Rangitaiki Tarawera Floodplain Management Strategy Stage 1

Prepared by Robbin Britton, Project Engineer

Environment Bay of Plenty
Strategic Policy Publication 2008/01
May 2008

5 Quay Street
P O Box 364
Whakatane
NEW ZEALAND

ISSN: 1176 4112

Working with our communities for a better environment
E mahi ngatahi e pai ake ai te taiao

Foreword

Concern for the security of the Rangitaiki and Tarawera floodplains is the reason behind Environment Bay of Plenty's preparation of a Floodplain Management Strategy for the Rangitaiki and Tarawera Rivers. This Floodplain Management Strategy reviews the flood hazards in the floodplains, current flood protection provided to property and people living on the floodplains and what, if any, additional protection needs to be provided.

Floodplain Management Strategies are not the same as Civil Defence Emergency Management (CDEM) Plans. Under the Civil Defence Emergency Act 2002 each regional and local council must prepare plans detailing how it will manage catastrophe events such as volcanic eruptions, tsunamis, storms, earthquakes and fires.

Construction of flood defences began in the catchment in 1971 and this was completed by the early 1980's. Since that period, components of the flood defence system have been reviewed and upgraded. Renewal work has been necessary following natural disasters such as the 1987 Edgecumbe earthquake and the July 1998 and 2004 floods. This Floodplain Management Strategy reviews the flood protection system for the Rangitaiki Tarawera catchment only. It identifies potential weaknesses in flood protection and lays out plans for risk reduction for future generations.

The words 'potential weaknesses' are used to describe both probable and possible weaknesses. Probable flood weaknesses are situations where flood defences have a higher likelihood of failure during an event (e.g. stopbanks are leaking excessively, eroding or are below design height). Possible weaknesses on the other hand describe uncertain risks such poor stopbank structural stability. Possible weaknesses can be confirmed (or otherwise) by carrying out geotechnical analysis and hydraulic modelling. The Floodplain Management Strategy endeavours to identify both types of weaknesses and plan mitigation measures accordingly. Approved mitigation measures will be incorporated into future Council Plans e.g. Annual Plans, Asset Management Plans, Ten Year Plans and District Plans etc.

The executive summary provides an overview of the report.

Part one describes the nature of the floodplain, and measures used to manage floods to date. The resulting issues for future floodplain management are collated in the conclusions section at the end of Part one.

Part two identifies the flood hazard by summarising a number of studies that have been undertaken to quantify the potential flood risk and impacts. Alongside these studies are the actual recorded impacts which resulted from July 1998 and July 2004 floods.

Part three outlines recommendations to be followed up in subsequent Stage 2 and three reports.

The Floodplain Management Strategy makes reference to floods in terms of say the '50 year flood' or '100 year flood'. These terms refer to the chances of a certain size of flood occurring over a given period of time. For example if a flood flow of a certain size occurred on average, once every 50 years the chances of a flood of similar size or greater occurring in any one year is said to be 1 in 50.

Predicting random events such as flooding is an approximate science. The following examples may help put risks of flooding of the Rangitaiki Tarawera floodplains into context:

Burglary in any one year	1 in 16
Drawing the ace of spades in any one draw	1 in 52
Peak discharge in Rangitaiki River in July 2004 was 770 cumecs	*1 in 95*
Infant mortality	1 in 119
Contracting heart disease in any one year	1 in 1000

(Source: non italic data from Wellington Regional Council, 1996)

Executive Summary

The underlying aim of floodplain management planning is to reduce the susceptibility/exposure to flooding to property and people within the scheme catchment. This Floodplain Management Strategy (FMS) comprises three stages. The aim of this Stage 1 report is to identify and describe existing flood issues within the Rangitaiki and Tarawera catchments, outline existing flood protection measures, identify potential hazards and elements at risk and identify what mitigation options are needed. Stage 2 identifies flood mitigation options and Stage 3 will provide further detail on how the selected options will be implemented.

This Stage 1 study has revealed that flood protection provided in the Rangitaiki Tarawera catchment requires further work to fully meet service level requirements as set out in the scheme asset management plan. However in saying that, Environment Bay of Plenty is generally aware of the challenges and has begun a number of measures that will ultimately reduce, mitigate or avoid identified flood risks. This FMS captures most measures currently being undertaken and adds further recommendations that will reduce risk further. To restore flood design service levels, the most pressing structural measures required includes stopbank top-ups (or renewals) on the Tarawera and Rangitaiki Rivers and Reid's Central Canal. The main question for stakeholders will be whether they are prepared to bring forward and implement some important renewal items earlier than anticipated.

The *main structural* recommendations are summarised briefly below with a proposed modified Long Term Council Community Plan (LTCCP) time schedule shown in Table 3.1 (refer to Part 3 of this report).

1 Tarawera River stopbanks require top-ups to achieve 100 year protection. The recommendation made at the 2 August 2007 Operations Committee meeting was that this renewal work be brought forward from 2012/13 to 2008/09 to restore service level requirements.

2 Stopbank top-ups are also required along the lower Rangitaiki River reach (which starts just downstream of Edgecumbe township and extends to the river mouth) to achieve the 100 year protection service level. Protection for the lower reach is currently provided for the 50 year flood event with 300 mm freeboard. The temporary 50 year protection was agreed to by the scheme liaison group and formalised as part of the June 2004 Rangitaiki Tarawera Asset Management Plan (Environment Bay of Plenty, 2004). Before topping up lower Rangitaiki stopbanks it is recommended that geotechnical stability be assessed and climate change effects be considered to 2030 and 2080 through updated modelling. Effects of a new Reid's Central spillway structure should also be considered in the modelling. Since Rangitaiki stopbank top-ups are not scheduled to commence until 2010/11 it is recommended that these additional studies commence in 2008/09.

3 Reid's Central Canal is narrow at some places greatly restricting its capacity. Studies carried out since July 2004 indicate water levels would be reduced significantly in the canal and Rangitaiki River if the canal were to be widened by 20 to 50m in the lower reach. Since Reid's Central canal top-ups are planned for 2009/10 it is recommended that geotechnical stability be assessed and climate change effects to 2030 and 2080 respectively be included 2030 in updated modelling. These studies need to commence in 2008/09 in order to meet the stopbank top-up renewals programme.

The *most significant non-structural* recommendations include:

4 Updating floodmaps of the Rangitaiki Plains as new catchment information becomes available. Updated floodmaps will help Whakatane District Council better plan for future development by keeping floodwaters away from development and development away from floodwaters. Flood risk maps for the area west of the Tarawera River and east of the Rangitaiki River to the Whakatane River will be produced by Environment Bay of Plenty in 2007/08.

5 The requirement for land developers to mitigate 100% the additional run-off generated by their developments so that the effects are less than or equal to existing (pre-development) levels. Mitigation should be applied to post development effects which might otherwise increase the flood risk to neighbouring properties. Mitigation options would be reviewed on a case-by-case basis however they might include provision of culverts and/or bridges to preserve overland flow paths, retention ponds, compensatory lowering of land and pumping equivalent volume of additional run off and lost storage e.g. Carter Holt Harvey/The Hub site. In floodplain management terminology 'structural measures' refers to a specific group of flood protection structural assets such as stopbanks, floodwalls and riprap etc. Culverts and bridges are structural assets but in this context they are used to help achieve the non-structural measure of providing 100% mitigation of post-development effects.

This FMS supports in principle the recommendations made by OPUS (2007) in their Edgecumbe flood mitigation study especially those related to the river scheme as a whole. Briefly these include constructing several low level stopbanks and pump stations around Edgecumbe township, completing stability assessment of rural stopbanks and implementing measures to restore factors of safety to accepted engineering levels, widening Reid's Central Canal (refer point 3 above) and constructing a spillway/control structure at Reid's Central Canal.

The decision making process will take place at the end of each of the three stages when Environment Bay of Plenty's Strategic Policy Committee and key stakeholders are invited to review results of the Strategy as it unfolds, assess the risks presented, provide feedback, approve or make alternative recommendations to those made by Council Officers.

In the Stage 2 report Environment Bay of Plenty will:

- report on the outcome of recommended tasks made in this Stage 1 report.
- identify the flood mitigation options that are available to reduce the flood risks identified.
- if necessary, provide an economic and environmental evaluation of the options.

In Stage 3, the Strategic Policy Committee will confirm the stakeholders' choice of mitigation options, prioritise strategies and set in place a programme to implement the choices made.

Contents

Part 1: Managing the Rangitaiki Tarawera Floodplains

1.1 Introduction

The original Rangitaiki Tarawera River Scheme provided 100 year flood protection along the lower reaches of the Rangitaiki River between Te Teko and its mouth and the lower reach of the Tarawera River between State Highway 30 and its mouth. Construction of the main river scheme protection works occurred between 1965 and 1983.

In 2006 the total catchment population was approximately 10,500 including Edgecumbe and Te Teko which are protected by major urban stopbanks. A scheme review can identify where improvements are necessary and facilitate implementation so that future populations can enjoy ongoing flood protection.

Environment Bay of Plenty is preparing a Strategy for the long term and sustainable management of flooding in the Rangitaiki and Tarawera River catchments. This is called a Floodplain Management Plan. This plan is to be known as the Rangitaiki Tarawera Floodplain Management Strategy (RTFMS).

Floodplain Management Strategies provide sustainable long term flood risk management which integrates structural and non-structural options, asset management, funding sources and community input to take the scheme into the next 50 or so years. The Floodplain Management Strategy (FMS) will be a plan which is a blueprint. It will propose the level of protection (or service) that the community (or stakeholders) wish to adopt. It will estimate costs, propose who will pay, prioritise work and suggest possible timing. This FMS will bring all these aspects together in an integrated way.

The RTFMS is not intended to become a statutory document in itself but rather provide direction and act as an input to Environment Bay of Plenty's Regional Plans and the Rangitaiki Tarawera Asset Management Plan (AMP). It also provides input to the District Plan and Emergency Management Plans produced by Whakatane District Council.

1.2 Objective

The purpose of this report is to complete the first of three stages that constitute successful floodplain management practice as outlined in the "Floodplain Management Planning (FMP) Guidelines" (OPUS, 2001).

1.3 Stages of Floodplain Management Planning

The stages of floodplain management planning are:

- Stage 1 – Establish the Context for Flood Hazard
- Stage 2 – Identify Mitigation Options
- Stage 3 – Treat Flood Problem

This Stage 1 report will consist of the following three parts as follows:

Part 1 – provides a description of the catchment's characteristics, its history of flooding and Environment Bay of Plenty's response by implementing appropriate flood protection measures. It summarises the results of recent reviews and assessments carried out on flood protection measures implemented to date.

Part 2 – outlines the results of flood modelling. It summarises the affects of the most recent major floods namely the July 2004 flood event. Flood hazards and elements at risk are identified.

Part 3 – summarises the key issues identified in parts 1 and 2 and presents a list of recommended tasks that need to be completed in the Stage 2 report in order to identify mitigation options.

1.4 Planning Framework

A floodplain management planning methodology is proposed in Figure 1.1. It is based on the framework provided in the FMP Guidelines.

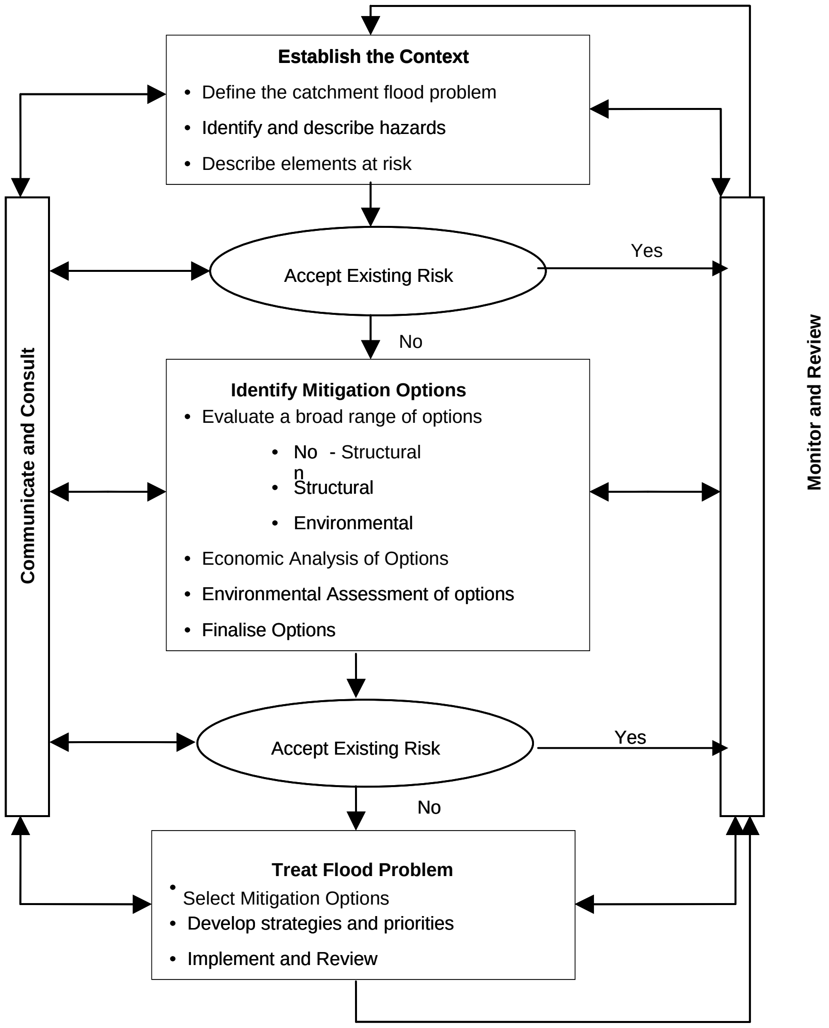


Figure 1.1 Floodplain Management Planning framework.

The project is to produce a non-statutory strategy of co-ordinated measures designed to achieve the floodplain management plan objectives.

The FMS can be regarded as an umbrella document that:

- draws on a number of different plans, procedures and polices;
- filters out relevant provisions of these; and
- massages them or adds to them to produce an integrated approach to dealing with the flood hazard.

The decision making process will take place at the end of each of the three stages when Environment Bay of Plenty's Strategic Policy Committee and key stakeholders are invited to review results of the strategy as it unfolds, assess the risks presented, provide feedback, approve or make alternative recommendations to those made by Council Officers.

Once all three stages of the RTFMS are completed it will outline the responsibilities of the following stakeholders:

- Environment Bay of Plenty (Bay of Plenty Regional Council)
- Whakatane District Council
- Kawerau District Council
- Commercial and industrial interests
- Landowners (including urban and rural communities, Federated Farmers)
- Utility service providers (e.g. TrustPower, TransPower Horizon, NGC, Telecom)
- River user groups
- Department of Conservation (DoC)
- Tangata Whenua
- Any relevant non-governmental organisations (e.g. Fish and Game)

As indicated in the planning framework Figure 1.1 consultation with key stakeholders is a fundamental requirement to ensure the success and acceptability of the FMS.

The relationship between the RTFMS and other local authority plans is summarised in Figure 1. 2.

