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Tapu flood protection scheme design report

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Prepared by:
Megan Wood (Wainui Consulting Limited)

For:
Waikato Regional Council
Private Bag 3038
Waikato Mail Centre
HAMILTON 3240

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Executive summary

Tapu is located on the west coast of the Coromandel Peninsula, 19 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. Tapu 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 Tapu community to develop a flood mitigation strategy to address the Tapu River flood hazard. Works have been undertaken to mitigate some of the flood hazard to the Tapu community from Tapu Stream, the details of which are provided in this Design Report.

The Tapu community is located at the base of the Tapu River catchment on a coastal alluvial fan. The community consists of mainly residential development on the true left bank of the Tapu River. The presence of parts of Tapu on the low-lying land adjacent to Tapu River means that these properties are subject to flood hazard from the river. The Tapu River is susceptible to short duration but high intensity rain events causing flash flooding and debris flow in the river 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 in the Tapu River channel to improve the condition of the channel and its capacity to convey flood flows. This work has improved the stability and capacity of the Tapu River channel and reduced the risk to the Tapu community by containing flood events that would otherwise inundate adjacent land.

The initial technical investigation results demonstrated that the Tapu River experiences flooding for the 10% to 5% AEP events, and while the stream maintenance discussed above would improve the channel capacity, it would not be adequate to prevent flooding. Hence, proposals to protect the Tapu community from flooding up to a design standard of the 1% AEP event by way of engineering works were developed and discussed with the community. The proposals included protection works upstream of the SH25 Bridge and works to protect the campground downstream of the bridge.

Following discussions with the working party and the general community, the works upstream of the bridge were not supported by the community, however due to the high risk to life within the campground, proposals to protect the campground were accepted. The campground is owned by the Thames Coromandel District Council and operated under special lease arrangement. Both parties (TCDC and the campground operator) agreed to the works.

The flood protection scheme developed for Tapu provided protection to only a small portion of the community as illustrated in the figure below.

Flood defences in Tapu

The flood protection scheme developed to protect the campground at Tapu comprises the following items:

- An overflow spillway channel located around the northern and eastern boundaries of the campground site. This is basically an excavated channel, around 160 metres long, that conveys flows around the campground and back into the Tapu River to the northwest, rather than down State Highway 25 and across the campground (in a south/southwest direction).

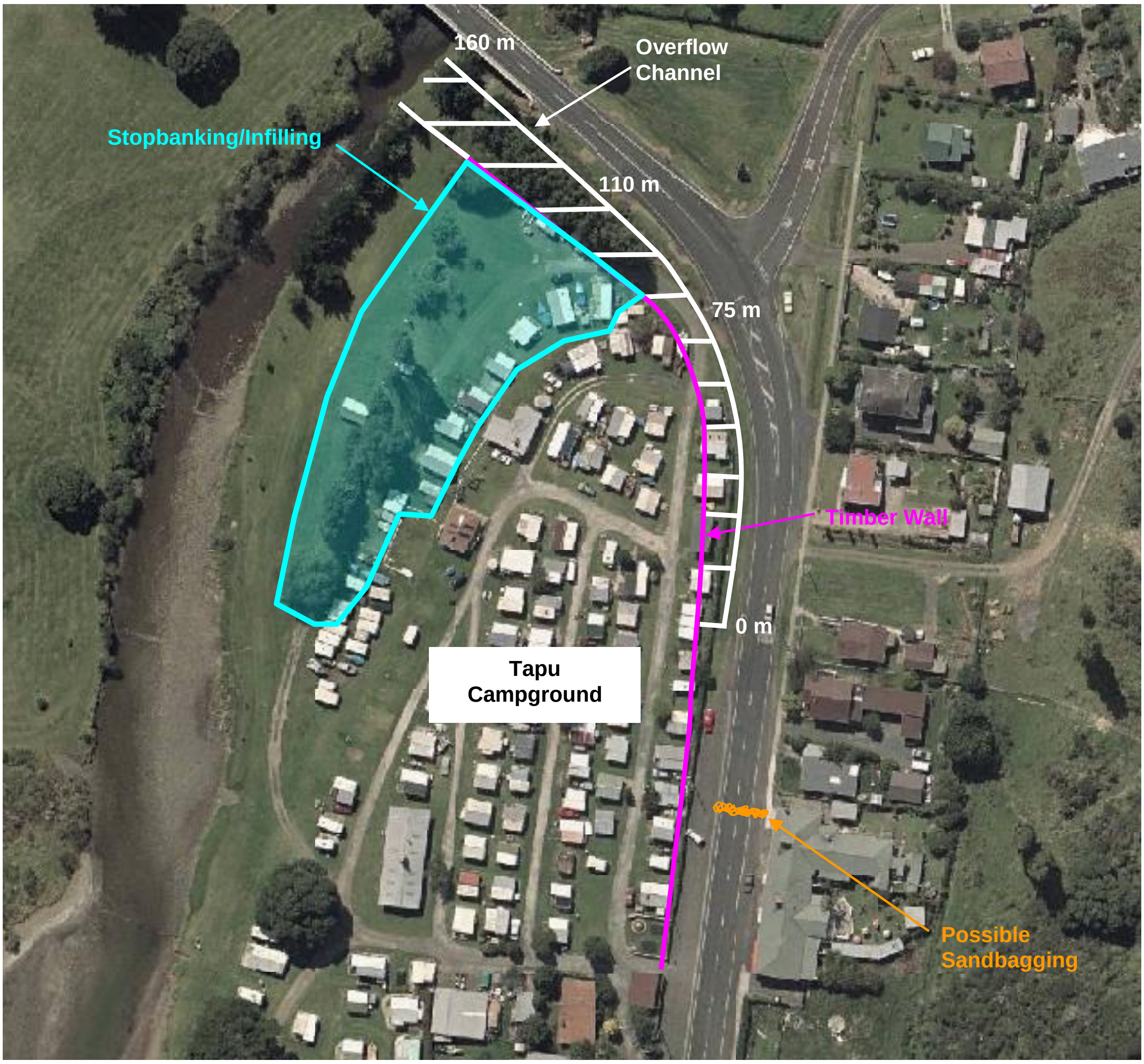
- The channel is 4 – 5 metres wide and 0.5 metres deep at the southern (‘upstream’) end, and extends around the campground and towards the river, where it is 10 – 11 metres wide and around 1 metre deep.

- The spillway is bordered on its western side by a timber floodwall structure designed to the 1% AEP flood level (with the works installed) plus a 0.5 metre freeboard.

- To ensure that overflows are directed into the overflow channel during major flood events sandbags may be required across State Highway 25 to prevent floodwaters from flowing south down the state highway.

- The lower terrace of the campground along the stream side has been protected from the 1% AEP flood event by raising the whole terrace above the flood level with 0.5 metre freeboard. This area has been formed as a stopbank with infilling behind it. The infilling is set back approximately 15-20 metres from the banks of the river.

A schematic of the completed work is illustrated in the figure below.



Tapu flood protection scheme

At this stage no further capital works are proposed to protect the Tapu 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 further upstream.

The flood protection scheme constructed at Tapu is unusual in that it only protects a commercial property, i.e. the campground. Waikato Regional Council constructed the scheme in 2009 with funds from Thames Coromandel District Council. The scheme has now been handed over to Thames Coromandel District Council to maintain, hence Waikato Regional Council does not have any agreed levels of service in relation to this scheme.

The main channel of the Tapu River is monitored and periodically maintained by the Waikato Regional Council to remove accumulated sediment and debris. This work maintains the capacity of the Tapu River 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 Tapu 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 Tapu 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

Tapu is located on the west coast of the Coromandel Peninsula, 19 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.

Tapu 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 Tapu community to develop a flood mitigation strategy to address the Tapu River flood hazard. Works have been undertaken at the mitigate some of the flood hazard from Tapu Stream, 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 Tapu to reduce the flood hazard from Tapu River, 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
- Scheme design
- 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

Tapu is located on the west coast of the Coromandel Peninsula, 19 kilometres north of Thames on SH25, refer to Figure 1 below.

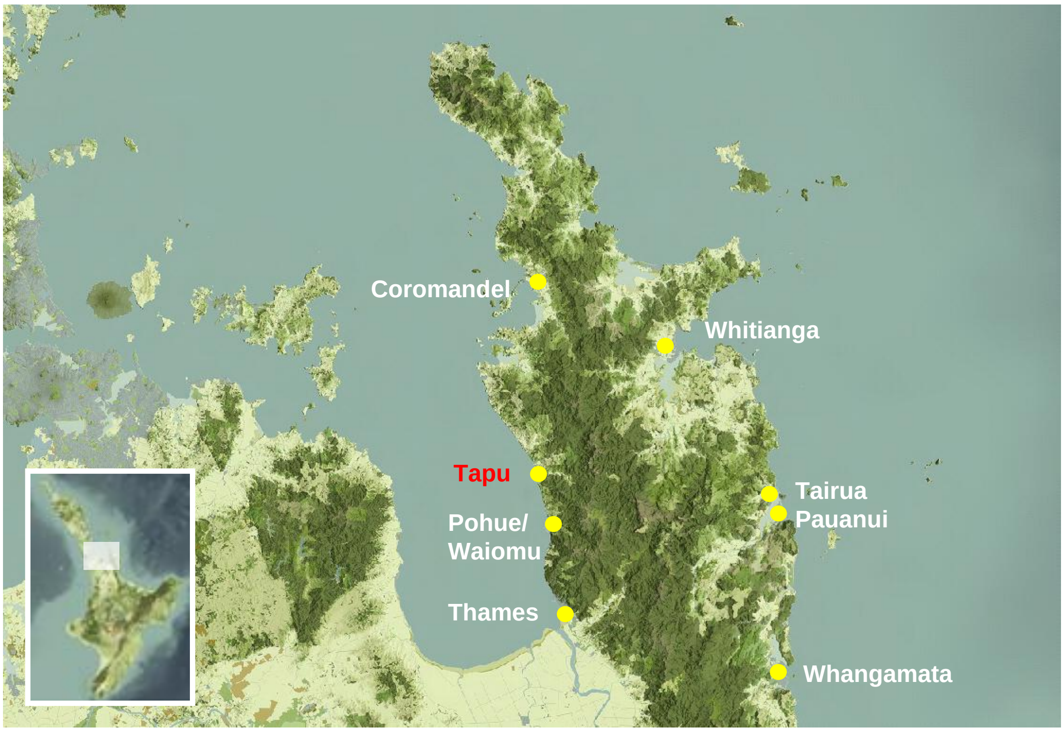


Figure 1 Thames-Coromandel district

The Tapu River has a 27 km^2 catchment that originates in the western Coromandel Ranges (refer to Figure 2). This catchment is relatively steep and covered in regenerating native vegetation and scrub. It is also susceptible to short duration but high intensity rainfall events that cause flash flooding and debris flows in the Tapu River with little or no warning.

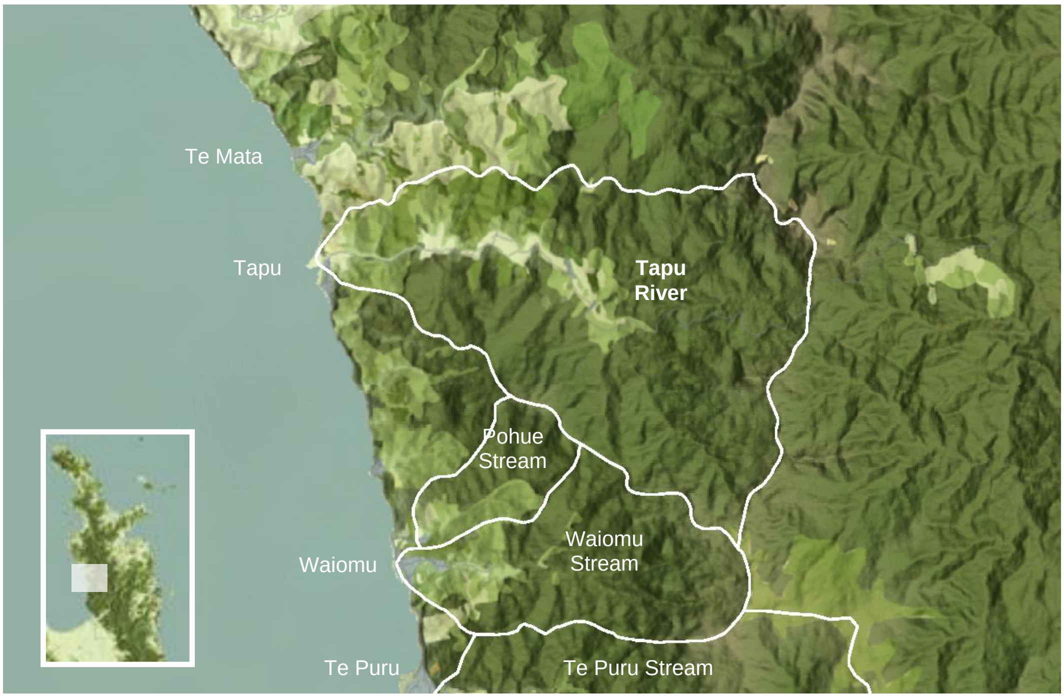


Figure 2 Tapu River catchment

2.2 Tapu River

The Tapu River flows out of the Coromandel Ranges and through the northern edge of the Tapu community before discharging to the Firth of Thames (refer to Figure 3).

