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Coromandel flood protection scheme design report

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Executive summary

Coromandel town is located on the west coast of the Coromandel Peninsula, 48 kilometres north of Thames on State Highway 25 (SH25). In response to the severe floods generated by the “Weather Bomb 2002”, Waikato Regional Council established the Peninsula Project to address river and catchment issues across the Peninsula through soil conservation, river management, animal pest control and flood protection measures. Coromandel town was one of the communities identified as having a very high risk to life and property, requiring actions that address these risks.

Since the introduction of the Peninsula Project in 2004, Waikato Regional Council and Thames Coromandel District Council, worked with the Coromandel community to develop a flood mitigation strategy to address the Whangarahi and Karaka Stream flood hazards. Works have been undertaken to mitigate some of the flood hazard from Whangarahi and Karaka streams, the details of which are provided in this design report.

Coromandel town is located at the base of the Whangarahi and Karaka Stream catchments on a coastal alluvial fan. The presence of parts of Coromandel town on the low-lying land adjacent to Whangarahi and Karaka streams means that these properties are subject to flood hazard from both streams. Both catchments are susceptible to short duration but high intensity rain events causing flash flooding and debris flow in the streams and surrounding land with little or no warning.

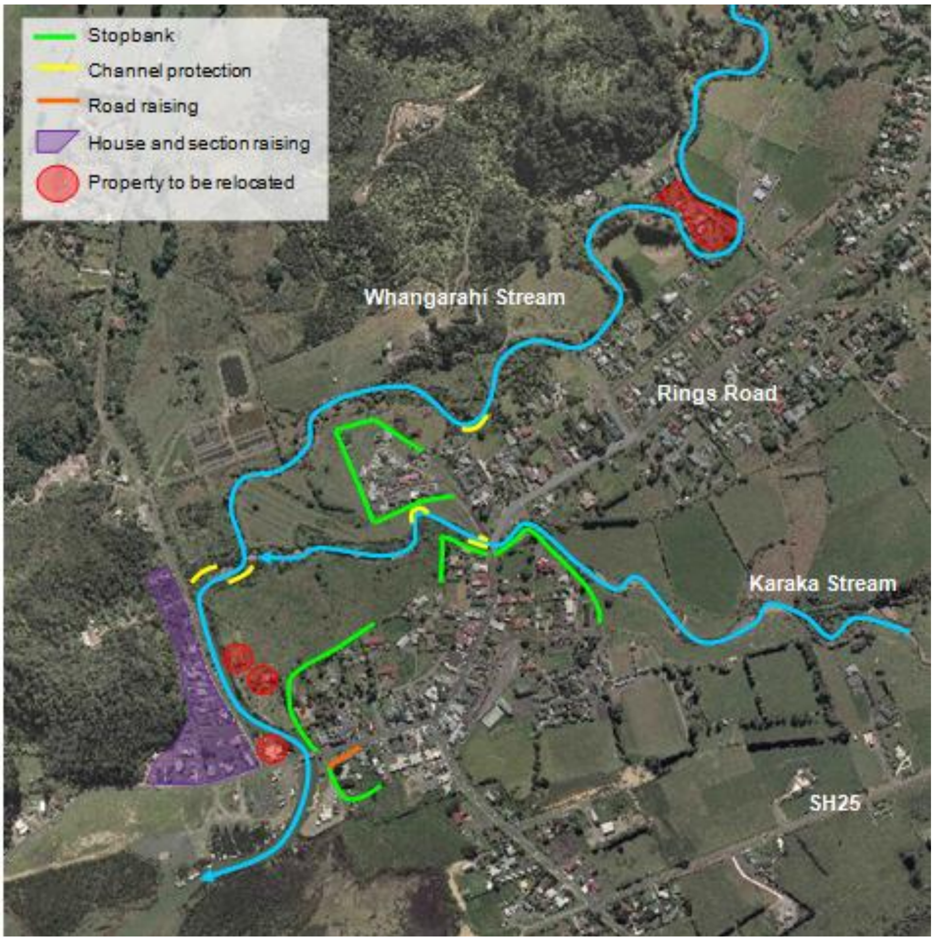
For the success of this project it was essential that the community was involved. A working party was established in the community to liaise with the various authorities, including Waikato Regional Council, as matters progressed. The working party met at regular intervals to scope the issues, discuss options and to work together to implement the project.

As a first step, the community agreed to Waikato Regional Council developing and undertaking an extensive channel maintenance program of the Whangarahi and Karaka Streams to improve the condition of the channels and their capacity to convey flood flows. This work has improved the stability and capacity of the Whangarahi and Karaka Streams and reduced the risk to the Coromandel community by containing flood events that would otherwise inundate adjacent land.

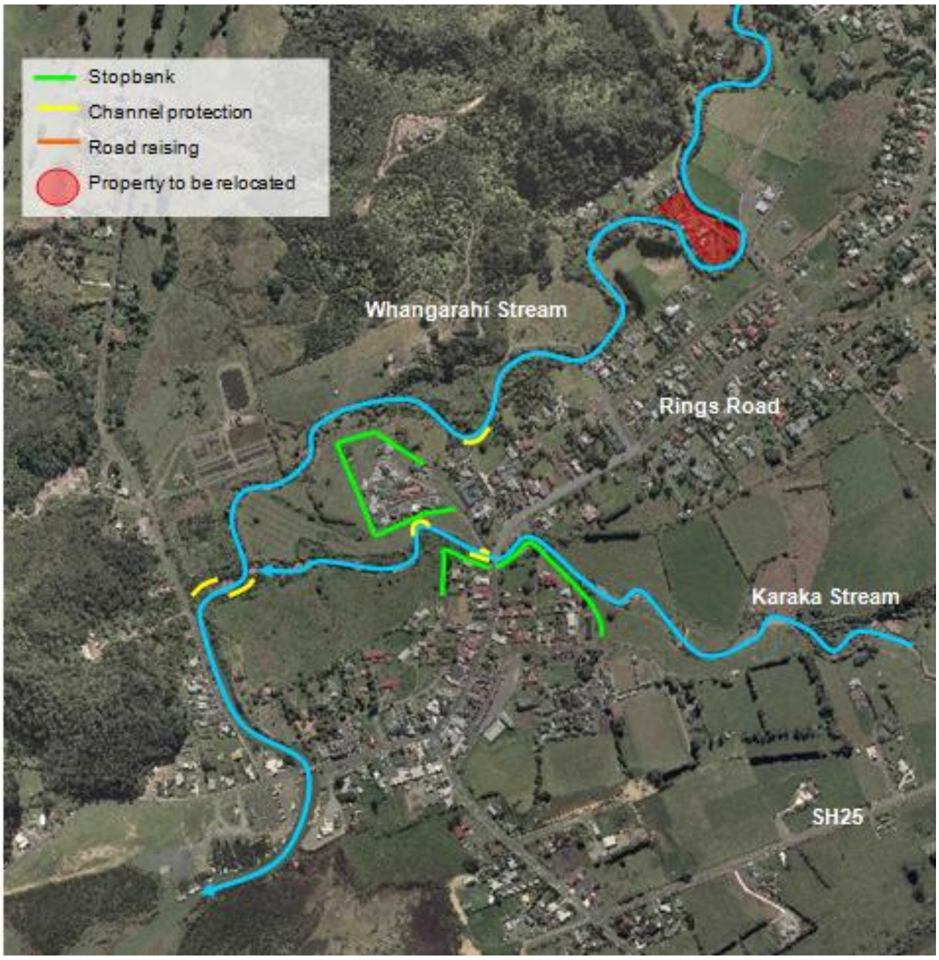
The initial technical investigation results demonstrated that while the channel maintenance discussed above would improve the channel capacity, it would not be adequate to prevent flooding. Hence, proposals to protect the Coromandel community from flooding up to a design standard of the 1% Annual Exceedance Probability (AEP) event by way of engineering works were developed.

A catchment assessment was undertaken for the Whangarahi and Karaka Stream catchments to inform the development of a MIKE-21 and MIKE-11 hydraulic model which were then used to develop a proposed flood mitigation strategy for Coromandel Town. A peer review of the MIKE-11 hydraulic model used to develop the design of the flood defences on Karaka Stream was commissioned to ensure robustness of the design.

WRC worked with the community via the Coromandel town working group to develop the flood mitigation strategy for Coromandel and then consulted with the community on what was proposed. The following figure illustrates the full proposal.



The community did not agree to the full scheme, so only a partial scheme was implemented that included the following components:



Catchment management and soil conservation works programmes have also been established in Whangarahi and Karaka Stream catchments to complement the flood mitigation works undertaken.

At this stage no further capital works are proposed to protect the Coromandel community from flood hazard. If at some point in the future the community decides it requires additional protection, and is able to fund the works, then council would look to extend the works to protect additional areas

The main channel of the Whangarahi and Karaka Streams are monitored and periodically maintained by the Waikato Regional Council to remove accumulated sediment and debris. This work maintains the capacity of both of the streams and reduces the risk to adjacent land that would otherwise be inundated more frequently.

'Residual flood risk' is a term used to describe a river flood risk that exists due to the potential for 'greater than design' flood events to occur. Residual flood risk applies to the Coromandel community from factors such as the incomplete nature of the works, the greater than the design event, the impact of debris flow during a flood event and that the model excludes obstructions such as buildings and walls which may have localised effects.

Based on the flood hazard status of land in the community, TCDC has various planning controls in place via the Thames Coromandel District Plan, that restrict what land use activities can be undertaken. Refer to the Thames Coromandel District Plan and TCDC staff for details.

The flood mitigation scheme for the Coromandel community should be reviewed in accordance with the Coromandel zone management plan. In addition if there are any significant changes in land use in the community the scheme would need to be reviewed. Due to funding constraints the full flood mitigation scheme was not constructed. If feedback from the community indicates that the community wants to increase their level of protection and are able to fund the works, then the scheme would be reviewed and completed if practicable.

1 Introduction

1.1 Background

Coromandel Town is located on the west coast of the Coromandel Peninsula, 48 kilometres north of Thames on State Highway 25 (SH25).

In response to the severe floods generated by the “Weather Bomb 2002”, Waikato Regional Council (WRC) established the Peninsula Project to address river and catchment issues across the Peninsula through soil conservation, river management, animal pest control and flood protection measures.

Under the Peninsula Project WRC and Thames Coromandel District Council (TCDC) worked together on flood mitigation plans for five Thames Coast communities. The work included risk assessments, technical investigations, development of risk mitigation options, development of a business case to central government for funding support and establishment of rating mechanisms. There was extensive community consultation on plans for these Thames coast communities.

Coromandel Town was one of the communities identified as having a very high risk to life and property, requiring actions that address these risks. Since the introduction of the Peninsula Project in 2004, WRC and TCDC worked with the Coromandel town community to develop a flood mitigation strategy to address the Whangarahi and Karaka streams flood hazard. Works have been undertaken at the mitigate some of the flood hazard from Karaka and Whangarahi streams, the details of which are provided in this design report.

1.2 Scope of report

The purpose of this design report is to provide a summary of the works that have been undertaken at Coromandel town to reduce the flood hazard from the Karaka and Whangarahi streams, including the rationale behind the scheme development, the agreed levels of service, the design details, as built information, the operation and maintenance requirements of the scheme, the residual flood risk and the scheme review requirements.

The design report includes the following sections:

- Catchment overview
- Hydrological assessment
- Hydraulic model development
- Flood protection scheme
- Future works
- Agreed levels of service
- Operation and maintenance
- Flood hazard assessment
- Residual flood risk
- Planning controls, and
- Scheme review.

2 Catchment overview

2.1 Catchment description

Coromandel town is located on the west coast of the Coromandel Peninsula; forty-eight kilometres north of Thames on state highway 25 (refer to Figure 1).

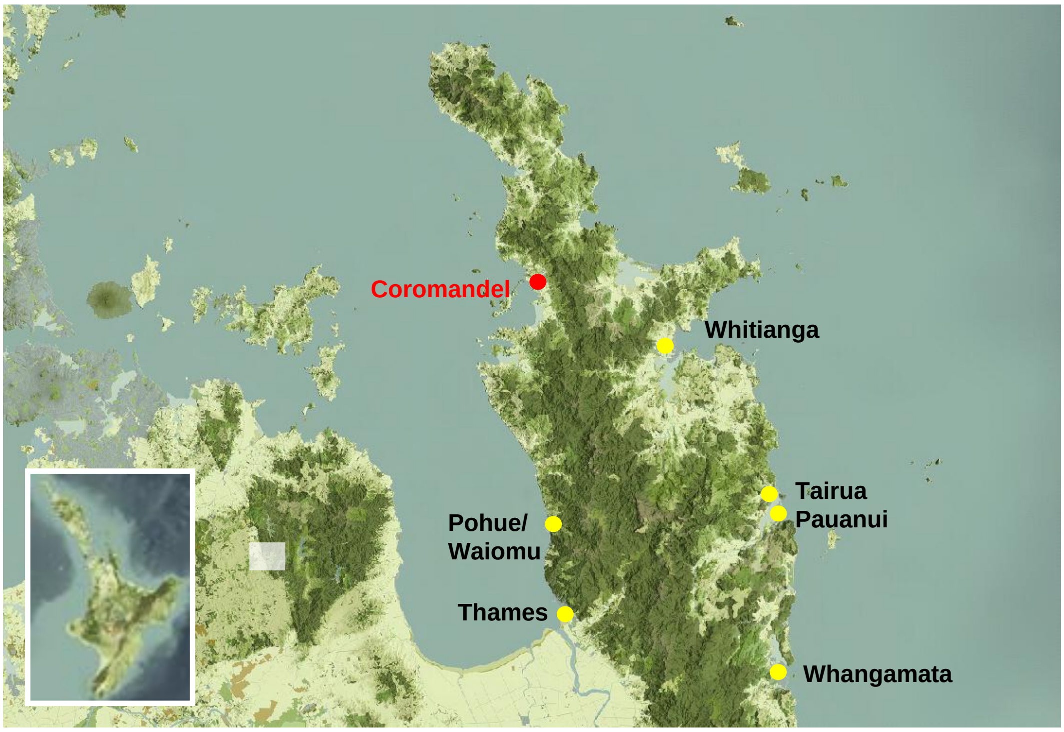


Figure 1 Thames-Coromandel District

The Whangarahi and Karaka streams have a combined 16 km^2 catchment that originates in the western Coromandel ranges (refer to Figure 2). These catchments are relatively steep and covered in regenerating native vegetation and scrub. These catchments are also susceptible to short duration but high intensity rainfall events that cause flash flooding and debris flows in the Whangarahi and Karaka streams with little or no warning.

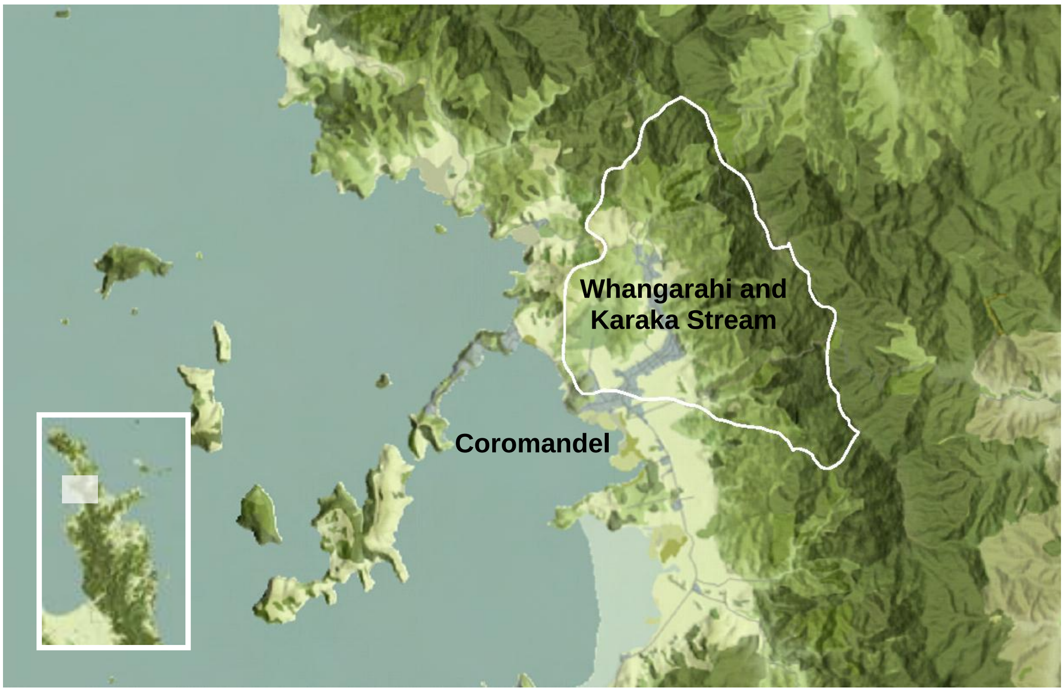


Figure 2 Whangarahi and Karaka Stream catchment

2.2 Whangarahi and Karaka Streams

The Whangarahi Stream flows out of the Coromandel ranges before draining to the Coromandel harbour. The Karaka Stream also originates in the Coromandel ranges, and flows through Coromandel town before draining into the Whangarahi Stream, refer to Figure 3.

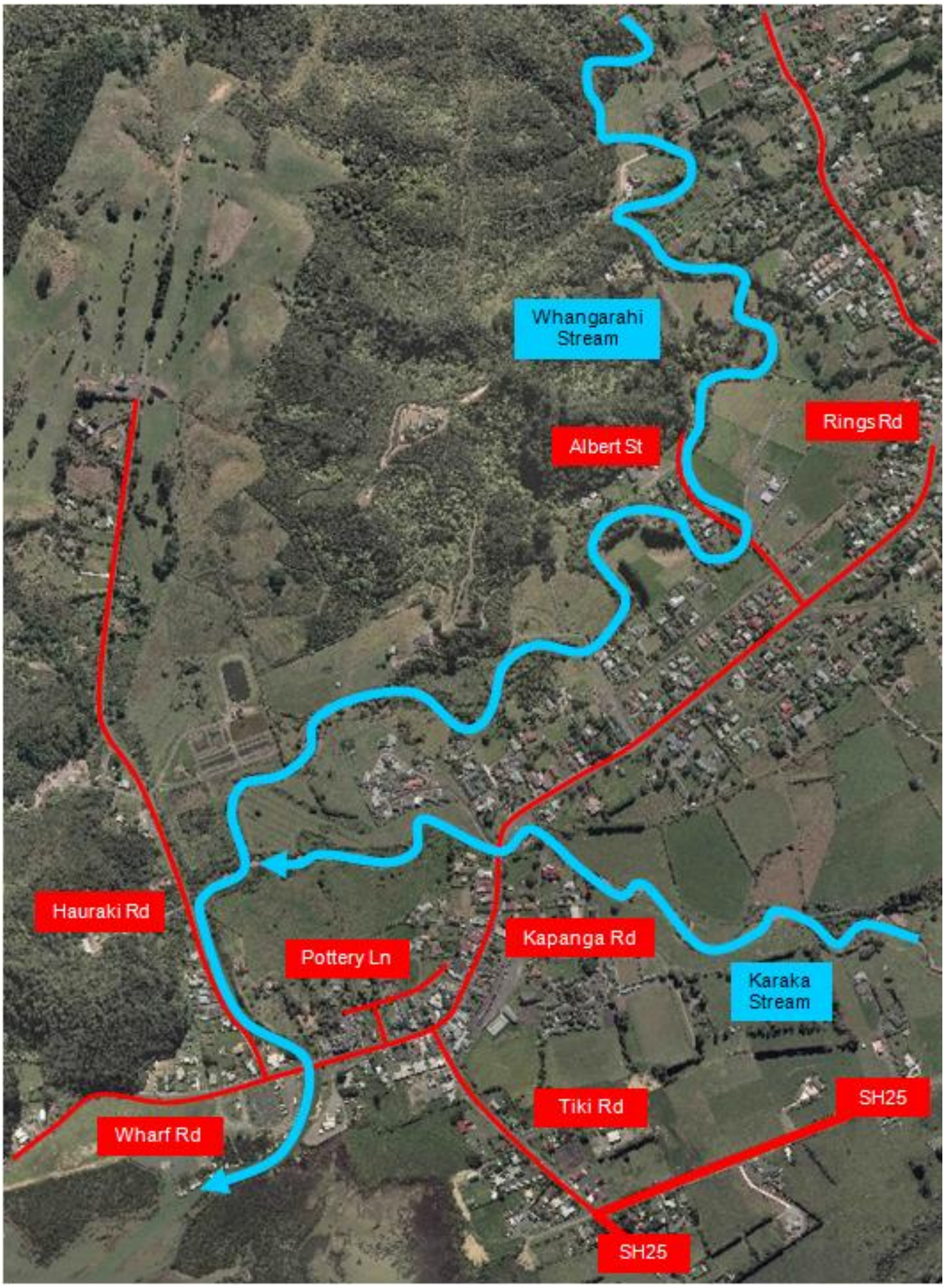


Figure 3 Coromandel town

Parts of Coromandel town are located on the floodplain and sediment/debris fan created by Whangarahi and Karaka streams. Refer to Figure 4 and Figure 5 which illustrate the relative ground levels in Coromandel Town.