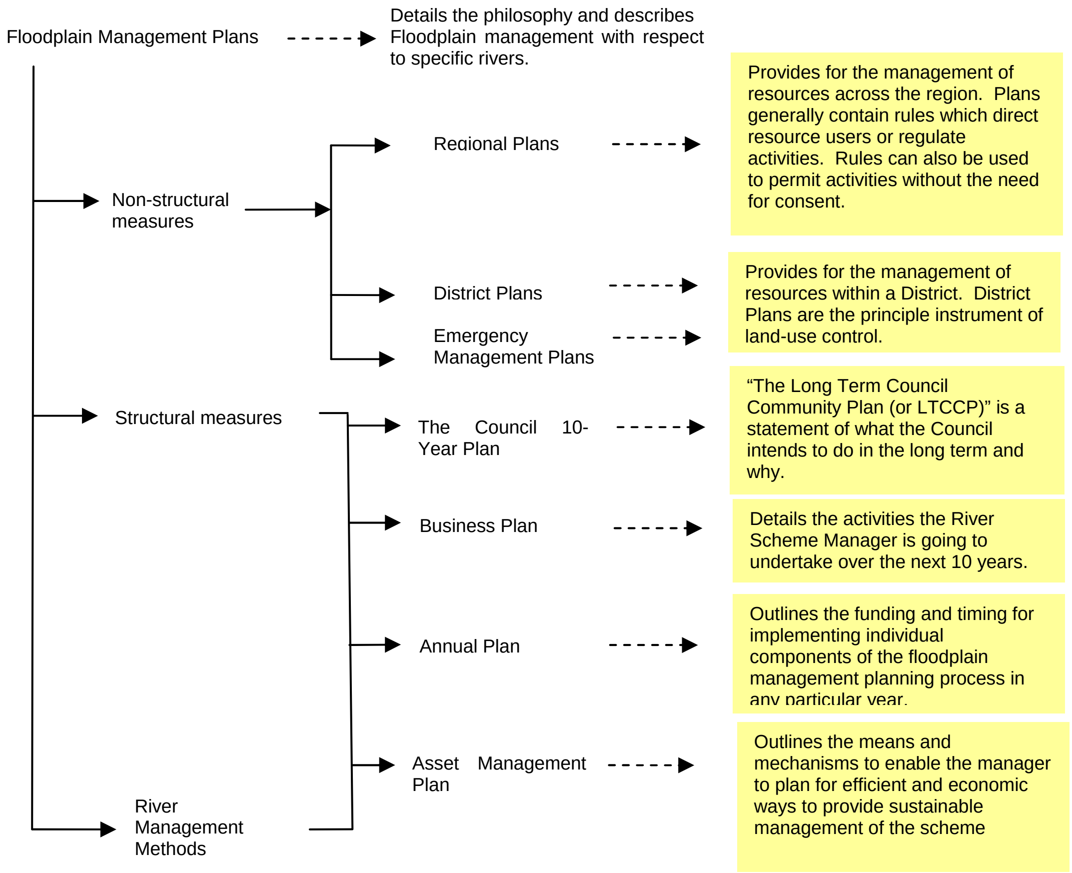


Figure 1.2 Relationship between Floodplain Management Strategies, regional and territorial authority plans.

1.5 The Rangitaiki Tarawera Catchment

The Rangitaiki Tarawera catchment is shown in Figure 1.3 and covers a total area of approximately 4,000 km^2, with 3,005 km^2 in the Rangitaiki catchment and 990 km^2 in the Tarawera catchment.

The Rangitaiki River has its headwaters 130 km from the Bay of Plenty coast and 32 km east of Lake Taupo at an elevation of about 800 m above mean sea level. From there it flows 64 km across the Kaingaroa Plains to Murupara. The Rangitaiki has been dammed towards the northern end of the plains, diverting some flow along the Rangitaiki Canal into the Wheao River, a major tributary joining the Rangitaiki upstream of Murupara, as part of the largely run-of-the-river Wheao power scheme.

Despite a catchment area above Murupara of over 720 km^2, the river at that point remains essentially similar in character to that above due to the small variation in flow. The flat pumice covered plains are very absorbent and regulate runoff to such an extent that flood flows are only two or three times normal flow.

Within 20 km downstream of Murupara, two major tributaries, the Whirinaki 527 km^2, and the Horomanga 218 km^2, enter the river on the eastern side. These rivers rise in the steep bush-covered Ikawhenua Ranges composed of greywacke rock, where the runoff is high and consequently they contribute relatively large flood flows (and quantities of shingle) to the main channel.

The river then continues over the Galatea Plains before it enters Lake Aniwhenua where it is used for electricity generation. Lake Rerewhakaaitu drains into the Rangitaiki at this point. Downstream of the dam, the main channel passes through a gorge and then out onto the Waiohau Plains. Several small tributaries arising in the Ikawhenua Ranges cross the Waiohau, contributing substantially to the flood flows downstream of Aniwhenua. The river travels for 13 km across the Waiohau Plains before it enters Lake Matahina where once again it is used for electricity generation.

Below Matahina the Rangitaiki passes through a well-defined valley before crossing the Rangitaiki Plains.

The headwaters of the Tarawera River include Lakes Okataina, Okareka, Tikitapu (Blue Lake), Rotokakahi (Green Lake) and Rotomahana. These lakes all drain into Lake Tarawera (elevation of just under 300 m), from where the Tarawera River begins.

Within 6.5 km of leaving Lake Tarawera the river has fallen to a level of 150 m. From this point to Kawerau the river falls steadily and moderately steeply through deep pumice country. The river valley is well developed and the bed lined with large boulders and aquatic plants. Below Kawerau the grade is gentler and the bed is perched above the general level of the Rangitaiki Plains on a ridge formed from flood deposits. (The lower Rangitaiki River is similarly perched). Below the State Highway 30 Bridge, the river is stopbanked.

The total catchment of the Tarawera is approximately 990 km^2. Significant tributaries are the Mangawhio, the Waiwhakapa and the Mangamate upstream of Kawerau, the Mangaone and the Ruruanga near Otakiri, and Awakaponga Stream near Matata. The deep pumice of the Tarawera catchment together with the ponding effect of the lake regulates the runoff from heavy storms so the maximum-recorded floods are only two to three times the normal flow.

The Tarawera catchment also includes much of the drainage network on Rangitaiki Plains. This network has been configured from the network of streams and river channels that existed in the 19th century. Major canals in the current network, constructed in the early 20th century, include the Awaiti, Omeheu, Awakaponga and the 109. The Old Rangitaiki Channel, the path of the Rangitaiki before it was diverted into the cut at Thornton, also forms part of the Tarawera catchment.

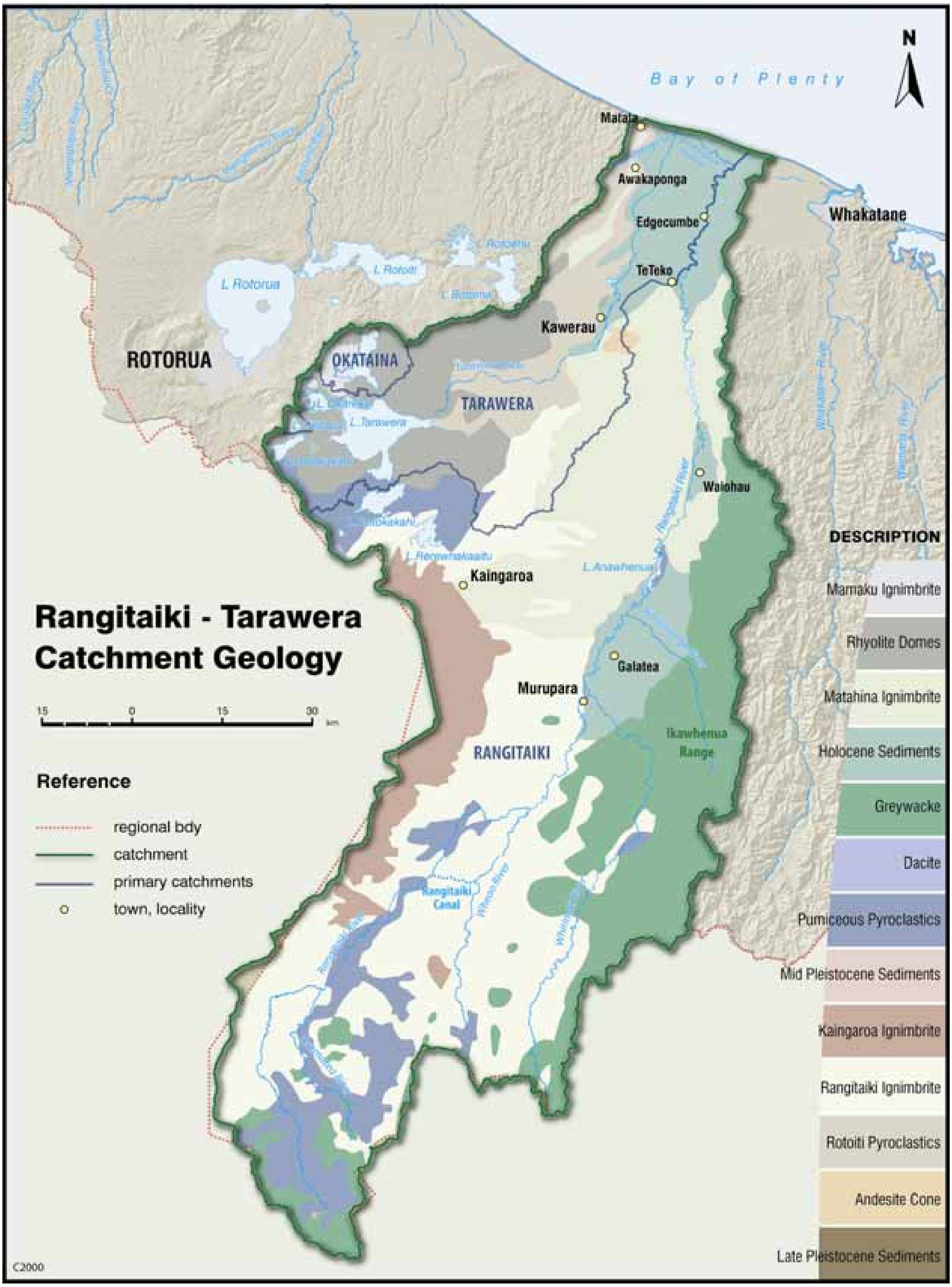


Figure 1.3 Geology of the Rangitaiki Tarawera Catchment.

1.6 Land Use

Land cover and usage affects run-off, which affects the magnitude of flooding. For example urban areas, which tend to have more impermeable surfaces typically increase runoff and flood risk. Heavily vegetated areas, such as forestry on the other hand tend to reduce run-off and lower the flood risk. A map of land usage for the Rangitaiki Tarawera catchment is shown in Figure 1.4.

9.74% of the catchment is rural with the remaining 0.26% being urban. Details of the rural and urban land use is described below.

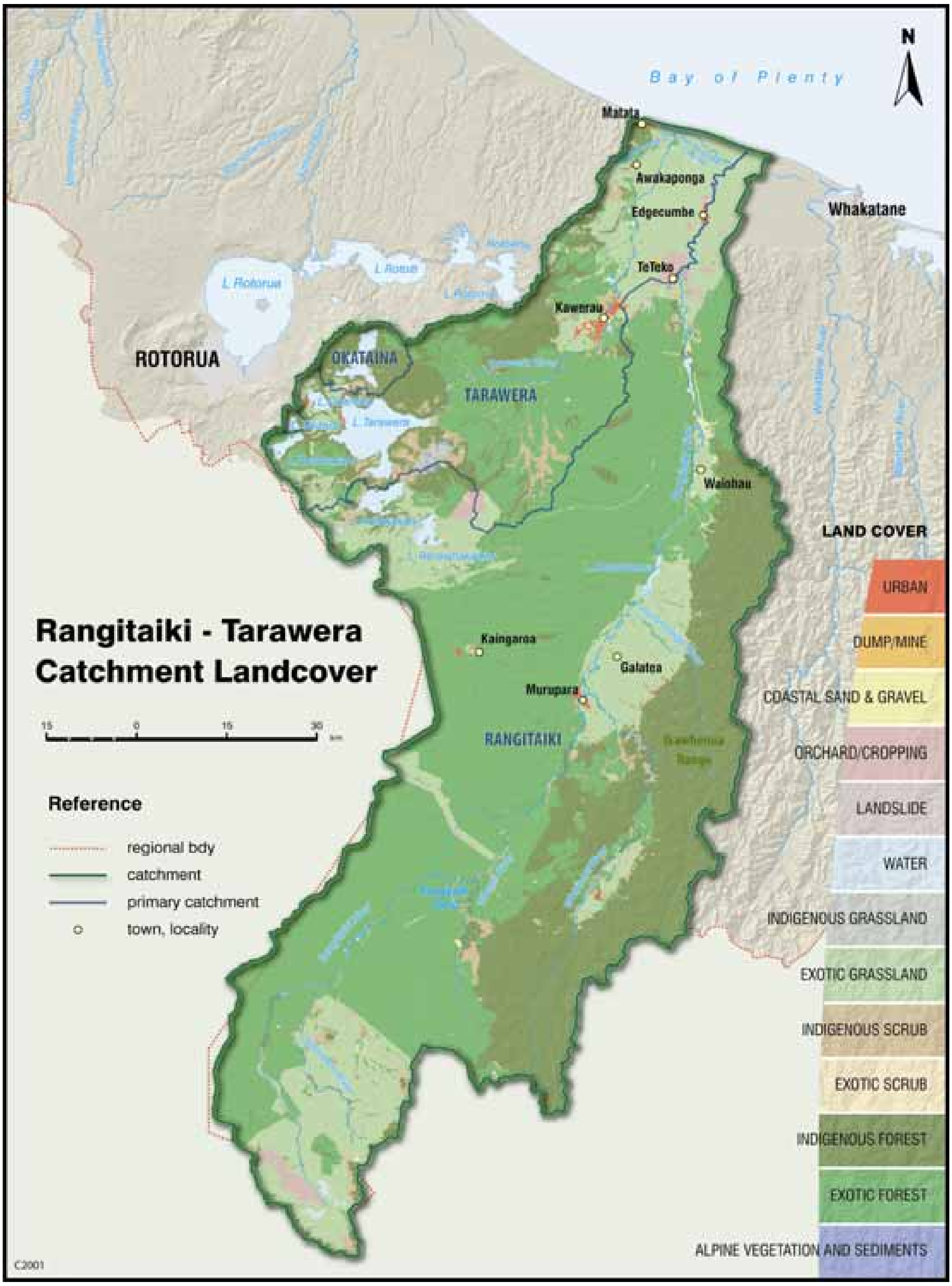


Figure 1.4 Land cover of the Rangitaiki Tarawera catchment.

1.6.1 **Rural**

Environment Bay of Plenty carried out a rural land-use survey of the Rangitaiki-Tarawera catchment in September 2007. The results are shown in Table 1.1 below.

Table 1.1 Rural land uses.

Land Use	Area (ha)	% Total Catchment	Productive ha	% Productive Land-use
Urban	1,041	0.26		
Dump/Mine	124	0.03		
Coastal sand and gravel	31	0.01		
Orchard/Cropping	4,098	1.03	4,098	5
Landslide	23	0.01		
Water	9,893	2.48		
Indigenous grassland	554	0.14		
Exotic grassland	77,002	19.31	77,002	95
Indigenous scrub	11,935	2.99		
Exotic scrub	1,580	0.40		
Indigenous forest	101,647	25.49		
Exotic forest	189,202	47.45		
Alpine vegetation and sediments	273	0.07		
Total Catchment	398,747	100	81,100	100

Exotic and indigenous forests are the most common land-uses accounting for 47.45% and 25.49% of the overall catchment area respectively. This is followed by exotic grassland which is presumably used for dairy and/or drystock farming.

The Rangitaiki-Tarawera River catchment extends as far south as Kaingaroa Plains, situated in the upper catchment 130 km from the coast. The majority of productive land (95%) is situated in the middle and lower catchment (Galatea basin and Rangitaiki Plains) within 60 kilometres of the Bay of Plenty coast.

1.6.2 **Urban**

Urban areas comprise residential, commercial and industrial uses. The residential urban environment comprises the largest component of the settlements and townships in the Whakatane district.

(a) Residential

In 2001 the total population in the Rangitaiki-Tarawera urban areas was approximately 10,500. Urban areas include Edgecumbe, Murupara and Kawerau that has a total population of 6,921.