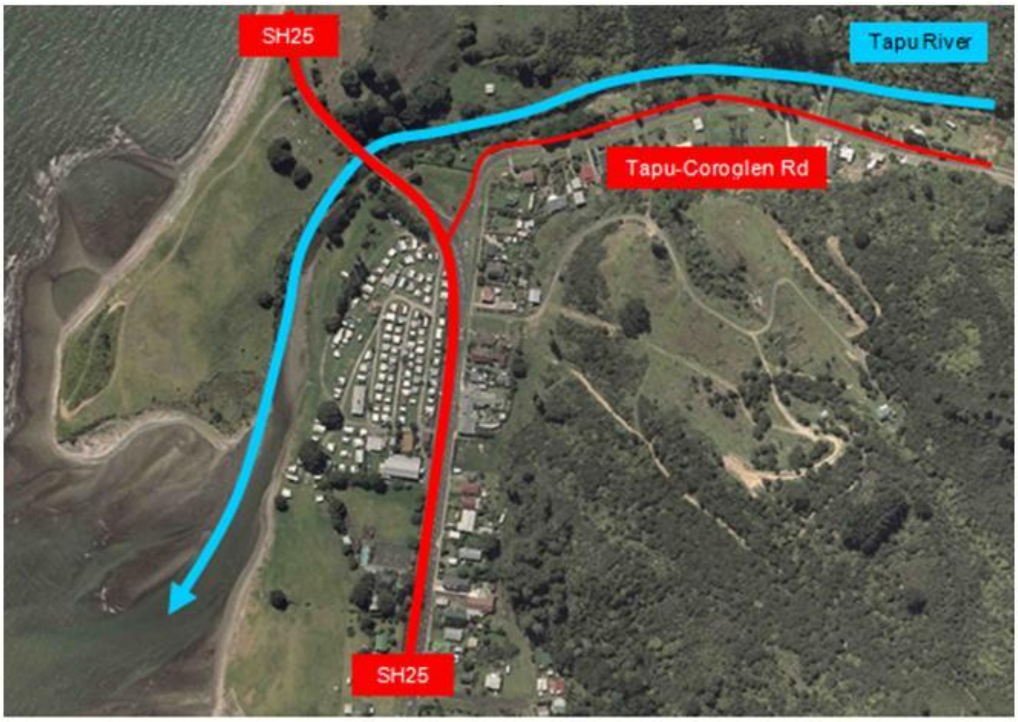


Figure 3 Tapu community

The Tapu community is located at the base of the Tapu River catchment on a coastal alluvial fan. The community consists of mainly residential development on the true left bank of the Tapu River. State Highway 25 runs through the Tapu community and crosses the Tapu River using a dual lane multi-span bridge. The Tapu-Coroglen Road runs parallel to the Tapu River. Parts of the Tapu community are located on the floodplain and sediment/debris fan created by the Tapu River (refer to Figure 4 and Figure 5 below).

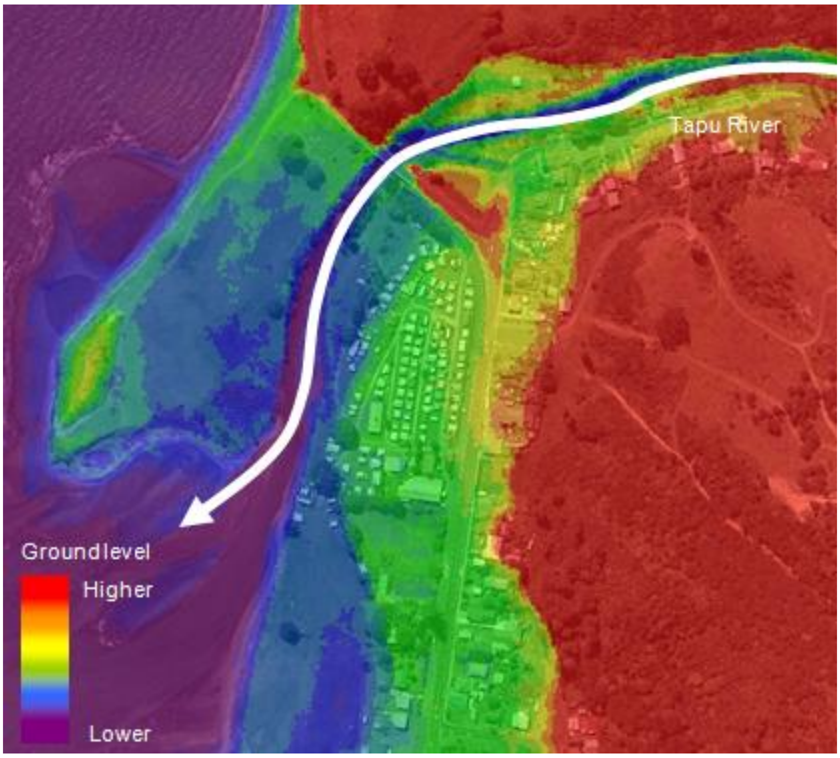


Figure 4 Ground level around the Tapu community

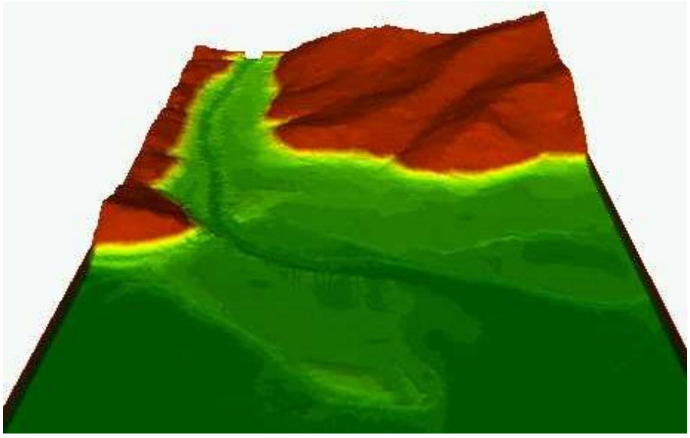


Figure 5 Tapu River coastal alluvial fan (looking inland from the Firth of Thames)

The presence of the Tapu community on this floodplain means that there is risk that people and property will be affected by flood events in the Tapu River.

2.3 Flooding issues

The presence of parts of Tapu on the low-lying land adjacent to Tapu River means that these properties are subject to flood hazard from the river. The Tapu River is susceptible to short duration but high intensity rain events causing flash flooding and debris flow in the river with little or no warning.

During significant flood events in the Tapu River, overland flow occurs along the Tapu-Coroglen Road. A proportion of this overland flow re-enters the Tapu River upstream of the State Highway 25 Bridge. The remainder flows around the southern approach to the State Highway 25 Bridge, through the Tapu Motor Camp and re-enters the Tapu River downstream of the State Highway 25 Bridge. Overland flow also occurs downstream of the State Highway 25 Bridge, where flood waters flow across the reserve on the true right bank of the Tapu River. A schematic of this flooding is provided on Figure 6 below.

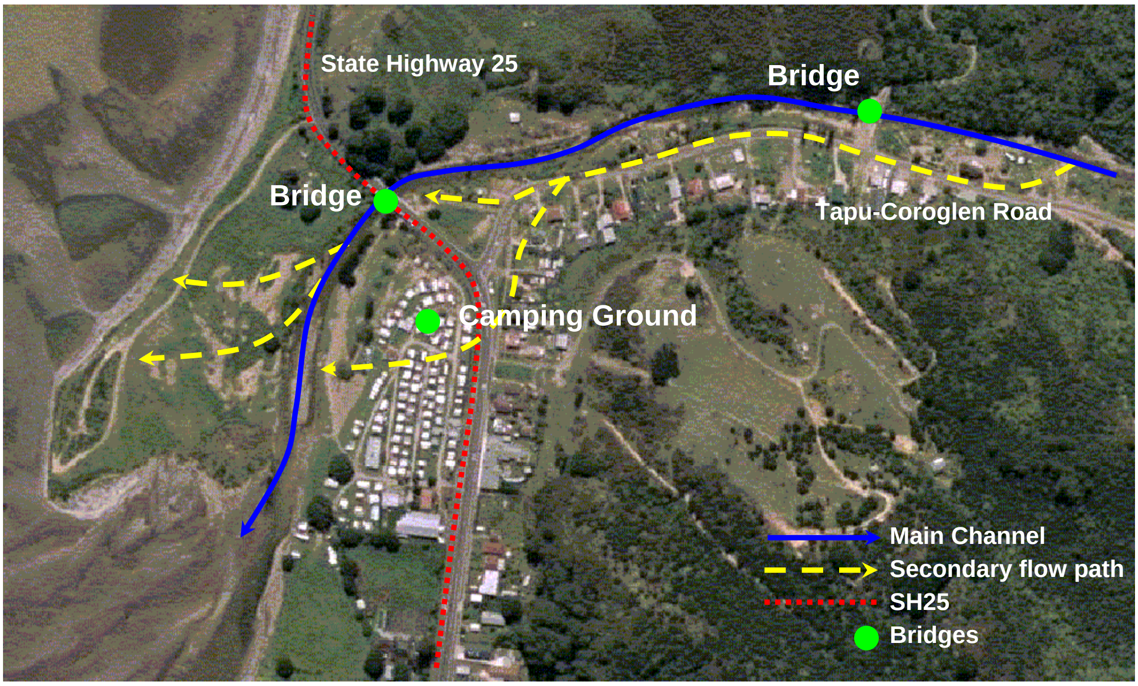


Figure 6 Predominant flooding mechanism at Tapu during a significant flood event

The significance of the flood hazard to the Coromandel Town 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). Tapu sustained significant damage during this event.

Damage to properties within the Tapu community was focused on those properties immediately adjacent to the Tapu River and those that were within the secondary flow paths. Figure 7 below illustrates the property damage that occurred within the Tapu community following the 'Weather Bomb'.

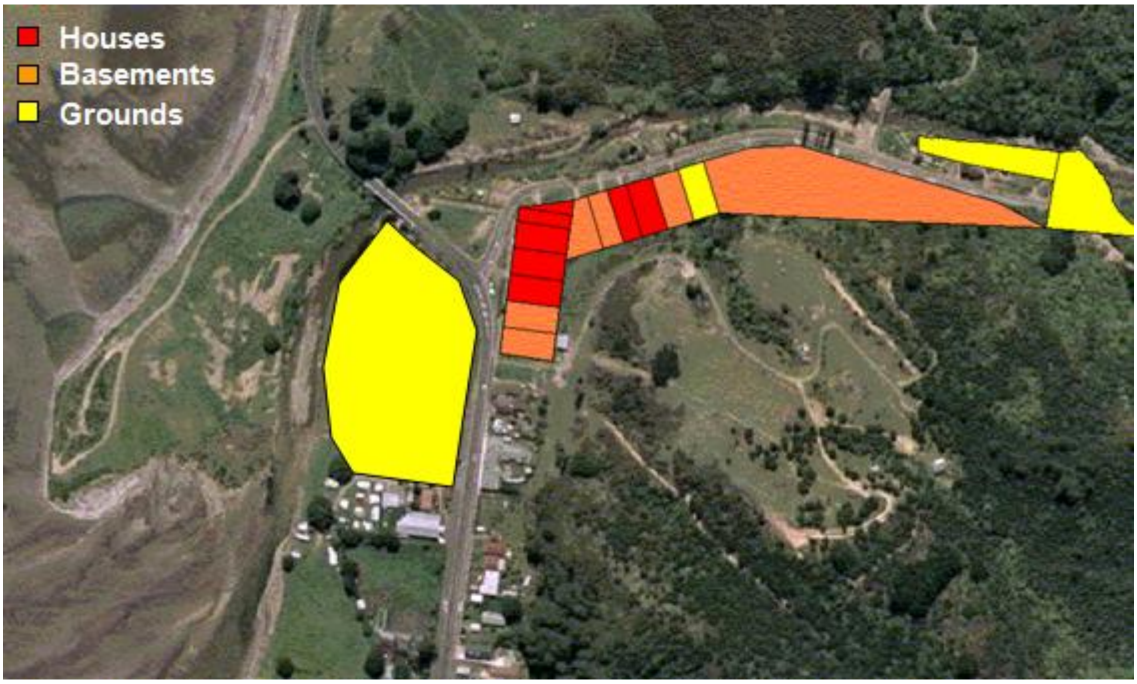


Figure 7 Property damage within the Tapu community during the 'Weather Bomb'

Following the 'Weather Bomb', the Waikato Regional Council and Thames Coromandel District Council 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 Tapu.

3 Hydrological assessment

3.1 Technical information

During the development of the Thames Coast Project, Waikato Regional Council collected a significant amount of technical information covering the Tapu 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 in Table 1 – Table 3 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 Tapu

Community	Previously completed technical investigations
Tapu	No technical investigations previously completed

Table 3 Summary of completed flood mitigation works at Tapu

Community	Previously completed works
Tapu	No flood hazard mitigation works have been previously completed within the Tapu community other than periodic clearing of the channel. The high ground between the Tapu River and the Tapu-Coroglen Road is not a formal embankment, rather a consequence of the periodic clearing of the channel.

Longsection information for Tapu (pre-scheme) has been detailed in a WRC document number WRC DM# 910515. This longsection includes the following information:

- Bed level
- Top-of-bank level
- Design flood level for a variety of flood events
- Levels associated with proposed works (eg floodwalls)

The existing channel performance prior to the scheme works being implemented was assessed to be the following for Tapu:

- Upstream of Russek's Ford 50% AEP (2 year ARI) event
- Downstream of Russek's Ford 20% AEP (5 year ARI) event
- Downstream of SH25 Bridge < 50% AEP (2 year ARI) event

3.2 Catchment characteristics

Tapu River catchment is located on the steep western slopes of the Coromandel Ranges. The catchment is covered with regenerating native forests and dense scrub. The catchment area and characteristics used in the model are described below.