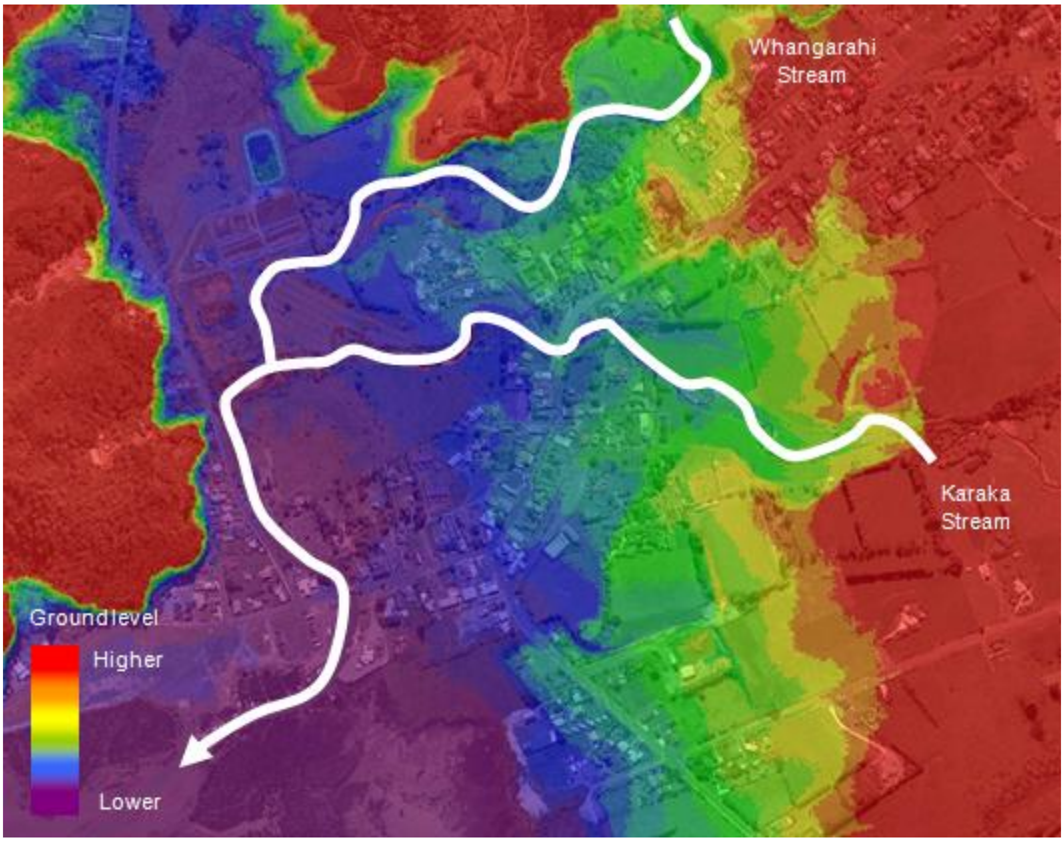


Figure 4 Ground level around Coromandel town

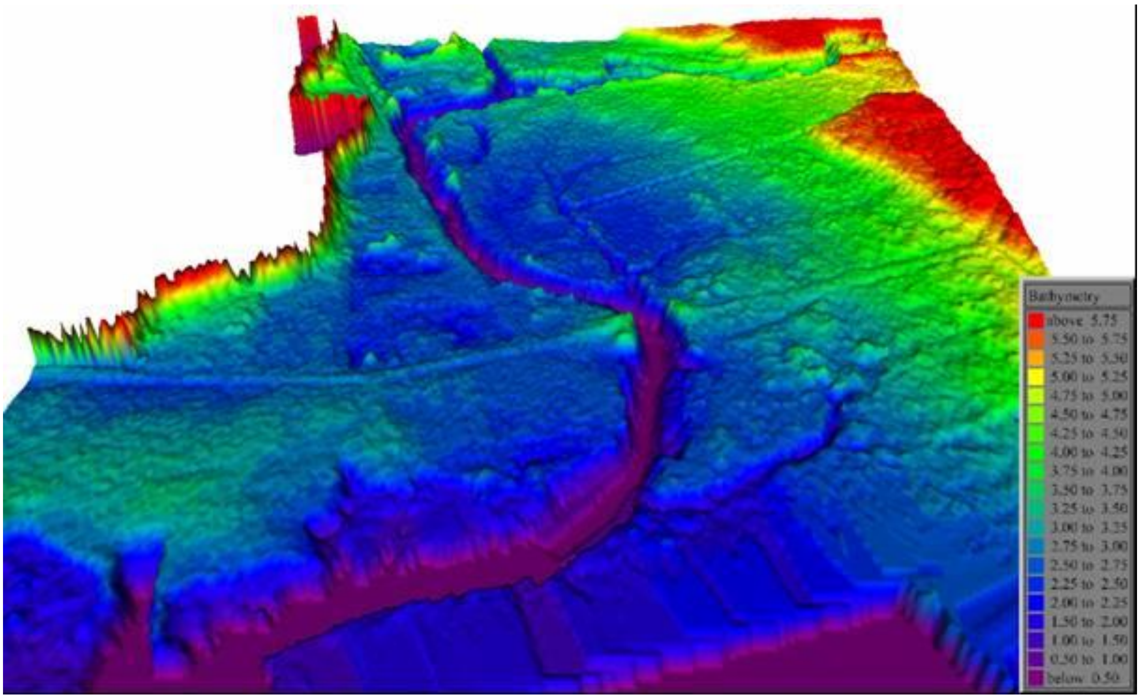


Figure 5 Coromandel town ground levels (looking inland from the Firth of Thames)

2.3 Flooding issues

The presence of parts of Coromandel town on the low-lying land adjacent to Whangarahi and Karaka streams means that these properties are subject to flood hazard from both streams. Both catchments are susceptible to short duration but high intensity rain events causing flash flooding and debris flow in the streams and surrounding land with little or no warning.

Coromandel town is located at the confluence of the Whangarahi Stream and the Karaka Stream on a coastal alluvial fan. The community consists of relatively significant commercial and residential development on the true left bank of the Whangarahi Stream and on both banks of the Karaka Stream. During significant flood events, overland flow occurs mainly in the following areas:

- On the Whangarahi Stream in the vicinity of the Albert Street and Pondarosa meanders.
- On the Whangarahi Stream in the vicinity of Hauraki Road.
- On the Karaka Stream in the vicinity of the Kapanga Road Bridge.

Figure 6 below illustrates the main areas where overland flow occurs in Coromandel town.

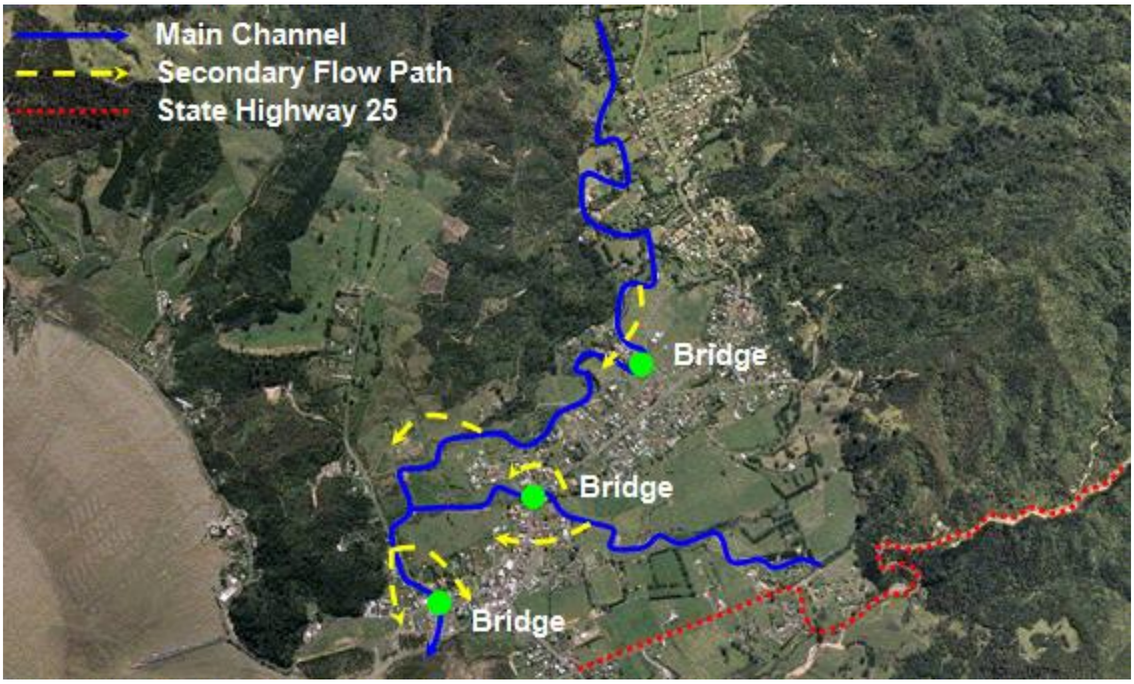


Figure 6 Indicative flooding mechanisms in Coromandel town

Based on the assessment of Coromandel town flood hazards at the time of developing the flood protection scheme, it was assessed that there were about 60 properties in Coromandel that were at risk from flooding from a 1% Annual Exceedance Probability (AEP) event. Of these properties, 35 were houses, 10 were basements or sheds and 15 were sections only. Most of the properties affected were identified to be located in the lower reaches of the Karaka Stream where it joins the Whangarahi Stream. This included a portion of the central business district (on the true left bank) and properties on Hauraki Road (right bank) in the vicinity of the Wharf Road bridge. Upstream, three properties on Albert Street (right bank) were also assessed to be prone to flooding. Figure 7 below illustrates the predicted flood extents at Coromandel for the 1% annual exceedance probability (AEP) event with an allowance for predicted climate change.

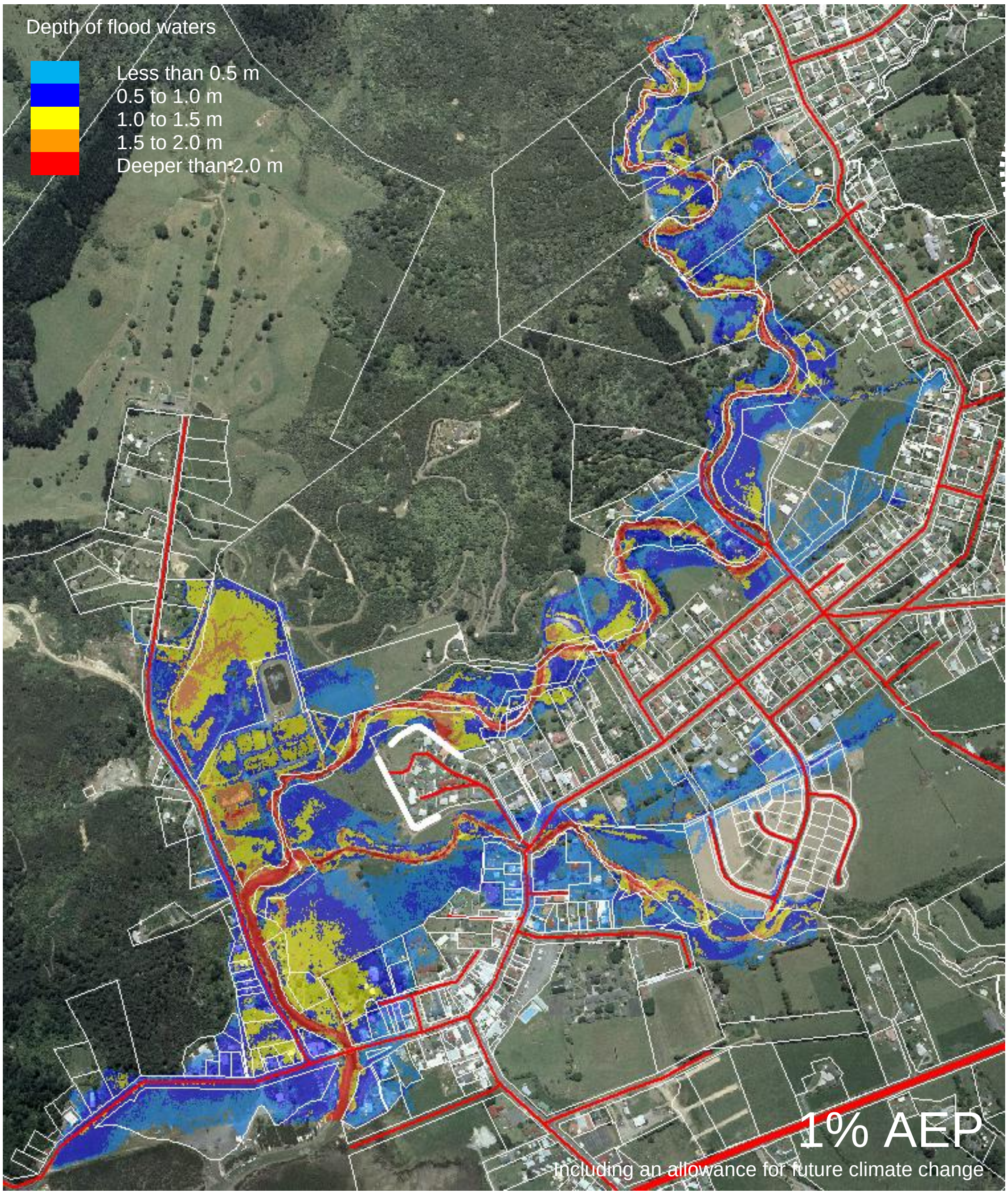


Figure 7 Predicted flood extents for 1% AEP event (with climate change)

The significance of the flood hazard to the Coromandel community was demonstrated during the storm event that occurred on June 21, 2002 (also referred to as the 'Weather Bomb'). This event brought torrential rainfall to the Coromandel Peninsula (with unconfirmed intensities of up to 125 mm in 25 minutes) and caused widespread damage across the Thames Coromandel and South Waikato districts (Munro, 2002). The Coromandel town community sustained significant damage during this event.

Damage to properties within Coromandel town from the Weather Bomb was focused on those properties immediately adjacent to the Whangarahi and Karaka streams, and those that are located within the secondary overland flow paths. Figure 8 below illustrates the property damage that occurred within Coromandel town during the 'Weather Bomb'.

Figure 8 Property damage within Coromandel Town during the 'Weather Bomb'

Following the 'weather bomb', WRC and TCDC initiated the Thames coast project to better understand the river flooding issues that affect the communities on the Thames coast. This project also involved the identification of works to mitigate the impact of river flooding on people and property along the Thames coast.

The Thames coast project focused on the five most vulnerable communities that were identified as being worst affected by both the weather bomb and historical flood events, which included Coromandel town.

3 Hydrological assessment

3.1 Technical information

During the development of the Peninsula Project, WRC collected a significant amount of technical information covering the Whangarahi Stream and Karaka Stream catchments. This information is presented in WRC's Technical Report 2004/13 and includes:

- Historical research
- Catchment hydrology
- Lower channel hydraulics (1 dimensional)
- Floodplain hydraulics (2 dimensional)
- Flood hazard analysis (including extent and severity).

Some of the key data sources and findings that have informed technical investigations are summarised below.

Table 1 Summary of technical reports covering flood events on the Thames coast

Flood Event	Technical reports
April 1981	HCB Report 109 and 123 (Sep 1981 and June 1982)
February 1985	HCB Report 190 (October 1985)
Cyclone Bola	No technical reports located
Cyclone Drena	No technical reports located
January 2002	No technical reports located
June 2002	EW Report 2002/10 (July 2002)

Table 2 Technical reports covering flood mitigation and management at Coromandel

Community	Previously completed technical investigations
Coromandel Town	Flood Hazard Mgmt – Draft EW Report (Apr 2002)

Table 3 Summary of completed flood mitigation works at Coromandel

Community	Previously completed works
Coromandel Town	No significant flood hazard mitigation works have been previously completed within Coromandel Town other than periodic clearing of the channel.

3.2 Catchment characteristics

The catchment for the streams that drain through Coromandel town is located on the steep western slopes of the Coromandel ranges. The catchment is relatively steep and has elements of bush, pasture and urban cover. The main stream flowing through Coromandel town is the Whangarahi Stream. The catchment area and characteristics for the Whangarahi Stream are described below.

**Figure 9	Whangarahi Stream catchment boundary**

**Table 4	Whangarahi Stream catchment summary**

Catchment area	16.3 km^2
% urban	Moderate
% indigenous forest/ scrub	High
Channel slope	8%
Time of concentration	45 minutes

The development of a hydraulic model to represent the Coromandel town catchment is fairly complex because of the high number of contributing subcatchments. These subcatchments and their areas are listed below.

Table 5 Coromandel town subcatchment areas

Coromandel – subcatchment areas	
Catchment	**Area km2**
Upper catchment	5.48
Whakaneke	2.40
Taumatawahine	0.75
Golf course	1.70
Karaka	5.31
Town	0.67

It was necessary to determine flow contributions from each of the subcatchments. The methodology used to determine these contributions is described in Section 3.3 below.

3.3 Rainfall

Rainfall data was taken from NIWA's High Intensity Rainfall Design System (HIRDS) Version 2 (the most current version of HIRDS at the time of the model development). The standard error was added to the rainfall depth to give a conservative rainfall estimate and is shown below.

Table 6 Whangarahi Stream catchment predicted rainfall intensities (existing)

	Rainfall summary 45 minute duration event					
Annual exceedance probability (AEP) event	50%	20%	10%	5%	2%	1%
Predicted rainfall intensity (mm/hr)	30	37	44	52	65	80

Climate change effects have been estimated following the methods outlined by the Ministry for the Environment guidelines (MfE, May 2004 – the most current guidelines at the time of the assessment). The guidelines predict that the temperature within the Waikato region will rise by up to 1.4^{0}C by 2030 and up to 3.8^{0}C by the year 2080. The guidelines also suggest that rainfall intensity will increase 7% to 8% per degree ^{0}C increase. Based on the above the rainfall intensities were estimated as outlined in the following table.

Table 7 Whangarahi Stream catchment predicted rainfall intensities (future)

	Rainfall summary 45 minute duration event					
AEP event	50%	20%	10%	5%	2%	1%
Predicted rainfall intensity 2030 (mm/hr)	33	41	48	58	72	88
Predicted rainfall intensity 2080 (mm/hr)	39	47	56	67	84	103

3.4 Flow estimates

The peak inflow for Whangarahi Stream including an allowance for climate change has been determined using several methods; the rational method, relative rational method, and the revised regional flood estimation method. The results have been compared with previous reports and historic events.