Te Teko and Edgecumbe urban areas are protected by stopbanks and the Proposed Whakatane District Council Plan has performance standards, which control activities carried out in the vicinity of the stopbanks (refer Section 4.1.5 of the District Plan, 2004). Performance standards are also provided in Section 4.4.1 of the District Plan to protect dwellings from flooding and inundation. For example any activity (subdivision and land use) on land which is located within the Rangitaiki Floodway is a discretionary activity and permission must be sought from Whakatane District Council and Environment Bay of Plenty beforehand.

(b) Commercial

Existing businesses in Edgecumbe and Kawerau support the dairy and forest industries as well as the power generation and transmission sectors. Edgecumbe is protected by urban stopbanks but Kawerau is not since flood design levels remain below and within the natural riverbanks of the Tarawera River.

(c) Industrial

Edgecumbe township's main activities include the primary industrial sites such as Fonterra Dairy factory and Eastpack. TransPower Substation in Edgecumbe supplies power to most of the eastern Bay of Plenty, some urban areas as well as retail, business and other community services.

Kawerau's main industry is pulp and paper manufacturing. A new geothermal power station is being built by Mighty River Power in the town. The new power station provides some employment opportunities for the local population.

1.7 Hydrology

1.7.1 Hydrologic Data

Based on Environment Bay of Plenty's latest Environmental Data Summaries (December 2000) the following hydrologic data sets are available for the Rangitaiki and Tarawera River system catchments:

- River flow records for the Tarawera River at the Awakaponga site (from 1949 to 2000) and the Lake Outlet (from 1971 to 2000)
- River flow records for the Rangitaiki River at the Te Teko site and the Murupara site (from 1949 to 2000) and the Murupara site (from 1971 to 2000)
- River flow records for the Whirinaki River at the Galatea site (from 1953 to 2000)

Tables 1.2 and 1.3 indicate return period flows for each river, based on data available between the periods stated above.

Table 1.2 Predicted Peak Flows in the Rangitaiki and Whirinaki Rivers.

Return Period (years)	**Rangitaiki at Murupara [1] Flow (m^3/s)**	**Rangitaiki at Te Teko[2] Flow (m^3/s)**	**Whirinaki at Galatea Flow[3] (m^3/s)**
200	111	920	425
100	99	780	380
50	87	650	330
20	73	505	265
10	62	410	215
5	52	320	165
2.33	40		100

Table 1.3 Predicted Peak Flows in the Tarawera River.

Return Period (years)	**Tarawera at Awakaponga Flow (m^3/s)**
200	110
100	100
50	90
20	78
10	71
5	61
2.33	52

1.7.2 Climate Change Impacts

Environment Bay of Plenty is developing its policy covering provision for climate change in the region's river and drainage schemes.

Climate change and in particular the global warming has the potential to increase the magnitude, level and frequency of flooding. Hence the capacity of existing flood protection assets must be reviewed periodically when the new flow data becomes available.

At present Environment Bay of Plenty evaluates the potential effects of global warming on a case by case basis (Blackwood, 2005). Assessment of effects considers:

- certainty of available information.
- cost of retrofitting new or renewed structures.
- assets design life span.

[1] These flow estimates were calculated by Blackwood using average of Log Pearson fitted by Bobee and Gumbel.
[2] These flow estimates from Blackwood (2000)
[3] These flow estimates were calculated by Blackwood using EV11 method.

1.7.3 Sea Level Rise

The Intergovernmental Panel on Climate Change (IPCC) issues projections on the impact of global warming on sea levels at five yearly intervals. In 2007 the IPCC predicted increases between 0.18 m – 0.59 m around New Zealand coastlines by 2100AD. There could be an extra 0.10 – 0.20 m on the upper range if there is an increase in the rate of melting of the major ice sheets (MfE, 2007).

In addition to the 0.128 m rise over the last century (1900-2000) IPCC predictions are for a rise of between 0.28 m and 0.79 m over the next 100 years.

Environment Bay of Plenty has adopted the IPCC estimates for the purpose of the Proposed Bay of Plenty Regional Coastal Environment Plan.

Currently, some provision for sea level rise is included in some of the schemes. The impacts of this are limited to the lower reaches of rivers and are relatively small compared to the magnitude of storm surges. An example of the impact of sea level rise is to assets downstream of Thornton Bridge. Sea level rise effects should be considered when determining the levels to which stopbanks are topped up.

1.7.4 Increased Frequency and Magnitude of Flooding

A second, but less quantified adverse effect of global warming is that the frequency and magnitude of high intensity rainfalls are expected to increase.

Dr Andy Resinger, from the Ministry of the Environment, in his visit to Environment Bay of Plenty advised that the frequency of floods of a particular size is estimated to increase between zero and four-fold by the year 2070AD.

In response to an enquiry, Dr Resinger indicated that a doubling in frequency would be a reasonable approach.

Advice from the New Zealand Climate Change Office (2003) is that the forecast mid-range estimate for increase in temperature in the Bay of Plenty as at 2080 is 2^0C above present temperatures. Based on this temperature increase, rainfall intensities for critical storm durations are likely to increase by 11 to 14 per cent and flood magnitudes by 17 (Whirinaki) to 22 per cent (Ikawhenua tributaries). Whilst these figures are preliminary they would mean that there would be a significant increase in flood frequency by the year 2080. As an illustration a preliminary study of the Whakatane River hydrology shows that there would be a forecast threefold increase in flood frequency for the major floods by that date, with the current 300 year flood becoming the 100 year flood by 2080.

It will be important to take account of increased frequency and magnitude of flooding when reviewing the flood protection of assets. When key structures and those difficult to retrofit (e.g. flood walls) come up for construction or renewal then they should be designed for the likely intensification of flows during their design life.

1.7.5 Impact of Interdecadal Pacific Oscillation

The Interdecadal Pacific Oscillation (IPO) is a climate cycle affecting the majority of the Pacific. This cycle has more immediate impact on flood frequency than global warming and is to be considered in any future review of flood protection of assets.

The IPO cycle is strongly correlated to heavy rainfall and floods in the Bay of Plenty resulting in successive “benign” and “active” phases. These phases persist for 20 to 30 years. The cycle shifted to a “benign” phase in the mid-1970’s and subsequently to an “active” phase around 1997-98. For the Rangitaiki River, which has a long term average flow of 254.8 cumecs the flow during the ‘active’ period, is expected to be 285 cumecs (+12%) and during the ‘benign’ period it is 210.4 cumecs. The influence on the larger floods is more pronounced (as demonstrated in a report by Dr Alistair I McKercher, NIWA in Tephra).

The impact is that we can expect a series of floods with above average magnitude over the next 20 years.

1.8 Historical Flooding

Flood level data has been recorded since 1949. Prior to this period flood level information was obtained from local residents and it is apparent that exceptionally high floods occurred in 1906 and in 1925. Little is known about the 1906 flood but records of latter floods are available and these are provided below.

Flood protection structures were constructed as part of the Rangitaiki Major River Scheme in the period 1965-1980.

A timeline graph showing historical floods and their magnitude are provided in Figure 1.5. A description of flood events follow.

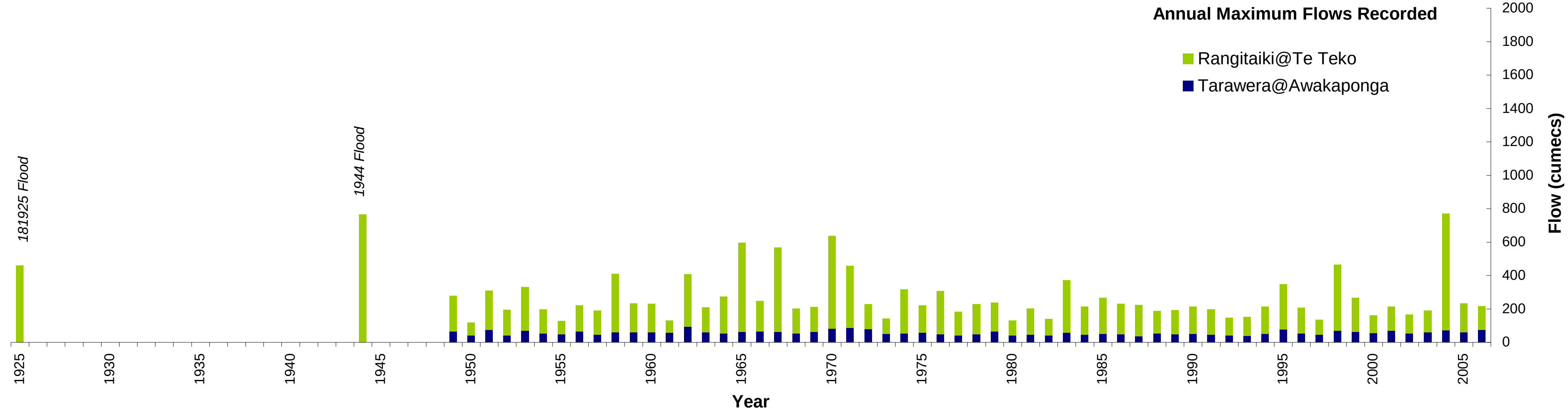


Figure 1.5 Flood History of Rangitaiki and Tarawera Rivers.

1.8.1 22-24 May 1925

The biggest floods experienced for 20 years caused extensive and widespread flooding throughout the district. Rangitaiki River was in high flood, but no inundation occurred along the river (Cowie, pg 41, 1957).

1.8.2 24-25 June 1925

The Rangitaiki River caused much flooding, and serious stock losses were reported in the area. The peak discharge above Edgecumbe was 459 m^3/s (16,225 cusec), and 57 m^3/s (2,000 cusecs) escaped at the peak of the flood. (Cowie, pg 42, 1957).

1.8.3 28-29 June 1925

Further flooding of the Whakatane and Rangitaiki Rivers, following heavy rain caused extensive inundation over the Rangitaiki Plains. 12,141 ha (30,000 acres) were flooded and considerable damage was done to pastures, stock and fences. Roads suffered severe damage, and many small bridges were washed away. (Cowie, pg 42, 1957).

1.8.4 22-23 July 1925

A strong north-easterly gale, accompanied by heavy rain brought floods to the Bay of Plenty area. The Rangitaiki River overflowed above Riversleigh, but stock losses generally were small because of timely warning. (Cowie, pg 42, 1957).

1.8.5 8-10 October 1926

Heavy rain throughout the district caused most of the rivers to rise, but although some local flooding resulted no serious damage occurred. Some roads were blocked in the Rotorua district, and the Rangitaiki River overflowed its banks and flooded an area of 2,833 ha (7,000 acres). (Cowie, pg 42, 1957).

1.8.6 12-13 February 1934

An exceptionally long spell of wet weather was followed by torrential downpours of rain in some areas. The Rangitaiki River overflowed at Thornton, and the Whakatane River inundated some land above Whakatane. Numerous slips occurred on roads and flood waters making some roads impassable. (Cowie, pg 42, 1957).

1.8.7 20-21 June 1934

Heavy rain in the eastern end of the district caused serious damage to roads throughout the district through slipping and washouts. Rivers were in high flood and at Te Teko the highway bridge was 1 m (3 feet) under water. Some stock losses were reported. (Cowie, pg 42, 1957).

1.8.8 24-25 June 1935

Serious flooding occurred in many parts of the district as a result of heavy rain. The Rangitaiki River overflowed its banks near Edgecumbe flooding areas on the east bank, and the nearby dairy factory to a depth of 225 mm (9 inches) (Cowie, pg 42, 1957).

1.8.9 23 February 1944

A 24 hour rainfall period (a record up to this time) centred over Rotorua saw 144 mm (5.76 inches) fall, the majority of which fell within three hours. Further east heavy rain caused the Rangitaiki River to rise, and flooding on an extensive scale took place on the Rangitaiki Plains, with large stock losses. The peak discharge was estimated at 765 m^3/s (27,000 cusecs) at Te Teko. (Cowie, pg 44, 1957).

1.8.10 21 May 1962

On Monday, 21 May 1962 the Rangitaiki River was flowing almost bank full following heavy rain of up to 250 mm (10 inches) centred near Waiohau. The situation at 4.00 pm appeared to be safe and no overflows had occurred. However at 4.30 pm a share milker on Mr Reynolds property located close to the Rangitaiki River at river distance 4.8 km (3 m 00ch) observed a spout of water appear in the paddock approximately 81 m (4 chains) from the Rangitaiki River. By 5.00 pm the land between the spout and the river had completely subsided and a good proportion of the Rangitaiki River was raging through the breach. It is possible that this breach of the banks reduced water levels in the river nearby and prevented other imminent overflows. (BOPCC, 1985, p14).

1.8.11 1 June 1962

Further heavy rain caused a second flood peak of 416 m^3/s (14,700 cusecs) and on Friday, 1 June the newly repaired bank was again breached and severe flooding occurred once more. But worse was still to come. During the night of 1-2 June the Tarawera River overtopped and breached the right bank at 3.61 km (2 m 70 ch) and on Saturday, 2 June the Kopeopeo West Canal burst its banks and by that evening over 3,238 ha (8,000 acres) was inundated. (BOPCC, 1985, p14).

Figure 1.7 Stopbank breach at Reynolds Bend, Rangitaiki River in 1962 (river flow direction is from right to left in downstream direction).

1.8.12 February 1965

High floods occurred again in February 1965, 596 m^3/s (21,050 cusecs) and overflow at Pepperells Bend on Rangitaiki River flooded approximately 1,416 ha (3,500 acres) (BOPCC, 1985, p14).

Figure 1.6 Photo from over the Board Mills looking towards Whakatane West Station (i.e. the Rangitaiki Plains) (February 1965).

1.8.13 February 1967

High floods occurred again in February 1967, 566 m^3/s (20,000 cusecs) and overflow at Pepperell's Bend flooded approximately 1,416 ha (3,500 acres). (BOPCC, 1985, p14).

1.8.14 February 1971

Failure of the left bank occurred approximately 3.9 km upstream of the Tarawera River mouth (Mexted property) and flooding occurred to the west (left bank) of the river between the Matata-Edgecumbe Road and State Highway 2. (BOPCC, Report on Tarawera River Stopbanks 1983, p5).

1.8.15 February 1979

A right bank failure occurred on the Tarawera River in the Awaiti area at the seaward end of Sutherland Road. The highest river stage recorded at the Awakaponga gauge station (just upstream of the Matata-Edgecumbe road) during this flood was 2.89 metres or about one metre above normal river stage. The water level during this flood would not have generally risen above river bank level (i.e. the base of the stopbanks). (BOPCC, Report on Tarawera River Stopbanks 1983, p5).

1.8.16 **1-16 July 1998**

Over the period 1-16 July 1998 the Bay of Plenty and in particular the eastern Bay of Plenty was subjected to heavy rainfall. During this 16-day period, four storms caused four flow peaks in the Bay of Plenty rivers.

In October 1998 NIWA carried out a peer review of an Environment Bay of Plenty report on the meteorology and hydrology of the July 1998 floods (Ellery, 2000). The return period floods in the Tarawera River ranged between 5-10 year flood and in the Rangitaiki River between 10-20 year flood. (Source: Glenn Ellery, Environment Bay of Plenty).

1.8.17 **14-18 July 2004**

Heavy rain began falling in the Bay of Plenty on Thursday, 15 July 2004 and continued for the following three days. In the period between 14 and 18 July some 284 mm of rainfall was recorded at the NIWA rain gauge located in Edgecumbe. This rainfall caused widespread flooding throughout the region effecting Edgecumbe, the Rangitaiki Plains, Whakatane and Opotiki. The extent of flooding in the Rangitaiki Tarawera catchment is shown in Figure 1.9. A great deal of the flooding was a result of Sullivan's bend breaching.

The following text is taken from a joint council report on the July 2004 flood event (Environment Bay of Plenty, 2004)

Flood flows in the Rangitaiki River were gauged at 1% AEP (100 year return period) level on Sunday, 18 July.