Figure 8 Catchment boundary

Table 4 Catchment summary

Catchment area	26.7 km^2
% urban	Low
% indigenous forest/ scrub	High
Channel slope	7%
Time of concentration	1 hour 30 minutes

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 5 Tapu River catchment predicted rainfall intensities (existing)

	Rainfall summary 1 hour 30 minute duration event					
Annual Exceedance Probability (AEP) event	50%	20%	10%	5%	2%	1%
Predicted rainfall intensity (mm/hr)	23	28	33	39	49	59

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 6 Tapu River catchment predicted rainfall intensities (future)

	Rainfall summary 1 hour 30 minute duration event					
AEP event	50%	20%	10%	5%	2%	1%
Predicted rainfall intensity 2030 (mm/hr)	25	31	37	43	54	65
Predicted rainfall intensity 2080 (mm/hr)	29	36	42	50	63	76

3.4 Flow estimates

The peak inflow for Tapu River including an allowance for climate change was determined using several methods; the Rational Method, Relative Rational Method, and the Revised Regional Flood Estimation Method. The results were compared with previous reports and historic events.

Table 7 Tapu River peak flow estimates

	Peak flows estimates					
AEP event	50%	20%	10%	5%	2%	1%
Existing peak flow - 2006 (m^3/s)	111	135	231	271	313	344
Future peak flow - 2030 (m^3/s)	121	149	254	299	346	380
Future peak flow - 2080 (m^3/s)	140	172	294	346	401	442

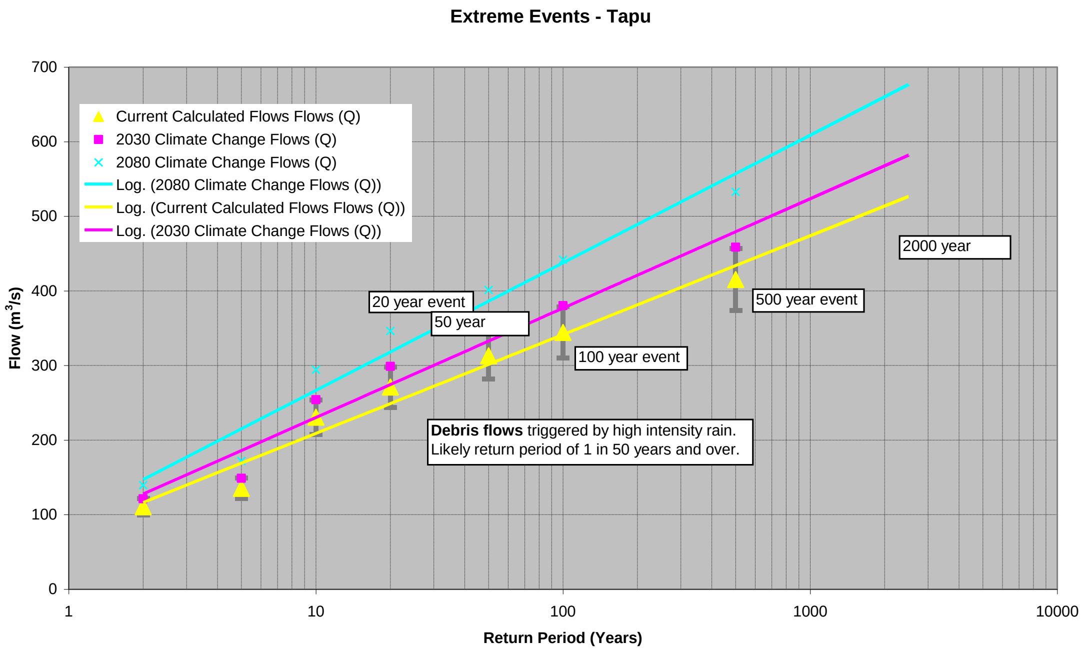


Figure 9 Tapu River hydrological summary

From the above figure, the predicted future 1% AEP event flood flows in 2080 equate to approximately 417 m^3/s. This flow was adopted as the future 1% AEP flood flow for modelling purposes. Note a revised flow estimate of 290m^3/s was adopted for the 1% AEP existing peak flow, refer spreadsheet WRC DM#974906.

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.

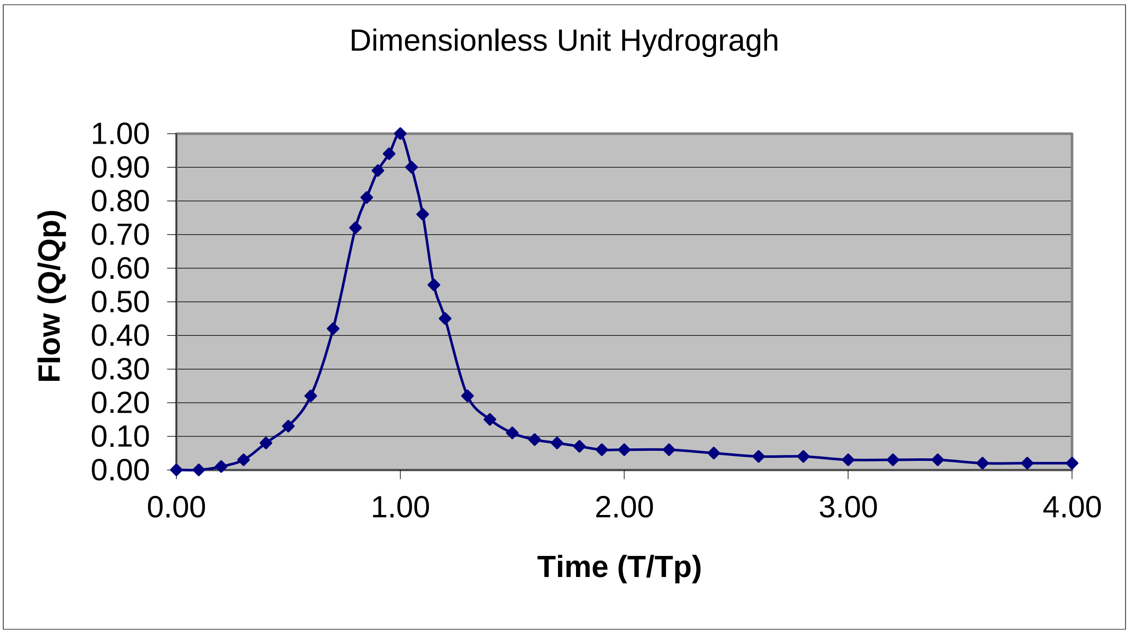


Figure 10 Dimensionless unit hydrograph

This was used to produce a unit hydrograph for the Tapu River catchment. Where Tp used is the time of concentration and Qp is the peak flow.

4 Hydraulic model development

4.1 Introduction

A two-dimensional hydraulic model was built to represent the Tapu River and associated flood plain in the vicinity of the Tapu community to first assess the flood hazard affecting the community, and secondly to develop a flood protection scheme.

For this purpose the stream and surrounding area was modelled using an unsteady state, two-dimensional computational hydraulic model using the MIKE-21 software. This model provides detailed information in regard to extent, depth and velocity of flooding. The MIKE-21 model was also used to do the bulk of the design work for the flood protection scheme.

A one-dimensional hydraulic (MIKE-11) model was also built for the spillway to refine the design of the spillway.

This section outlines the development of both of the hydraulic models.

4.2 MIKE-21 model

4.2.1 Model setup

For details about the MIKE-21 model set up refer to Environment Waikato Internal Series Report 2006/24 (Martin N, April 2006).

4.2.2 Model inputs

Ground contour

A digital terrain model (DTM) based on ground survey (LiDAR) was used in the hydraulic model to represent the ground contours of the study area. The DTM was based on a 2m by 2m grid of the whole stream and flood plain with an accuracy of +/- 0.15m.

Upper boundary condition

The upper boundary of the hydraulic model consists of an inflow hydrograph to represent the peak flow for the catchment for the 1% AEP event. Inflow hydrographs for the existing and future 1% AEP events were run through the model. The derivation of these flows is discussed in Section 3.

- Existing 1% AEP flow is 290 m^3/s
- Future 1% AEP flow is 417 m^3/s

Lower boundary conditions

The lower boundary of the Tapu River is the Firth of Thames. The spring high tide level was used to replicate the backwater effect at the lower end of the stream. The existing spring high tide level is RL1.1m above mean sea level. This is predicted to rise 0.5m by the end of the century according to MfE guidelines (MfE, May 2004), hence the lower boundary condition used for the future 1% AEP event scenario model was RL1.6m above mean sea level.

Resistance

The variation in resistance across the flood plains has been taken into account. In MIKE-21 a separate resistance file has been created. In this file, resistance values for different areas are assigned. MIKE-21 uses Manning's M to represent roughness, which is the inverse of Manning's n value. In the hydraulic model the resistance was assigned as follows:

Stream/river	= 33
Flood Plain	= 10

Note that the resistance values are assigned with only limited accuracy based on the aerial photographs for the study area. This is considered an appropriate level of detail in hydraulic modeling practice.

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 the proposed scheme in place**- Present day 1% AEP event discharge with inclusion of proposed stopbanks.
- **1% AEP event (future) with proposed scheme in place** – 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.

4.2.3 Model location

The MIKE-21 hydraulic model used to develop the Flood Hazard Map for Tapu is located in the WRC system in the following folder:

G:\RCS\Technical Services\Projects\RHEM\TCDC Hydraulic Modelling Stage 1\Hydraulic Models

The MIKE-21 hydraulic model used for design purposes for Tapu is located in the WRC system in the following folder:

G:\RCS\Technical Services\Projects\Coromandel Zone\Tapu\Hydraulics\MIKE 21

4.2.4 Model validation

The river flood maps produced as part of model development process were compared with observations made during previous flood events in the Tapu River. This comparison, which includes the review of several Hauraki Catchment Board and Waikato Regional Council reports, showed that the maps were a reasonable representation of flooding in the Tapu River as illustrated in Figure 11 below.

Figure 11 Comparison of modelled and observed flood extents

4.2.5 Model assumptions and limitations

The following outlines the assumptions made when building the 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 flood hazard risk. Alterations to the catchment that may affect the hydrology significantly include, land use changes, deforestation and development. Following significant alterations to the catchment the hydrology should be reviewed and possible adjustments should be made to the flood hazard.

- The modelling work has been undertaken for the current floodplain topography. Aerial survey data (LiDAR) is taken and converted into 2 metre cell Digital Terrain Model (DTM). The DTM incorporates ground levels but excludes features such as fences, trees and buildings. Water is allowed to flow across the DTM to determine the extent and magnitude of the flood hazard risk.

- The flood modelling work is for the Tapu River only. Coastal hazards have not been included as part of the modelling work.

- 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. Actual events typically have elements of debris and sedimentation movement. While the model does not include these elements specifically, the derivation of the flows used in the hydraulic model does. 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 0.

4.3 MIKE-11 model

4.3.1 Model set up

A simple MIKE-11 model was developed to refine the design of the spillway. Design cross sections were developed for the spillway and these were inserted into the model to represent the spillway. A fixed flow of 35 m^3/s was used as the inflow/upstream boundary condition to test the spillway design (refer Section 5.4.1 for the basis for this flow rate). A time series representing the tidal effects in the Tapu River was used as the downstream boundary condition (ranging from a level of 1.2m to 3.93m). The spillway design was then optimised to ensure the spillway could accommodate this flow.

4.3.2 Model location

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

G:\RCS\Technical Services\Projects\Coromandel Zone\Tapu\Hydraulics\MIKE 11\03 - Design simulations (proposed)\03 - August 2006 - Spillway design

4.4 Peer review

A peer review was undertaken of the MIKE-21 and the MIKE 11 design models by Dr Steven Joynes (Hydraulic Modelling Services) to ensure robustness of the design. The findings of the peer review are included in Appendix 1.

5 Flood protection scheme

5.1 Community input

For the success of this project it was essential that the community was involved with the development of the project. 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.

5.2 Channel improvements

As a first step, the community agreed to Waikato Regional Council developing and undertaking an extensive channel maintenance program in the Tapu River channel to improve the condition of the channel and its capacity to convey flood flows. The specific activities associated with this programme included:

- Removal of accumulated gravel, sand and debris from the Tapu River upstream of the SH25 Bridge (approximately 580 metres of channel).
- Removal of accumulated gravel, sand, silt and debris from under the SH25 Bridge that crosses the Tapu River. This included 'unblocking' the left hand opening of the bridge.
- Removal of accumulated sand, silt and debris from the Tapu River between the SH25 Bridge and the Firth of Thames (approximately 220 metres of channel).
- Disposal of excavated gravel, sand and silt on the local foreshore below the high tide level.

Consents for the annual channel maintenance works were obtained and works were undertaken accordingly.

This work has improved the stability and capacity of the Tapu River channel and reduced the risk to the Tapu community by containing flood events that would otherwise inundate adjacent land.

5.3 Scheme development

The initial technical investigation results demonstrated that the Tapu River experiences flooding for the 10% to 5% AEP events, and while the stream maintenance discussed above would improve the channel capacity, it would not be adequate to prevent flooding. Hence, proposals to protect the Tapu community from flooding up to a design standard of the 1% AEP event by way of engineering works were developed and discussed with the community. The proposals included protection works upstream of the SH25 Bridge and works to protect the campground downstream of the SH25 Bridge and are summarised below:

1. Protect the residential area along the SH25 and Tapu-Coroglen Road to a 5% AEP (20 year ARI) level without freeboard by way of the following:
    a. Improve the channel capacity to accommodate the 5% AEP flow (eg. 20 year ARI flow of approximately 260 – 270 m^3/s).
    b. Removal of vegetation and gravel obstructing the flows.
    c. Formalising the bund along the left bank (eg. Between the Tapu-Coroglen Road and the stream bank) by infilling the gaps in the bund and maintaining a crest level profile at the 5% AEP flood level profile.
2. Protect the campground up to a 1% AEP (100 year) standard by way of:

a. Upgrading and formalising the overflow channel to divert overflows of $35m^3/s$ (the difference between the 5% AEP and 1% AEP flood flows) over the SH25 reserve back into the river channel.

b. Construct a floodwall along the campground fence to retain the overflows within the SH25 road reserve and direct it back into the river. The wall height being 0.5m above the 1% AEP flood level.

c. Infilling/stopbanking along the river left bank to a level of 0.5m above the 1% AEP flood level downstream of the SH25 Bridge.