Table 8 Whangarahi Stream peak flow estimates

	Peak flows estimates					
AEP event	50%	20%	10%	5%	2%	1%
Existing peak flow - 2006 (m^3/s)	96	117	155	183	211	253
Future peak flow - 2030 (m^3/s)	105	129	172	202	233	280
Future peak flow - 2080 (m^3/s)	122	150	200	235	272	326

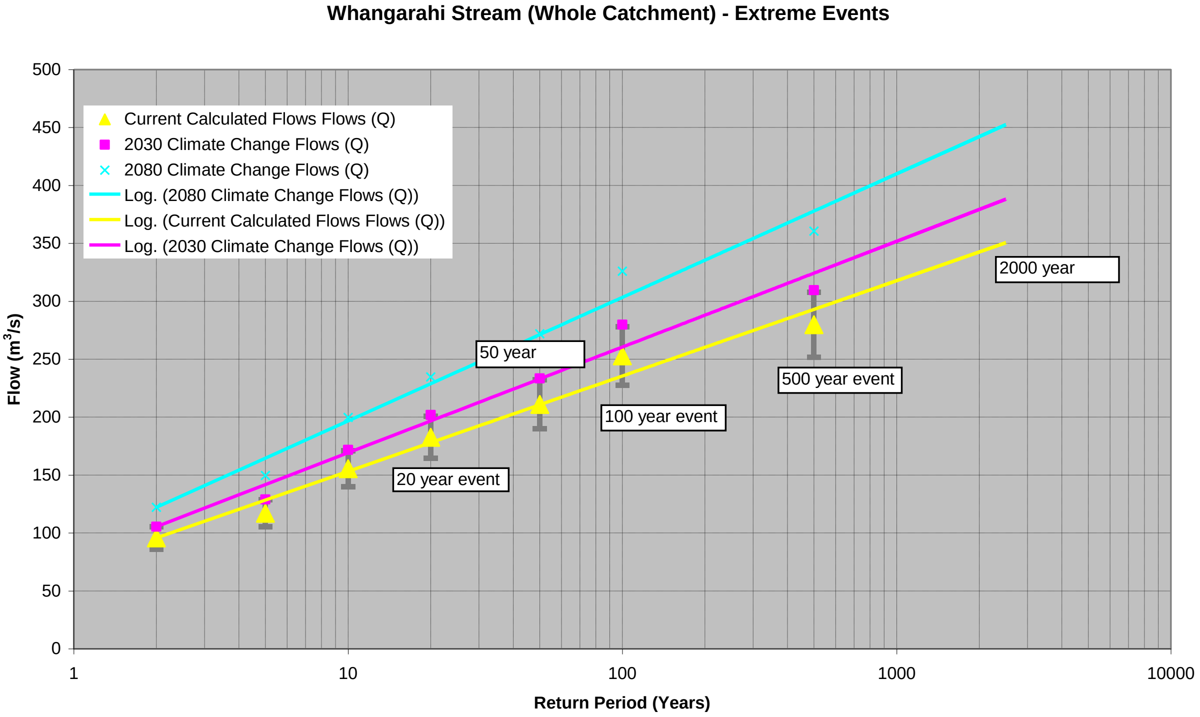


Figure 10 Whangarahi Stream hydrological summary

From the above assessment, the predicted future 1% AEP event flows for the Whangarahi Stream is estimated to be approximately $304m^3/s$. It was this flow which was then used to determine each subcatchment contribution.

The peak flow for each subcatchment was determined by multiplying the ratio of each subcatchment by the peak flow for the Whangarahi Stream or total catchment. The peak flows and the times of concentration for each subcatchment are shown below.

Table 9 Subcatchment peak flow summary

Catchment	**Area (km^2)**	**Area ratio (%)**	**Time of concentration (mins)**	**Peak flow (m^3/s)**
Upper catchment	5.48	34	30	102
Whakaneke	2.40	15	20	45
Taumatawahine	0.75	5	5	14
Golf Course	1.70	10	15	32
Karaka	5.31	33	30	99
Town	0.67	4	5	12

3.5 Hydrograph

To allow realistic modelling it was necessary to create a hydrograph to input flows into the model. A dimensionless unit hydrograph was created by examining five historic floods recorded on the Kauaeranga River at Smiths (WRC recording site 9301). The dimensionless hydrograph used is shown below.

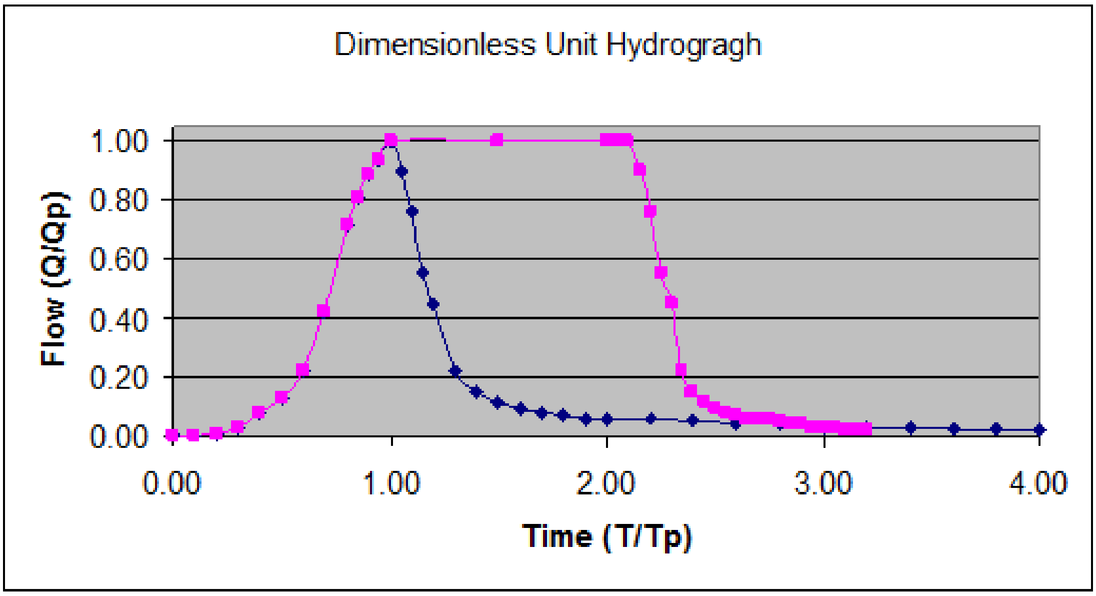


Figure 11 Dimensionless unit hydrograph

A sustained period of peak flow was also included for this assessment. This was considered appropriate given that the initial calculation related to the time of concentration of the whole catchment (Whangarahi catchment). A rainfall event of this nature would be expected to produce extended peak flows in the smaller subcatchments. This also ensured that the peaks of the smaller catchments would coincide and give peak flows at the mouth of the Whangarahi Stream similar to the Whangarahi Stream peak flow calculation.

The above dimensionless unit hydrographs above are examples of what was used to produce unit hydrographs for the modelling. Here Tp is the time of concentration and Qp is the peak flow.

4 Hydraulic model development

4.1 Introduction

A one dimensional computational hydraulic model was built to represent the Whangarahi and Karaka streams using MIKE-11 software (as these two streams were the focus of the flood protection scheme). This model provides detailed information regarding flow, flow depth and velocity within the modelled stream channel and associated stream berm and was used to develop a detailed design model sufficient to inform the design of components of the flood protection scheme, such as stop banks and flood walls. This section outlines the development of both of the hydraulic models.

4.2 Model inputs

4.2.1 Model datum

The model datum relates to a local datum - Origin of coordinates: SS70 S57224 (C3FK) – lead plug in Kapanga Road bridge. The model has been developed with data relating to this datum, including any LiDAR information which has been corrected to this datum to complete cross sections where survey extents didn't extend far enough.

4.2.2 Channel cross section data

Cross section survey data was used to define the channel dimensions. The survey was undertaken by FW Millingtons Ltd in September 2004. Cross sections were surveyed at nominal 100m intervals. These cross sections were input into the MIKE-11 model to define the channel capacity.

4.2.3 Upper boundary condition

The upper boundary of the hydraulic model consists of a number of inflow hydrographs to represent the peak flows for the contributing subcatchments to the Whangarahi Stream for the 1% AEP event. The development of the inflow hydrograph is discussed in Section 3 above. The following table summarises the breakdown of inflow data for the catchment for the existing and predicted future 1% AEP events.

Table 10 Catchment peak inflow summary

Catchment	1% AEP (existing) (m^3/s)	1% AEP (future) (m^3/s)
Upper catchment	85	102
Whakaneke	37	45
Taumatawahine	12	14
Golf Course	27	32
Karaka	82	99
Town	10	12
TOTAL	**253**	**304**

4.2.4 Lower boundary condition

The lower boundary of the Whangarahi Stream is the Firth of Thames. The same downstream water level of RL2.88m has been used for the existing and future scenario, which is a conservative value (i.e. the value is greater than RL2.6m which was used to represent the climate change scenario for the MIKE-21 model developed for

Coromandel). A sensitivity analysis has been undertaken around the value of the downstream boundary level and is discussed in the peer review letter in Appendix 1.

4.2.5 Roughness

MIKE-11 uses Manning's 'n' value to define channel roughness. The MIKE-11 model for Whangarahi and Karaka streams has been set up with a constant Manning's 'n' value of 0.05. This 'n' value has been selected to provide a conservative assessment for design purposes.

A Manning's 'n' value of 0.013 has been applied at the Kapanga bridge model culvert; this is the default value and is considered appropriate.

4.2.6 Model location

The MIKE-11 hydraulic model is located on the WRC system in the following folder:

G:\RCS\Technical Services\Projects\Coromandel Zone\Coromandel Town\ Hydraulics\ MIKE 11\4 - Karaka Stream design model (Sep 09)

4.3 Design models

Three model scenarios were developed, as follows:

- **1% AEP event (existing) -** Present day 1% AEP event discharge for existing situation.
- **1% AEP event (existing) with stopbanks** - Present day 1% AEP event discharge with inclusion of proposed stopbanks.
- **1% AEP event (future) with stopbanks** – Future climate change 1% AEP event discharge (i.e. with climate change) with inclusion of stopbanks.

The design models were used to test the proposed flood protection works during the option development stage, and to ensure that the proposals did not exacerbate any existing flood risk to any built up areas.

4.4 Model validation

Modelling of a natural system can never represent the actual environment exactly hence it is important to validate modelling results with actual events to check the overall fit of the modelling results. The estimated flood levels predicted by the MIKE-11 model for the existing climatic conditions scenario were compared with observations made during previous flood events. Comparison showed that the model was providing a reasonable representation of flooding in the Whangarahi and Karaka streams.

4.5 Model assumptions and limitations

The following outlines the assumptions made when building the MIKE-11 hydraulic model and model limitations:

- The modelling work has been undertaken for the current catchment characteristics. Any significant alteration to the catchment will affect the hydrology which will then affect the extent and magnitude of the design flood event. Alterations to the catchment that may affect the hydrology significantly include, land use changes, deforestation and development. Following significant alterations to the catchment a design review should be considered.

- The modelling work has been undertaken using channel cross sections surveyed in 2004. Any changes to the cross sections since this date have not been included in the model.

- The flood modelling work is for the Whangarahi Stream and contributing subcatchments only.

- All flood modelling has been undertaken for clear freely flowing water and does not model actual debris and sediment movement. However the derivation of the peak flows has been undertaken using methods derived from actual events. Therefore the modelling result capture the effects of debris and sediment load in a way similar to that experienced historically.

- While the model results capture typical debris and sediment movement effects, the results do not represent larger debris flows or blockages. Such occurrences are considered greater than design events and are considered a residual risk which is described in Section 10.

4.6 Peer review

Hydraulic Modelling Services were commissioned to undertake a peer review of the MIKE-11 hydraulic model used to develop the design of the flood defences on Karaka Stream to ensure robustness of the design. The peer review report is attached in Appendix 1.

As part of the peer review process, improvements were made to the WRC model including improved representation of the Kapanga Road bridge and various other components. The outcome of the review was that with the HMS improvements incorporated in the hydraulic model, the predicted design flood levels for the existing 1% AEP event were on average 290mm lower than those predicted by WRC's initial model. The lower design flood levels were adopted for the design of the flood protection works.

5 Flood protection scheme

5.1 Long-term vision

Addressing flood risks within Coromandel town needed to be considered within the context of a long term flood risk management plan incorporating a range of the options including planning controls, flood warning and response, floodway designations and flood control works. These in conjunction with appropriate catchment management practices can achieve the best community outcomes in the long term.

The ideal long-term vision for flood management for Coromandel town would be the following:

- Floodways of the Karaka and Whangarahi streams to be well defined with no buildings or obstructions within them, so as to provide sufficient capacity to pass the flood flows for up to the future 1% AEP event.

- Floodway capacity to be sufficient to account for debris and bed load that is characteristic of flood events in the Coromandel, and also for tidal/coastal flooding arising from sea surge and wave action.

- All houses and sections to be located outside of the designated floodway and to be raised above the future 1% AEP flood level.

A full flood protection scheme was developed by WRC for Coromandel town which is illustrated in Figure 12 below. The flood protection works proposed included the following components:

- Provision for adequate floodway within the current floodplain, by relocating several at-risk properties on the left and right bank of the Whangarahi Stream that are located in the floodway (four residential on Albert Street, and two residential and one commercial in the lower reaches of Whangarahi Stream). This property purchase would help to keep the Whangarahi Stream floodway free of obstructions and ensure no future development in this area.

- Channel protection works to increase the capacity of the stream channels and to provide stream bank erosion protection at critical bends.

- The provision of a stopbank/floodwall along the left bank of the Karaka Stream in the vicinity of Kapanga Road bridge, and the provision of a formalised spillway on the right bank at this location.

- The provision of a stopbank/floodwall and localised road raising along the left bank of the Whangarahi Stream in the lower CBD.

- Raise the land and buildings on the right bank of the Whangarahi Stream on Hauraki Road.

- Planning controls to be applied to areas at flood risk restricting future development within the area via the proposed Natural Hazards Variation to the Thames Coromandel District Plan, to ensure that the floodway is defined and protected into the future, with no buildings located in the floodway.

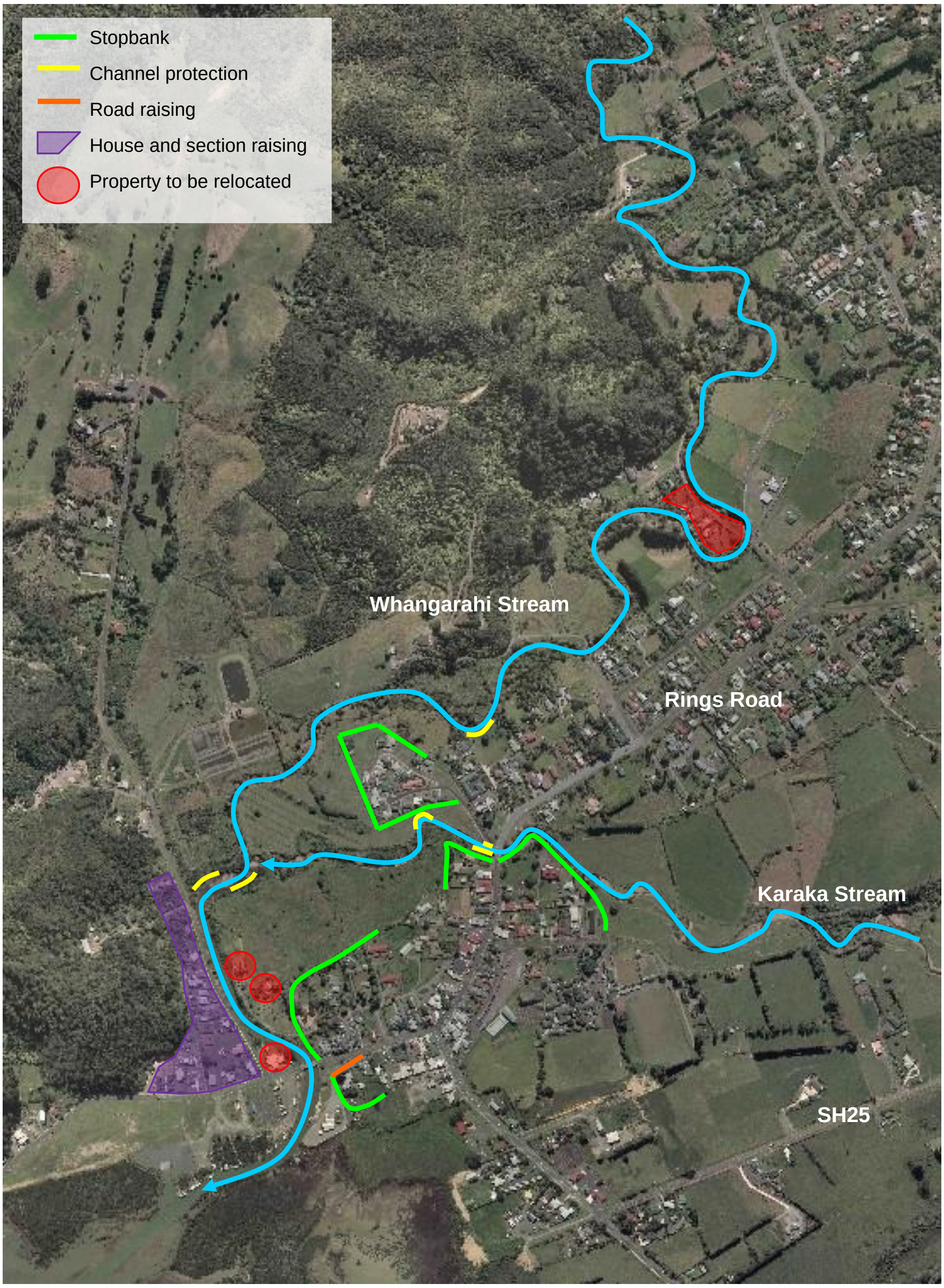


Figure 12 Proposed flood protection scheme for Coromandel

Consultation was undertaken with the community about the proposed scheme however feedback indicated that there was not a consensus to implement the full protection scheme. WRC worked with the community to implement a partial flood protection scheme for Coromandel town as discussed below.

5.2 Scheme evolution

Over the duration of the Peninsula Project, WRC undertook a staged approach to implementing a flood protection strategy for the Coromandel community. The various elements of the flood protection strategy were consulted on with the community and only those items that the community and Coromandel town working party agreed to were progressed.

In the first stage of this project, a full flood protection scheme was developed to address the flood hazard from the Whangarahi and Karaka streams to Coromandel town. However the community and the Coromandel town working party approved only three elements of WRC's proposed flood protection strategy including channel maintenance works, protection of the Elizabeth Park Retirement Village and channel improvement works. These three items were completed by 2005.

Early on in the project four properties on Albert Street were identified as being at particularly high risk and the councils agreed purchase and removal was necessary. Purchase of three of the properties was completed by 2008, with the final property being purchased in 2012.

A subsequent stage of works that was approved and completed included flood protection works on Karaka Stream in the vicinity of Kapanga Road bridge. These works provide protection to the central business district (CBD) and residential dwellings located in this area. These works were completed in 2010. A number of additional measures to reduce flood risk to the community in the lower CBD were also proposed at this time however the Coromandel town working party didn't approve the full suite of works. This is further discussed in Section 6.

Catchment management and soil conservation works programmes have also been established in Whangarahi and Karaka streams catchments to complement the flood mitigation works undertaken.

The components of the completed works are illustrated in Figure 13 below and are discussed in more detail in the following sections.