From early on 18 July, staff, contractors and volunteers sandbagged to prevent stopbanks overtopping on the true left bank in the lower river at Laws Bend. Contractors and staff were also treating critical stopbank seepages at several locations in the vicinity of Edgecumbe including a site on the bank adjacent to the Fonterra factory.

At approximately 10.00 am on 18 July, a 100 m wide section of the main Rangitaiki true right stopbank upstream of Edgecumbe failed without warning. This breach immediately sent between a quarter and a third of the Rangitaiki floodwaters onto the Plains which flowed both northwards and eastwards overwhelming the Reid's Central Canal floodway as it did so. Over the next two days the breach floodwaters seriously inundated thousands of hectares of farmland and associated property infrastructure. Much of the Lower Rangitaiki/Tarawera River Scheme and Rangitaiki Drainage Scheme infrastructure was also overwhelmed.

Some of the floodwater flowed through part of the Fonterra Factory near Edgecumbe and residential areas of Edgecumbe on the eastern side of the river and also resulted in local roads and the Awakeri-Edgecumbe Highway (State Highway 30) being closed on the afternoon of 18 July.

On the afternoon and evening of 18 July a major effort by Environment Bay of Plenty staff and contractors to temporarily bund the very vulnerable Transpower/Horizon Substation on the right bank downstream of the breach proved to be successful. This work in conjunction with some on-site pumping kept the facility dry. Loss of the substation to floodwaters would have resulted in a power outage to the whole of the Eastern Bay of Plenty and would have catastrophically escalated the Civil Defence emergency.

The breach induced floodwaters continued to spill onto the Plains and flowed towards the coast reaching the Whakatane-Tauranga Highway at Thornton by late Monday, 19 July. On that day a controlled cut was made by Environment Bay of Plenty in the vicinity and upstream of Thornton to allow the ponded Plains floodwater to flow back into the river. At the same time plans were being developed to block the main breach above Edgecumbe.

On Tuesday and Wednesday 20 and 21 July, several more controlled cuts were made to help get ponded water on the Plains back into the river. Innovative use of shipping containers was made by placing them in the cuts so as to act like "non-return valves" and prevent back flow of tidal river waters during incoming tides.

On 21 July an access road was completed to allow heavy machinery access to the 100 m wide and up to 5 m deep main breach. Huge volumes of rock material were carted to the site by a fleet of trucks operating 24 hours a day. The breach was blocked using approximately 16,000 m^3 of compacted material by 24-25 July.

Once the event developed, as far as possible the Matahina dam was operated to reduce the peak flows in the system. The corollary, of course, was that high levels were maintained far longer than in the natural flow situation. As the river levels slowly lowered, sections of the Rangitaiki true left stopbank between Te Teko and Edgecumbe were found to be severely damaged and extremely vulnerable on a number of bends. Collapse and undermining had continued due to prolonged elevated river levels and the saturated state of the banks and adjacent land.

The swarm of earthquakes concurrent with the flood may well have contributed to the damage to both stopbanks and edge protection works. In the case of the damage to the stopbank at Kokohinau Bend it was evident that the damage occurred in discrete stages. That is sizeable portions of the collapse occurred in several distinct episodes. The earthquakes would have placed significant loading on the saturated stopbanks and what was on first sight a drawdown failure would have been seriously aggravated by the earthquakes. Similar episodic failure occurred at other erosion sites. For example, blocks of two to five metres of riverbank collapsed in essentially one go at Pryor's Bend during the earthquake swarm.

In addition to the array of controlled cuts employing gravity to help drain the flooded Plains, a major pumping operation was commenced on 21 July. Some 60 large capacity transportable pumps were brought into the area from throughout New Zealand to augment the 45 Environment Bay of Plenty managed pumping stations. These diesel tractor driven or electric pumps operated for 24 hours a day for a period of up to two weeks. Major logistics were involved in allocating, positioning, shifting and servicing the pumps.

Figure 1.8 Stopbank breach at Sullivan's Bend, Rangitaiki River July 2004.

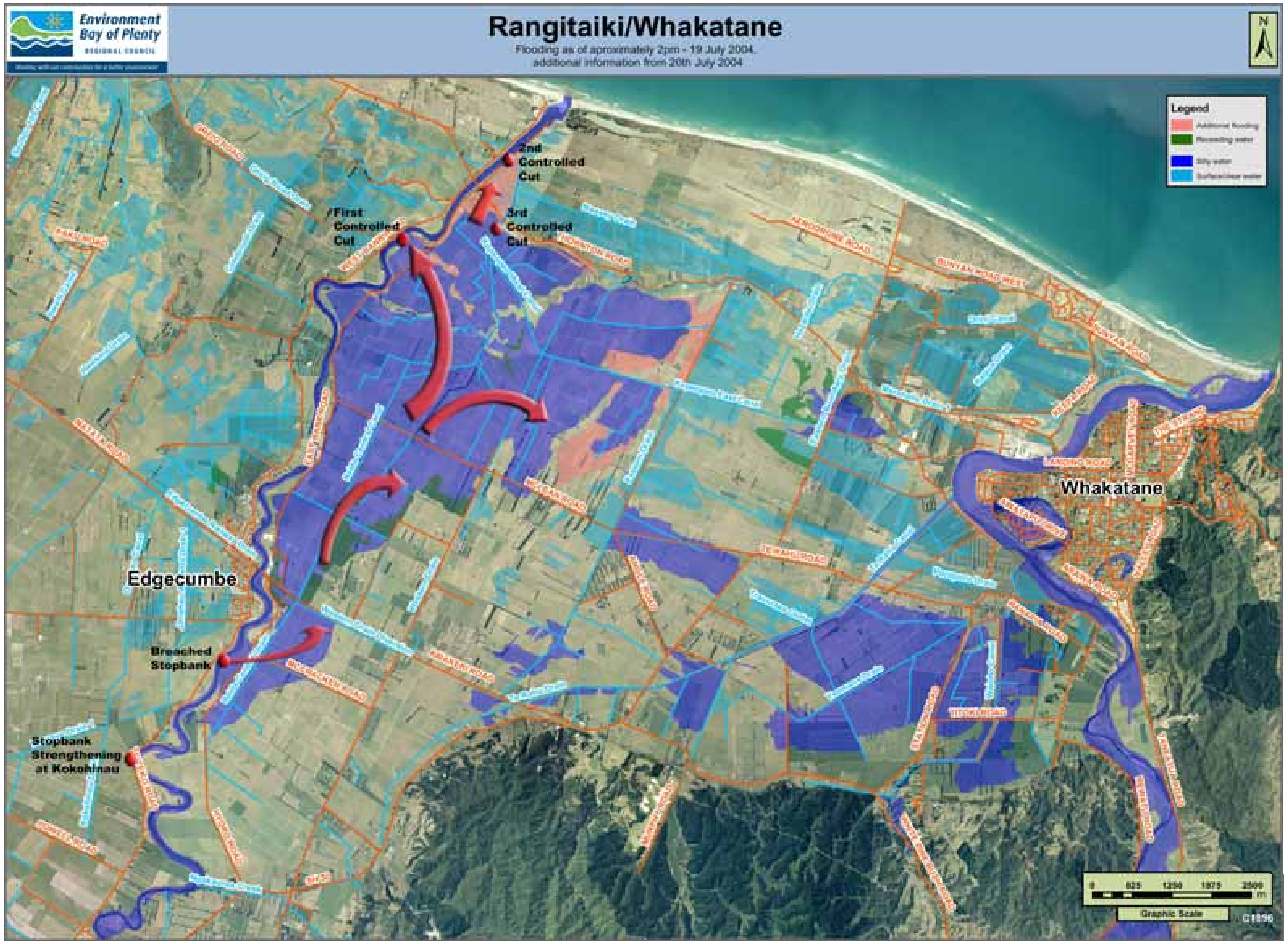


Figure 1.9 Extent of July 2004 floods in Rangitaiki Plains.

Flood response and recovery work for the Rangitaiki-Tarawera scheme was initially estimated to total $5.4M (Environment Bay of Plenty, 2004) however by June 2006 this estimate had risen to approximately $8.4M (Environment Bay of Plenty, 2006). Part of this cost increase was due to additional damage caused by a flood event in December 2004. These cost estimates were only for repairs to the flood protection assets and included replenishing rock edge protection, repairing fences to stop stock accessing scheme plantings, de-silting canals and drains.

Figure 1.10 View of Rangitaiki River looking downstream at Edgecumbe with TransPower substation to right, July 2004.

1.9 Response to Flooding: Structural Works

Structural measures involve constructing physical works designed to contain floods and limit erosion. In essence, structural measures are constructed to keep the river away from people, possessions and development and constitute the more traditional tools for reducing flood risk.

The Rangitaiki River Scheme is a river and drainage scheme that includes; substantial stopbanking of the main rivers and some major canals, floodgates, gravity and pumped drainage outlets, considerable channel edge (bank) protection and plantings and flood proofing. The scheme includes the Rangitaiki and Tarawera Rivers and the Rangitaiki (or Reid's Central) Floodway, Awaiti, Omehu, Old Rangitaiki, Awakaponga and 109 canals.

The aim of the original scheme was to:

- Alleviate flooding on the Rangitaiki Plains by providing 100-year flood protection along the Rangitaiki River between Te Teko and the river mouth, and on the Tarawera River between State Highway 30 (State Highway 30) and the sea.

- Alleviate flash flooding from tributary streams and rivers of the Galatea Plains by planting to stabilise shingle fans, confine the floodway, and filter out heavy debris that causes most of the damage during floods.

- To control the channels of the rivers so as to reduce land loss through erosion by removing overgrown or unplanned willow areas and riprap placement on riverbanks between Te Teko and Matahina Dam on the Rangitaiki river and minor channel improvements and bank stabilisation between State Highway 30 and Kawerau Mills on Tarawera River.

Prior to the scheme, extensive flooding was a common event for the Rangitaiki and Tarawera floodplains due to river bank overflows or from stopbank failures. During the period 1944 to 1964, 15 floods occurred on the Rangitaiki River that caused extensive flooding to the surrounding areas. Ad hoc stopbanks had been constructed along the Tarawera River, in which a breach occurred in 1962. In addition, all riverbanks suffered from erosion, and the Galatea plains were subject to considerable gravel deposition.

Scheme construction commenced in 1971 and was completed in 1983.

The Edgecumbe earthquake of 1987 had a significant impact on the Scheme. Physical damage to the stopbanks, floodwalls and riverbanks occurred, while general ground subsidence led to a lowering of the standard of flood protection. (Jones, 1987). Rehabilitation works after the earthquake included stopbank reconstruction and floodwall raising. As well as repairs on the Rangitaiki and Tarawera stopbanks, the remedial works included repairs or topping up of stopbanks along the Awaiti, Omeheu, Awakaponga and Old Rangitaiki Channel (these stopbanks being considered part of the river scheme). Floodgates on the Awaiti were also installed at this time, to improve drainage during incoming tides, while a pump station at the outlet of the Old Rangitaiki Channel was built in 1991.

In 1996 Environment Bay of Plenty concluded that while the original objectives of the scheme were valid and supported by ratepayers, the objective of channel control had not been fully achieved. A maintenance review of the scheme was performed in 1996 (Titchmarsh, 1996), recommending a programme of works to achieve a stable channel and meander pattern. These works which became known as the Rangitaiki-Tarawera Restoration project included:

- clearing overgrown willows and vegetation;

- layering willows, trenching anchored willows;

- providing additional rock work;

- shingle extraction;

- diversion by tree groynes or by shingle extraction; and

- planting and fencing.

Since the July 1998 floods remedial works have been carried out on the Rangitaiki River. Section 1.10.2 provides more detail but works included:

- raising crest levels along the lower Rangitaiki River;

- providing seepage control for stopbanks at Edgecumbe;

- dredging of the channel along the Lower Rangitaiki (planned for 2008/09).

Since the July 2004 floods an extensive review of the Rangitaiki stopbanks has being carried out to determine what measures are necessary to improve the resistance against piping failure. Sullivan's breach was the result of piping failure in the stopbank foundation soils and since July 2004 several other stopbank sites have been identified as having similar low factors of safety against piping failure. The swarm of earthquakes concurrent with the floods may well have contributed to the damage to both stopbanks and edge protection. In the case of the damage to the stopbank at Kokohinau bend it was evident that the damage occurred in discrete stages. That is sizable portions of the collapse occurred in discrete stages. The earthquakes would have placed significant loading on the saturated stopbanks that was on first sight a drawdown failure would have been seriously aggravated by the earthquakes. (Environment Bay of Plenty, 2004). Remedial works following the July 2004 floods included:

- reinstatement of stopbanks that breached or suffered damage;
- riprap armouring of the river banks that protect the berms and stopbanks;
- installation of toe drains on landward side of stopbanks; and
- installation of seepage cut-off walls through the middle of stopbanks.

1.9.1 Stopbanks

The Rangitaiki River Scheme comprises approximately 109 km of stopbanks built along the Rangitaiki and Tarawera riverbanks and some major canals. The stopbanks were initially constructed in the 1960's and the last major stopbank works were completed in 1983 (Tarawera).

The ability of the stopbanks to contain floodwaters to at least design capacity depends partly on how well they have been constructed and maintained. Of equal importance is the suitability of stopbank foundation soils. A well engineered and maintained stopbank can still succumb to say piping failure if foundation soils are unsuitable. Based on geotechnical investigations carried out to date on Rangitaiki Plains stopbanks it appears there will always be a residual risk of foundation piping failure since the soils are very porous. Appendix 1, Figure A1.1 shows location plan of existing urban and rural stopbanks in the catchment.

1.9.2 Stopbank Capacity

The Rangitaiki River Scheme has been subject to two previous capacity reviews in 1988 (Dines) and 2000 (Blackwood). OPUS Consultants have also carried out a capacity review as part of the Edgecumbe flood hazard study (OPUS, 2006). Stopbank capacity reviews are a requirement of the Rangitaiki Asset Management Plan. Ideally capacity reviews are carried out at least one year ahead of any remedial works. The *capacity review* program outlined in the AMP and subsequently modified by the LTCCP for the next two years is:

2007/08 Reach 10 Canals – Awaiti, Omehu, ORC, Awakaponga and 109.

2008/09 Reach 10 Canals – Reid's Central Canal/Floodway.

Appendix 1 provides a summary of reviews carried out on the Rangitaiki River scheme plus its adjacent canals. These have resulted in physical works to return the stopbanks to a level that meets the schemes design service levels as shown in Table 1.4.

Table 1.4 Design service levels for Rangitaiki River scheme stopbanks

Location	**Design Service Level**
Tarawera Right Bank	100 year plus 300 mm freeboard
Tarawera Left Bank Below Taneatua Branch Railway	100 year plus 300 mm freeboard
Tarawera Left Bank Above Taneatua Branch Railway	100 year plus 150 mm freeboard
Rangitaiki River — Rural	100 year plus 300 mm freeboard
Rangitaiki River — Urban (Te Teko, Edgecumbe, Thornton)	100 year plus 600 mm freeboard
Rangitaiki Floodway (or Reid’s Central Canal)	100 year plus 250 mm freeboard
Awaiti, Omeheu, 109 Canals	5 year plus 300 mm freeboard
Awakaponga	10 year plus 300 mm freeboard
Old Rangitaiki Channel	5 year plus 150 mm freeboard

(a) Tarawera River

Design levels of the Tarawera stopbanks were reviewed in 1986 (Pemberton), and the actual freeboard found to have increased.

An updated estimate of the 100-year flood peak was made in 1986. The revised value of 99.3 m^3/s was lower than the value of 113.3 m^3/s used in the original design. Even after allowing for some settlement after construction, the available freeboard was still greater than design freeboard (Pemberton, 1986). Subsequent estimates of design flood flows (Iremonger and Stringfellow, 2000) have shown the value is close to 100 m^3/s.