Following discussions with the working party and the general community, the works upstream of the SH25 Bridge were not supported by the community, however due to the high risk to life within the campground, proposals to protect the campground were accepted. The campground is owned by the Thames Coromandel District Council and operated under special lease arrangement. Both parties (TCDC and the campground operator) agreed to the works.

The flood protection scheme developed for Tapu provided protection to only a small portion of the community as illustrated in Figure 12 below.

Figure 12 Flood defences in Tapu

5.4 Scheme design

The flood protection scheme developed to protect the campground at Tapu comprises the following items:

- An overflow spillway channel located around the northern and eastern boundaries of the campground site. This is basically an excavated channel, around 160 metres long, that conveys flows around the campground and back into the Tapu River to the northwest, rather than down SH25 and across the campground (in a south/southwest direction).

- The channel is 4 – 5 metres wide and 0.5 metres deep at the southern ('upstream') end, and extends around the campground and towards the river, where it is 10 – 11 metres wide and around 1 m deep.

- The spillway is bordered on its western side by a timber floodwall structure designed to the 1% AEP flood level (with the works installed) plus a 0.5 metre freeboard.

- To ensure that overflows are directed into the overflow channel during major flood events sandbags may be required across SH25 to prevent floodwaters from flowing south down the state highway.

- The lower terrace of the campground along the stream side has been protected from the 1% AEP flood event by raising the whole terrace above the flood level with 0.5 metres freeboard. This area has been formed as a stopbank with infilling behind it. The infilling is set back approximately 15-20 metres from the banks of the river.

A schematic of the proposed work is illustrated in Figure 13 below.

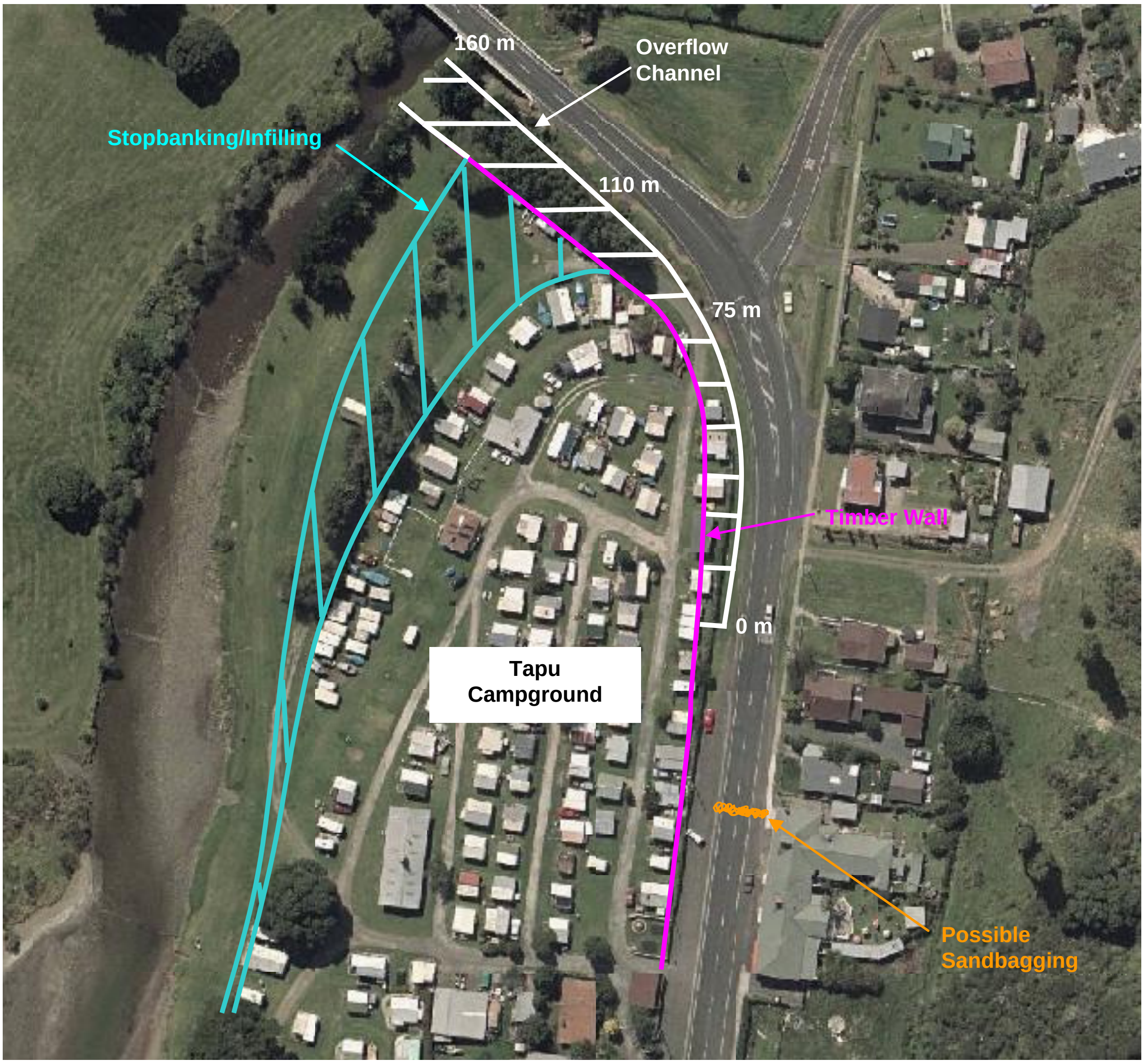


Figure 13 Flood protection scheme

For further details about the development of the scheme design refer to Environment Waikato Internal Series Report 2006/24 (Martin N, April 2006)

5.4.1 Spillway design

The design objective of the spillway and floodwall was to divert overland flow around the Tapu Campground and into the Tapu River without increasing the upstream flood level. A two-dimensional hydraulic model was constructed to simulate the inundation caused by a 1% AEP flood flow. This identified a number of flooding mechanisms, refer to Figure 14 below. The flooding mechanism that is applicable to the proposed spillway and floodwall is the overland flow path across SH25 which is illustrated on Figure 14 below.

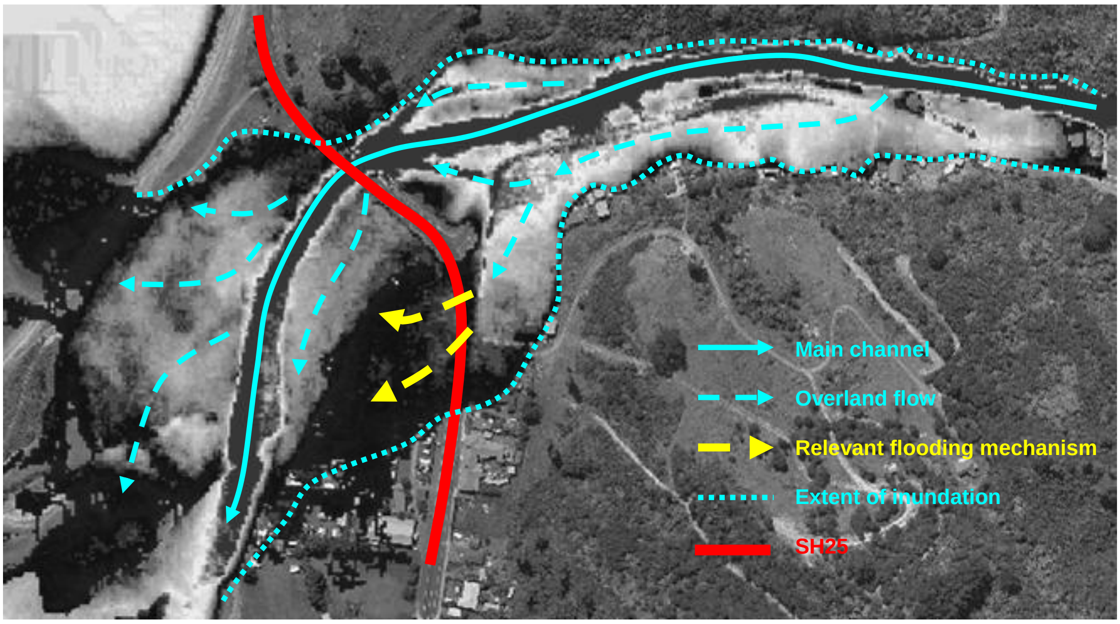


Figure 14 Flooding mechanisms relevant to spillway design

The magnitude of the overland flow path across SH25 and the Tapu Campground was estimated as follows:

Average depth of spill across SH25:	0.42 m
Average velocity of spill across SH25:	0.81 m/s
Width of spill across SH25:	102 m

Using the above observations, the magnitude of the flow across SH25 was estimated.

Area of spill across SH25:	102 m x 0.42 m = 42.84 m^2
Flow across SH25:	42.84 m^2 x 0.81 m/s = 34.7 m^3/s

Therefore, the overland flow path across SH25 and the Tapu Campground (and the design flow for the proposed spillway) was estimated and adopted for design purposes as 35 m^3/s.

The overland flow path across SH25 consists of the road acting as a weir (and a hydraulic control). To avoid an increase in flood levels on adjacent property, it is essential that this hydraulic control is retained (i.e. if the proposed spillway and floodwall significantly increased flood levels, the road weir may be drowned, the hydraulic control would no longer exist and increased flood levels would be allowed to propagate onto adjacent properties). Therefore, the proposed spillway and floodwall were designed to pass the required flow (35 m^3/s) with a flood level that does not exceed the existing level of overflow across SH25 (i.e. RL 4.5 m).

The required dimensions of the spillway were first estimated using Manning's Formula for open channel flow. They were then "fine-tuned" using a one-dimensional hydraulic model that took into account the impact of the Tapu River backing up the proposed spillway during the design flood event. The resulting dimensions of the spillway are summarised in the following table and further design details are provided in Appendix 2.

Table 8 Spillway design details

Chainage	Channel base width	Channel depth	Batter slope	Channel slope
0 m	3 m	~ 0.5 m	3H:1V	1.0 %
100 m	9 m	~ 1.5 m	3H:1V	1.0 %
146 m	9 m	~ 1.0 m	3H:1V	1.0 %
186 m	9 m	~ 1.0 m	3H:1V	0.3 %

Given that the proposed spillway and floodwall were designed to be capable of passing the design flow (ie 35 m^3/s) without causing the SH25 weir to become drowned, it was concluded that the flood level increase on neighbouring properties due to the proposed spillway and floodwall will be negligible.

5.4.2 Floodwall design

The flood wall was designed to the 1% AEP (existing climate scenario) flood level plus 500mm freeboard. The design levels are summarised as follows:

Chainage 0m (at the start of the spillway) - RL5.0m
Chainage 50m - RL4.75m
Chainage 100m - RL4.55m
Chainage 120m - RL4.5m

The design of the flood wall at Tapu was based on input received from a structural engineer (David Shilton) for the design of the flood wall at Tararu, specifically the following recommendations (WRC DM#992792):

Table 9 Flood wall design recommendations

		Timber posts		
Design	**Maximum height**	**Diameter**	**Spacing**	**Trench depth below ground**
1	1.0 m	150 mm SED	1.5 m	1.10 m
2a	1.5 m	200 mm SED	1.0 m	1.35 m
2b	1.8 m	200 mm SED	1.0 m	1.70 m

The following notes accompanied these recommended dimensions:

- Timber posts to be H5 treated.
- Planks to be continuous over two poles and staggered.
- A reinforced concrete top collar is necessary where the retained height exceeds 600 mm.

At Tapu the floodwall was also required to act as a retaining wall as well as a flood wall to convey flood waters, hence the design philosophy considers two scenarios and uses the "worst case" to dictate the wall dimensions. The requirements of the retaining wall scenario and flood wall scenario have been considered as follows:

Scenario 1 Retaining wall

When a flood event is not occurring, the Tapu Campground floodwall acts as a retaining wall. The height retained is summarised in the following table.

Table 10 Retaining wall scenario

Chainage	Height retained	Design implied
0 to 50 m	< 1.0 m	1
50 to 90 m	1.0 m to 1.5 m	2a
90 m to 120 m	1.5 m to 1.8 m	2b

Scenario 2 Flood wall

When a flood event is occurring, the Tapu Campground floodwall acts as a floodwall. The height of this wall above the existing ground level (including a 0.5 m freeboard) is summarised in the following table.

Table 11 Flood wall scenario

Chainage	Wall height (including freeboard)	Design implied
0 to 25 m	1.0 m to 1.5 m	2a
25 to 120 m	> 1.0 m	1

The combination of these scenarios results in a critical design for the wall, as presented in the following table.

Table 12 Flood wall design details

Chainage	Retaining wall design	Flood wall design	Critical design
0 to 25 m	1	2a	2a
25 to 50 m	1	1	1
50 to 90 m	2a	1	2a
90 to 120 m	2b	1	2b

The design details for the flood wall that are based on the assessment discussed above are provided in Appendix 2.

An important aspect to this design is the side of the posts that the planks are fastened to. Under the retaining scenario, the planks should be sandwiched between the posts and the retained ground. However, under the flood wall scenario, the planks should be on the opposite side of the posts.

To overcome this issue, the planks have been fastened in a manner that satisfies the retaining scenario (i.e. the long-term load), but continuous galvanised straps have also been proposed where the wall is entirely above ground. This improves the strength of the connection between the planks and posts when the wall must contain flood waters.

As-built survey drawings are provided in Appendix 3.