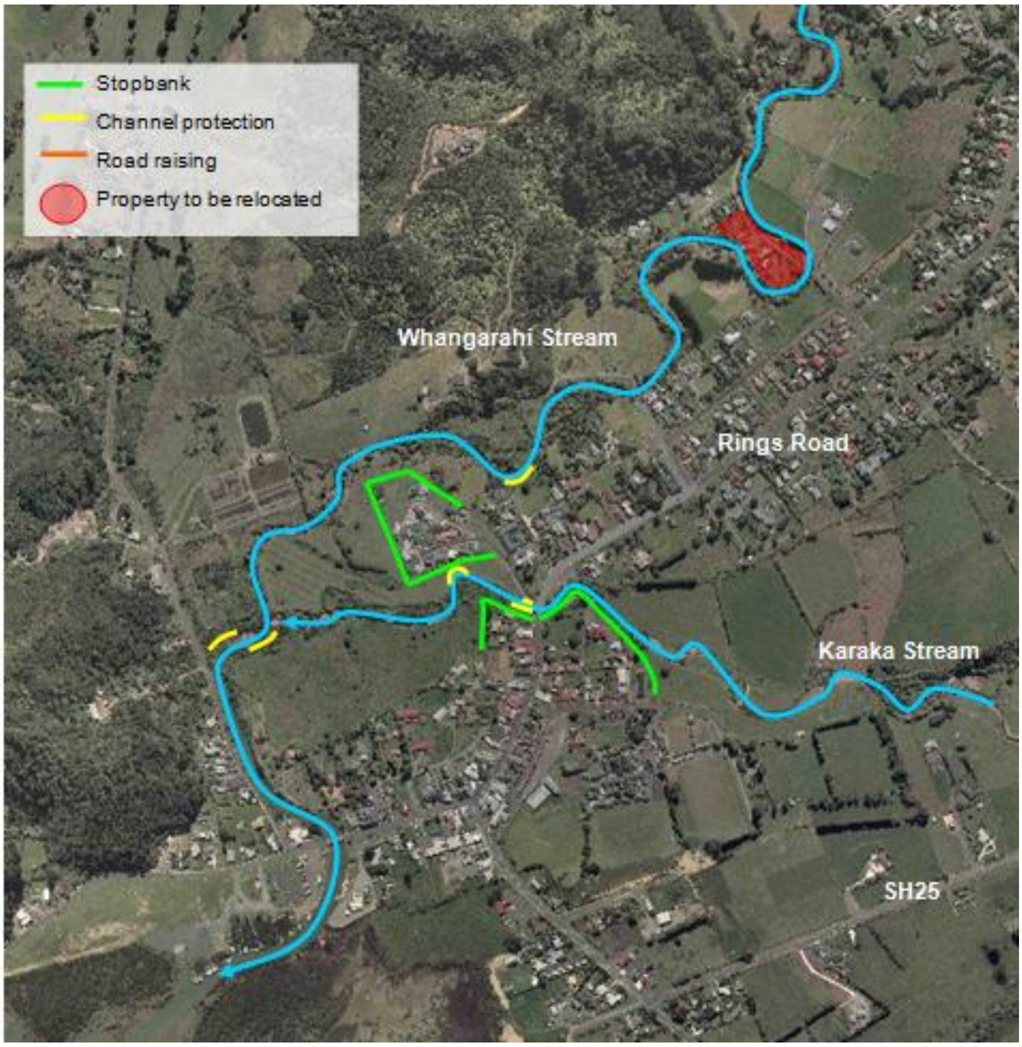


Figure 13 Completed flood mitigation works at Coromandel

5.3 Channel improvements

The Whangarahi and Karaka streams have been enlarged by WRC to remove localised restrictions. This work, which included some erosion protection, has improved the stability and capacity of these streams and reduced the risk to Coromandel town by containing flood events that would otherwise inundate adjacent land.

The proposed channel improvement works were aimed at enlarging the capacity of the existing channels to the maximum achievable capacity. The maximum capacity which can be achieved without destabilising the natural channel, causing significant effects on adjacent properties and the environment is generally the 10% AEP event. This upgrade was difficult to achieve within the lower sections of the Whangarahi Stream, as the 200 metre reach immediately upstream of the Wharf bridge is controlled by the tide level.

The channel improvements included the following works:

- Removal of channel restrictions identified by either WRC (work included the removal of 6,500m^3 of gravel from the stream beds) or the community (including the removal of riparian vegetation that was encroaching into the stream channel).

- Construction of erosion protection works (consisting of rock rip rap with gravel filter cloth cover) on the stream banks at critical bends (refer to Figure 14 for proposed extent of works).
- Construction of works to improve the management of flood flows from the 'golf course' catchment (ie channel widening and an improved waterway crossing for the Coromandel town wastewater treatment plant).
- Fencing and riparian planting along the Karaka Stream between the Kapanga Road bridge and SH25 for a 1000m channel length. Refer to Figure 15 for the indicative alignment.

Figure 14 Erosion protection works in the Whangarahi and Karaka streams

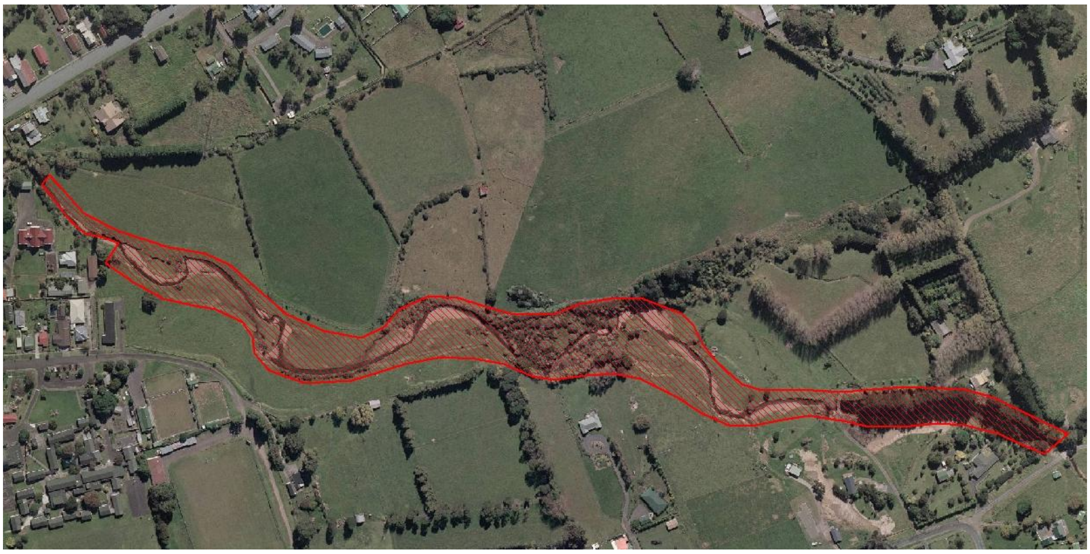


Figure 15 Fencing and planting along the Karaka Stream (upstream of Kapanga Road bridge)

5.4 Albert Street properties

Early on in the investigations for Coromandel town, it was identified that four properties on Albert Street were at particularly high risk from flooding from Whangarahi Stream. These four properties experienced severe flooding in the 2002 Weather Bomb and another event that occurred within a year of the weather boom. The four properties are unique in that they are bounded by the Whangarahi Stream to both the north and to the south due to a sharp loop in the stream's channel. Figure 16 below shows the location of the four properties on Albert Street.

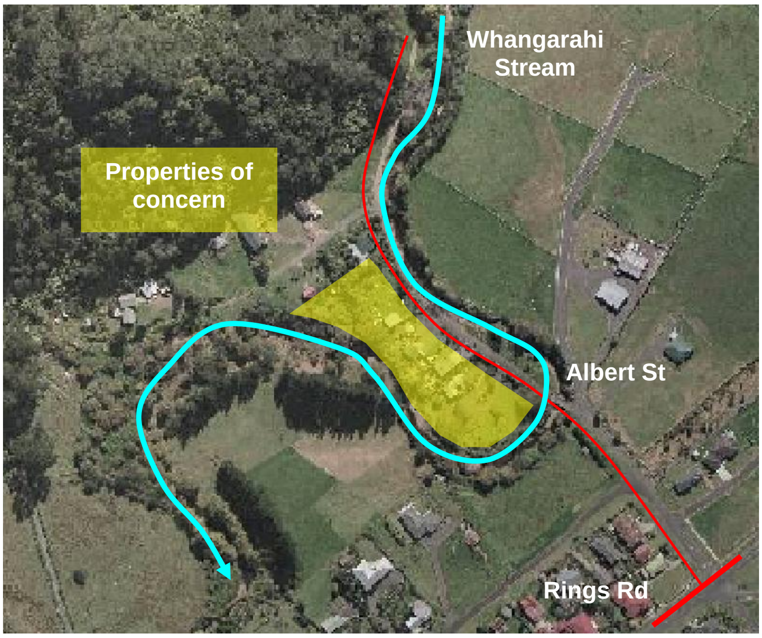


Figure 16 North western section of Albert Street

A risk assessment for the Albert Street properties identified:

- The properties are situated in the middle of the floodplain of the Whangarahi Stream.
- The properties experience flooding in events just exceeding the 20% AEP (5 year ARI) flood events and the risk to life exists in a 5% AEP (20 year ARI) event and above. Refer to Figure 17 below for an illustration of the overland flowpaths.
- The 1% AEP (100 year ARI) event flood through the Albert Street properties is characterised by flows coming in waves at around one metre deep, velocities exceeding 1m/s, carrying debris and silt, and with very little or no time for warning.
- The risk to life arising from a 1% AEP flood event is very high for properties in this area and is also above accepted international standards.
- Engineering solutions to protect these properties were explored and assessed as being not feasible technically and economically. In addition, any engineering solution would have a high residual risk.
- The removal of the properties from the floodway provides the only acceptable long term sustainable solution. Future use for this area of land should be restricted to open floodplain and/or development as a local purpose reserve.

In 2004 the two Councils sought and received a 30% contribution from central Government towards the cost of purchasing and retiring high risk properties as part of Peninsula Project, this included a contribution toward the purchase of the four Albert Street properties. The first three properties were purchased by 2008, and the final property was purchased in 2012.

Purchase of these properties completely removes the risks to life for these houses and doesn't incorporate residual risks. It also provides opportunities to improve the amenity values and access to the stream. It provides a long term solution for these properties and contributes substantially to improve the long-term community outcomes of the whole project.

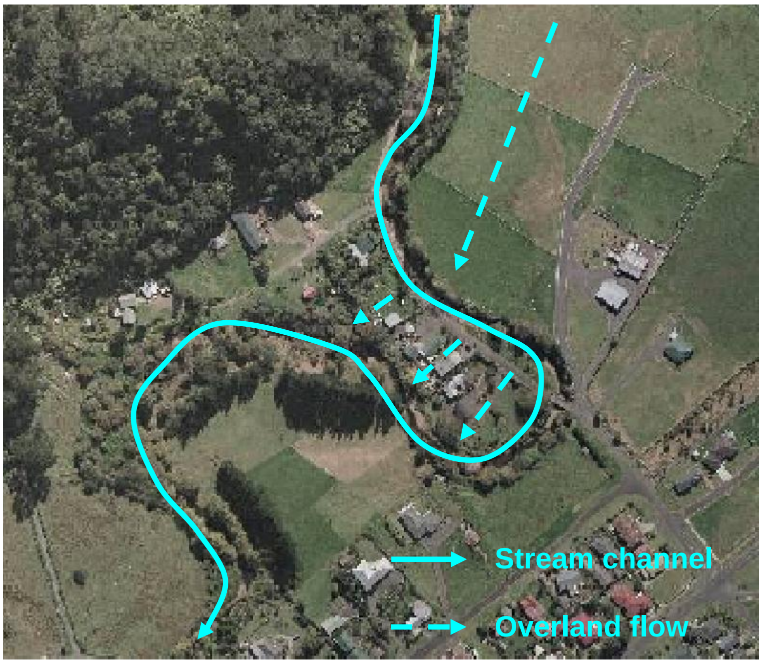


Figure 17 Overland flow across the Albert Street meander during significant flood events

5.5 Flood defences

WRC has constructed flood defences in Coromandel town, however, these defences only provide protection to a small number of properties (refer to Figure 18).

As illustrated, flood protection works have been constructed at two locations in Coromandel. The first provide protection to Elizabeth Park Retirement Village and the second were constructed to protect a portion of the CBD area and residential dwellings, in the vicinity of Kapanga Road bridge. This section provides details about what was constructed.

Figure 18 Flood defences in Coromandel town

5.5.1 Elizabeth Park Retirement Village flood defences

The retirement village residents through their representative on the Coromandel town working party requested that WRC construct flood defences (in the form of a stopbank) around their village to provide protection from the 1% AEP flood event.

The works included the construction of a 1-2m high stopbank around the Elizabeth Park Retirement Village, on retirement village property. The design standard for the stopbank is the 1% AEP flood level plus 500mm freeboard. The indicative alignment of the constructed flood defences is shown in Figure 19. As-built survey information for the flood defences is provided in Appendix 3.

Figure 19 Flood defence constructed at Elizabeth Park Retirement Village

5.5.2 Karaka Stream flood defences

The community agreed to the construction of flood defences on the Karaka Stream in the vicinity of Kapanga Road bridge. The flood defences included the construction of a flood wall/stopbank on the left bank and spillway provision on the right bank to the north of Kapanga Road bridge. The latter item is to formalise the existing spillway from the right bank, to the north of the bridge that spills over Kapanga Road and then re-enters the channel.

Design details for what was constructed are included in Appendix 2 and WRC DM#1536543. The design standard for the stopbank is the 1% AEP flood level plus 500mm freeboard. The indicative alignment of the constructed flood defences is shown in Figure 20. As-built survey information for the flood defences is provided in Appendix 3.

Figure 20 Flood defence constructed at Kapanga Road bridge

6 Future works

6.1 Outstanding scheme components

As discussed above, the Coromandel community did not agree to the implementation of the full flood protection scheme that WRC proposed. This means that parts of the community are still subject to flood hazard from stream flooding from the Whangarahi and Karaka streams. The flood hazard is discussed further in Section 9.

Of the proposed full scheme the following items are still outstanding:

- Provision for adequate floodway within the current floodplain, by relocating several at-risk properties located in the lower reach of the Whangarahi Stream floodplain (two residential and one commercial). The locations of the properties are illustrated in Figure 21 below. This property purchase would help to keep the Whangarahi Stream floodway free of obstructions and ensure no future development in this area.

- The provision of a stopbank/floodwall along the left bank of the Whangarahi Stream in the lower CBD.

- Raise the land and buildings on the right bank of the Whangarahi Stream on Hauraki Road.

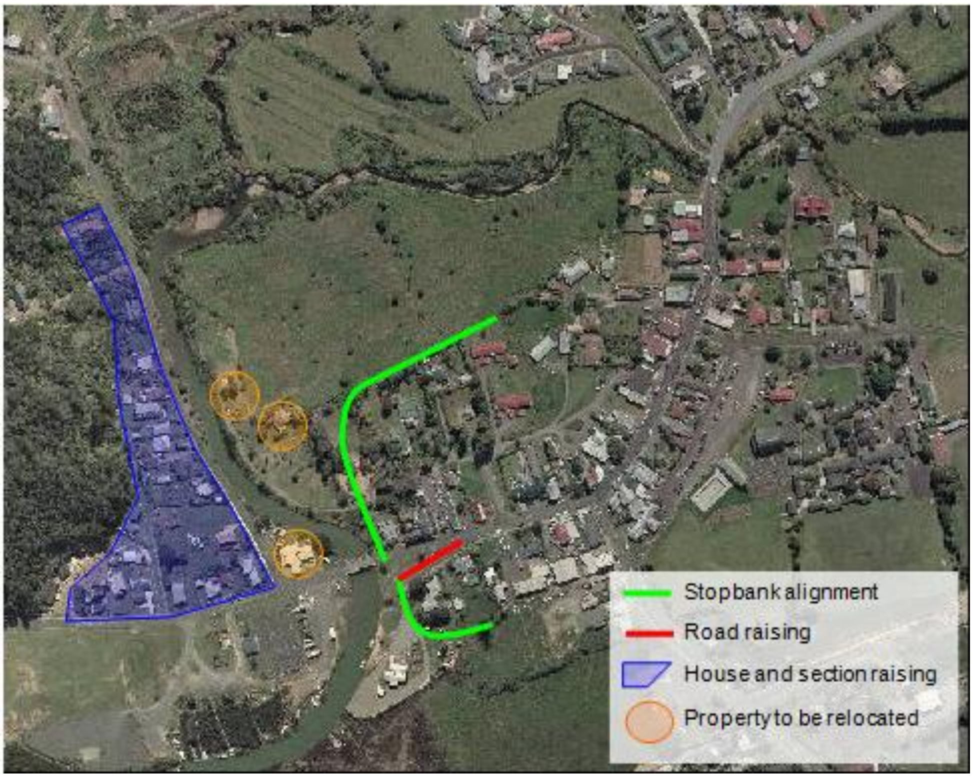


Figure 21 Proposed future flood protection mitigation measures

The following outlines the key aspects of these components of the full proposed scheme:

Whangarahi Stream left bank (Wharf Road/Pottery Lane)
Construction of a stopbank along the property boundaries, excluding a wide floodplain along the left bank of the Karaka Stream, which then runs along the left bank of the lower

Whangarahi Stream down to the Wharf Road bridge, and then to the south of the bridge to tie in to high ground. Road raising is also recommended for this option to protect the properties to the south of Wharf Road in case of flows spilling across Wharf Road from the north.

Several private properties (0 & 1 Pottery Lane) would need to be relocated to ensure adequate floodway is retained to pass future flood events at appropriate levels.

Whangarahi Stream right bank (Hauraki Road/Wharf Road)
On the right bank of the Whangarahi Stream there are nineteen residential dwellings that would need to be raised, and a motel with eight buildings, seven of which would need to be raised to be above the design flood level (future 1% AEP flood level). A survey would need to be undertaken to assess the "raise-ability" of these buildings.

There is one commercial premises (226 Wharf Road) that is located in the centre of the Whangarahi Stream floodway that would need to be relocated to ensure adequate floodway, or some other form of management option would need to be provided.

There are a number of options of how house raising could be delivered:

- Raise houses only. Properties would still be at risk of flooding and there would be flood hazard issues associated with accessibility to properties during a flood event.
- Raise houses and fill the low ground within the sections. This option provides huge benefits for the property owners and is considered to provide the most sustainable community outcomes. The disadvantage relates to the discomfort during the redevelopment period and the raising of the houses.

It is important that the house raising on the right bank is undertaken prior to the stopbanking works on the left bank as the stopbank will divert flood waters back into the floodplain, hence increasing flood levels on the right bank. The level to which houses are raised along the right bank would take into account the diversion of flood waters from the stopbank.

There is an opportunity to progress with house and section raising of the properties on the immediate right bank of the Whangarahi Stream, thereby producing a barrier to protect the low lying houses on Wharf Road to the west of the bridge (filing would need to be continuous along Hauraki Road). This could reduce the overall number of house and sections that would need raising.

6.2 Managing the existing scenario

It is proposed that the community is consulted on the above listed scheme items at regular intervals to check whether there has been a shift in opinion about whether works could be progressed. It is possible that after the next big flood there may be a change in opinion.

The alternative to the implementation of the flood protection works discussed above is for the properties in the CBD area to remain as they are with no protection works to mitigate flood risk, other than those already provided by Waikato Regional Council (including flood defences, catchment management, channel maintenance and improvement works).

Under this existing scenario, planning controls are applied to areas at flood risk restricting future development within the area via the proposed natural hazards variation to the Thames-Coromandel District Plan.

It is important that residents and property owners are aware of the level of flood hazard that they are still exposed to and the implications on their future plans for their properties under the existing scenario.

7 Agreed levels of service

The Coromandel zone management plan (River and Catchment Services et al, 2011) outlines the agreed levels of service for the Coromandel. The agreed levels of service provided for the Coromandel zone were initially developed when the Peninsula Project was established in 2004. The current service levels were confirmed through an extensive consultation process initially undertaken in 2003/04, and subsequently updated by the LTP processes in 2006 and 2009.

In the Coromandel zone management plan the Thames coast, including Coromandel town, is identified as a high priority area for flood protection schemes and for upper catchment protection through animal pest control (feral goats and possums). Additional works could focus on hill side erosion and stabilising erosion prone pastoral lands. The Thames Coast has a direct relationship to the Firth of Thames.

The flood protection scheme on Whangarahi and Karaka streams in Coromandel is identified as needing to be maintained and managed to ensure the level of service for flood protection assets is maintained. The level of service provided by the scheme at Elizabeth Park Retirement Village and on Karaka Stream in the vicinity of the Kapanga Road Bridge is the existing 1% AEP event (without climate change) plus 500mm freeboard. The general location of the flood protection assets is shown in Figure 22 below. Refer to Appendix 2 for design details for the flood protection works on Karaka Stream. As-built survey data is provided in Appendix 3.

Figure 22 Flood defences in Coromandel town

Routine river management is identified for high priority catchments to reduce the risks of localised flooding through removal of willow congestion and blockages and to provide long term environmental benefits through improved water quality, keeping stock out of stream and fencing and planting of stream banks to reduce stream bank erosion. Details of the annual operation and maintenance programme undertaken on the Whangarahi and Karaka streams is discussed in Section 8.