Environment Bay of Plenty (2005) completed a second capacity review of Tarawera stopbanks. Hydrological data updated to 2001 resulted in the 100 year flood peak being calculated as 100.2 cumecs. Based on 2002 cross-section survey data and review of roughness Manning’s ‘n’ values stopbank top-ups were identified as being necessary on both banks downstream of river distance 9900m. The 2005 capacity review indicates some stopbank top ups are required to restore service levels. Design of the Tarawera River stopbank top-ups is scheduled for 2008/09. Refer also to s2.4 for recommendation on construction timetable.

(b) Rangitaiki River & Reid’s Central Canal

Design levels of the Rangitaiki stopbanks were reviewed following the 1987 Edgecumbe earthquake (Dine, 1988), and the banks reconstructed to the updated design. The review assumed a sea level rise of 0.14 m to 2020.

A further study of the flood hazard from the Rangitaiki was undertaken in 1995 (Barnett Consultants, 1995). As well as investigating the effect of several breach scenarios, overtopping scenarios were also considered. The study concluded that a freeboard of 500 mm is maintained in a 1 in 100 year event (AEP = 1%). Even in a 1 in 250 year (AEP = 0.4%) freeboard is generally maintained in the main channel although not in the floodway. In a 1 in 500 year event (AEP = 0.2%), the water levels are not contained by the freeboard, but only exceed bank levels in isolated locations within the main channel. No sea level rises were assumed in the 1995 study. Not available to this review was the July 1998 flood level data, which has resulted in the conclusions for the main channel being superseded.

OPUS International Consultants reviewed the stability of Edgecumbe stopbanks following the July 1998 floods. This was carried out because seepage and slight heaving was observed during the flood. OPUS undertook further geotechnical investigations in 2000 to assess the effects of the subsurface conditions. **OPUS concluded 'that none of the (*five investigated) Edgecumbe* stopbank sections are stable under steady state seepage conditions[4]' (OPUS, 2000, pg 13).** That is none of the sites could withstand bank full levels for an indefinite duration. However, under a slightly longer than predicted flood hydrograph (with water levels within one meter of the peak for 72 hours) all but three sections were stable during a "bank full" (essentially 100 year flood event plus freeboard) flood. On this basis several remedial options were recommended to improve the stability and drainage capacity of the Edgecumbe stopbanks. Stabilisation works on the three sections identified above were completed between 2000 and 2002.

In 2000 a review of the flood carrying capacity of the Rangitaiki River downstream of Edgecumbe was completed (Blackwood, 2000). Using a state of the art computer software package called MIKE 11 and July 1998 river flood data the report concluded that stopbanks needed to be raised by up to 700 mm over a reach of about 6.6km in order to maintain the scheme standard as set out in this asset management plan. As a result of the 2000 flood capacity review:

- Edgecumbe stopbanks have been upgraded to provide protection against a 100 year flood event by providing seepage relief to the stopbank at the Transpower sub-station and the floodwalls at College Road and Anchor Milk plant.
- Lower Rangitaiki (rural) stopbanks have been upgraded to provide protection against a 50 year flood event (with 300 mm freeboard). This was accepted as an interim/temporary solution for the reach between Edgecumbe (downstream of the town starting at the Domain Reserve at river distance 8750 m[5]) and Thornton. Floodwalls were constructed at East Bank Road and West Bank Road. The expectation was that the 100 year flood protection would be achieved through natural channel degradation processes at this location. If this option failed then dredging would be investigated and implemented in 2008/09 following the next AMP review scheduled for 2007/08.

[4] At the time of the schemes conception, in the late 1960's, stopbank design philosophy usually assumed that flood peak levels would be short and the risk of steady state seepage regimes developing almost non-existent. Today steady state seepage scenarios are usually considered in design to reduce risk of seepage and stability failures occurring.
[5] Distance 8750 m corresponds approximately with Environment Bay of Plenty river survey cross-section marker R21

Capacity of the Rangitaiki stopbanks is influenced by discharges from Matahina dam located upstream of Te Teko. Although storm flows can be managed by the dam by controlling outflows Matahina dam does have limited storage and so its ability to always keep discharges low is limited by how fast the reservoir is filling up.

Matahina dam is owned and operated by TrustPower Ltd and comprises an earth dam, a concrete spillway structure and hydroelectric power station. TrustPower has a comprehensive Emergency Action Plan (EAP) and procedures that outline how floods, earthquakes and volcanic activity will be jointly managed by its own management staff, emergency services, Whakatane District Council and Environment Bay of Plenty. Discharges from the dam spillway gates and power station penstocks are controlled by its resource consent conditions. Given the downstream stopbanks are designed for a 100 year design flow at 780 cumecs TrustPower has developed a three staged approach to flood management. The procedures allow TrustPower to optimise the power stations production and yet still comply with its consent conditions. Brief descriptions of the flood management stages follow (TrustPower, 2006):

Stage 1 Alert: TrustPower receives a severe weather warning from the Met Service and alerts operations staff of a potential flood situation.

Stage 2 without Lake Drawdown: For floods that are expected to be less than 500 cumecs TrustPower will increase generation with discharges up to 135 cumecs. If lake level rises above the normal operating maximum level then the spillway gates will begin opening.

Stage 3 with Lake Drawdown: For floods that are expected to be greater than 500 cumecs and/or upon the request from Environment Bay of Plenty to lower lake level. TrustPower will lower lake level and maintain it at a level below the normal operating minimal level. If the lake inflow exceeds 550 cumecs then TrustPower will manage outflows so that it maintains a 550 cumec outflow. If lake level still continues to rise above the normal operating maximum level then TrustPower will increase the total discharge to 600 cumecs.

TrustPower's flood management procedures were put to the test during the July 2004 floods when the equivalent of a 100 year flow was recorded at Te Teko. In its request for funding submission to Central Government Environment Bay of Plenty reported that sections of stopbank particularly on the true left between Te Teko and Edgecumbe were severely damaged. It was suggested that *"collapse and undermining had continued due to prolonged elevated river levels and the saturated state of the banks and adjacent land* (Environment Bay of Plenty, 2004).

Since July 2004 TrustPower and Environment Bay of Plenty have embarked upon a joint contract with NIWA to improve flood forecasting at Matahina dam. Refer s1.13 for further detail. TrustPower and Environment Bay of Plenty are also preparing a joint Memorandum of Understanding that will improve dam operation during flood events.

TrustPower have outlined the potential consequences of a sudden failure of Matahina earth dam on a sunny day in the EAP. The EAP also documents the emergency management controls TrustPower will implement in such an event. If a large flood causes the Emergency then the incremental consequence will be less at most but not all downstream locations. A flood map showing inundated areas resulting from a dambreak of Matahina Dam during a dry day is shown in drawing 8/1275/92 provided in Figure A2.4, Appendix 2.

At present Environment Bay of Plenty's Flood Warning Manual does not refer to the Matahina EAP and flood procedure. It is recommended that text related to the Matahina in the Environment Bay of Plenty Flood Warning manual be cross-checked against TrustPower's Matahina dam EAP and flood procedures. The Matahina dambreak flood map should also be appended to the Flood Warning manual.

In 2006 OPUS completed a flood mitigation study for Edgecumbe township and the surrounding rural areas including the Rangitaiki River and Reid's Central Canal. Their study excluded the Tarawera River and surrounds. The OPUS study concluded that:

- the hydraulic conveyance of the design flood event in the Rangitaiki River and Reid's central canal below Edgecumbe is marginal.
- Reid's Central canal is narrow at some locations which greatly reduces its overall capacity.
- the Rangitaiki stopbank foundation conditions are prone to piping failures under flood conditions.
- dredging is unlikely to significantly increase long term flow capacity of the Rangitaiki River.
- local stormwater is a problem in the town of Edgecumbe particularly in the southwest where low lying parts of the urban area are reliant upon a rural standard drainage standard.

OPUS explored a number of mitigation options to reduce the flood risk. Measures included land use controls, to flood defences of critical areas, to schemes which improve the overall flood capacity of the river system. Discussion of land use controls and flood defences of critical areas is found in sections 1.12 of this report.

OPUS concluded that the highest priority for the Rangitaiki River/Edgecumbe area should be to implement a number of works that would protect the integrity of the river scheme as a whole. Specific works that gave the best return on investment are shown in Figure 1.11 and summarised in Table 1.6.

This FMS supports in principle the recommendations made by OPUS in their Edgecumbe flood mitigation study especially those related to river scheme as a whole.

Environment Bay of Plenty and Whakatane District Council prepared a cost benefit analysis (2007)[6] for the mitigation options and their results are shown in Table 1.5. The analysis showed that if Scheme 5 were to be completed then that would significantly reduce the likelihood of a 100 year flood affecting the urban area. A sensitivity analysis was also conducted to assess the changes in the benefit-cost ratio if calculated benefits were reduced by 20%. The sensitivity analysis indicated that even if benefits were overestimated by 20% all of the recommended flood mitigation schemes would still remain economically viable.

Environment Bay of Plenty and Whakatane District Council are currently seeking financial assistance from central government to help pay for the mitigation options. Depending on the level of any Government contribution to these works regional council rate increases (by 2011) could range from:

- between 45-75% for an average sized dairy farm (135 ha).
- up to 180% for an average Edgecumbe urban ratepayer (plus an additional $500 pa for District Council Rates since Edgecumbe is a 'directly benefiting area').

Table 1.5 Summary of cost benefit analysis (Environment Bay of Plenty/WDC, 2007)

Category	**Scheme**	**NPV Benefit**	**Scheme Cost**	**Benefit Cost Ratio**
Edgecumbe Urban Area	Scheme 1	874,000	381,419	2.3
	Scheme 2	1,620.000	808,946	2.0
	Scheme 3	1,456,000	818,235	1.8
	Scheme 4	3,045,000	1,050,125	2.9
Wider Rangitaiki Plains	Scheme 5	16,154,000	10,125,000	1.6

[6] Ref: Environment Bay of Plenty/WDC (2007) Improved Hazard Mitigation In Whakatane District: Business Case, in response to the invitation to jointly present an integrated cross-council business case for solutions to reduce community risk from the Whakatane and Rangitaiki Rivers, August 2007, Ref: CBC (Min (05) 7/20

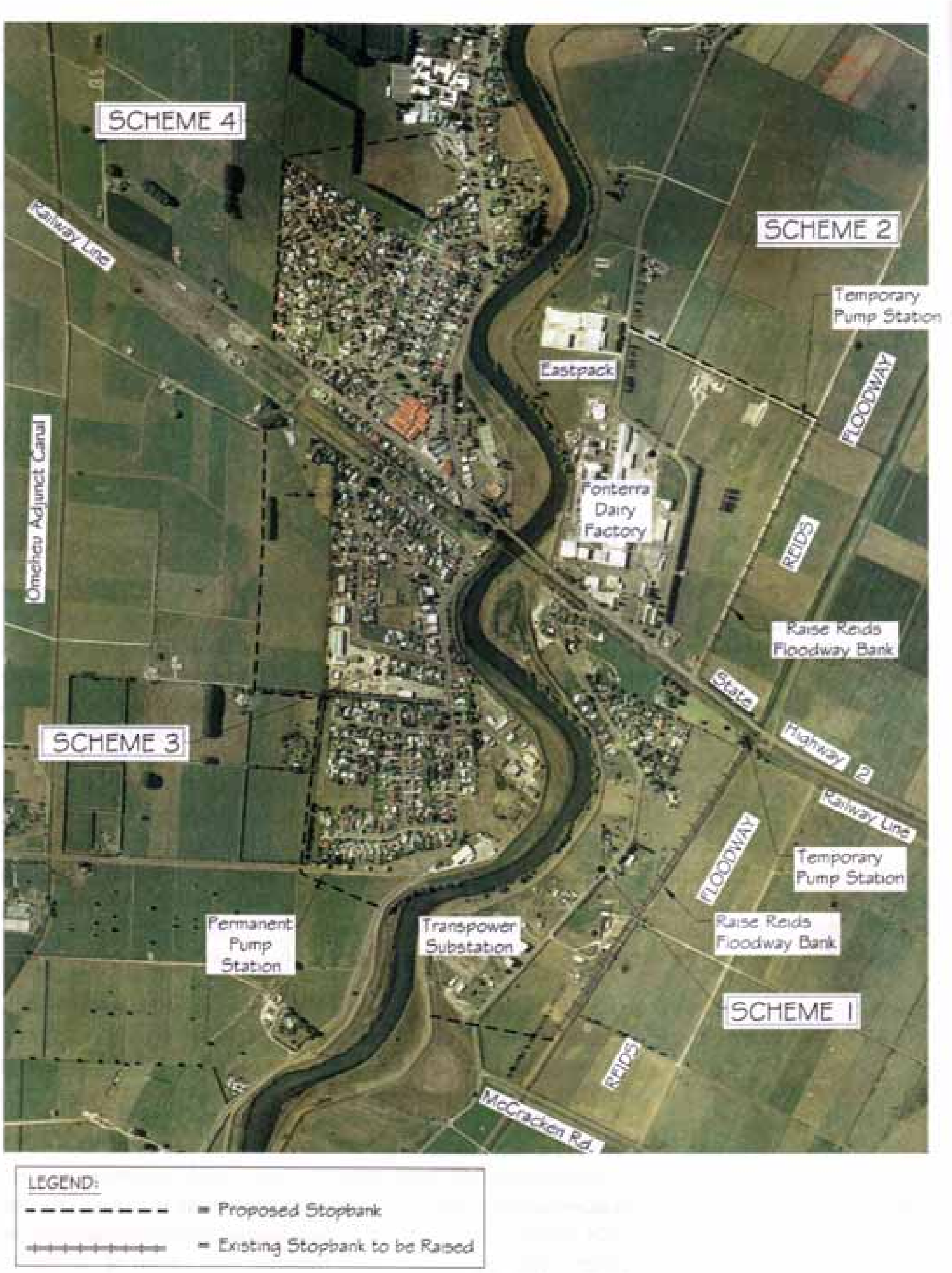


Figure 1.11 Edgecumbe flood defence options (OPUS, 2007)

Table 1.6 Flood protection issues, recommended remedial works and benefits (Environment Bay of Plenty/WDC, 2007)

Issues	**Recommended remedial works**	**Benefits**
Edgecumbe south east – breach of Rangitaiki River or Reid's stopbanks (Scheme 1)[7].	Raise western floodway bank, build a new deflector bank by TransPower substation and provide an emergency pump station upstream of the State Highway 2 bridge. Complete improvements on existing Rangitaiki stopbanks (refer section 1.10.3 for more detail on stopbank improvements).	Protection to Hydro Rd and Konini Place, TransPower and Fonterra site.
Edgecumbe north east – breach of Rangitaiki River or Reid's stopbanks (Scheme 2).	Raise western floodway bank, build new bank back to high ground and provide an emergency pump station downstream of State Highway 2. Complete improvements on existing Rangitaiki stopbanks (refer section 1.10.3 for more detail on stopbank improvements).	Protection to Fonterra and Eastpack.
Edgecumbe south west – regular local stormwater flooding, low lying earthquake settlement. Omehu canal has 5-10 year capacity, breach of upstream Rangitaiki stopbanks (Scheme 3).	Provide 0.8 m high ring bank to south and west of Edgecumbe and construct permanent pump station in south west corner. Complete improvements on existing Rangitaiki stopbanks (refer section 1.10.3 for more detail on stopbank improvements).	Protection to Edgecumbe urban area and sewerage system.
Edgecumbe northwest – local stormwater flooding of low lying land. Omehu canal has 5-10 year capacity, breach of main Rangitaiki stopbanks (Scheme 4).	House raising is preferred over provision of new low 1m high stopbanks since more cost effective.	Protection to Edgecumbe NW urban area and sewerage system.
Wider Rangitaiki River Scheme Works – Reid's Central Canal overtops in design event causing flooding rural areas and elevated flood levels in Rangitaiki River (Scheme 5).	Widening of the lower 4 km of Reid's Central Canal by 50 m will reduce flood levels in the canal and Rangitaiki River. Adding a control/spillway gate to Reid's Central Canal will improve control of water flow between the Rangitaiki River and Canal during severe floods thus reducing pressure on stormwater drainage in Edgecumbe urban area.	Doubles the capacity and reduces water levels in the Rangitaiki River by 0.5 m.
Wider Rangitaiki River Scheme Works – Uncertain stopbank condition and foundation (Scheme 5).	Investigate stopbank condition and provide remedial works to raise factors of safety particularly against piping failure (refer section 1.10.3 for more detail on stopbank improvements).	Raises certainty that stopbanks will remain stable during longer periods of high water level.