5.4.3 Stopbank and infilling design

The lower terrace of the campground along the stream side has been protected from the 1% AEP flood event by raising the whole terrace above the flood level with 0.5 m freeboard. This area has been formed as a stopbank with infilling behind it. The infilling is set back approximately 15-20 metres from the banks of the river.

A smaller area was infilled than originally proposed as the filling wasn't required to the expected extent as the original ground was at the design protection level. The finished filled area is illustrated on Figure 15 below.

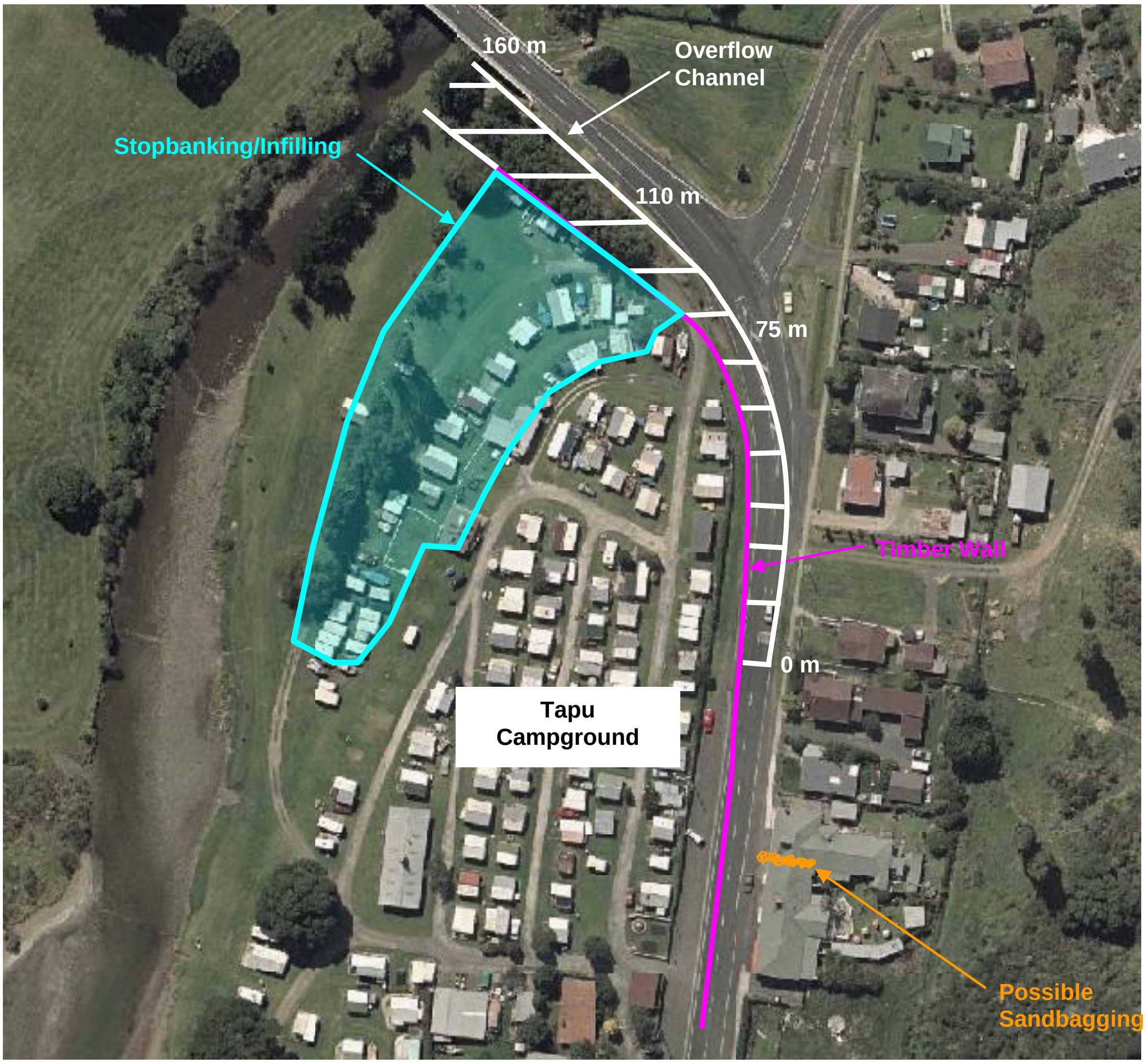


Figure 15 Completed infill at the Tapu Campground

The flooding mechanism that is applicable to the proposed stopbank and infilling within the campground is the overland flow path across the existing river terrace as illustrated in Figure 16 below.

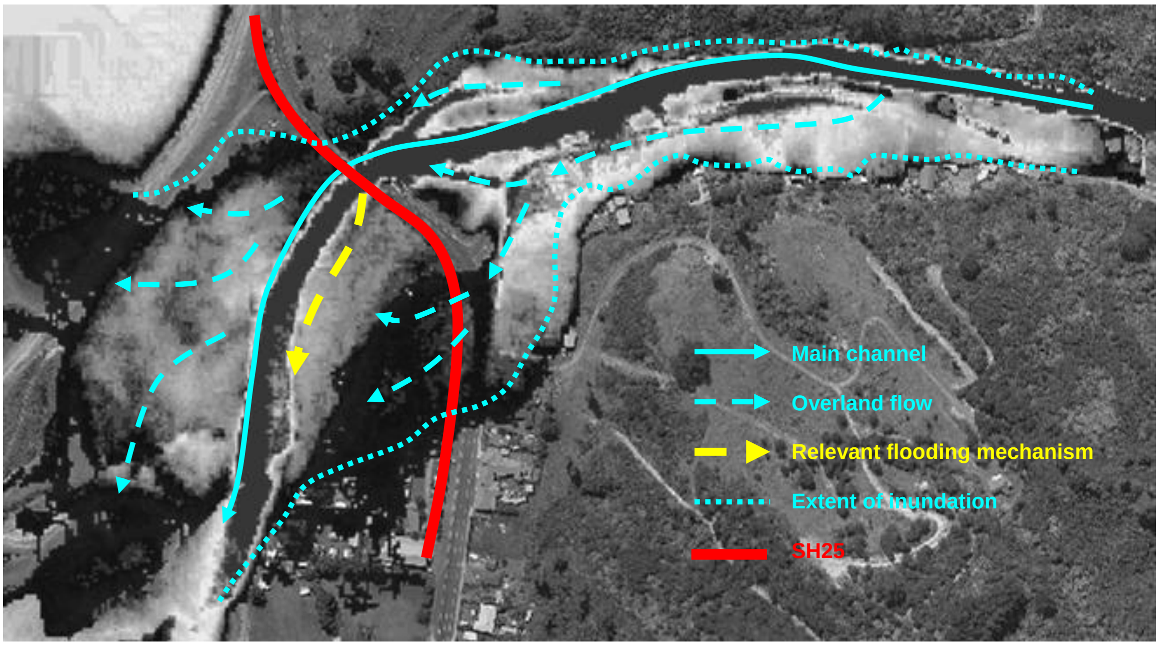


Figure 16 Flooding mechanism relevant to stopbank and infill design

The impact of the proposed stopbank and infilling (including the proposed spillway and floodwall) was assessed by amending the hydraulic model to represent the proposed works. This amended hydraulic model was then re-run to simulate the 1 % AEP flood event and the results were compared to the pre-scheme conditions. An increase in flood level was predicted to occur on land on the opposite side of the river from the area of infill (on the right bank downstream of the SH25 Bridge). Given the likely magnitude (i.e. < 0.3 m) and extent (i.e. within TCDC reserve land) of the predicted flood level increase, it was concluded that the effects on neighbouring properties of the proposed infilling of the Tapu River floodplain would be insignificant.

5.5 Future works

Waikato Regional Council originally developed a proposal that included works upstream of the SH25 Bridge and works to protect the campground downstream of the SH25 Bridge. However following discussions with the working party and the general community, the works upstream of the bridge were not supported by the community. Due to high risk to life within the campground, proposals to protect the campground were accepted and progressed.

At this stage no further capital works are proposed at Tapu. 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 include more of the community if practicable.

6 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 Tapu, 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 constructed at Tapu is unusual in that it only protects a commercial property, i.e. the campground. Waikato Regional Council constructed the scheme in 2009 with funds from Thames Coromandel District Council. The scheme has now been handed over to Thames Coromandel District Council to maintain, hence WRC does not have any agreed levels of service in relation to this scheme. The level of service is still summarised below to record the design standards and objectives applied to the scheme constructed at Tapu.

The level of service provided by the scheme at the Tapu Campground is the existing 1% AEP event (without climate change) plus 500mm freeboard. The general location of the flood protection assets is shown in Figure 17 below. Refer to Appendix 2 for design details for the flood protection works at Tapu. As-built survey data is provided in Appendix 3.

Figure 17 Flood defences in Tapu

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.

7 Operation and maintenance

The main channel of the Tapu River is monitored and periodically maintained by the Waikato Regional Council to remove accumulated sediment and debris, refer to the figure below for the indicative extent of maintenance works. This work maintains the capacity of the Tapu River and reduces the risk to adjacent land that would otherwise be inundated more frequently, and also helps to maintain the performance of the flood protection scheme.

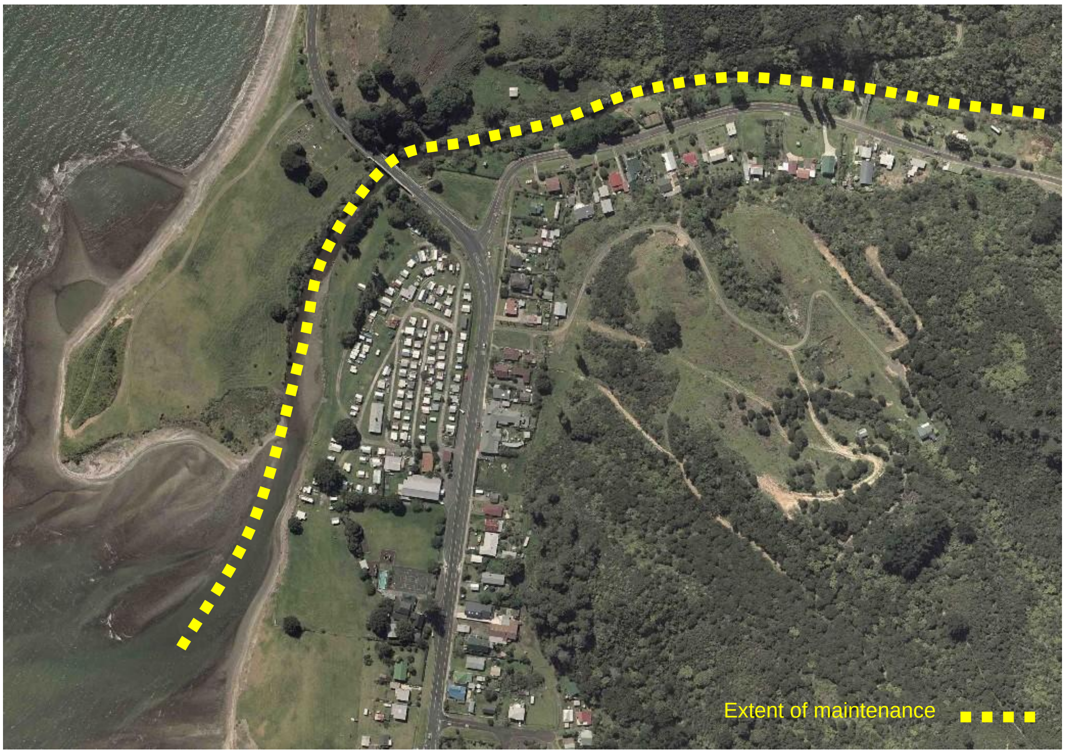


Figure 18 Extent of channel maintenance

The following activity is undertaken:

- The river is walked over along the extent shown in Figure 18 at least once a year to undertake a condition survey.
- Below the SH25 Bridge and a short section upstream of the bridge de-silting and gravel management works are undertaken once every two years. The bridge is on a bend hence materials build up on the southern side of the bridge (left bank). Foreshore deposition is undertaken using this extracted material.
- Above the bridge the channel was widened just prior to the flood works and this capacity is maintained as required, usually once every three years.
- Just upstream of the community the river channel and floodway was cleared in 2010.
- Vegetation management/spraying is completed annually along the entire extent of maintenance illustrated in the figure above.
- After rain events, access is gained to the relevant sections of the stream to clear the channel and restack rocks along the bank.

8 Flood hazard assessment

8.1 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 13.

Table 13 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 been 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 19).

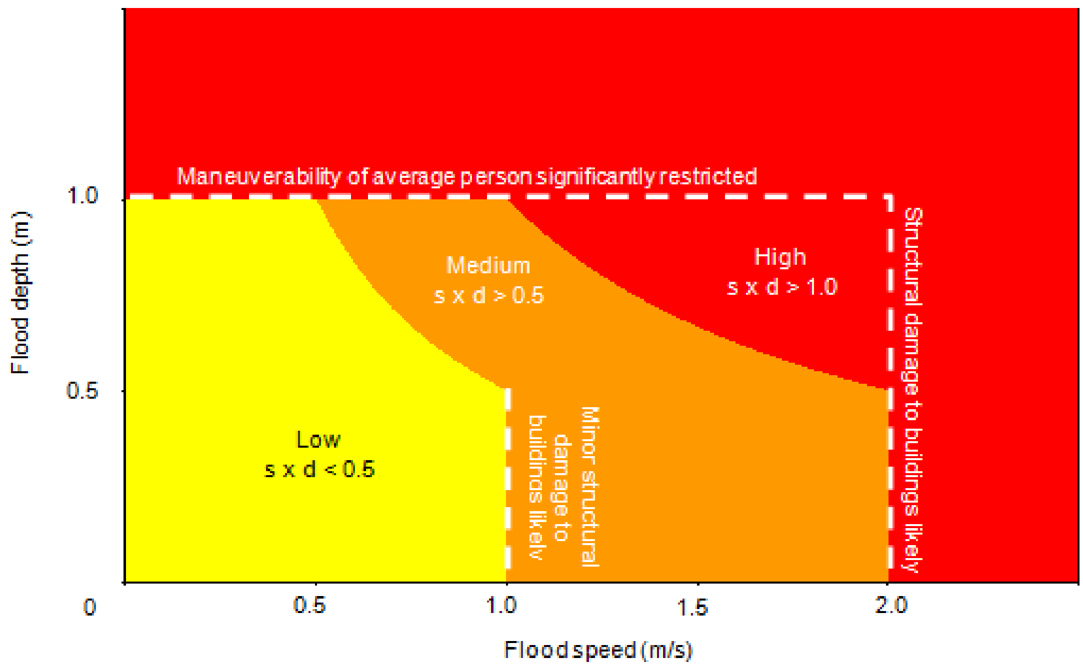


Figure 19 River flood hazard classification matrix

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).