8 Operation and maintenance

The Whangarahi and Karaka streams are monitored and periodically maintained by the WRC to remove accumulated sediment and debris, refer to Figure 23 below for the indicative extent of works. This work maintains the capacity of these streams and reduces the risk to adjacent land that would otherwise be inundated more frequently from stream flooding.

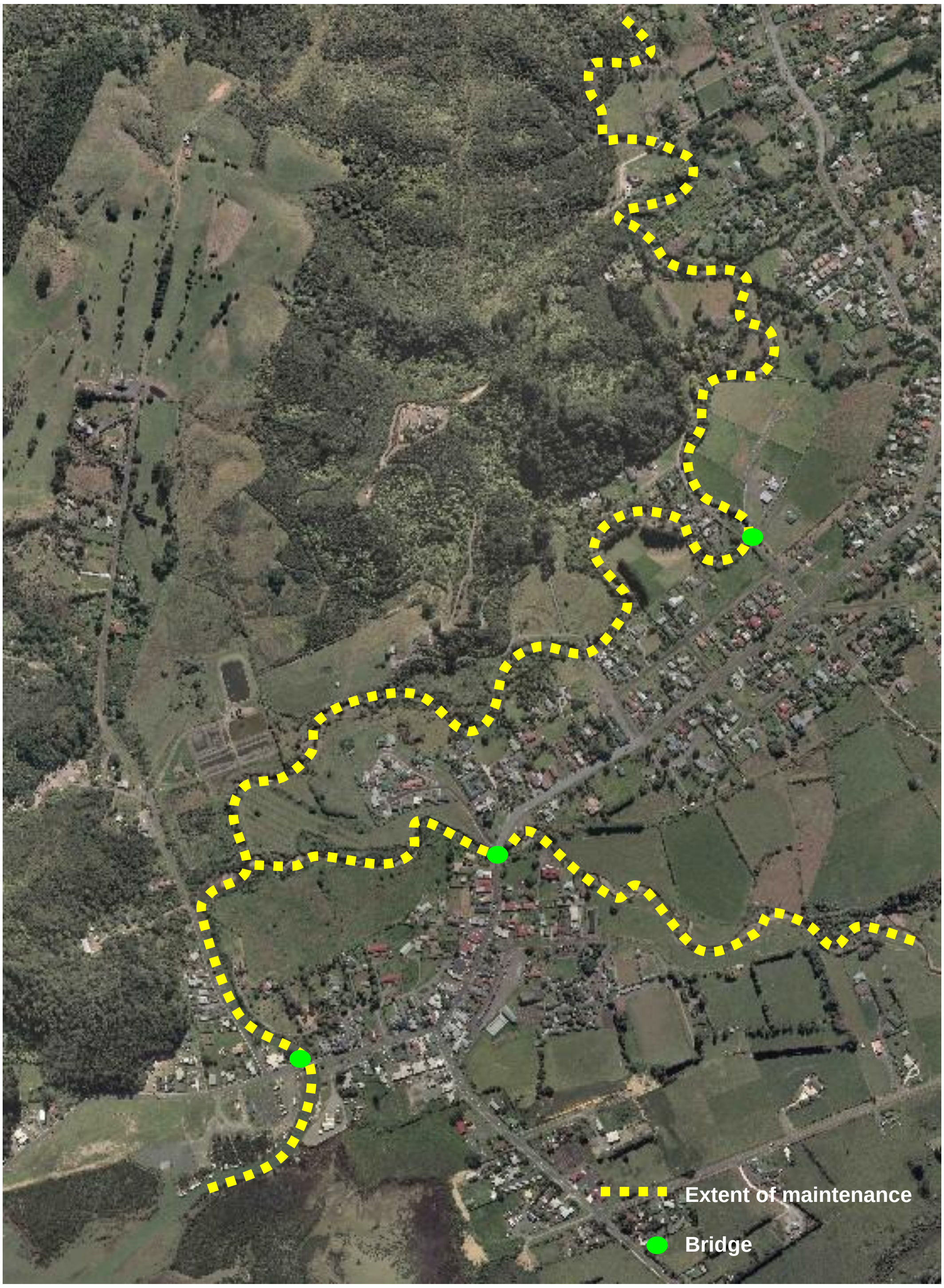


Figure 23 Extent of channel maintenance

The annual maintenance programme includes the removal of accumulating gravel and sediment in the Whangarahi and Karaka streams, based on current cross sectional areas. These works are carried after annual inspection and monitoring of changes in the streams. The specific activities associated with this annual work programme include:

- Removal of accumulated gravel, sand and debris from a 3730 m section of the Whangarahi Stream (refer to diagram for proposed extent).

- Removal of accumulated gravel, sand and debris from a 1500 m section of the Karaka Stream (refer to diagram for proposed extent).

- Removal of accumulated gravel, sand and debris from under the Albert Street bridge across the Whangarahi Stream and under the Kapanga Road bridge across the Karaka Stream.

- Removal of accumulated sand, silt and debris from the 430 m long tidal section of the Whangarahi Stream (refer to diagram for proposed extent).

- Removal of accumulated sand, silt and debris from under the Wharf Road Bridge across the Whangarahi Stream.

Constructed flood protection works at Elizabeth Park Retirement Village (constructed clay stopbank) and on Karaka Stream (predominantly flood wall with some combination flood wall and clay bulking and some sections constructed clay stopbank) are inspected annually for:

- Visible damage to the sections of flood wall.

- Visible damage to the batter slope and crest of the sections of clay stopbank.

- Any associated stream channel erosion and scour and potential undermining of flood protection assets.

Any necessary repair work is undertaken as required.

Stopbank crest level surveys are undertaken on a 10 yearly cycle and topped up where necessary.

This maintenance programme is consistent with other stopbanks managed by WRC in the Waikato region (eg the Lower Waikato Waipa Control Scheme).

9 Flood hazard assessment

9.1 River flood hazard classification

A river flood hazard classification describes the significance of river flooding with regard to the likely impact on people and property. The classification that forms part of this assessment has been developed using the following considerations:

- Floodwaters have the potential to cause a person to become unstable and unable to manoeuvre. International research suggests that there is a danger of being knocked over when the product of the flood depth and flood speed exceeds 0.5, with a significantly greater risk to life when the same product exceeds 1.0.

- Floodwaters have the potential to impede a person's ability to rescue themselves or others. When the flood depth exceeds 1.0 m (i.e. waist depth), a person's ability to navigate through flood waters (both on foot and using a vehicle) is restricted, therefore impeding the rescue of themselves and others.

- Floodwaters have the potential to damage buildings, both superficially and structurally. International research suggests that structural damage is likely when the flood speed exceeds 2 m/s. It is also likely that structurally weak points such as doors and windows will be damaged when the flood speed exceeds 1 m/s.

These considerations have been translated into a river flood hazard classification by first defining four distinct levels of river flood hazard based on the likely impact on people and property. These levels are outlined in Table 11.

Table 11 Description of river flood hazard categories

Category	Impact on people	Damage to property
Low	The combined depth and speed of floodwaters are unlikely to impede the manoeuvrability or stability of the average person.	Damage to property is likely to be non-structural and mainly due to inundation and deposition of sediment.
Medium	The combined depth and speed of floodwaters are likely to start to impede the manoeuvrability or stability of the average person.	Damage to property is unlikely to be structural provided that weak points such as windows and doors are retained above flood level.
High	The combined depth and speed of floodwaters are likely to significantly impede the manoeuvrability or stability of the average person.	Damage to property is likely to be widespread and structural, including instances where buildings have been raised above the 'flood level'.
Defended	This flood hazard category identifies land that is within an identified river flood hazard area but has subsequently included in a flood protection scheme that is managed and maintained by the Waikato Regional Council.	

The three levels of river flood hazard (low, medium and high) have then been quantified through the creation of a matrix that assigns a river flood hazard level based on the predicted depth and speed of flooding (refer to Figure 24).

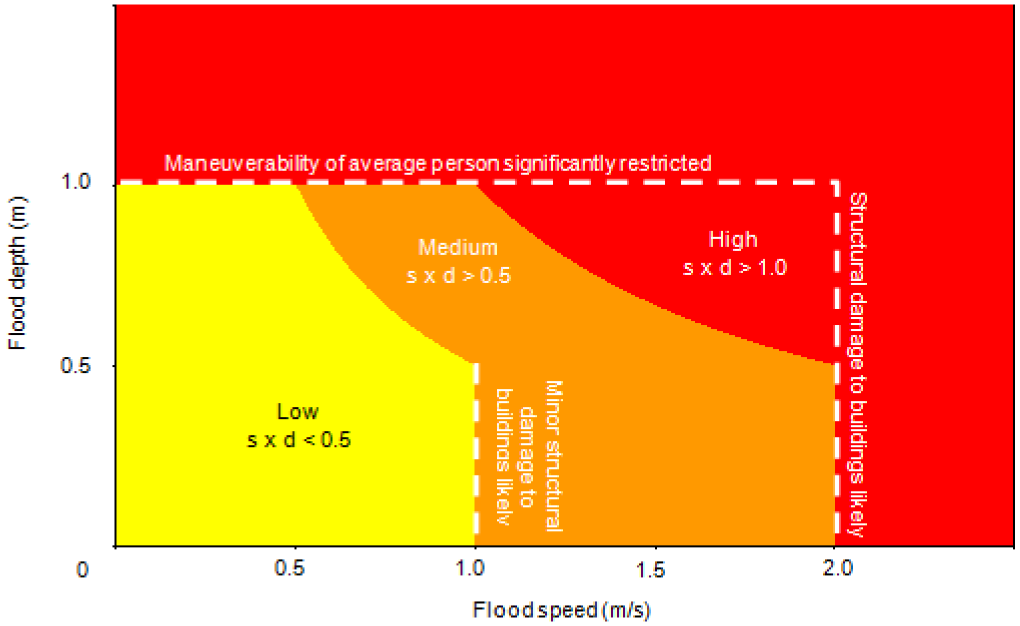


Figure 24 River flood hazard classification matrix

The following two scenarios also result in a 'high' flood hazard classification:

- Land that is surrounded by flooding that is classified as a 'high' flood hazard.
- Instances where floodwaters are directed by flood defences, including formal spillways.

The fourth level of flood hazard (i.e. defended) is intended to represent instances where a property is located within the natural floodplain but benefits from flood defences (e.g. floodwalls and stopbanks).

9.2 River flood hazard map

The river flooding information described in the sections above has been used to produce a river flood hazard map for Coromandel town due to the Whangarahi and Karaka streams. Figure 25 shows the flood hazard map for Coromandel town with the area that is now protected by the scheme shaded in blue to represent its 'Defended' status.

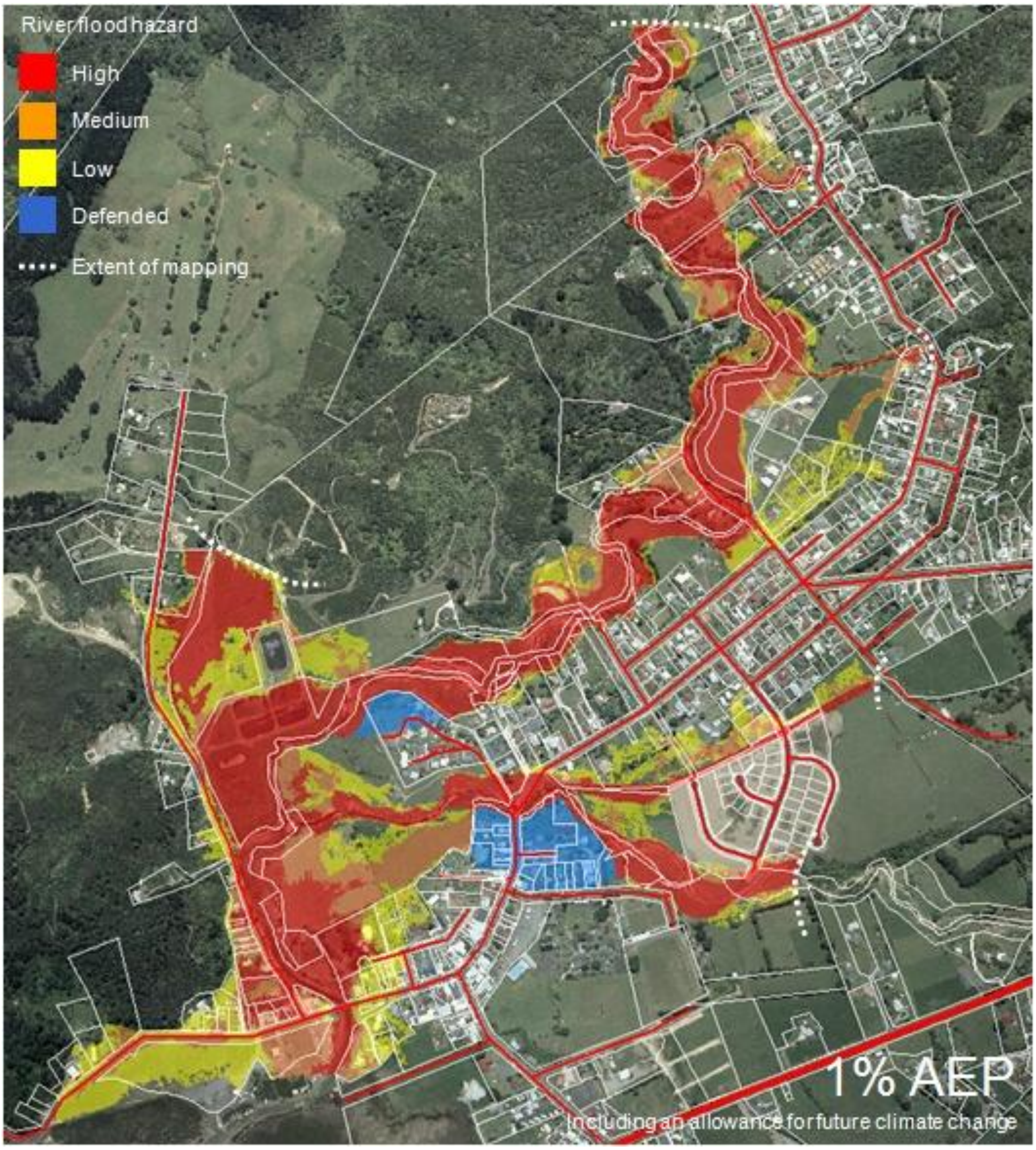


Figure 25 River flood hazard map for Coromandel

10 Residual flood risk

‘Residual flood risk’ is a term used to describe a river flood risk that exists due to the potential for ‘greater than design’ flood events to occur. The concept of residual flood risk is relatively new, but provides a more complete assessment of risk when compared with traditional approaches that rarely look beyond ‘design conditions’.

The residual flood risks that affect the Coromandel town are described as follows:

- Various parts of Coromandel town are subject to flood hazard from the Whangarahi and Karaka streams. A full flood protection scheme was developed for Coromandel town which was consulted on with the community, however the community decided that they only wanted a partial scheme constructed, hence there are still parts of Coromandel town that are subject to flood hazard.

- The river flood model used to design the flood protection scheme is based on a ‘design flood event’. There is however the potential for larger flood events to occur, resulting in wider, higher and faster flood waters.

- The river flood model used to design the flood protection scheme is based on surveyed channel cross sections for Whangarahi and Karaka streams and detailed ground level information, but excludes obstructions in the streams and associated floodplains such as informal bridges, buildings and walls. These obstructions may result in wider, higher and faster flood waters.

- The river flood model used to design the flood protection scheme incorporates the impacts of sediment and debris. However, there may be instances where sediment and debris causes localised changes to the flood extent, depth and speed. This includes debris flow events that will produce significantly different flooding characteristics.

- This river flood model used to design the flood protection scheme is only relevant to flooding caused by the Whangarahi and Karaka streams. However, there is also the potential for flooding to occur in other waterways and due to the overwhelming (or lack) of local land drainage infrastructure.

- The river flood model is based on the existing condition of the Whangarahi and Karaka streams catchments. Any significant change to this condition will affect the river flood hazard that affects the Coromandel town. For example, land use changes, deforestation and the intensification of development. Where significant changes do occur, this river flood model and associated flood protection scheme should be reviewed.

11 Planning controls

The proposed engineering works if completed in entirety, combined with river and catchment management activities, would protect most residential properties in Coromandel town from flood hazard from the Whangarahi and Karaka streams for the 1% AEP design event. Due to the incomplete nature of the works at Coromandel town, parts of the community are still subject to flood hazard from stream flooding as discussed in Sections 6 and 9.

Based on the flood hazard status of land in the community, TCDC has various planning controls in place via the Thames Coromandel District Plan, that restrict what land use activities can be undertaken. The planning controls include measures such as:

- No development or re-development allowed in the floodway, and in residual high risk areas.

- Minimum floor level restrictions and construction requirements (e.g. flood proofing) for areas not protected by the works.

- For other protected areas within the present flood hazard areas, limited floor level restrictions would have to apply.

Refer to the Thames Coromandel District Plan and Thames Coromandel district council staff for details.

12 Scheme review

The Coromandel zone management plan outlines agreed levels of service for the flood protection schemes on the Coromandel, including commentary on scheme reviews. It is stated that river and flood protection schemes will provide the standard of flood protection agreed with the community, and that this will be achieved by:

- Maintaining stopbanks to the design heights, achieving performance grade 3 or better.
- Responding to flood events by alerting communities prior to events, continuously monitoring river systems, undertaking emergency remedial works and reviewing system performance and maintenance requirements following flood events.
- Undertaking ongoing visual inspections of flood protection structures, reporting formally on an annual basis and following up on maintenance and repair requirements following flood events.
- Reporting annually to the subcommittee and Catchment Services Committee on flood protection performance measures.
- Undertaking flood protection works within consent conditions.
- Making the likelihood and consequences of greater-than-design flood events clear to communities and providing advice for communities on managing these risks (residual flood risks).
- Conducting all flood protection work in accordance with Council health and safety policies.

The following procedures will measure whether performance targets are achieved:

- Annual performance and condition inspections.
- Yearly performance measures reports to subcommittee and Catchment Services Committee.
- Assessing ongoing changes to catchments, and undertaking design flood level reviews once every 5 years as required.
- Annual health & safety audits.

The river flood model and hence the design of the flood mitigation scheme is based on the existing condition of the Whangarahi and Karaka streams catchments. Any significant change to this condition, for example land use intensification or deforestation, will affect the assumptions of the river flood model and hence compromise the basis of the scheme design. Where significant changes do occur, the river flood model and associated flood mitigation scheme should be reviewed.

Due to feedback from the community the full flood mitigation scheme for Coromandel town was not constructed. If feedback from the community indicates that the community wants to increase their level of protection and are able to fund the works, then the scheme would be reviewed and completed if practicable.

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Appendix 1 Peer review of hydraulic model

Environment Waikato
P O Box 4010
Hamilton East 3247

10 September 2009

Attention: Megan Wood

Dear Megan

Peer review of bridge modelling on Karaka Stream, Coromandel

1. Introduction

Kapanga Road bridge spans the Karaka Stream to the north of the Coromandel CBD. Environment Waikato (EW) is designing stopbank defences on the left bank both upstream and downstream of the bridge. An operational spillway across Kapanga Road is present on the right bank which is believed to pose minimal flood risk to buildings for at least the design flood event, being the 100 year annual recurrence interval (ARI) flood event.

Stopbank design crest levels are to be based on the results of a MIKE11 model originally developed by EW for the present day 100 year ARI plus a 500 mm freeboard. The design crest levels will also be checked against the future climate change 100 year event to ensure that adequate freeboard is retained. The MIKE11 hydraulic model includes the Whangarahi Stream and its tributary the Karaka Stream, including the spillway.

The primary interest of this review is the Karaka Stream reach and the Kapanga Road spillway and bridge structure, although some other related model features outside this area have been examined.

Recently a footbridge has been constructed on the upstream side of the Kapanga Road bridge, aligned parallel and immediately adjacent, this has been taken into account in the model developed by EW.