[7] Scheme numbers are those used by OPUS in their 2006 report.

(c) Awaiti, Omehu, 109, Awakaponga Canals and Old Rangitaiki Channel

A study of the Awaiti-Omeheu drainage system commenced in 1997 and was finalised in 2002 (Wallace, 2002). Results suggested that the canals currently have sufficient capacity for the design flows, but with a 0.49 m sea level rise due to global warming[8] and 1% AEP storm surge conditions freeboard would be compromised.

At present only the Awaiti-Omeheu drainage study has included water level changes as a result of global warming sea rises. However Rangitaiki and Tarawera flood studies have both considered tidal storm surges and this is considered adequate for the present. Affects of global warming will be revisited in future asset management plans.

Capacity reviews of the above canals are planned for 2007/08.

1.9.3 Stopbank Condition

The condition of stopbanks is reviewed regularly by Environment Bay of Plenty. Reviews have resulted in physical works to return the stopbanks to a level that meets the scheme design service levels.

(i) Tarawera River

The Tarawera River stopbanks were the subject of a review between 1983 and 1986, in response to seepage problems caused by underlying coarse pumice material that the river had previously deposited. Material was dredged from the Tarawera River bed to toe-load the banks so as to reduce these problems.

The 1987 Edgecumbe earthquake caused some cracking of the stopbanks, which was repaired with emergency works. However, the earthquake did not result in any subsidence of the stopbanks.

Everitt & Medwin (2006) completed a condition evaluation of Tarawera stopbanks in 2006. The results concluded that the stopbanks themselves are generally in good condition although some sections are well below their design service levels (refer s1.9.2) and some maintenance is necessary to reduce risk of erosion. Refer to condition evaluation report for maintenance recommendations.

Two sites in particular that were inspected in detail are to be attended to promptly due to their low crest levels and damage caused by stock erosion. Sites are on the true left bank at approximate chainage distances 1.6 km and 7.6 km. Refer Figure A3.6 in Appendix 3 for location.

The condition evaluation report noted that inspection was undertaken at low river levels when any deficiencies caused by the “sandier than ideal stopbanks” and “foundations more permeable than ideal” would not be visible.

[8] In 1995 the International Panel on Climate Control (IPCC) estimated water levels would rise between 0.49m to 2.1m as a result of global warming.

This Floodplain Management Strategy endorses the inspector's maintenance recommendations *"that a detailed inspection be undertaken during raised river levels particularly of the landward toe of the banks and beyond"* (Everitt & Medwin, 2006). This can occur at the same time as the seepage and stability study planned for 2007/08. Refer s2.6.1 for further details.

(ii) Rangitaiki River

The 1987 earthquake caused both physical damage to and general subsidence of the stopbanks. As part of the investigations into the stopbank capacity that were performed after the earthquake, a revised estimate of the 100-year event peak, below Matahina Dam, was produced. At 755 m^3/s, this was lower than the original design value of 780 m^3/s. Subsequently the stopbanks and floodwalls were reconstructed to the revised 100-year standard.

In some locations, for example around 4 km downstream and 5 km upstream of Edgecumbe, the stopbank crest has been used for stock access, resulting in removal of the grass protection to the crest. This increases the likelihood of erosion during an overtopping event. Also around the latter location, the stopbank crest is variable, again highlighting the need for a regular longitudinal survey. In some localised areas between Te Teko and Edgecumbe the stopbank batters are steeper than the 2:1 minimum currently adopted by Environment Bay of Plenty in design.

Steep batter slopes have a higher risk of slumping and failure during or following flood events, when water drains away quickly from the embankment slope causing it to become unstable. Environment Bay of Plenty recommends that stopbank slopes be 1V:3H or less for stability purposes.

Stopbank integrity is also compromised by toe erosion, by stock access and by the existence of old, large trees on the bank. These problems are exacerbated by the lack of an adequate berm in some locations. Ongoing maintenance works will steadily address these. However it is possible that capital works may also be needed in the future. Consequently capital works commenced in 2006/07 to stabilise the riverbank edges at Kokohinau. Given the proximity of a road to the stopbank in these problem areas, major works will be needed to improve the stopbank geometry.

As a result of concern over possible seepage problems around Thornton School, an investigation into the risk posed was undertaken in 1992 by Williams (1992). The results indicated the factor of safety against seepage failure of the stopbanks was adequate and that the risk of failure was not significant.

In September 1999 Council staff carried out an inspection of the stopbanks. The inspection report concluded the stopbank was 'in reasonable condition over much of its length' (Wallace, 1999). Specific conclusions made were:

- Stock damage and minor slumping is evident in a number of places along stopbank batters.
- Gorse covers upper stopbanks (towards Te Teko). Gorse obscures inspection and increases channel resistance.
- Continuous access along stopbank crest is difficult. This obscures inspection and makes maintenance difficult.

- The land being in private ownership hinders maintenance and inspection of stopbanks.

- Kokohinau bank stability.

Following the 1998 and 2004 floods a number of potentially weak sections along the main river stopbanks were identified by Council staff and nearby residents. In their report OPUS (2006) summarised the issues identified as follows:

- Underlying permeable soil layers that raises the risk of piping failure

- Settlement of foundations that result in ongoing need to top up stopbanks

- Earthquake damage which weakened stopbanks by cracking and loss of strength in the foundations

- Main river perched on natural levees some 2m above natural ground level which increases the risk of piping failure

- Stopbanks closely follow the riverbank therefore stopbank shape is constrained at some locations to fit between the river and say houses and roads. This can lead to erosion of the stopbank at major bends such (e.g. Kokohinau)

- Built from insitu sandy silt soils which results in higher permeability.

- Little foundation improvement such as cut-off trenches, toe loading or relief drainage

OPUS have recommended against wholesale topping up of Rangitaiki stopbanks because of the abovementioned geotechnical issues. In their report OPUS state

In other situations raising stopbanks to provide more channel capacity and freeboard would be a preferred option. However for the Rangitaiki scheme this is not a preferred proposition for the reasons set out above. Raising the stopbanks directly increases the risk of structural (piping) failures. Major stopbank raising (as opposed to the topping up of low spots to restore current design profiles) could only be considered as part of a complete investigation and extensive reconstruction of stopbanks and foundations.

There are 35 km of stopbanks on the main river, six kilometres of which are being currently reviewed by Environment Bay of Plenty. The review includes investigating some 76 sites over a distance of six kilometres along both sides of the river between the river mouth and Te Teko. To increase the factor of safety against stopbank failure a number of remedial measures are to be implemented including provision of rock protection on the river banks, construction of filter drains on the landward toe as well as toe loading.

The remaining 29 km of Rangitaiki stopbank and 20 km of Reid's Central stopbank should also be investigated in detail to confirm adequate stability exists.

Geotechnical investigations to assess stopbank stability should commence before top-ups are implemented. Rangitaiki stopbank top-ups are scheduled for Rangitaiki between the rivermouth and Edgecumbe in 2010/11 and between Edgecumbe and Te Teko in 2011/12 in 2011/12. Reid's Central stopbank top-ups are scheduled for 2009/10.

1.9.4 Concrete Flood Walls

Concrete walls carry out the same function as the stopbanks. They are constructed when physical constraints prevent construction of stopbanks.

The concrete walls described in Table 1.7 are all in good condition and are inspected on a regular basis. Any structural defects are repaired promptly.

Table 1.7 Design service levels for Rangitaiki River scheme concrete walls

Location	**Design Service Level**
Rangitaiki River – Urban (Edgecumbe, Thornton)	100 year plus 600 mm freeboard

1.9.5 Structures

The Rangitaiki Tarawera Rivers system has several floodgates, pump stations and a sluice gate. Environment Bay of Plenty own, maintain and operate the:

- Awaiti and Old Rangitaiki Channel floodgates.
- Old Rangitaiki Channel pump station.

Inspection and maintenance is carried out regularly on the system structures and working parts. At present all structures retain their structural integrity.

1.9.6 Edge Protection

Rock work and live protection are erosion control works that are designed to protect the stopbanks and/or natural channel banks from erosion and consequential flood overflows, to maintain channel stability and to reduce the erosion and subsequent release of sediment into the lower reaches of the river system.

The condition of the live edge protection in the scheme varies depending on its age and its previous maintenance.

Desirable species such as shrub willows, *S. matusdana x alba* hybrids for example the male hybrids such as Hiwinui or Moutere and clones are now being used as live flood edge protection. As the stock of these species increases along the rivers, much of the existing crack willow will be displaced. Having a mix of species and clones reduces the vulnerability of edge protection to a disease or insect infestation – as different species have different resistance to particular diseases or insect. Leaf rust, sawfly, silverleaf and Armillaria are examples of common problems that can strike willows. Field staff maintains a watch for signs of disease, particularly as diseases such as leaf rust can evolve.

Trials of various hybrid species of willows, in particular golden willow hybrids (*matsudana x alba vitelina)* are being assessed, and findings from crown research institutes are being obtained to further help identify suitable species to use as bank protection.

In order to create more native edge protection plantings and to reduce the risk of sawfly damage to willows, Environment Bay of Plenty is carrying out field trials of native edge protection plantings.

Whilst early results of these trials are showing potential at present; they take years to establish and evaluate therefore a cautious transition from willows to natives is prudent.

A regular layering programme is already in place and this will intensify as new areas of edge protection age and thus require layering.

1.9.7 Buffer (or Berm) Zone

The buffer (or berm) zone has no definitive design standard and the width allowed is a matter of judgement on a site-by-site basis. For consistency a minimum width of vegetation is maintained in most circumstances.

At present cattle are permitted to graze in some buffer zones. One benefit is that weed growth is controlled naturally. Unfortunately the presence of cattle in the buffer zone pollutes adjacent waterways and worsens bank erosion. As a result Council is investigating what additional buffer zones require retirement, which entails fencing off of selected buffer zones. The cost of additional fence maintenance will be taken into account before making its recommendations.

1.9.8 Flood Proofing

Flood proofing a building prevents water damage to a building. Flood proofing measures can be incorporated during the early stages of design or retrofitted to existing buildings. Flood proofing measures include:

- Relocating buildings.
- Raising floor or foundation levels.
- Surrounding the building with flood proof masonry or concrete walls or bunds (low earth embankments).
- Sealing all building openings below potential flood levels, either temporarily or permanently (“dry” flood proofing).
- “Wet” proofing so that floodwaters are allowed in to counteract the pressure on the outside walls, but with the building materials and internal furnishings designed so that minimal damage is caused.

However, more commonly flood proofing refers to the latter two. Flood proofing is not a failsafe measure; there is still a need to consider whether it is appropriate at all to build at a flood prone site. It should be regarded as a means of protecting individual existing structures.

1.10 River Management and Planning

1.10.1 Regional River Gravel Management Plan

The Regional Gravel Management Plan is prepared under Section 65 of the Resource Management Act (RMA). Its objectives are:

- The management of gravel to reduce flooding and river bank erosion risks (Clause 16.1.1 (a)).
- The management of gravel to assist the maintenance of identified standards of control and drainage (Clause 16.1.1 (c)).

The Regional Gravel Management Plan requires Environment Bay of Plenty to manage extraction locations and quantities via a resource consent process. The Plan also notes that Environment Bay of Plenty may negotiate with extractors to extract where there is no demand, if required for flood/erosion control purposes. Gravel extractions are also defined in the Whakatane District Plan as a discretionary activity under Rule 3.8.1.3 (5) unless provided by Rule 4.1.3. This means that resource consents are required from both Councils before extractions can take place.

1.10.2 River and Stream Channel Monitoring Programme

In 1993/94 Environment Bay of Plenty commenced its river and stream channel-monitoring programme. Monitoring of channel cross-sectional shape allows identification of quantities of gravel available for extraction. Extraction is either encouraged or limited in order to stabilise the river systems. For example:

- If the bed level is too high or the waterway congested flooding is more likely.
- If the bed is too low, banks are high and have to take the full force of flow during a flood. Protection works are undermined; more gravel is transported downstream to build up elsewhere.

Defining desirable bed levels for each river and stream protects the river assets and public in general.

Extracted gravel is used for commercial purposes.

To encourage stable channels, the following factors need to be promoted:

- Maintaining bed levels within a desirable range.
- Maintaining good river alignments.
- Keeping roughly in balance with natural supply rates.
- Compatibility with existing assets.

1.10.3 Gravel Management in the Rangitaiki Tarawera River Catchments

Gravel extraction does not occur to the same extent as in other catchments such as Whakatane Waimana and Waioeka Otara areas. In the last five years gravel has been extracted mainly from the Horomanga River above Lake Aniwhenua. There are two primary reasons for this:

- River Management: planned gravel removal is necessary for the maintenance of channel flood flow capacity and clearance of vegetation of beaches. Without gravel extractions beaches quickly become vegetated which restricts gravel transport and flood flows. Extraction operations get rid of unwanted vegetation at no cost to the river scheme.

- Commercial Use: demand for gravel as construction and roading aggregate.

The aim of sound gravel management is to establish a balance between supply and demand for gravel and to mitigate undesirable effects, such as:

- Aggradation of the riverbed, which decreases the ability of the river channel to carry floods. This results in greater erosion pressure on riverbanks, increased flooding of productive land, and the infilling of the beds.

- Degradation (erosion) of the riverbed and the undermining of structures.

Since the 1990s, major rivers and streams in the Rangitaiki Tarawera catchment have been regularly surveyed at a series of cross-sections. As well as providing data for hydraulic modelling, the surveys allow riverbed aggradation and degradation to be estimated. A brief summary of gravel extractions undertaken in the catchment follows (Environment Bay of Plenty NERMN, 2006).

Environment Bay of Plenty is presently discussing gravel removal with potential contractors who are looking for financially viable gravel sources.

Should there be a lack of demand to extract gravel from areas where it needs to be removed then Environment Bay of Plenty should consider removing a predetermined quantity each year. Extracted gravel could be stockpiled or sold as a low cost resource however cartage costs may be too high. One idea might be to offer subsidies to contractors to remove the gravel. In any case an item for gravel extractions should be added to the maintenance budget contained within the scheme asset management plan. Other alternatives include reducing the service level of protection where gravel build up has occurred and/or raining stopbanks.

(a) Rangitaiki River (mouth to Te Teko)

Surveys carried out to 2004 indicate the bed is degrading in the lower reaches of the Rangitaiki River and no extraction has been carried out since that period. Reasons for the degradation may be that the floods of July 1998 and July 2004 transported more sediment from upstream thus having a flushing effect further downstream. Other possible causes might be that Matahina Dam is limiting sediment passage or that the river gradient has changed as a result of the 1987 Edgecumbe earthquake. This could be artificially encouraged to give adequate flood capacity. (Environment Bay of Plenty NERMN report, 2006, pg iv).

(b) Rangitaiki River (above Lake Aniwhenua)

There has been very little (if any) gravel extraction above Lake Aniwhenua. Surveys have not been carried out in this reach since 2001. Between 1996 and 2001 a total volume of 95,000 m^3 was gained and landowners in the area have complained that flooding has increased as the capacity of the lake has decreased. Reduction of gravel will reduce flooding and increase the storage capacity of Aniwhenua hydroelectric dam which is owned and operated by Bay of Plenty Electricity.