8.2 River flood hazard map

The river flooding information has been used to produce a river flood hazard map for the Tapu community due to the Tapu River. Figure 20 shows the flood hazard map for Tapu where the land that is protected by the scheme is shaded in blue to represent its 'Defended' status.

Figure 20 River flood hazard map post-scheme

9 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 Tapu River community are described as follows:

- 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 constructed flood protection scheme only protects a small portion of the community, hence the unprotected community is still subject to flood hazard from Tapu River.

- The river flood model used to design the flood protection scheme is based on detailed ground level information, but excludes obstructions such as 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 Tapu River. 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 Tapu River catchment. Any significant change to this condition will affect the river flood hazard that affects the Tapu community. 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.

10 Planning controls

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 TCDC staff for details.

11 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. The flood protection scheme constructed at Tapu is different to schemes constructed elsewhere in that it only protects a commercial property, i.e. the campground. Waikato Regional Council constructed the scheme in 2009 with funds from Thames Coromandel District Council. The scheme has now been handed over to TCDC to maintain, hence WRC does not have any agreed levels of service in relation to this scheme, nor standard requirements for scheme review.

The constructed flood protection scheme at Tapu only protects a small portion of the community. Waikato Regional Council proposed a complete flood protection scheme that included works to protect other at-risk portions of the community however the community did not want to progress the complete scheme. 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 models

Environment Waikato
P O Box
Hamilton

Tuesday, 17 November 2015

Attention Greg Ryan

Tapu Campground Spillway Design

Scope
To review the appropriateness of the hydraulic modelling and to critique to conclusions reached in examining the impacts of the new works.

Information received
I received memo file no. Z21 S240 from Environment Waikato. I spent time with Greg Ryan looking at the 1D and 2D models to visualize and verify the data and result outputs.

Observations
The scale of the proposed spillway channel was such that it could not be modelled accurately within the 2D grid. Therefore the use of a 1D model to examine the hydraulic-grade-line along the channel was appropriate. Unfortunately the 1D and 2D grids could not be coupled. The methodology of extracting the 2D road overflows into the 1D channel was reasonable. The 2D model still had the caravan park sheet flow so therefore, as long as the 1D model did not increase flood levels at its 2D connection, then the methodology is appropriate.

The steady-state approach using the peak overflow of $35m^3/s$ meant the worst case scenario was analysed in the design of the timber wall height. I checked that the 1D hydraulic boundaries and the 2D grid were synchronised at the height of the flooding. The synchronisation was good and demonstrated the 1D model reflected the storage and peak flows generated in the 2D model.

Figure 6 in the memo shows 4 areas where flood increases have been calculated by the 2D model. Areas 1, 2 and 3 are generated by old models with different physical parameters. Area 4 shows the flood increase due to the proposed infill and channel. This increase is expected due to the concentration of flows in the proposed channel back into the river and the restricted channel capacity due to the infill. The fact that the increase is on Thames-Coromandel District Council land is beneficial since they appear to have given consent.

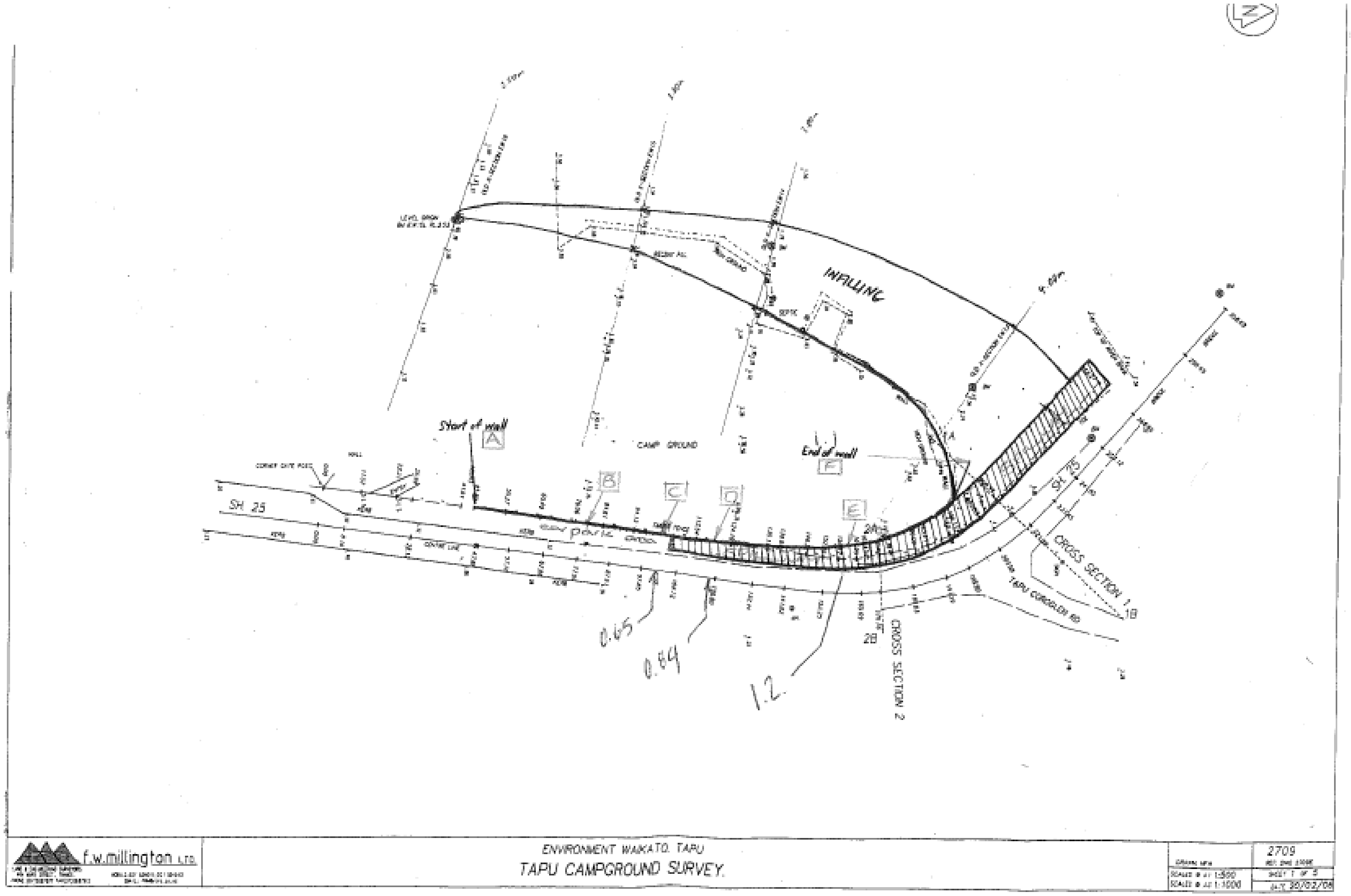
Conclusion
The key to the success of this project is that the proposed channel can convey the overflows in a safe and efficient manner back into the river instead of spreading across in a sheet flow through the caravan park without impacting upstream properties. This has been demonstrated by the matching of flood levels in the 1D and 2D models. Perhaps a table of 1D and 2D peak flood levels at chainages 0m, 100m and 146m would support this.

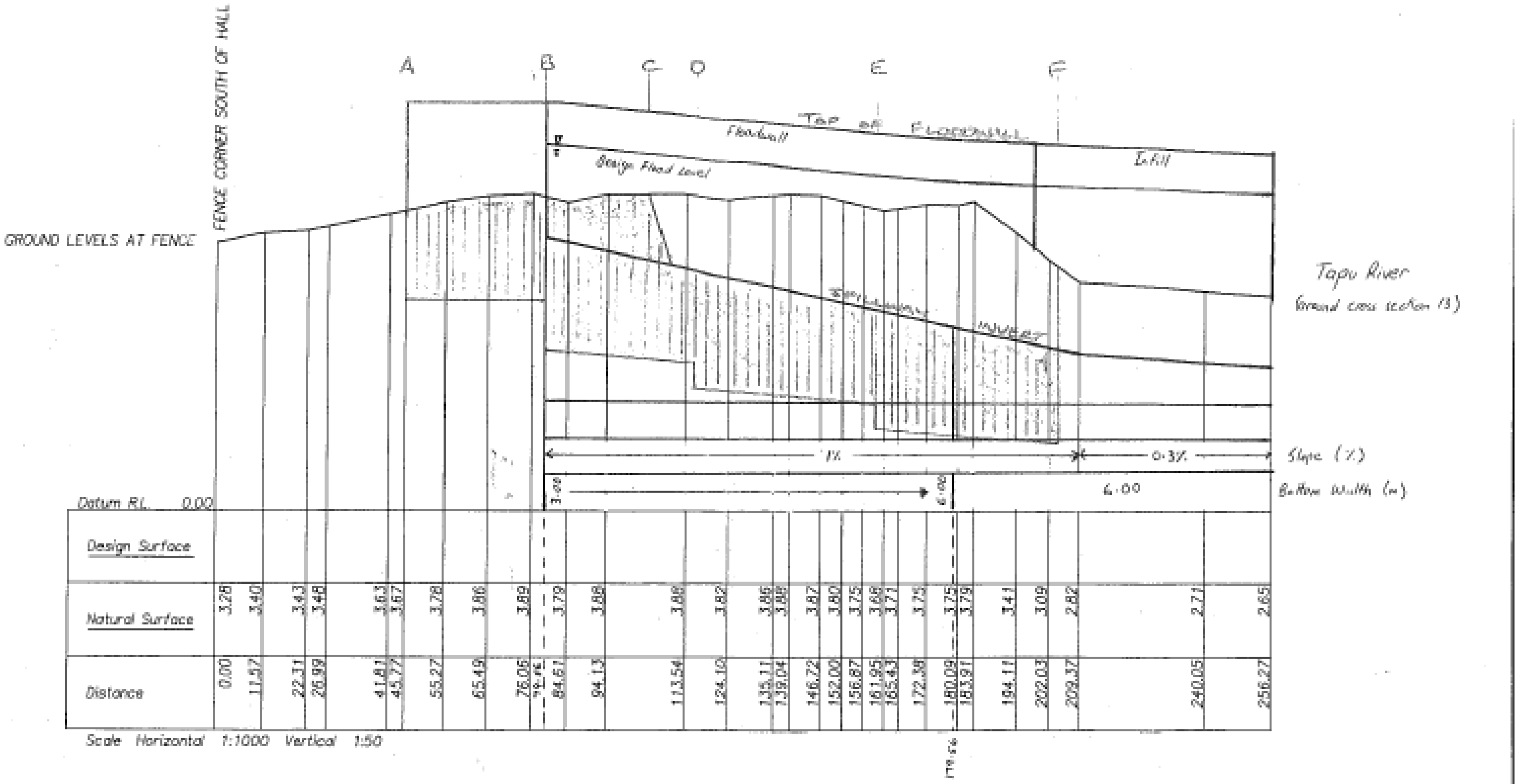
The modelling methodology was appropriate and shows the 1D model conveys the overflows in a safe and efficient manner without affecting upstream properties

Yours sincerely

Dr Steven Joynes
Senior Hydraulic Modeller

Appendix 2 Design details





f.w.millington ltd
LAND & ENGINEERING SURVEYORS
404 MARY ST, THAMES, NEW ZEALAND.
PHONE 07 8687977. FAX 07 8687973