2. EW Hydraulic Models

EW has provided 3 different MIKE11 hydraulic models:

- 100y Existing - Present day 100 year ARI discharge for existing situation.
- 100y with stopbanks - Present day 100 year ARI discharge with inclusion of proposed stopbanks.
- 100y CC with stopbanks – Future climate change 100 year ARI discharge with inclusion of stopbanks.

3. Model Datum

EW documents state that the model datum relates to a local datum (origin of coordinates: SS70 S57224 (C3FK) – lead plug in Kapanga Road bridge). The model has been developed with data relating to this datum, including any LiDAR information which has been corrected to this datum. This information including relation to downstream sea level boundaries is assumed to be correct.

4. EW Model Review

The model network includes the Whangarahi Stream and its tributary the Karaka Stream, including the spillway. The primary interest of this review is the Karaka Stream between cross-sections ch.0 m and ch.420 m ('ID' 1-8), the Kapanga Road spillway, and bridge structures. These model components are most relevant to the proposed left bank defences.

4.1 Karaka Stream Cross-sections

The modelled reach of the Karaka Stream includes 11 ground survey cross-sections over 680 m. The surveyed cross-sections are 40 m to 100 m apart and provide reasonable representation of the channel.

All cross-sections in the model have the Radius Type set to Resistance Radius which for the

Karaka Stream and spillway is appropriate considering the channel geometry.

EW has added 2 estimated cross-sections at ch.260 m and ch.279 m for the purposes of modelling the bridge; these are discussed further in section 4.3.

4.2 Spillway Cross-sections and Weir

The Karaka spillway reach has been modelled by adding 7 cross-sections along its 100 m length. The cross-sections are derived from LiDAR data corrected to the local datum. The spillway reach is connected to the Karaka Stream reach where floodwaters are likely to exit and re-enter the main channel, ch.200 m and ch.360 m respectively. This appears reasonable based on the local topography and confirmed by previous MIKE21 modelling undertaken by EW which clearly shows the route of this right bank floodplain flowpath.

The crest of the spillway is essentially the centreline of Kapanga Road. A 'broad-crested weir' has been applied to the model at this location, the weir represented by the road centreline cross-section (spillway ch.24 m). Flow is initiated over the 'weir' when modelled flood levels exceed RL 7.17 m. Free overflow Q/h relations have been calculated based on the spillway cross-sections.

Orientation of the spillway cross-sections and representation of the spillway is considered appropriate. Although the two upstream cross-sections including the weir crest need to be extended above all modelled flood levels. This has been done as part of the HMS remodelling in section 5.

4.3 Kapanga Road Bridge & Footbridge

The Kapanga Road bridge spans the Karaka Stream, more recently a footbridge has been constructed on the upstream side of the road bridge. The new footbridge has been constructed in parallel and immediately adjacent. Construction drawings provided by EW indicate that the footbridge structure does not change the existing bridge opening, and the footbridge soffit is above that of the road bridge.

EW has modelled both bridges as a single structure which is reasonable given their alignment, proximity and geometry. The bridges have been modelled using the 'culvert' function which is common practice; with a total culvert length of 12.7 m being the distance from the upstream edge of the footbridge to the downstream edge of the road bridge.

The culvert has been modelled with upstream and downstream inverts of RL 3.59 m and RL3.46 m respectively. The bridge soffit has been modelled 2.00 m above the upstream invert at RL 5.59m with a total cross-sectional area of 12.13 m2. According to EW documentation the culvert has been modelled with 37% blockage compared to as-built drawings. This explains the modelled soffit level being lower than the surveyed level of RL 6.32m provided by EW. As part of this review EW has requested that HMS update the modelled bridge with recent survey and not include allowance for blockage, this is discussed in section 5.

Modelling of the bridge does not allow for overtopping, which is suitable when modelled floodwaters immediately upstream of the bridge remain below deck level (RL 7.96 m – EW pers. com.). Floodwaters upstream of the bridge in excess of the soffit are able to form a backwater and head up to the spillway crest level of RL 7.17 m before this flowpath is activated. Overtopping of the bridge would occur when flood levels reached the deck level of RL 7.96 m, although handrails on both structures and potentially debris would inhibit overtopping at this level.

EW model results have been checked to ensure flood levels do not exceed the deck level. The 100y Climate Change model exceeds this flood level at ch.260 m with a peak flood level of RL 7.99 m. However, this is not significant in terms of overtopping considering handrails and potential debris, and it does not appear necessary to include an overtopping function for the events modelled.

Bridge 'culvert' cross-sections required upstream and downstream of the structure have been estimated at ch.260 m and ch.279 m. The modelling software calculations dictate that these cross-sections are to be greater in width than the culvert opening at all levels. The EW model has been developed to comply with this but by doing so the model creates greater cross-sectional area at lower elevations than the adjacent natural cross-sections surveyed. This is addressed in section 5 when updating the model with recent bridge survey.

4.4 Roughness

The EW model adopts a constant Manning's 'n' value of 0.05. This has been done to provide a conservative assessment for design purposes and is considered appropriate.

A Manning's 'n' value of 0.013 has been applied at the Kapanga Bridge model culvert; this is the default value and is reasonable.

4.4 HD File

The HD file is as per default settings apart from the following changes which are all considered appropriate:

- Wave Approximation is set to Higher Order Fully Dynamic.
- Global Manning value set to 0.05.
- Computation scheme Delta value increased from 0.5 to 0.6.

4.5 Inflows

Hydrology has not been reviewed as part of this scope of works, however all inflow time series are noted to have flat topped hydrographs. This may be due to the relationship between rainfall intensity throughout the event and the determined time of concentration. This is a matter for EW to ensure they are satisfied with the hydrology and discharge hydrographs used in the modelling.

Two inflow hydrographs are applied in the Karaka Stream, with peak discharges from both sources coinciding for a period of time:

- At the upstream extent (ch.0 m) a peak discharge of 82.5 m^3/s is applied, the peak is reached after 30 min and is constant for 15 min.
- At ch.200 m near the spillway confluence, a second smaller hydrograph is applied with a peak discharge of 10.4 m^3/s, the peak is reached after 5 min and is constant for 40 min.

Application of inflow time series is appropriate.

4.6 Downstream Boundary

The downstream boundary used in the model is a constant tide level of RL 2.88 m for both the existing and climate change scenarios, as the tidal effect on flood levels was deemed outside the area of influence for the study area.

EW advises that the lower boundary for the 100 year tide level is RL 2.2 m, and the 100 year climate change is RL 2.7 m, therefore the RL 2.88 m tide level used is conservative in both cases.

The tidal influence was tested lowering the boundary condition for the existing 100 year level from RL 2.88m to RL 2.2 m and found to have less than 20mm reduction in the area of interest.

The latest MfE climate change guidelines, "Preparing for coastal change: A guide for local government in New Zealand: (March 2009) make the following recommendations for sea level rise:

We recommend that for planning and decision timeframes out to the 2090's (2090-2099):

i. a base value sea-level rise of 0.5 m relative to the 1980-1999 average be used, along with
ii. an assessment of potential consequences from a range of possible higher sea-level rise values.

At the very least, all assessments should consider the consequences of a mean sea- level rise of at least 0.8 m relative to the 1980-1999 average. For longer planning and decision timeframes beyond the end of this century, we recommend an additional allowance for sea-level rise of 10 mm per year beyond 2100.

On this basis, a 0.5 m allowance for sea level rise is considered reasonable, although the effect of a 0.8 m increase should also be assessed.

In addition, the EW model does not appear to allow for storm surge as a result of low barometric pressures and strong persistent winds in a storm. MfE recommends a 1 m allowance is made for possible storm surge effects.

Considering the above, a test was undertaken on the '100 year CC with stopbanks' model in which the downstream boundary was set to RL 4.0 m, being the 100 year climate change tide level of RL 2.7 m plus 0.8 m sea level rise and a 1 m storm surge. Whilst the joint probability of such an event involving a 1 m storm surge, 100 year tide level and 100 year river discharge in both watercourses are greater than the 1% annual exceedance probability, the effect on water levels was assessed to be an increase ≤ 160 mm in lower Karaka Stream, ≤ 90 mm in the area of interest relating to the proposed stopbank, and ≤ 20 mm effect in spillway.

5. HMS Model Modifications

EW has requested that HMS make any changes considered appropriate to the model as part of this review. The following has been undertaken:

- Incorporate recent bridge survey data.
- Extending cross-sections (based on LiDAR data corrected to local datum) where necessary as modelled water levels exceed cross-section extents.
- Some modifications to channel markers. These are described in detail in the following sections.

5.1 Re-Modelling of Kapanga Bridge Structures

EW has requested that recent bridge survey detail be updated in the model and that blockage modelled at the bridge be removed. The recent survey gives a bridge opening cross-sectional area of 24.2 m^2, considering the minimum width of 9.1 m. This is approximately double that modelled by EW using 2004 survey and considering blockage.

The updated bridge survey was at first modelled for the 100 year existing case using a culvert function, and this enabled all flow to pass via the bridges with no activation of the spillway. This method does not allow for bridge skewness and also requires that cross-sections upstream and downstream of the culvert be greater in width than the culvert opening at all levels. This would give greater cross-sectional area at lower elevations than the surveyed natural channel both upstream and downstream of the bridge.

The bridges were remodelled as a single bridge structure using FHWA WSPRO bridge function allowing for skewness of 45 degrees and submergence of the entrance between soffit and deck level. Natural channel survey (Millington 2004 K6) immediately downstream of the bridge was used as upstream and downstream cross-sections at ch.260 m and ch.290 m, with the spacing between based on bridge opening width and bridge length. The invert of ch.260 m was raised based on the average channel grade to the upstream surveyed cross-section ch.210 m. The 2009 bridge survey data provided by EW was then used to model the internal bridge cross-section opening at ch.275 m; the bridge invert and soffit are RL 2.72 m and RL 6.32 m respectively, and joint bridge length of 12.7 m was retained, a roughness of Manning's M=70 was used.

5.2 Cross-section Extensions & Channel Markers

Various cross-sections in the EW model did not fully extend above modelled flood levels for all events. This review has only focused on cross-sections in the Karaka Stream upstream of ch.420 m, and those in the spillway. Left and right markers did not always reflect channel geometry and these were also revised.

Surveyed cross-sections transect coordinates were added in order to check orientation to flow and undertake cross-section extension with LIDAR corrected to local datum where necessary.

The following changes were made:

Karaka reach:

- ch.0 m adjusted LB and RB channel markers.
- ch.50 m extended LB by -20 m to RL 9.0 m.
- ch.50 m adjusted RB channel marker.
- ch.110 m extended LB by -5 m to RL 8.8 m.
- ch.110 m extended RB by 1 m to RL 8.5 m.
- ch.150 m adjusted LB and RB channel markers.
- ch.200 m extended LB -20 m to RL 8.0 m.
- ch.200 m extended RB 50 m to RL 8.0 m.
- ch.360 m extended LB -30 to RL 6.0 m.
- ch.360 m adjusted RB channel marker.
- ch.420 m extended LB -10m to RL 6.0 m.
- ch.420 m adjusted LB and RB channel markers.

Spillway reach:

- ch.0 m extended RB 30m to RL 8.0 m.
- ch.24.43 m extended RB 10m to RL 8.0 m.
- Weir Q/h recalculated accordingly.

6. Model Results

The HMS model produces lower flood levels primarily due to the representation of cross-sectional area at the bridge opening. The EW model accounted for 37% blockage, whilst the HMS modelling did not include this blockage as requested by EW. Recent survey of the bridge opening was also incorporated in the modelling and the bridges were modelled in a different way using the 'bridge' as opposed to 'culvert' function, allowing for skewness.

In the area of interest relating to the stopbanks (ch.0 m to ch.420 m), HMS modelled flood levels upstream of the bridges which were lower than the EW model results by ≤ 290 mm, and ≤ 110 mm at the spillway. Differences in modelled flood levels downstream of the bridges are ≤ 10 mm. This is the case for both present day and future climate change 100 year ARI events.

Tables 1 and 2 provide the results for both the EW and modified HMS models, including predicted flood levels, peak velocities and discharges at the bridge and spillway structures.

7. Conclusions

An EW MIKE11 model of the Karaka Stream including the Kapanga Road bridges and spillway has been reviewed. The model has also been updated with recent bridge survey and some changes made to various components.

Key changes which alter the modelled flood levels are representation of Kapanga Road bridges, removal of blockage allowance at the structures and inclusion of recent bridge survey. Other model modifications with less impact include the extension of various cross-sections above modelled floodwater levels and the positioning of channel geometry markers.

Modelling of the both the present day and future climate change 100 year ARI events shows that the flood levels modelled by HMS are ≤ 290 mm than those modelled by EW.

8. Applicability

This report has been prepared for Environment Waikato with respect to the brief provided to us and it may not be relied upon in other contexts or for any other purpose without review and agreement.

Prepared by:

Duncan Grant

Hydraulic Modelling Services Ltd

Table 1: Peak floodwater levels (RL m).

Chainage (m)		100y Existing			100y with stopbanks			100y CC with stopbanks		
Karaka Stream		EW	HMS	Difference	EW	HMS	Difference	EW	HMS	Difference
0		8.86	8.85	-0.01	8.93	8.90	-0.03	9.13	9.09	-0.04
50		8.67	8.66	-0.01	8.75	8.71	-0.04	8.96	8.91	-0.05
80		8.55	8.52	-0.03	8.61	8.57	-0.04	8.8	8.77	-0.03
110		8.28	8.23	-0.05	8.30	8.24	-0.06	8.48	8.44	-0.04
150		8.05	7.94	-0.11	8.06	7.93	-0.13	8.22	8.1	-0.12
200		7.96	7.85	-0.11	7.96	7.85	-0.11	8.09	8	-0.09
230		7.88	7.70	-0.18	7.88	7.71	-0.17	8.02	7.9	-0.12
260	HMS US Bridge XS	7.84	7.55	-0.29	7.85	7.56	-0.29	7.99	7.73	-0.26
279 [EW only]	EW US Bridge XS	6.30	n/a	n/a	6.38	n/a	n/a	6.46	n/a	n/a
290 [HMS only]	HMS DS Bridge XS	n/a	6.23	n/a	n/a	6.34	n/a	n/a	6.43	n/a
300 [EW only]	EW DS Bridge XS	6.05	n/a	n/a	6.14	n/a	n/a	6.24	n/a	n/a
325 [HMS only]		n/a	5.90	n/a	n/a	6.07	n/a	n/a	6.18	n/a
330 [EW only]		5.81	n/a	n/a	5.96	n/a	n/a	6.08	n/a	n/a
360		5.76	5.76	0.00	5.86	5.87	0.01	6.06	6.06	0.00
390		5.59	5.59	0.00	5.58	5.59	0.01	5.79	5.79	0.00
420		5.47	5.47	0.00	5.47	5.47	0.00	5.71	5.71	0.00
465		5.33	5.34	0.01	5.34	5.34	0.00	5.61	5.61	0.00
510		5.23	5.23	0.00	5.23	5.23	0.00	5.51	5.52	0.01
545		5.15	5.15	0.00	5.15	5.15	0.00	5.45	5.45	0.00
580		5.06	5.07	0.01	5.07	5.07	0.00	5.39	5.39	0.00
630		5.01	5.01	0.00	5.01	5.01	0.00	5.35	5.35	0.00
680		4.98	4.98	0.00	4.99	4.99	0.00	5.33	5.33	0.00
Spillway		EW	HMS	Difference	EW	HMS	Difference	EW	HMS	Difference
0		7.96	7.85	-0.11	7.96	7.85	-0.11	8.09	8	-0.09
45.94		7.44	7.33	-0.11	7.44	7.33	-0.11	7.57	7.47	-0.10
69.54		7.04	6.95	-0.09	7.04	6.95	-0.09	7.15	7.07	-0.08
78.32		6.67	6.58	-0.09	6.68	6.59	-0.09	6.81	6.73	-0.08
89.42		6.47	6.39	-0.08	6.49	6.40	-0.09	6.61	6.55	-0.06
99.18		5.76	5.76	0.00	5.86	5.87	0.01	6.06	6.06	0.00

Table 2: Peak discharges and velocities at bridges and spillway.

Peak discharge (m^3/s)	Existing 100y stopbanks		100y with stopbanks		100y CC with stopbanks	
	EW	HMS	EW	HMS	EW	HMS
Bridges	57.72	68.89	57.79	68.93	59.07	72.62
Spillway Weir	35.14	23.97	35.07	23.93	52.36	38.82
Peak Velocity (m/s)	Existing 100y stopbanks		100y with stopbanks		100y CC with stopbanks	
	EW	HMS	EW	HMS	EW	HMS
Bridges	4.76	4.50	4.77	4.30	4.87	4.42
Spillway Weir	1.90	1.74	1.90	1.74	2.05	1.94

Appendix 2 Flood defences design

Memo

File No:	Z21 F350
Date:	2 November 2009
To:	Roger Spooner
From:	Megan Wood
Subject:	**Karaka Stream flood protection - Design memo**

1.0 Introduction

The following provides design details for the flood protection works at Karaka Stream, Coromandel.

2.0 Design basis

The design is based on design flood levels derived from a MIKE-11 hydraulic model. The model was set up using cross section survey data from a survey undertaken by Millingtons (Dwg Ref 2474, 28/09/04).

The stopbank/floodwall has been designed to have a crest level that is equivalent to the 100 year design flood level plus 500mm freeboard. The design crest levels have been checked against the future 100 year event (climate change) plus 300mm freeboard.

A peer review has been undertaken of the hydraulic model by Hydraulic Modelling Services (HMS) refer to EWDOCS#1546257 (HMS, 10 September 2009) for the findings. As part of the peer review, HMS corrected any issues that were identified with the model. The reviewed and improved hydraulic model was then adopted as the design model.

3.0 Datum

The datum for the design is as per Millingtons survey (Origin of coordinates: SS70 SO57224 (C3FK) – lead plug in Kapanga Road Bridge)

4.0 Survey data

Millingtons survey produced cross sections along Karaka Stream. Cross sections K1 to K8 are relevant to the area of interest for these works.

Additional spot levels have been attained, refer to Attachment 1 (EWDOCS#1515368).

5.0 Flood protection works

<u>Existing situation</u>

The main controlling feature of the channel flow is the Kapanga Road Bridge. The Kapanga Road Bridge can pass flows in the order of 70 m^3/s, whereas the 100 year flow for Karaka Stream is in the order of 83 m^3/s. Flows in excess of the bridge capacity come out of channel upstream of the bridge and spill over the right bank, over Kapanga Road, through the TCDC property, before entering back into the channel downstream of the bridge. The spill location is shown on Figure 1 below.

<u>Proposal</u>
The flood protection works comprise the construction of approximately 355 metres of a combination of earth stopbank and timber floodwall on the left bank of Karaka Stream upstream and downstream of Kapanga Road Bridge. Where space permits an earth stopbank would be constructed in favour of a flood wall, however where there is insufficient space a flood wall will be constructed.

The following figure shows the key features of the system, including the existing spillway, and provides a preliminary alignment for the stopbank/flood wall. Note that the alignment will be finalised pending discussions with affected landowners, hence being shown as a dashed line.

Figure 1 Karaka Stream flood protection works

The following table provides design crest levels at cross sections K1 – K8, derived from the peer reviewed hydraulic model.

Table 1 Design crest levels

Cross section	Design crest levels (mRL)[1]
K1	9.4
K2	9.21
K3	8.74

K4	8.43
K5	8.38
K6	6.57
K7	6.37
K8	5.97

Note: [1] Based on 100 year design flood level with stopbanks plus 500mm freeboard

Using the above detailed design crest levels, the following provides a schedule of levels along a proposed alignment (a spreadsheet long section is provided in Attachment 2) using surveyed spot level information. A longsection and plan for construction will be developed following a detailed ground survey.

Note that the proposed crest level for the section of flood wall downstream of Kapanga Road Bridge has been raised above the required design level to provide a 900mm high wall to enable building a fence to a standard height. The design levels as provided in Table 1 are the consented levels and are what should be used for future service level reviews.