It is recommended that a cross-section survey and assessment of gravel volumes be undertaken on the Rangitaiki River upstream of Aniwhenua to determine the extent to which flooding has worsened as a result of gravel build up. Removal of gravel build up will reduce flood risk and increase storage capacity for Aniwhenua hydroelectric dam.

(c) Horomanga River (between Lake Aniwhenua and Galatea)

Between 1996 and September 2004 there was an average loss of 6,500 m^3 per annum of gravel from the Horomanga River. Gravel extraction in the Horomanga River should be suspended in the upper part of the reach and instead directed to the lower reaches. Complaints of flooding have been reported by landowners in the lower reaches where the bed is severely perched and significant extraction is required to avoid undue flooding of field drains and farmland or avulsion (migration of the river channel). (Environment Bay of Plenty NERMN report, 2006, pg iv).

As recommended in the 2006 NERMN report the bed level of the lower reaches of the Horomanga River needs to be lowered initially by an average of 0.5m over the 70m design fairway width.

(d) Ruarepuae Stream (Galatea)

Desirable bed levels for the Ruarepuae Stream were set in 1986, and surveys in recent years have shown that bed levels are near those desired. Extraction should now be limited to where gravel builds up excessively. (Environment Bay of Plenty NERMN report, 2006, pg iv).

In June 2004 the stream survey showed an overall volume gain of 25,760 m^3 whereas in the December 2005 survey there was only an overall loss of 760 m^3. This indicates that extraction is now warranted in those areas where gravel has built up.

The 2006 NERMN report suggests the Ruarepuae River bed is aggrading in the lower reaches (cross-sections 1 to 3) and degrading in the upper reaches (cross-sections 4 to 6). It is therefore recommended that extraction concentrate in the lower reaches.

(e) Whirinaki River

Estimates for the Whirinaki River indicate supplies are typically of the order of 23-24,000 m^3 per year. Extraction should generally be encouraged in the aggrading reaches.

The most recent survey in September 2005 showed a substantial volume gain of some 83,500 m^3 since the previous survey in 2003. Volume changes increased throughout the reach fairly evenly.

In the fluvial processes report prepared for Whakatane and Whirinaki Rivers (Bailey, 2006) river characteristics and sediment processes have been studied on the Whirinaki River. Design widths of 50 m plus a buffer zone of 30 m have been developed for the narrow managed fairway option on the lower Whirinaki River. Bed load transport equations were developed to estimate an average annual bedload transport of 23,000 m^3/year. This compared well to the initial estimate of 24,000 m^3 per supply year.

As recommended in the 2006 NERMN report a detailed design is required to define desirable bed levels at each cross-section in the Whirinaki River. Extraction should be encouraged at the aggrading reaches around cross-sections 4 and 5.

(f) Tarawera River

No extraction is carried out in Tarawera River at present, and with the lowering of the whole bed it is recommended no sand extraction be allowed in the short to medium term. (Environment Bay of Plenty NERMN report, 2006, pg v).

1.11 Response to Flooding: Statutory Non Structural Measures

Non-structural measures are the means by which people are kept away from floodwaters. Legislation that provides the mandate for local and regional councils to create policy for non-structural measures are:

- Government Policy.
- Regional Plans.
- District Plans.

1.11.1 Government Policy

Legislation that can support non-structural measures includes:

- Resource Management Act
- Local Government Official Information and Meetings Act 1987
- Building Act 2004
- Building Regulations
- Civil Defence Emergency Management Act

(a) Resource Management Act

The Resource Management Act (1991) gives regional and district councils the legal mandate to manage natural hazards such as flooding and erosion within its boundaries. For example the RMA requires councils to:

- Control the use of land for the purpose of avoidance or mitigation of natural hazards (Part 4: Section30, 1.a.iv).

- Make available information that relates to natural hazards.

- Obtain off consent applicants an assessment of environmental effects related to natural hazards.

- Protect conservation values by hazard mitigation.

(b) Local Government Official Information and Meetings Act

Land Information Memorandum (LIM's) provides statements of known hazards associated with land parcels.

Under Section 44A of the Local Government Official Information and Meetings Act 1987, people can acquire a LIM in relation to matters affecting any land in the district of the authority. The LIM identifies any special feature of the land concerned that may be subject to, but not limited to, say potential erosion or inundation.

(c) Building Act 2004

Under Section 71 to 74 of the Building Act 2004, a territorial authority shall refuse a building consent if:

- The land is subject to inundation or erosion; or

- The building work shall worsen the inundation or erosion of that or any other property.

Exceptions may be made to these rulings if the authority is satisfied that adequate provision has been made or will be made to:

- Protect the land or building work or that other property concerned from erosion or inundation; or

- Restore any damage the land or that property concerned as a result of the building work.

However under Section 72, if:

- The land on which the work is to take place is subject to inundation or erosion; and

- The work itself will not worsen the inundation or erosion of that or any other property.

The authority can issue a building consent upon condition that the existence of the hazard is made known to the Building Industry Authority (BIA) and stated on the land title. BIA suspect territorial authorities do not always inform them of waivers that allowed buildings to be constructed below flood levels (email P West, Environment Bay of Plenty, 5/9/07).

Section 71 to 74 helps to prevent potential damages from flood events from increasing. Section 72 shifts the burden of risk from the community more towards the landowner (and in doing so may also act as a deterrent to the building work) and ensures that subsequent owners of the land are aware of the hazard. The Insurance Council advises that unless building owners have cleared it with their insurers a Section 72 note on the title will mean building owners are not covered.

People can acquire a Project Information Memoranda (or PIM) on any land parcel. PIM's confirm if building work can proceed subject to satisfying other Acts apart from the Building Act. The PIM report is produced by Whakatane District Council and includes specific information such as potential erosion, subsidence, slippage and flooding. Refer also to Section 5 of the Buildings Regulations.

Upon request Whakatane District Council also produces Land Information Memorandum's or LIM's reports. These reports contain all information Council holds on land and buildings. One recommendation for the LIM's report is for the addition of a statement which indicates whether flood protection assets comply with Council stopbank bylaws.

The Bay of Plenty Regional Council Floodway and Drainage Bylaw 2002 was adopted by Environment Bay of Plenty in 2003. The Bylaw is potentially a powerful tool in maintaining the integrity of flood defences, with Environment Bay of Plenty having the power to prevent, for example:

- constructing any structure, planting or growing shrubs and trees etc, between the river edge to 12 m beyond the landward toe of a stopbank or floodwall.
- excavating or undertaking earthworks within 20 m of a stopbank or floodwall.
- overgrazing of stopbanks.
- other interference with stopbanks and floodwalls.

However this power has not yet been tested, nor has there been any significant educational or promotional campaign on the existence of the bylaw. An upcoming exercise to address encroachments, structures and plantings on the Whakatane stopbanks will show in practice how well the bylaw works.

One mechanism for promoting the bylaw would to be make a note in a LIM where a property is within 20 m of a stopbank or floodwall. That would require a GIS overlay of such areas to be created and given to the District Councils.

It is recommended that Whakatane District Council consider placing a note on their LIM reports that confirms stopbank bylaw compliance (or otherwise).

(d) Building Regulations

When issuing a building consent, Clause E1.3.2[9] of the Building Regulations binds the territorial authority to restricting floor levels.

Surface water resulting from a storm having a 2 % probability of occurring annually, shall not enter buildings. E1.3.2 shall apply only to Housing, Communal Residential and Commercial Non-residential buildings.

This regulation tends to be enforced by specifying minimum floor levels above the 2 %AEP (or 50 year) flood level. In cases of doubt the local authority concerned normally seeks advice from Environment Bay of Plenty.

In 2006 Whakatane District Council and Environment Bay of Plenty agreed to use the 50 year flood levels to set minimum building floor levels. Flood levels would be based on rainfall intensities expected in 2055. As a result current 100 year flood levels are used since they are equivalent to the 50 year flood level expected in say 50 years time due to global warming effects. In addition it was also agreed that the 50 year flood levels expected in 2055 can be used for setting minimum subdivision platform levels (Blackwood, 2006). Setting development levels at the current 100 year flood level in subdivisions is recommended in s4.3.2.5.1 of NZS4404:2004 Land Development and Subdivision.

Flood maps provided in this FMS can be used by Whakatane District Council planners. To assist in the process of determining 50 year flood levels (expected in 2055) Environment Bay of Plenty has produced:

- 50 year flood maps of Rangitaiki Plains between the two major rivers. Refer Figure A2.1 and A2.2 in Appendix 2 (Environment Bay of Plenty drawings G127).

- 50 year flood map of the Kope – Orini basin. Refer Figure A2.3 in Appendix 2 (Environment Bay of Plenty drawing R745).

Local authorities also sometimes set minimum floor level conditions for consents under the RMA. The buildings need not necessarily be residential. In such instances, wider resource management issues are considered (eg the sustainability of the community) rather than just the effects on the building concerned.

(e) Civil Defence Emergency Management Act

Under the Civil Defence Act 1983 regional councils were required to prepare regional civil defence plans, identifying major natural hazard threats to the region, and defining regional policy to manage threats.

District councils were required to prepare civil defence plans for their districts, giving effect to regional plans. This system has been changed under the new Civil Defence Emergency Management Act 2002. In the future only one plan, a Group CDEM plan, is required for the Groups area. It is expected that this plan will combine the broad policies and coordination issues of regional plans with the practical response measures of district plans to achieve much the same desired results of the previous system.

[9] Refer to Schedule 1: The Building Act

1.11.2 **Regional Plans**

(a) The Bay of Plenty Regional Policy Statement (BOPRPS)

The statement document provides an overview of resource management issues, and policies and methods to achieve integrated management across the region. It provides guidance to both regional and district councils as to how to manage the Whakatane Waimana flood hazard.

Section 11 (Natural Hazards) of the BOPRPS is of particular relevance. Amongst the Objectives, Policies and Methods of Section 11.3, is a declaration that Environment Bay of Plenty will continue to manage the flood control schemes of the region. It outlines what and how various councils will work together to achieve the 10 specific Anticipated Environmental Results stated in Section 11.4.

(b) Proposed Bay of Plenty Regional Water and Land Plan

The purpose of this document is to address specifically water and land management issues in the region. It aims to promote soil conservation and sustainable land management. Its methods include education measures, incentives and rules. Amongst the rules relevant to flood issues (indirectly via runoff and erosion) are those on indigenous vegetation clearance, earthworks, stream crossings and wetland modifications.

The Water and Land Plan treats all land and soil disturbance resulting from vegetation clearance exactly the same, regardless of whether the vegetation clearance involves exotic or indigenous vegetation. (The clearance of significant vegetation is controlled through District Council rules). Earthworks and clearance of vegetation in critical areas (in close proximity to watercourses, steep headwaters or in the ephemeral watercourses of the upper Rangitaiki Catchment) are regulated through rules in the Water and Land Plan.

In recent times there has been some discussion regarding wholesale land use changes from forestry to pasture in the Bay of Plenty region. These land use changes were not foreseen, and were not directly provided for under the Water and Land Plan, even though some of the conversion works are arguably earthworks with high potential impacts on local streams. Potential land use changes on the easy Class IVe volcanic plateau country that may result in increased peak runoff flows are generally not regulated under the Water and Land Plan. In a recent study carried out by Environment Waikato, peak runoff rates on pumice country adjacent the Waikato River were estimated to at least double with a conversion from forestry to pastoral land use (Mullholland, 2006).

A direct adverse effect of increased peak run off is a subsequent increase in water course flood flows and levels. Given 47% of the Rangitaiki Tarawera catchment is currently in exotic forest suggests current downstream flood protection and emergency measures could become overwhelmed in the event of wholesale land use change from forestry to pasture.

Peak flows in the main rivers and tributaries are based on current catchment topography and land usage. A catchment wide study is recommended that investigates the impacts of possible future land use changes and climate change. Scenarios to be investigated could include the effect of run-off and peak flows resulting from harvesting areas of exotic forest and catchment wide replacement of exotic forest with exotic grassland (for pasture). If peak flow's increase significantly then restrictions on land use changes may be required to minimise the impact on downstream flood protection assets. Regulations would be incorporated into future editions of the Water and Land Plan.

(c) Bay of Plenty Regional Coastal Environment Plan

This plan covers the rules applicable to the coastal marine area of the region, which includes the Whakatane River mouth. The most significant parts of the plan for flood hazard management deal with dredging within this coastal marine area.

1.11.3 District Plans

The District Plan, prepared by Whakatane District Council, consists of objectives, policies, rules and planning maps. Planning maps enable people to find which zoning applies to the property and other standards that will be relevant. Each zone includes controls and performance standards and general rules. There are separate sections concerning landscape and the coastal environment, cultural heritage, natural hazards, work and utilities, and hazardous substances, which apply on a site-specific basis.

Work done at or near stopbanks, floodgates and associated culverts is defined by Whakatane District Council as a controlled activity (refer Rule 4.8.1 (25)). Work proposed around such structures is checked beforehand to ensure that it does not compromise stopbank safety that could otherwise breach and cause flooding. The operation and maintenance of stopbanks (in existence on 1 January 1998) are permitted activities under Rule 4.8.1 (38).

1.12 Current Non-statutory and Non-structural Measures

Non-statutory and non-structural measures include land use planning methods, voluntary actions and steps floodplain residents, businesses and utility and emergency services can take to prepare for floods. These measures aim to keep people, possessions and development away from flood prone areas. Non structural measures improve the community's ability to respond to and recover from floods. They enable a community to be more resilient to flooding now and in the future. Such measures include:

- Flood monitoring and flood warning.
- Education and emergency preparedness.

Environment Bay of Plenty is responsible for flood monitoring and flood warning in the region including the Rangitaiki-Tarawera catchment.

Environment Bay of Plenty and NIWA operate a series of telemetered rain gauges, river level recorders and river flow recorders. Alarms are set to page Environment Bay of Plenty personnel when a threshold (that is, a certain river height or intensity of rainfall) is reached.

Environment Bay of Plenty maintains a Flood Warning Manual that documents procedures for staff to follow in the event of heavy rainfall or flooding. Figure 1.12 summarises typical responses to be actioned when water level in the Rangitaiki River reaches certain levels. A similar Figure exists for the Tarawera River at Awakaponga Station (M566, Sheet 17A).

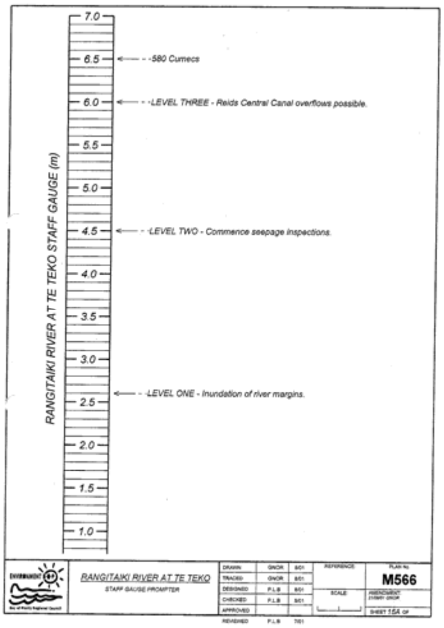


Figure 1.12 Flood warning chart for the Rangitaiki River based on the Te Teko gauge readings.

In most instances the procedures are initiated after a warning is received from the Meteorological Service (MetService), but they can also be initiated if alarms are triggered from the telemetered rainfall or river level recorders.

The Metrological Office can issue warnings that fall into one of three categories. They are Severe Weather Warning, Severe Weather Watch and a Special Weather Advisory.

(a) MetService will issue a Severe Weather Warning whenever there is an expectation that widespread rainfall greater than 50 mm within 6 hours or 100 mm will occur within 24 hours.