ENVIRONMENT WAIKATO

LONG SECTION ON CAMPGROUND FENCE LINE

DATE: 20/02/06
SCALE: AS SHOWN
2709
REF: DWG2709B
SHEET 3 OF 5

Table A- Floodwall details

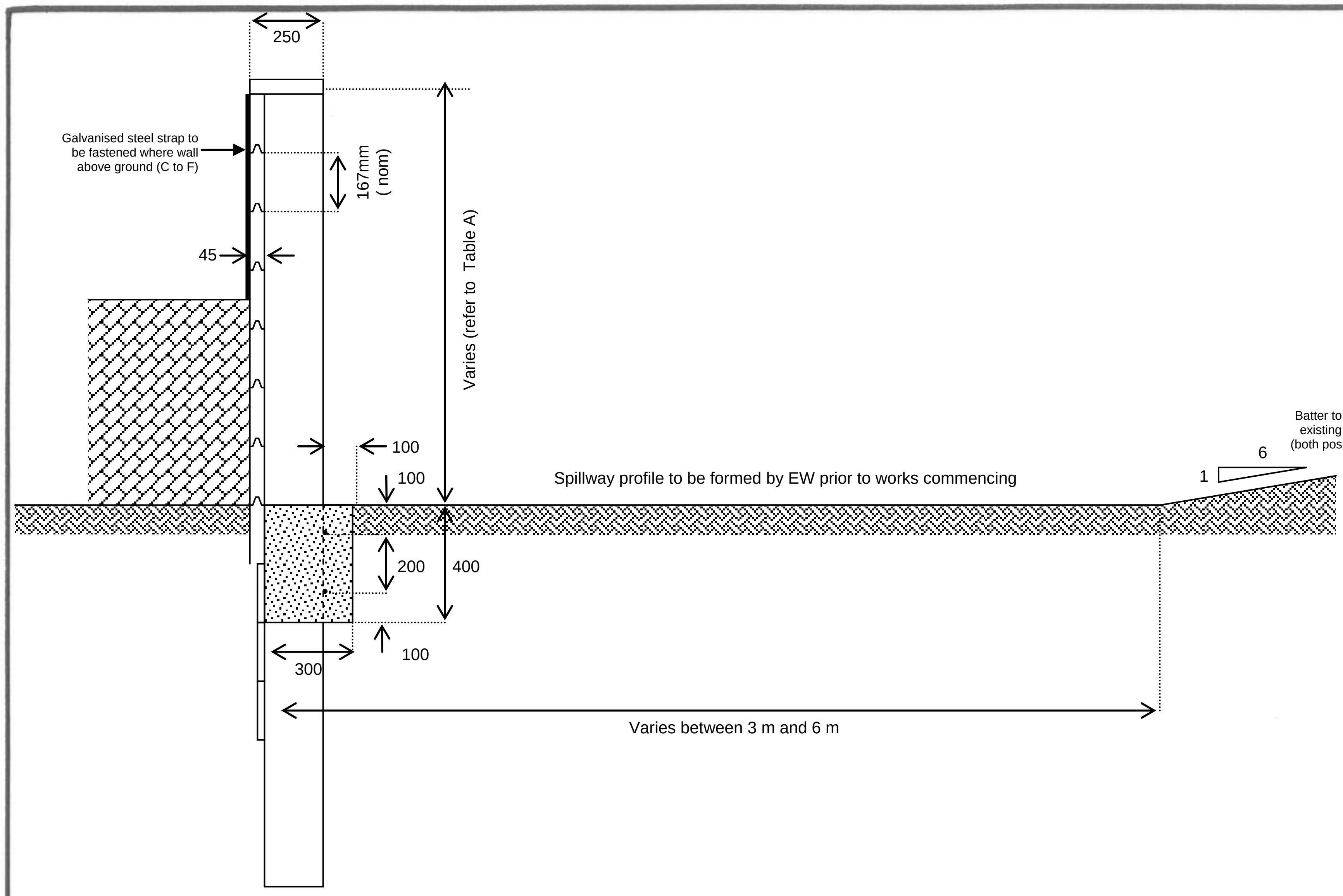
Section of wall	Length of wall (m)	Pole length (m)	Number of poles	Distance between poles (m)	Approx trench depth (m)	Approx wall height (m)	Approx depth of backfill behind wall (m)	Planks fastened to poles
A to B	33	2.4	34	1.0	1.2	1.3 to 1.2	-	Road side
B to C	25	3.0	25	1.0	1.8 to 2.0	1.2 to 1.0	-	Road side
C to D	14	3.0	14	1.0	1.2	1.8	0.8	Camp side
D to E	41	3.3	41	1.0	1.2	2.1	0.9 to 1.2	Camp side
E to F	47	3.6	47	1.0	1.2 to 1.3	2.3 to 2.4	1.2 to 1.6	Camp side
Total	**160 m**		**161**					

Notes to accompany Tapu Campground floodwall design

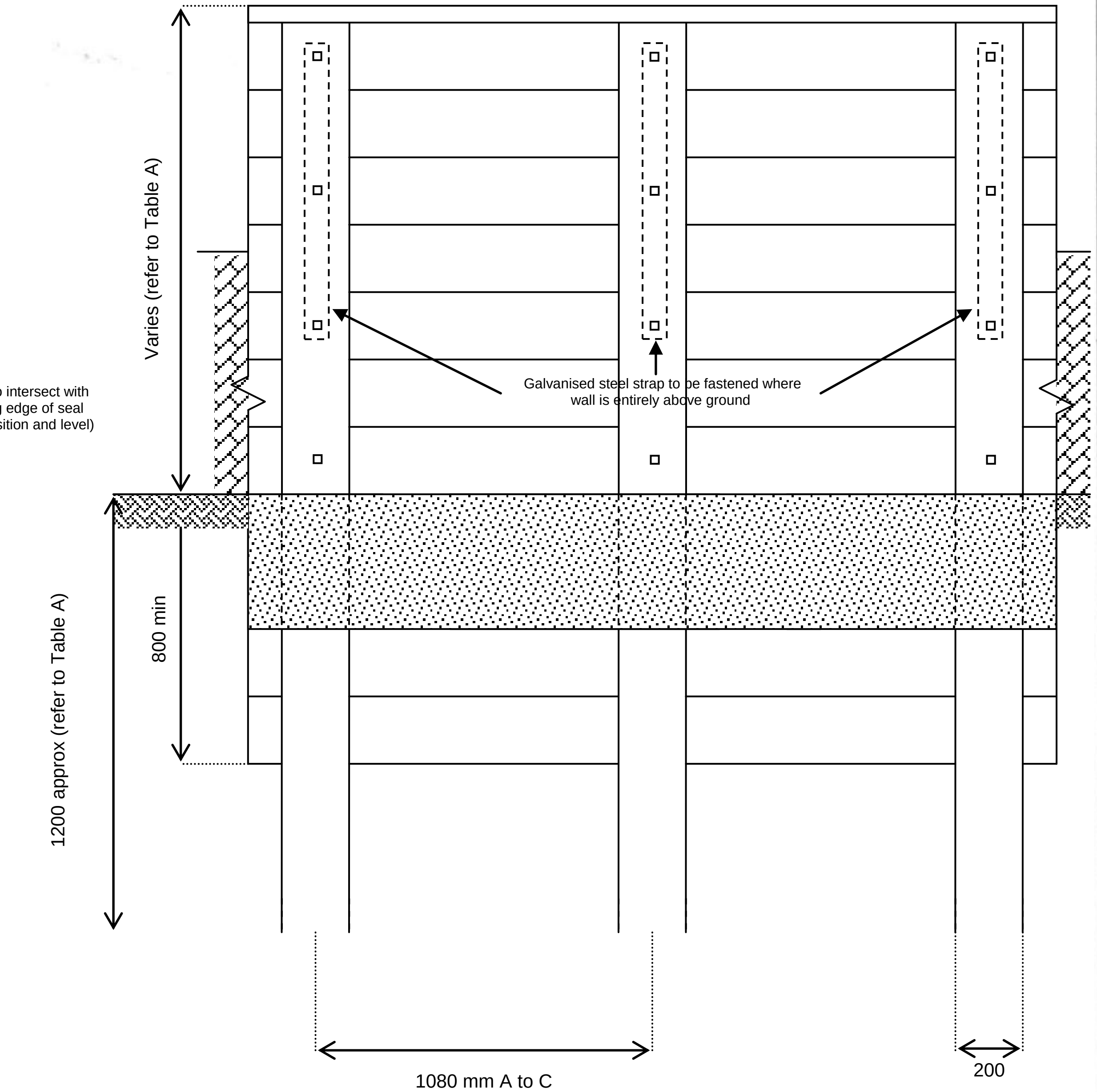
Posts:	200 mm SED timber poles at 1080mm centres (A to C) and 900mm centres (C to F) Heights vary (refer to long sections and table A)
Planks (above ground):	167 x 45 mm timber tongue and groove (ex 200 x 50). Every second plank anchored with 12 mm hot dip galvanised engineers bolts with square washers. Remaining planks to be nailed. Tongue and groove planks to extent one board (minimum) below existing ground level. Continuous hot dip galvanised straps to be fastened vertically to planks where wall is entirely above ground (refer to drawing) – Section C to F
Planks (below ground):	200 x 25 mm rough sawn timber. To start below tongue and groove timber, which extends one board (minimum) below existing ground level. Planks to be nailed.
Capping board:	250 x 50 mm nailed to each post and to the top plank at 200 mm centres. Galvanised bracing straps at every 3rd post.
Foundation (below ground):	Excavated to a minimum depth to 1.2 m (see Table A) Trench backfilled with compacted clay.
Foundation (ground level):	Plank side - 100 x 100 mm concrete mowing strip flush with final ground level. Pole side - 300 x 400 mm concrete pad flush with final ground level, including steel reinforcement (two 12 mm diameter reinforcing bars stapled to each post with a cover of 100 mm and vertical spacing of 200 mm).
Timber treatment:	H4 planks, H5 posts.
Concrete:	17.5 MPa.
Drawing key:	Concrete Existing ground Retained ground Timber

AMENDMENTS		
28/02/07: First draft (for review by RP Spooner) 01/02/07: Second draft (for review by DJ Shilton) 16/03/07: Third draft (reviewed by DJ Shilton)	SURVEYED DESIGNED DRAWN TRACED CHECKED RECOMMENDED DATE APPROVED — CHIEF ENGINEER	WAIKATO REGIONAL COUNCIL Tapu campground floodwall Floodwall construction details

JOB No.	FIELD BOOK No.
	LEVEL BOOK No.
SCALE 1:20	DRAWING No. Tapu
FILE REF. Z21 F240	SHEET No. 2a



Side Elevation



Rear Elevation (spillway)

AMENDMENTS		
28/02/07: First draft (for review by RP Spooner) 01/02/07: Second draft (for review by DJ Shilton) 16/03/07: Third draft (reviewed by DJ Shilton)	SURVEYED DESIGNED DRAWN TRACED CHECKED RECOMMENDED DATE APPROVED	CHIEF ENGINEER

WAIKATO REGIONAL COUNCIL

Tapu campground floodwall
Floodwall construction details

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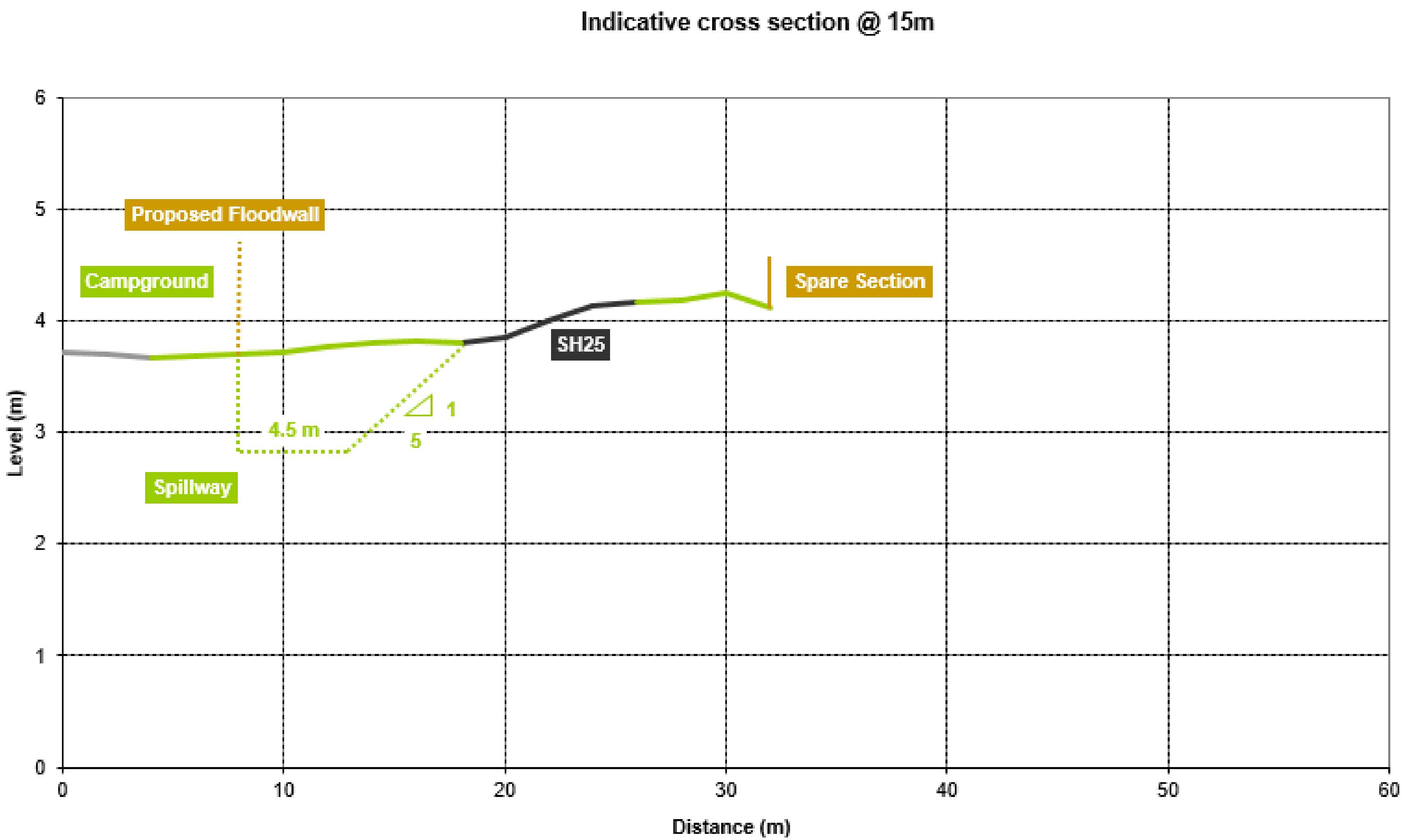
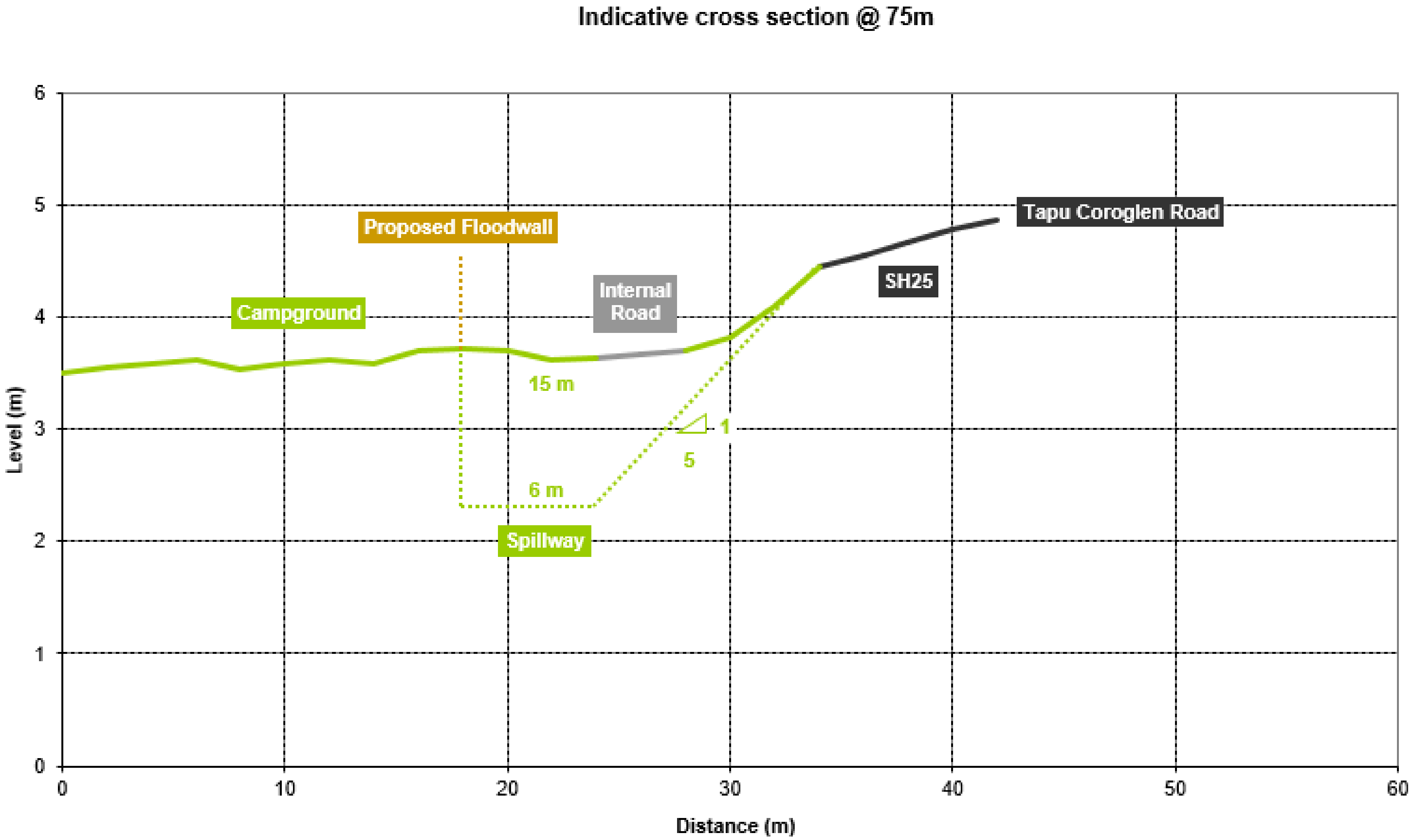
	LEVEL BOOK No.
SCALE	DRAWING No.
FILE REF. Z21 F240	SHEET No. 2b