Table 2 Schedule of levels along proposed alignment

Chainage (m)	Location[1]	Approx. ground level (m RL)	Crest level (m RL)	Approx. height (m)	Comment
Left bank - upstream Kapanga Road Bridge					
0	V – U (K1)	9.49	9.40	-	Tie into high ground
42.4	T	8.84	9.31	0.47	
71.1	R (K2)	7.93	9.21	1.28	
98.2	Q	7.88	9.00	1.12	
130.8	P (K3)	8.79	8.74	-	
154.5	N	8.28	8.59	0.31	
180.8	XS K4		8.43		
193.3	K	7.93	8.41	0.48	
216	XS K5		8.38		
233.1	J	7.38	8.32	0.94	
264	I	7.86	8.21	0.35	
285.5	G – H	7.84	7.96	0.12	Tie into highway embankment
Left bank - downstream Kapanga Road Bridge					
0	A	6.57	7.47	0.90	Tie into highway embankment
34.7	B	6.17	7.07	0.90	
68.7	C	5.42	6.38	0.96	Follow back boundary to high ground

Note: [1] Refer to Attachment 1 for spot level locations A - V

6.0 Channel works

The current channel and bridge alignment is such that there is an almost 45 degree bend at the entrance to the Kapanga Road Bridge. This means there is increased risk of erosion and scour for the bridge abutment on the outside bend, and also for accumulation of debris during low flows.

It is proposed that the removal of sediment, gravel and debris is undertaken on the left bank upstream of the Kapanga Road Bridge, to widen the channel, and to smooth the approach to the bridge, hence improving the conveyance of flows.

The materials would be removed from the left bank for a distance of approximately 30 metres from the upstream edge of the bridge, for a width of approximately 5 metres, assuming a bank height of 2 metres the estimated volume of material to be removed is approximately 300 m^3. Due to the constant state of flux that streams are in, the amount of material to be removed would be ascertained on site at the time of works.

Once the flood protection works are constructed, it will be important to inspect the channel for areas of erosion, in particular the outside bend adjacent to 450 Kapanga Road and upstream of the bridge. Bank armouring may be required in these locations at some point in the future. Depending on the extent of works required this could be undertaken as part of regular channel maintenance.

7.0 Assessment of affected properties

With the construction of the stopbank, the flood waters are controlled to stay within the channel, hence there is generally a corresponding increase in flood level.

Predicted flood levels along the affected reach of the Karaka Stream have been reviewed for the pre-scheme and post-scheme scenarios to assess the difference in flood levels and the change is generally small. This is because the Kapanga Road Bridge is the main controlling factor on the conveyance of flood flows for this system for both scenarios.

The following table provides the flood level comparison for the 100 year design event for all properties located along the portion of Karaka Stream in the area of works.

Table 3 Flood level comparison

Property	**100 year flood level pre-scheme (m RL)**	**100 year flood level post-scheme (m RL)**	**Change in flood level (m)**	**Proposed protection status**
Property				
Main channel left bank				
185 Woollams Ave	8.66	8.71	0.05	Protected
155 Woollams Ave (Coromandel Area School)	7.94	7.94	0	Protected
230 Kapanga Road	7.94	7.94	0	Protected
279 Kapanga Road	5.83	5.97	0.14	Protected
283 Kapanga Road	5.83	5.97	0.14	Protected
Main channel right bank				
315 Woollams Ave	8.85	8.90	0.05	No protection
510 Kapanga Road	7.94	7.94	0	No protection
450 Kapanga Road	7.88	7.88	0	No protection

Property	100 year flood level pre-scheme (m RL)	100 year flood level post-scheme (m RL)	Change in flood level (m)	Proposed protection status
Spillway				
405 Kapanga Road	7.57	7.57	0	No protection
355 Kapanga Road	7.33	7.33	0	No protection
301 Kapanga Road	5.76	5.87	0.11	No protection
Accessway only				
3 Allman Drive (Elizabeth Park Retirement Village)	6.95	6.95	0.01	Retirement village protected
329 Kapanga Road	6.58	6.59	0.01	No protection
365 Kapanga Road	7.57	7.57	0	No protection
375 Kapanga Road	7.57	7.57	0	No protection
377 Kapanga Road	7.57	7.57	0	No protection
381 Kapanga Road	7.57	7.57	0	No protection
383 Kapanga Road	7.57	7.57	0	No protection
385 Kapanga Road	7.57	7.57	0	No protection
395 Kapanga Road	7.57	7.57	0	No protection

In general there is no increase in flood level, except at the upstream end of the proposed works (predicted increase of 50mm at 315 and 185 Woollams Ave) and at the outlet of the spillway downstream of Kapanga Road Bridge (predicted 140mm increase at 283 Kapanga Road and 110mm increase at 301 Kapanga Road). Of these properties 185 Woollams Ave and 283 Kapanga Road are to be protected, and for the remaining properties (315 Woollams Ave and 301 Kapanga Road) the effects are considered to be no more than minor given there are no buildings on these properties.

Several properties have been assessed in more detail due to their proximity to the stream channel or the spillway. The following table provides a comparison of floor levels to the 100 year design flood level.

Table 4 Flood level comparison – specific properties

Property	Floor level (m RL)	100 yr flood level pre-scheme (m RL)	100 yr flood level post-scheme (m RL)	Change in flood level (m)	100yr CC[1] flood level post-scheme (m RL)	Freeboard post-scheme (m)
450 Kapanga Road	7.86	7.88	7.88	0	8.03	-0.17
510 Kapanga Road	8.67	7.94	7.94	0	8.10	0.57
510 Kapanga Road (garage)	8.38	7.94	7.94	0	8.10	0.28
405 Kapanga Road	8.1	7.57	7.57	0	7.72	0.38

(Police Station)						
405 Kapanga Road (Police Station garage)	7.7	7.57	7.57	0	7.72	0.02
355 Kapanga Road (TCDC building)	7.95	7.33	7.33	0	7.47	0.48

NOTE:
[1] CC refers to climate change scenario (in general for habitable dwellings, TCDC requires 500mm freeboard above 100 year flood level taking into account climate change)

450 Kapanga Road is located on the right bank of Karaka Stream just upstream of the Kapanga Road Bridge. Flood wall/stopbank is to be constructed on the opposite side of the stream from this property. The floor level of the house at this property is RL7.86m which is lower than the pre-scheme existing 100 year flood level of RL7.88m; hence this building is currently vulnerable to flooding. With the works in place there is predicted to be no increase in flood level at this property, hence there is no requirement to provide flood protection. The most sustainable option for this property is for the landowner to raise their building and grounds to provide the appropriate freeboard.

510 Kapanga Road is located on the right bank, adjacent to 450 Kapanga Road. The floor level of the house at this property has sufficient freeboard above the climate change 100 year flood level (570mm). With the works in place there is predicted to be no increase in flood level on this property, hence there is no requirement to provide flood protection.

The floor levels of the police station and TCDC buildings are above the future 100 year flood levels (as these properties are commercial buildings they do not require 500mm freeboard above the climate change 100 year flood level). With the works in place there is predicted to be no increase in flood level at these properties, hence there is no requirement to provide flood protection.

8.0 Conclusion

Flood protection works are to be constructed on the left bank of the Karaka Stream, upstream and downstream of the Kapanga Road Bridge in Coromandel Town.

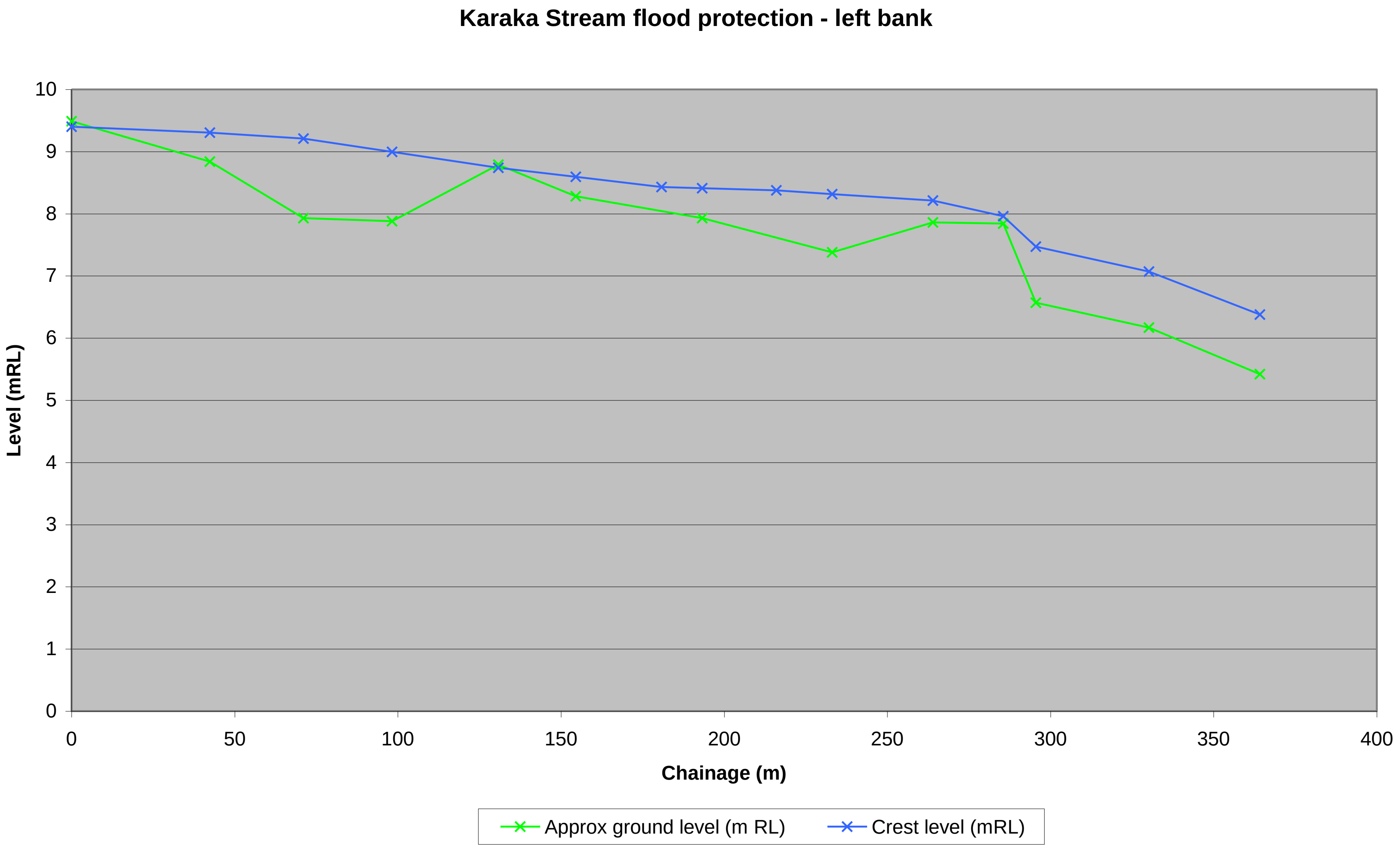
Works are to include:

- The construction of an earth bund stopbank where space permits, or a timber flood wall where space is limited, and
- Some minor channel works to smooth the channel alignment upstream of the bridge.

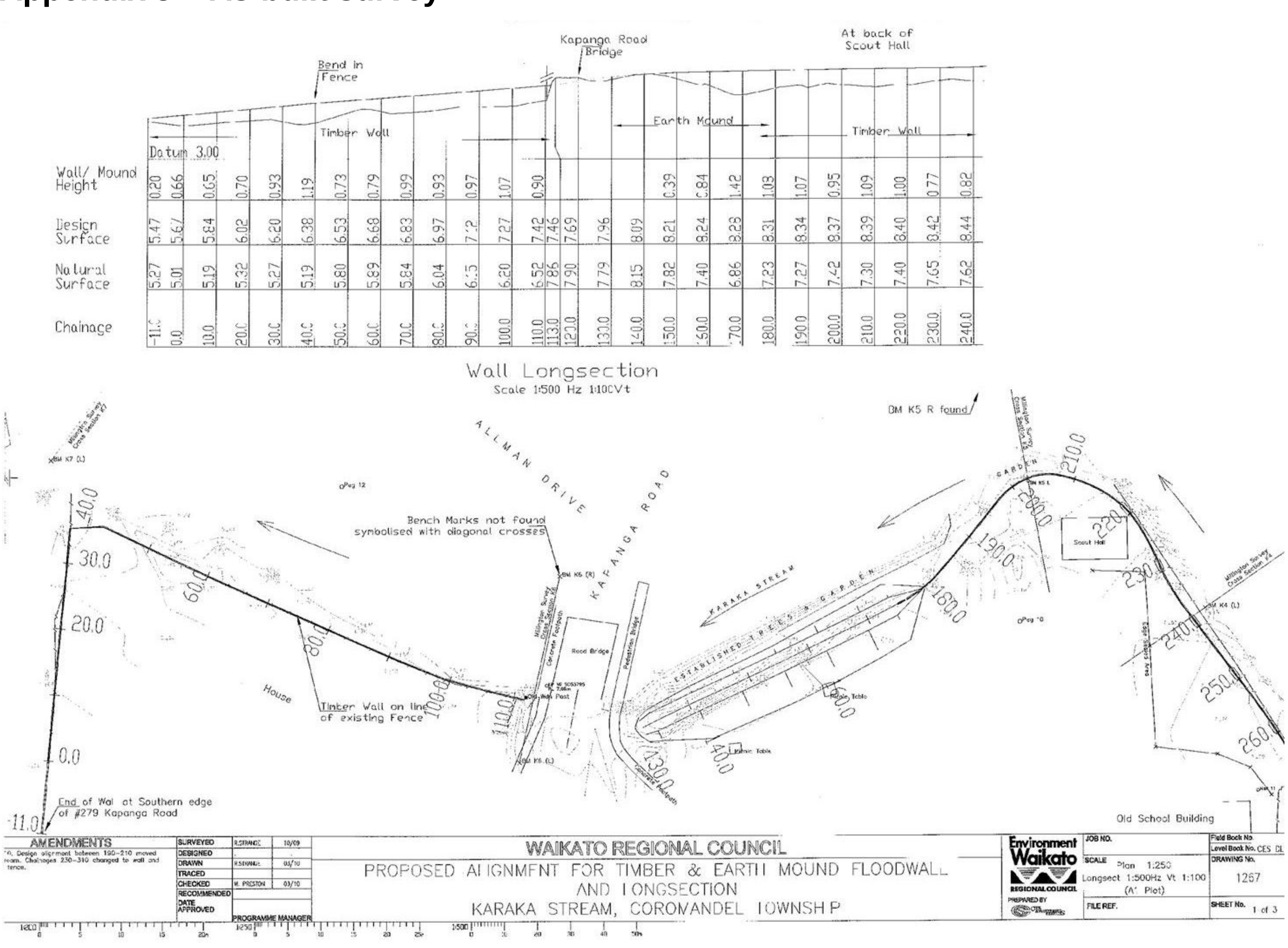
This memo provides design details for the works, sufficient for consultation with landowners. Once consultation is completed and the design is finalised, design drawings will be prepared.

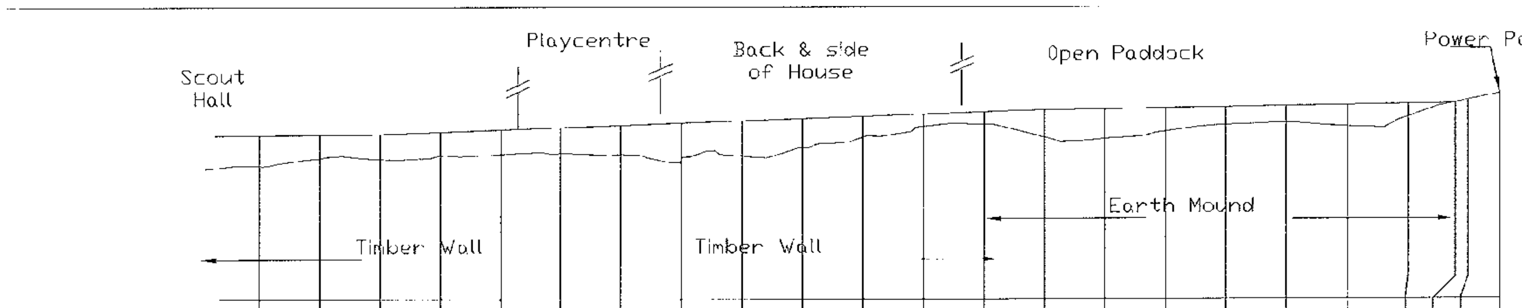
Attachment 1 Spot level locations

Attachment 2 Longsection



Appendix 3 As-built survey





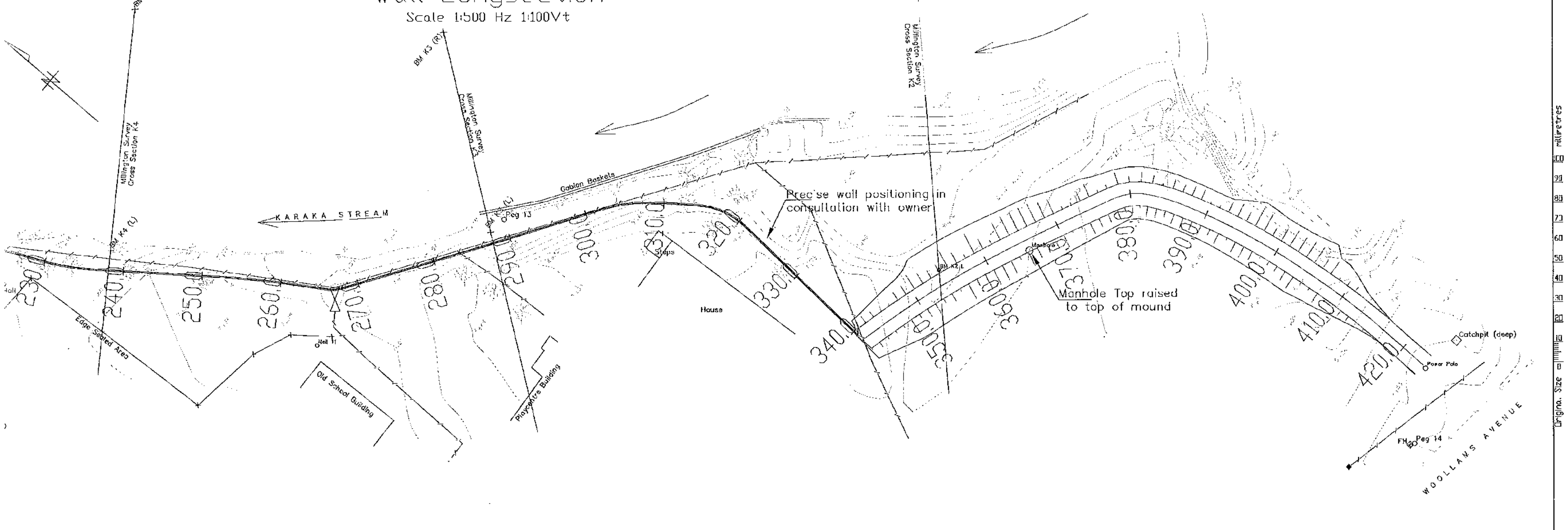
Chainage	Wall/ Mound Height	Design Surface	Natural Surface
220.0	1.00	8.40	7.40
230.0	0.77	8.42	7.65
240.0	0.82	8.44	7.62
250.0	0.79	8.51	7.73
260.0	0.81	8.59	7.78
270.0	0.85	8.66	7.81
280.0	0.96	8.73	7.77
290.0	1.24	8.80	7.56
300.0	1.16	8.87	7.72
310.0	0.95	8.95	8.00
320.0	0.68	9.02	8.33
330.0	0.41	9.09	8.68
340.0	0.41	9.16	8.75
350.0	0.89	9.22	8.33
360.0	0.97	9.25	8.28
370.0	0.77	9.28	8.51
380.0	0.58	9.31	8.73
390.0	0.56	9.34	8.79
400.0	0.70	9.37	8.67
410.0	0.42	9.40	8.98
417.8		9.43	9.44
420.0			9.53
425.3			9.69

