ends of a reach. A team of three including a certified electric fishing technician would then fish out the reach before any works would commence. This was adopted as the best practicable method for minimising the effects on fish and works were programmed to commence.

6 PHYSICAL WORKS

The physical works commenced mid-October with the reach isolation and electric fishing being undertaken to then allow the dredging to commence. The isolation and sediment control nets along with the electric fishing team are shown in Figure 8.


Figure 8: Erosion and sediment control and fish relocation

The records from the first three days of fish relocation are listed below -

10 October 2016 Electric Fishing Weir to Coastlands Mall Overpass

- 150-180 Elvers, numerous tiny Tuna;
- 15 Tuna 1ft-1 ½ ft long, 3 long fin;
- 2 Tuna 3ft-4ft long, both long fin;
- 5 Redfin Bullys;
- 50 + Common Bullys;
- 2 Koura;
- 100 + Inanga;
- 20 Banded Kokopu.

All released above Vera Lane up to Redwood close.

17 October 2016 Coastlands Mall Overpass to Rimu Rd Bridge

- 3 large Tuna 4+ft long, 2 were long fin;
- 6 Bluegill Bullys;
- 50 + Common Bullys;
- 8 Redfin Bullys;
- 50 + Inanga;
- 10 + Banded Kokopu;
- 3 large Koura.

All released at Kaitawa reserve to Riwai Street weir.

19 October 2016 Rimu Road Bridge to Library Corner

- 250-300 Elvers and Tuna to 2ft long;
- 40+ Tuna 2ft-3ft +ft long, long fin and short fin;
- 5 Redfin Bullys.
- 20+ Inanga.
- 2 Koura.

- 4 Bluegill Bullys.

All released above Riwai Street up to weir below golf course.

As evidenced from these records many hundreds of fish were present in these reaches and were safely relocated prior to any in stream works being undertaken.

Figure 9: Tuna (left), Bluegill Bully (upper right) & Koura (lower right)

Once the isolated reaches had been fished the main earthmoving equipment moved in to excavate the channel down to the required depth and width as well as construct the erosion protection works. Where possible work was undertaken from the bank edge, but in the confined section, where the Coastlands building is over the top of the stream, machinery had to be in the stream (See Figure 10.). The excavators were equipped with on-board GPS tracking so were able to accurately cut down to the required design profile.

In some reaches material was stockpiled next to the channel before being removed off site but in other areas this was not possible so it was loaded directly into trucks and carted away. A total of close to 3000 m^3 of material (solid measure) was removed by the dredging operation.

Figure 10: Working in the stream through confined Coastlands Section (left) and from bank edge further downstream (right)

6.1 POST CONSTRUCTION

The effects of the dredging are most dramatically shown at the main stormwater outlet from the Coastlands Shopping Mall (Figure 11). Prior to dredging, during normal flows this outlet was completely drowned. Following dredging the water level dropped by approximately 700 mm and the water stored in the stormwater network drained away over a period of several hours. It is noted that during periods of high flows in the main Wharemauku Stream that this outlet will be drowned but the timing of the peaks from the large rural catchment affecting the main channel and the commercial area will be sufficiently different that water will much more effectively be able to drain away from this area. Through anecdotal observations, the November 2016 flood event caused much less inundation of roads and properties in this area compared to a smaller event that occurred in June 2016 prior to the dredging being undertaken.

Figure 11: Before & after at main (625 mm diameter) stormwater outfall

Further downstream the effects on the open channel are clearly evident with a much increased width and capacity as well as erosion protection works completed and in-channel riffle-pool-run sequences as shown in Figure 12.

Figure 12: Before (left) & after (right) at Triest Way

7 FUTURE WORK

The dredging programme has been very successful in returning the system to its intended 1994 design capacity. However, a number of other projects are ongoing to provide improved levels of service and account for the increases in flood size and frequency that are expected as the climate changes in the future. As highlighted earlier in the paper there are also a number of properties in the lower reaches which do not benefit from dredging so a floodwall/stopbank solution is being investigated in these areas. A brief summary of potential future projects is listed below -

- Wharemauku Detention Dam – reduce flood flows throughout lower catchment and reduce sediment loads.
- Moa Road – Alexander Road upgrade – flood wall and bridge upgrade to reduce flood vulnerability in lower reaches where dredging has no benefit.
- Epiha Street Culvert upgrade – Reduce flooding to upstream properties but will require downstream capacity upgrades or detention dam to go ahead.
- Paraparaumu Town Centre Redevelopment – Opportunity to integrate stormwater infrastructure including treatment devices.
- Stormwater Network Upgrades – Large parts of the network under capacity but need to complete downstream upgrades first to prevent transferring flood risk downstream.
- Open Drain Maintenance – Separate consent being sought to undertaken maintenance on numerous tributary channels.
- Ongoing Gravel Removal from Sediment Trap – 200 m^3 removed every 3-4 months to minimise sediment moving further downstream.
- Monitoring of Stream Bed Levels – Required annually by current consent.
- New Resource Consent – In progress.

8 CONCLUSIONS

1. Monitoring the morphology of river and stream channels and keeping hydraulic models up to date is essential for understanding potential changes in the level of service of flood protection assets and the stormwater network.

2. Where changes in morphology have occurred, particularly aggradation, consideration should be given to dredging as a potential option to "reinstate" previous levels of service.

3. Careful consideration should be given to the extent and depth of dredging required to ensure it is providing the desired hydraulic benefit.

4. The dredged channel profile should be designed in a way to replicate or improve the habitat diversity of the existing channel by paying particular attention to run-riffle-pool sequences.

5. Where possible, riparian vegetation should remain intact to provide shading and bank stabilisation.

6. Dredging will often highlight or amplify areas of bank erosion, which can significantly add to overall project costs.

7. Erosion and sediment control during construction is important for protecting downstream habitat.

8. Avoiding key spawning times and isolating reaches with fish-proof nets and relocating fish out of the working area can significantly reduce the overall environmental impact.

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