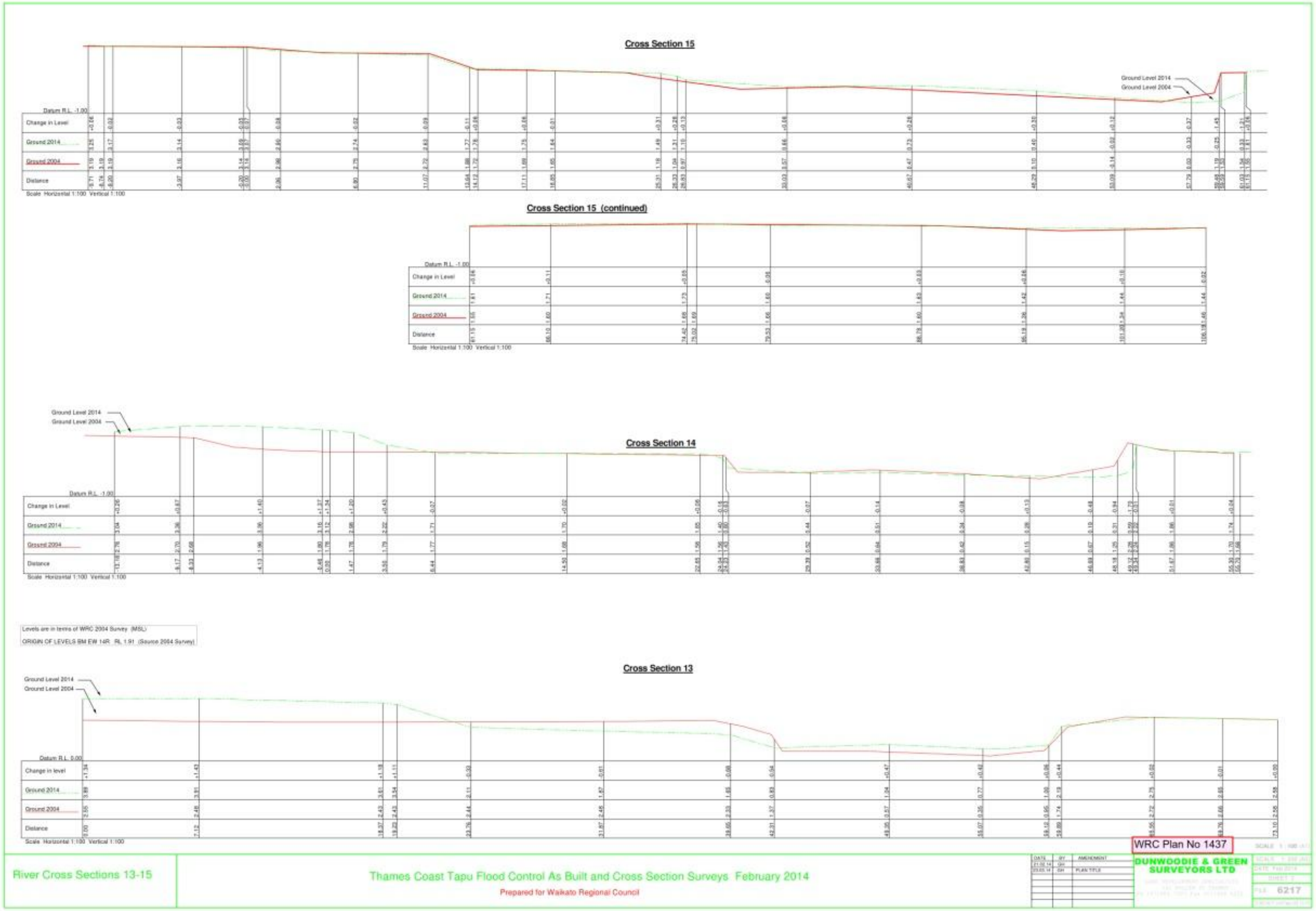

Indicative cross section @ 15m
Proposed Floodwall
Campground
Spare Section
SH25
4.5 m
1
5
Spillway
Level (m)
Distance (m)
0
1
2
3
4
5
6
0
10
20
30
40
50
60



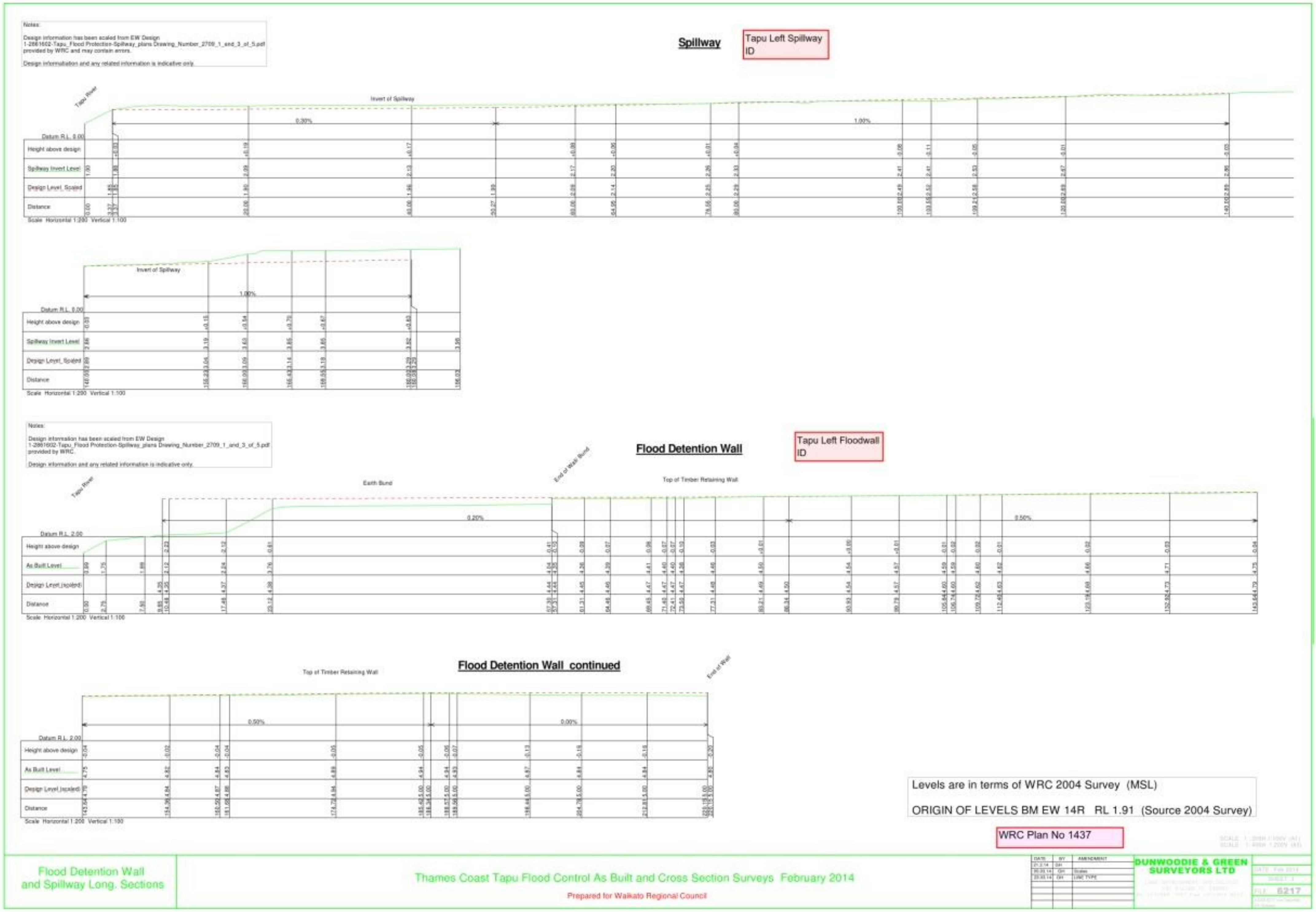
Indicative cross section @ 75m
Proposed Floodwall
Tapu Coroglen Road
SH25
Internal Road
Campground
15 m
1
5
6 m
Spillway
Level (m)
Distance (m)
0
1
2
3
4
5
6
0
10
20
30
40
50
60

Note: refer approximate chainages on Figure 13 in main body of report

Appendix 3 As-built survey



Cross Section 15
Ground Level 2014
Ground Level 2004
Datum R.L. -1.00
Change in Level
Ground 2014
Ground 2004
Distance
Scale Horizontal 1:100 Vertical 1:100
Cross Section 15 (continued)
Cross Section 14
Levels are in terms of WRC 2004 Survey (MSL)
ORIGIN OF LEVELS BM EW 14R RL 1.91 (Source 2004 Survey)
Cross Section 13
Datum R.L. 0.00
WRC Plan No 1437
River Cross Sections 13-15
Thames Coast Tapu Flood Control As Built and Cross Section Surveys February 2014
Prepared for Waikato Regional Council
DUNWOODIE & GREEN SURVEYORS LTD
6217


Notes:
Design information has been scaled from EW Design 1-2861602-Tapu_Flood Protection-Spillway_plans Drawing_Number_2709_1_and_3_of_5.pdf provided by WRC and may contain errors.
Design information and any related information is indicative only.
Spillway
Tapu Left Spillway ID
Tapu River
Invert of Spillway
Datum R.L. 0.00
Height above design
Spillway Invert Level
Design Level_Scaled
Distance
Scale Horizontal 1:200 Vertical 1:100
Notes:
Design information has been scaled from EW Design 1-2861602-Tapu_Flood Protection-Spillway_plans Drawing_Number_2709_1_and_3_of_5.pdf provided by WRC.
Design information and any related information is indicative only.
Flood Detention Wall
Tapu Left Floodwall ID
End of Wall Bund
Earth Bund
Top of Timber Retaining Wall
Datum R.L. 2.00
Height above design
As Built Level
Design Level (scaled)
Distance
Flood Detention Wall continued
End of Wall
Levels are in terms of WRC 2004 Survey (MSL)
ORIGIN OF LEVELS BM EW 14R RL 1.91 (Source 2004 Survey)
WRC Plan No 1437
Flood Detention Wall and Spillway Long. Sections
Thames Coast Tapu Flood Control As Built and Cross Section Surveys February 2014
Prepared for Waikato Regional Council
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