Wall Longsection
Scale 1:500 Hz 1:100Vt

Survey Control Points <NZTM 2000 Datum>

No.	Northing	Easting	Elev	Code
520	5929102.91	1823010.91	7.96	LPVII SO53795
508	5929133.50	1823083.89	7.25	BM K5 L
509	5929159.16	1823079.11	6.89	BM K5 R
502	5929033.20	1823176.55	8.14	BM K2 L
500	5929015.18	1823253.52	9.21	BM K1 L
513	5929176.87	1822965.53	5.97	BM K7 R
10	5929112.32	1823082.54	7.95	Peg 10
11	5929086.74	1823118.47	7.71	Nail 11
12	5929132.98	1822979.85	6.53	PEG 12
13	5929079.00	1823145.84	7.47	PEG 13
14	5928973.49	1823198.71	9.80	PEG 14
Points not found				
501	5929065.88	1823215.05	8.80	BM K1 (R)
503	5929070.88	1823214.33	8.62	BM K2 (R)
504	5929079.28	1823143.51	7.27	BM K3 (L)
505	5929100.01	1823158.73	8.17	BM K3 (R)
506	5929114.33	1823110.59	7.68	BM K4 (L)
507	5929131.58	1823135.57	7.66	BM K4 (R)
510	5929091.31	1823006.78	7.56	BM K6 (L)
511	5929119.39	1823012.91	7.92	BM K6 (R)
512	5929136.89	1822935.67	4.84	BM K7 (L)
514	5929122.62	1822919.08	5.39	BM K8 (L)
515	5929183.28	1822886.25	6.40	BM K8 (R)

Notes:
-Heights in Mean Sea Level off 0LPVII S053795
RL 7.96m & marks on Millingtons survey September 2004.
-Contours at 0.2m interval
-Peg 13 & Nail 11 not intervisible



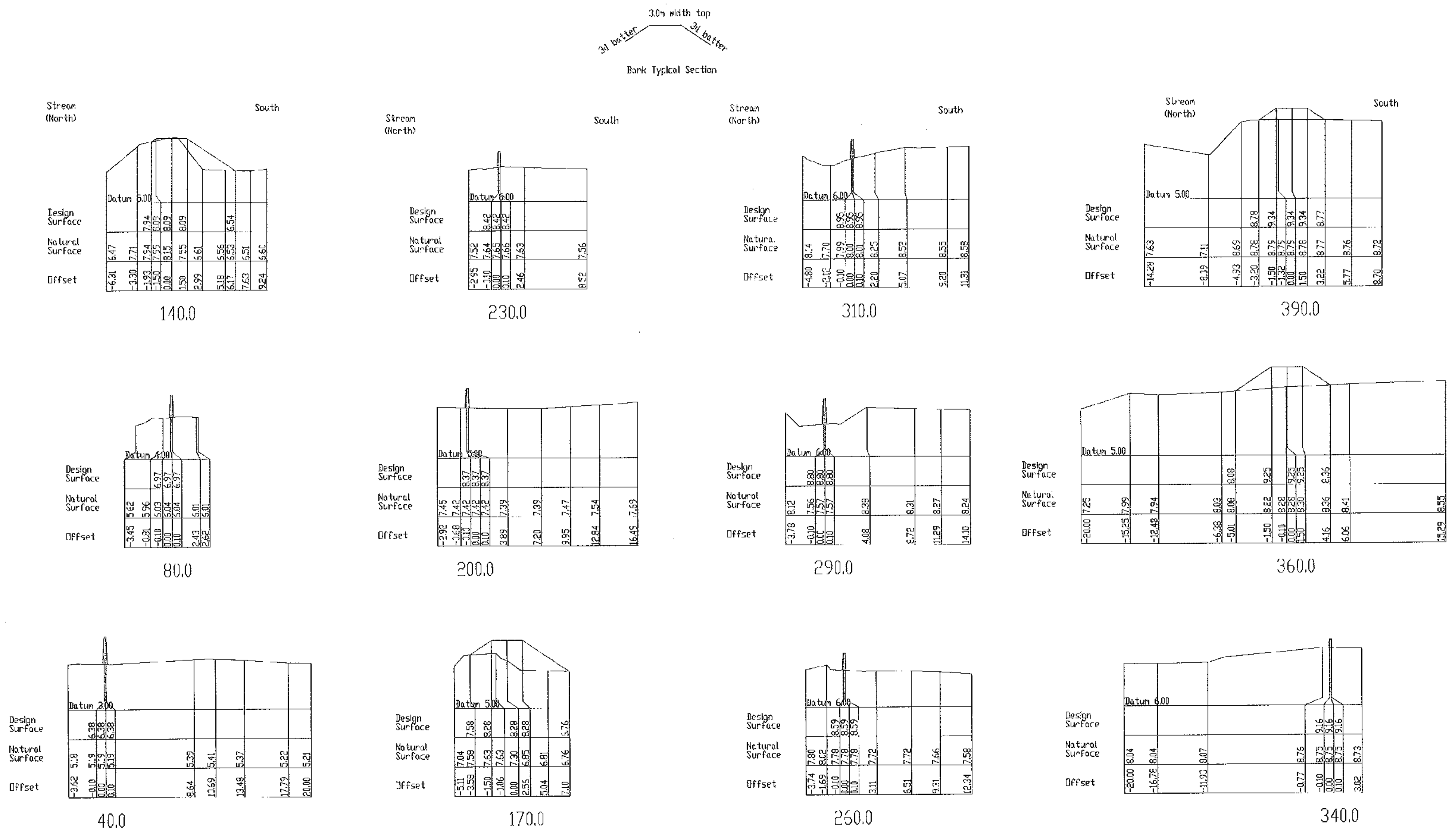
AMENDMENTS			
10. Design alignment between 190–210 moved (stream). Chainages 230–310 changed to wall and fence.	SURVEYED	R.STRANGE	10/09
	DESIGNED		
	DRAWN	R.STRANGE	03/10
	TRACED		
	CHECKED	M. PRESTON	03/10
	RECOMMENDED		
	DATE APPROVED	PROGRAMME MANAGER	

WAIKATO REGIONAL COUNCIL
PROPOSED ALIGNMENT FOR TIMBER & EARTH MOUND FLOODWALL AND LONGSECTION
KARAKA STREAM, COROMANDEL TOWNSHIP

Environment Waikato REGIONAL COUNCIL
PREPARED BY

JOB NO.		Field Book No.
SCALE	Plan 1:250 Longsect 1:500Hz 1:100Vt (A1 Plot)	Level Book No. CES DL
		DRAWING No. 1267
FILE REF.		SHEET No. 2 of 3

1:200 0 5 10 15 20m
1:250 0 5 10 15 20 25m
1:500 0 10 20 30 40 50m



ts in Mean Sea Level off OLPVII SC53795 RL 7.96m & marks on
ons survey September 2004.
Design Height from FW #doc 1537013 Preliminary design memo 3.

AMENDMENTS			
010. Design alignment between 190–210 moved ... tream. Chainages 230–310 changed to wall and ... fence.	SURVEYED	R.STRANGE	10/09
	DESIGNED		
	DRAWN	R.STRANGE	03/10
	TRACED		
	CHECKED	M. PRESTON	03/10
	RECOMMENDED		
	DATE APPROVED	PROGRAMME MANAGER	

WAIKATO REGIONAL COUNCIL

PROPOSED ALIGNMENT FOR TIMBER & EARTH MOUND FLOODWALL AND LONGSECTION

KARAKA STREAM, COROMANDEL TOWNSHIP

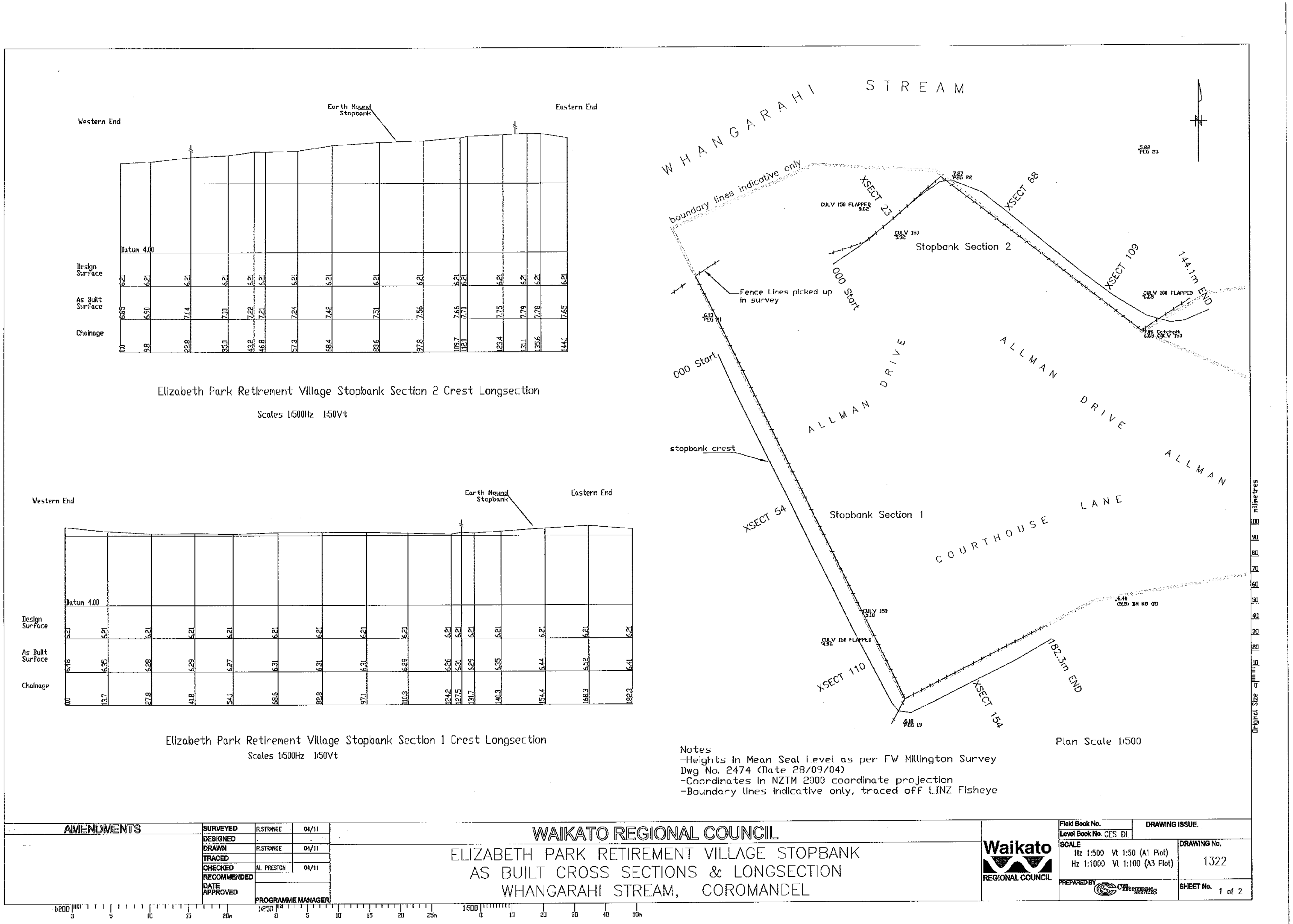
Environment Waikato REGIONAL COUNCIL

PREPARED BY

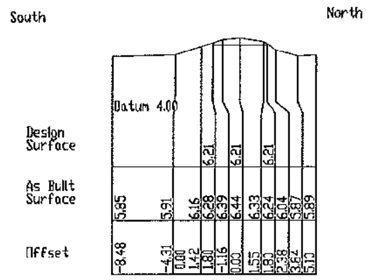
JOB NO.	
SCALE	1:200 Hz 1:100Vt (A1 Plot)
FILE REF.	

Field Book No.	
Level Book No.	CES DL
DRAWING No.	1267
SHEET No.	3 of 3

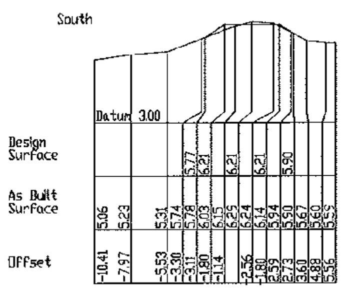
1:200 0 5 10 15 20m
1:250 0 5 10 15 20 25m
1:500 0 10 20 30 40 50m


WHANGARAHI STREAM
boundary lines indicative only
XSECT 23
XSECT 68
XSECT 109
XSECT 54
XSECT 110
XSECT 154
000 Start
144.1m END
182.3m END
Stopbank Section 2
Stopbank Section 1
Fence Lines picked up in survey
stopbank crest
ALLMAN DRIVE
ALLMAN DRIVE
ALLMAN
COURTHOUSE LANE
Plan Scale 1:500
Western End
Earth Mound Stopbank
Eastern End
Datum 4.00
Design Surface
As Built Surface
Chainage
Elizabeth Park Retirement Village Stopbank Section 2 Crest Longsection
Scales 1:500Hz 1:50Vt
Elizabeth Park Retirement Village Stopbank Section 1 Crest Longsection
Scales 1:500Hz 1:50Vt
Notes
-Heights in Mean Seal Level as per FW Millington Survey Dwg No. 2474 (Date 28/09/04)
-Coordinates in NZTM 2000 coordinate projection
-Boundary lines indicative only, traced off LINZ Fisheye
AMENDMENTS
SURVEYED R.STRANGE 04/11
DESIGNED
DRAWN R.STRANGE 04/11
TRACED
CHECKED N. PRESTON 04/11
RECOMMENDED
DATE APPROVED
PROGRAMME MANAGER
WAIKATO REGIONAL COUNCIL
ELIZABETH PARK RETIREMENT VILLAGE STOPBANK
AS BUILT CROSS SECTIONS & LONGSECTION
WHANGARAHI STREAM, COROMANDEL
Waikato REGIONAL COUNCIL
Field Book No.
Level Book No. CES 01
DRAWING ISSUE.
SCALE
Hz 1:500 Vt 1:50 (A1 Plot)
Hz 1:1000 Vt 1:100 (A3 Plot)
DRAWING No. 1322
PREPARED BY
SHEET No. 1 of 2

Stopbank Section 1

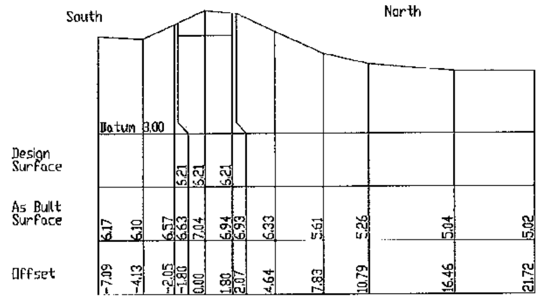


154.4

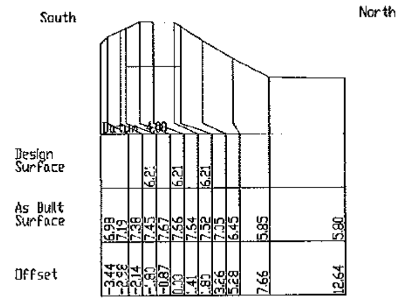


110.3

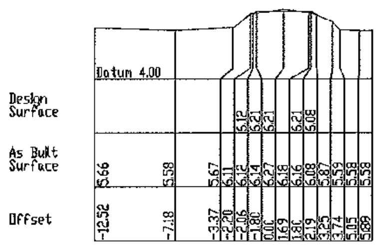
Stopbank Section 2



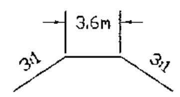
22.8



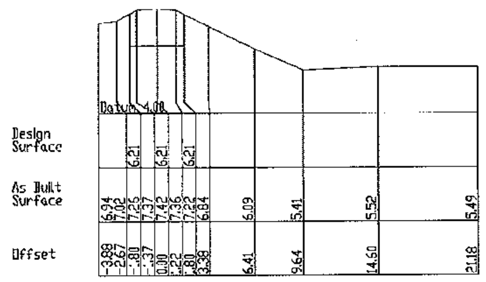
109.7



54.1



Design Stopbank Profile



68.4

Notes
-Heights in Mean Seal Level as per FW Millington Survey Dwg No. 2474 (Date 28/09/04)
-Coordinates in NZTM 2000 coordinate projection

Village Section 1 Crest NZTM Coords					
Northing	Easting	Height	Code	Chainage	Offset
5929262.29	1822759.11	6.484	CREST	0	0
5929249.77	1822764.78	6.346	CREST	13.736	0
5929237.2	1822771.03	6.278	CREST	27.776	0
5929224.65	1822777.28	6.291	CREST	41.795	0
5929213.62	1822782.79	6.268	CREST	54.126	0
5929200.63	1822789.1	6.309	CREST	68.569	0
5929187.85	1822795.45	6.311	CREST	82.838	0
5929175.04	1822801.68	6.31	CREST	97.087	0
5929163.35	1822807.81	6.291	CREST	110.278	0
5929151.01	1822814.3	6.261	CREST	124.23	0
5929148.46	1822816.41	6.307	CREST FCEL	127.535	0
5929147.91	1822820.5	6.288	CREST	131.666	0
5929151.64	1822828.29	6.349	CREST	140.301	0
5929157.98	1822840.84	6.439	CREST	154.365	0
5929164.14	1822853.37	6.519	CREST	168.327	0
5929171.11	1822865.51	6.413	CREST ST	182.324	0
5929170.32	1822791.94	4.964	CULV 150 FLAPPED		
5929179.44	1822805.15	5.183	CULV 150		

Control Points, NZTM Coords				
Point	Northing	Easting	Height	Code
520	5929102.91	1823010.91	7.96	LP VII SO53795
513	5929176.87	1822965.53	5.97	BM K7 R
514	5929122.62	1822919.08	5.39	BM K8 L
17	5929165.46	1822942.06	5.73	PEG 17
19	5929144.51	1822818.14	6.12	PEG 19
21	5929274.10	1822754.40	6.13	PEG 21
22	5929318.83	1822834.53	7.27	PEG 22
23	5929326.86	1822894.26	5.82	PEG 23

Village Section 2 Crest NZTM Coords					
Northing	Easting	Height	Code	Chainage	Offset
5929290.85	1822796.05	6.852	CREST ST	0	0
5929296.26	1822804.18	6.901	CREST	9.765	0
5929304.39	1822814.33	7.04	FCE	22.769	0
5929312.28	1822823.61	7.096	CREST	34.951	0
5929316.93	1822830.47	7.218	CREST	43.237	0
5929317.52	1822834.01	7.209	CREST	46.831	0
5929313.71	1822843.76	7.242	CREST	57.293	0
5929306.83	1822852.53	7.416	CREST	68.438	0
5929297.2	1822864.28	7.513	CREST	83.635	0
5929288.31	1822875.26	7.561	CREST	97.759	0
5929281.29	1822884.85	7.658	CREST	109.645	0
5929279.94	1822886.74	7.704	CREST	111.973	0
5929274.04	1822896.56	7.745	CREST	123.425	0
5929272.06	1822904	7.794	CREST	131.123	0
5929272.48	1822908.42	7.782	CREST	135.569	0
5929275.82	1822916.29	7.654	CREST	144.116	0
5929309.09	1822807.92	5.619	CULV 150 FLAPPED		
5929299.85	1822815.8	5.921	CULV 150		
5929280.24	1822895.47	6.654	CULV 100 FLAPPED		
5929269.09	1822895.34	6.654	CULV 100		
5929269.11	1822895.38	7.058	CATCHPIT		

AMENDMENTS

SURVEYED	R.STRANGE	04/11
DESIGNED		
DRAWN	R.STRANGE	04/11
TRACED		
CHECKED	M. PRESTON	04/11
RECOMMENDED		
DATE APPROVED		
	PROGRAMME MANAGER	

WAIKATO REGIONAL COUNCIL

ELIZABETH PARK RETIREMENT VILLAGE STOPBANK
AS BUILT CROSS SECTIONS & LONGSECTION
WHANGARAHI STREAM, COROMANDEL

Waikato REGIONAL COUNCIL

Field Book No.
Level Book No. CES DL
DRAWING ISSUE.
SCALE Hz 1:200 Vt 1:100 (A1 Plot) Hz 1:400 Vt 1:200 (A3 Plot)
DRAWING No. 1322
PREPARED BY
SHEET No. 2 of 2