(i) MetService will issue a Severe Weather Watch whenever there is an expectation that conditions may deteriorate to the thresholds specified for the issue of a Severe Weather Warning:

- After the next 24 hours but within 48-72 hours, or
- If there is a high level of uncertainty within the next 24 hours.

(ii) MetService will issue a Special Weather Advisory whenever a weather event is likely to cause significant disruption to the general public or specific industry groups within the next 48 hours, but the weather is not expected to deteriorate to an extent that would require the issue of a Severe Weather Warning. MetService may also issue a Special Weather Advisory following a severe storm that caused widespread disruption and damage in order to assist with any post-storm operations.

These forecasts are also supplied to the New Zealand Police and Civil Defence HQ in Wellington.

The Metrological Office issues Severe Weather Warnings to the media who have been asked to pass them on without their own interpretation.

(iii) New Doppler weather radars will be installed in the vicinity of the Mahia Peninsula (in 2009) and western Bay of Plenty (in 2010). The radars will increase the Met Services ability to predict arrival of high risk weather systems (MetService, 2007).

(iv) In 2007 Environment Bay of Plenty and TrustPower jointly contracted NIWA to implement a new rainfall and flood forecasting computer model. Results of the NIWA model will be checked and compared with Environment Bay of Plenty's own in-house flood forecasting model.

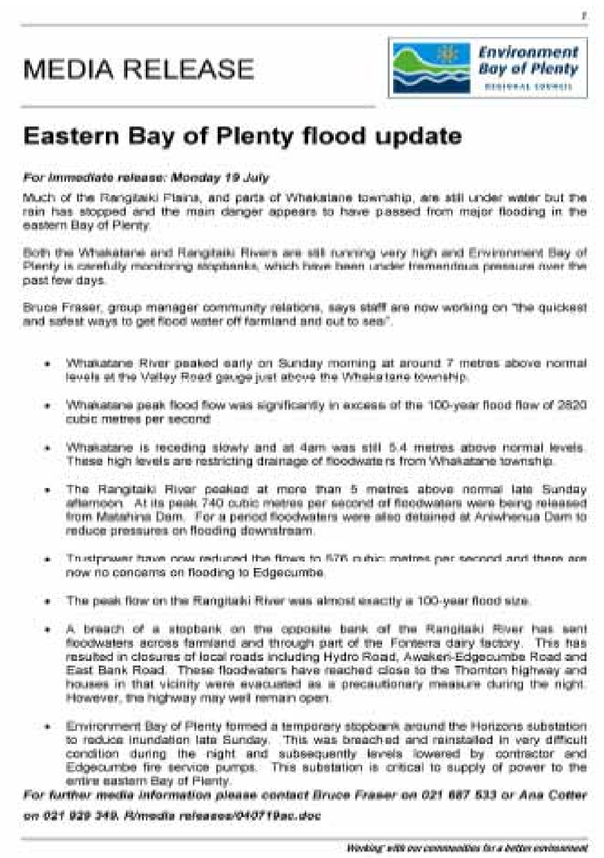
(b) Education and emergency preparedness

A range of measures is currently used, with varying degrees of effectiveness, to raise awareness of hazards and to increase readiness in the event of a flood. These include:

- Land Information Memorandum (LIM's) and Project Information Memoranda (PIM's). Refer section 2.2.4 a) i) above.
- Section 73 of the RMA, which requires notices to be placed on property titles.
- Emergency response information is made available to public via the inside back cover of the telephone directory.
- Environment Bay of Plenty and other organisations provide advice in occasional mails drops.
- Internet sites such as the Ministry of Civil Defence & Emergency Management checklist in the event of flooding. Refer Figure 1.13.
- Occasional press releases on flood issues issued by Environment Bay of Plenty or territorial authority Refer Figure 1.14.

A range of such measures is needed for the information to reach floodplain residents and users. These measures also need to be regularly repeated to maintain effectiveness. Section 35 of the RMA requires councils to keep records and make information available to the public.

Figure 1.13 Flood preparedness internet site.



MEDIA RELEASE

Environment Bay of Plenty

Eastern Bay of Plenty flood update

For immediate release: Monday 19 July

Much of the Rangitaiki Plains, and parts of Whakatane township, are still under water but the rain has stopped and the main danger appears to have passed from major flooding in the eastern Bay of Plenty.

Both the Whakatane and Rangitaiki Rivers are still running very high and Environment Bay of Plenty is carefully monitoring stopbanks, which have been under tremendous pressure over the past few days.

Bruce Fraser, group manager community relations, says staff are now working on "the quickest and safest ways to get flood water off farmland and out to sea".

- Whakatane River peaked early on Sunday morning at around 7 metres above normal levels at the Valley Road gauge just above the Whakatane township.
- Whakatane peak flood flow was significantly in excess of the 100-year flood flow of 2820 cubic metres per second.
- Whakatane is receding slowly and at 4am was still 5.4 metres above normal levels. These high levels are restricting drainage of floodwaters from Whakatane township.
- The Rangitaiki River peaked at more than 5 metres above normal late Sunday afternoon. At its peak 740 cubic metres per second of floodwaters were being released from Matahina Dam. For a period floodwaters were also detained at Aniwhenua Dam to reduce pressures on flooding downstream.
- Trustpower have now reduced the flows to 576 cubic metres per second and there are now no concerns on flooding to Edgecumbe.
- The peak flow on the Rangitaiki River was almost exactly a 100-year flood size.
- A breach of a stopbank on the opposite bank of the Rangitaiki River has sent floodwaters across farmland and through part of the Fonterra dairy factory. This has resulted in closures of local roads including Hydro Road, Awakeri-Edgecumbe Road and East Bank Road. These floodwaters have reached close to the Thornton highway and houses in that vicinity were evacuated as a precautionary measure during the night. However, the highway may well remain open.
- Environment Bay of Plenty formed a temporary stopbank around the Horizons substation to reduce inundation late Sunday. This was breached and reinstalled in very difficult condition during the night and subsequently levels lowered by contractor and Edgecumbe fire service pumps. This substation is critical to supply of power to the entire eastern Bay of Plenty.

For further media information please contact Bruce Fraser on 021 687 533 or Ana Cotter on 021 929 349. R/media releases/040719ac.doc

Working with our communities for a better environment

Figure 1.14 Example of an Environment Bay of Plenty press release

1.13 Recommended Floodplain Management Practices

Based on international observations recommended good practices for floodplain management include:

- a preference towards non-structural measures particularly in those areas where structural solutions have not worked.
- focus on land use and regulatory planning as the appropriate method of integrating structural and non-structural measures.
- encouraging ongoing community awareness.
- emergency management plans as a necessary component for responsible floodplain management.

To date several regional, district and unitary authorities have prepared Floodplain Management Strategies based on good practices as outlined in OPUS Consultants document titled "Floodplain Management Planning Guidelines" (OPUS, 2001). Environment Bay of Plenty contributed to these guidelines during the guidelines draft stage.

Since good practice places an emphasis on successful non-structural measures it is only logical to review current measures and supporting legislation.

Given the Rangitaiki-Tarawera catchment's recent experience with flooding in July 2004 there may be lessons to be learnt which may require some non-structural measures and legislation to be updated or amended.

1.14 Conclusions

Review of current Rangitaiki Tarawera floodplain management practices indicates flood protection mechanisms are well developed but the capacity and condition of some scheme stopbanks requires restoration to maintain service level requirements. Environment Bay of Plenty are currently dealing with a number of the issues identified in Part 1 and the manner in which these are addressed is described in Part 2.

Key issues identified in Part 1 include the need to:

- Complete stopbank renewal work where identified in recent capacity reviews and condition assessments for Tarawera and Rangitaiki Rivers. Geotechnical investigations should be undertaken before stopbank top up work commences to confirm such work is appropriate and will not reduce structural stability.
- Continue programmed reviews of stopbank capacity. Environment Bay of Plenty carries top ups stopbanks whenever service levels are not being met.
- Continue programmed condition assessments of stopbanks and implement remedial works where necessary.

- Gravel extractions can reduce flooding by increasing the flow capacity of waterways. Current gravel analysis indicates extraction can be undertaken in the Galatea basin namely on the lower parts of the Horomanga River and along aggraded reaches of the Ruarepuae and Whirinaki Rivers. Assessment is required to see where gravel can be extracted in Lake Aniwhenua to reduce flooding in the immediate vicinity.

- Consider the effects of global warming when refurbishing or constructing flood protection assets. Environment Bay of Plenty requires that design of structures allows for intensification of storm flows during the structures life i.e. if a structure has a life of say 50-70 years then its design needs to allow for the impact of higher flows, flood levels and storm frequency estimated over that period.

- Identify lessons learnt from July 1998 and July 2004 floods. Review performance of current non-structural measures and make changes where necessary.

Part 2: Identifying Flood Hazard and Elements at Risk

2.1 Introduction

Part 2 summarises the results of extensive flood modelling carried out recently on Rangitaiki River and Reid's Central Canal. Flood level modelling of the Tarawera River was completed in 2005 with design and construction proposed for 2008/09. Modelling was carried out to identify the flood hazards and elements that subsequently become vulnerable to greater risk of flood damage.

Flood modelling of the Rangitaiki River and Reid's central canal was carried out by OPUS (2007) and Hydraulic Modelling Services (HMS, 2007) respectively on behalf of Environment Bay of Plenty, WDC and Transit New Zealand. Flood modelling was carried out on these two water courses and their associated floodplains to determine the best flood protection measures needed for Edgecumbe Township, surrounding rural areas and infrastructural asset owners such as TransPower and Transit New Zealand.

Flood modelling compares river levels for various return period floods with current flood protection service level requirements. Flood modelling takes into account, to a certain degree, the effects of sea level rise and global warming and examines what future flood levels might be.

Part 2 also describes the actual social and economic impacts on people and property resulting from the July 2004 storm events.

2.2 Flooding in the Rangitaiki River and Reid's Central Canal

Performance of the lower Rangitaiki and Reid's Central Canal stopbanks during the 2004 floods confirmed that there was insufficient conveyance to pass the 100 year design flood.

To restore the lower Rangitaiki and Reid's central canal stopbanks to their 100 year service level OPUS (2007) modelled the effect of the current channel cross-sections on flood levels for the design events. HMS (2007) also modelled flood levels in Reid's Central Canal that might result from a widened channel and options to replace State Highway 2 Bridge. Summaries of the OPUS and HMS modelling completed are in Appendix 1.

Water levels were modelled for the following scenarios:

- Current design service levels namely the 100 year flood event and climate change.

- Dredging of the lower Rangitaiki River channel.

- Widened Rangitaiki river mouth.
- Widened Reid's central canal.
- State Highway 2 bridge replacement options.

Widening of the distance between Rangitaiki River stopbanks is not practical and was therefore not modelled. Rangitaiki River stopbanks are located upon natural raised levees that are at higher risk of piping failure due to its higher porosity.

2.2.1 Current design service levels and climate change

The expected effect of climate change in the Bay of Plenty is sea level rise and increased flood frequency and intensity.

Water levels for the current climate were compared with the scenario wherein a 0.5 m sea level occurs (that could be expected in 2080).

The current 300 year design flood (1000 cumecs) was also modelled *without* sea level rise. The current 300 year design flood is considered to be an "overdesign" event and assumed to be equivalent to the future 100 year design flood in the year 2080.

The Regional Council's MIKE11 model was calibrated by OPUS using 1998 and 2004 flood events and simulations were undertaken using current (2004) cross and long sectional survey data. Key modelling results are displayed in Figures 2.1 and 2.2 which show that:

- A 0.5m increase in sea level results in a maximum rise in Rangitaiki River levels of 0.5m at the river mouth and 0.012m upstream at the Edgecumbe Bridge.
- A 0.5 m increase in sea level results in a maximum Reid's Central Canal levels of 0.381 m at the confluence with the Rangitaiki River and 0.086 m at the State Highway 2 Bridge.
- The 300 year design flow results in water levels increasing along the entire length of the Rangitaiki River and Reid's Central Canal with the most significant rises arising in the latter. In the Rangitaiki River an increase of 0.279 m is expected at Edgecumbe and 0.195 m at the mouth. In Reid's Central Canal a relatively constant increase of about 1.6 m is expected from State Highway 2 to Reid's central Canal chainage 17,784 m before decreasing down to the confluence.

Although these results provide good information on the effect of sea level rise on flood levels future design levels should also take account of estimated changes in flood frequency/intensity data. Hence before renewal work is implemented scenarios presented in Table 2.1 should be modelled and design levels selected according based on its application.

Table 2.1 Design flood level scenarios

Design Scenario	Rainfall frequency/intensity data	Sea level	Application
Existing design service levels	Uses current data sourced from say Environment Bay of Plenty data and HIRDS[10] etc	Uses current sea level data based on Environment Bay of Plenty guidelines and Tidal Almanac	Current boundary conditions normally used in hydraulic models to calculate design flood levels in waterways[11]
2030 design flood levels	As above but apply MfE[12] factors to current rainfall that anticipates an average temperature increase of between 0.2^{o}C and 1.3^{o}C by the year 2030	Use MfE estimate of sea level rise at 2030	It is assumed that Environment Bay of Plenty stopbanks settle over a period of 20 years so adoption of 2030 design flood levels could be used to reflect the "lifecycle" of the stopbanks
2080 design flood levels	As above but apply MfE[13] factors to current rainfall that anticipates an average temperature increase of between 0.5^{o}C and 3.8^{o}C by the year 2080	Use MfE estimate of sea level rise at 2080 (current expected rise is 0.5m)	Design flood levels should be selected to reflect the lifecycle of structures such as floodgates, bridges, floodwalls and pump stations etc. Hence if concrete structures last say 70 years than it would be appropriate to use design flood levels expected in say 2080

It is recommended the climate change scenarios for 2030 and 2080 and outlined in Table 2.1 be modelled in future capacity reviews undertaken by Environment Bay of Plenty. This will help Council decide what provision for future proofing can be done today. These scenarios should be modelled before detail design commences of the remedial works proposed for Edgecumbe and the wider Rangitaiki River scheme works (Refer s1.10.2, in particular Table 1.5).

[10] HIRDS (High Intensity Rainfall Data System) is a rainfall intensity/frequency database produced and supported by NIWA.
[11] Some Environment Bay of Plenty modelling includes a 0.5m sea level rise expected in 2080.
[12] MfE is Ministry of Environments Climate Change Guidelines (2004).
[13] MfE is Ministry of Environments Climate Change Guidelines (2004).

2.2.2 Dredging

Various dredging options for the Rangitaiki River were modelled however the largest water level reduction that could be achieved was 200 mm. The area of benefit due to reduced water levels would be the rural land downstream of Edgecumbe and the Edgecumbe urban area. The dredging has several limitations namely:

- A large quantity of material (approximately 280,000 m^3) has to be dredged.
- Uncertain and potentially high cost of dredging say approximately $4M to achieve a relatively small drop in water level.
- Not a permanent solution as sediment volume and movement patterns arriving from upstream is uncertain.
- Dredging could restore channel to a desired service level but no provision exists for over design events or future more intense storms (i.e. global warming effects).
- Water level reduction due to dredging would be negated over time due to sea level rise.

Based on the limitations associated with dredging OPUS (2007) did not consider this a first choice option for restoring the service level in the lower reach.

Modelling of dredging excluded global warming effects.

Dredging of the Lower Rangitaiki is scheduled in the Rangitaiki Tarawera Asset Management Plan and LTCCP for 2008/09. Given the low benefit/cost ratio dredging is not a recommended flood mitigation solution.

2.2.3 Rivermouth Widening

Modelling of the Rangitaiki River mouth width showed that under the 100 year design flow, if the mouth did not scour water levels would be some 200 mm higher than for a scoured cross-section. However observation from past floods is that the sandbar does scour relatively quickly on the rising limb of the flood and is likely to have eroded when most needed at the time of peak flow.

It is recommended that Environment Bay of Plenty monitor the Rangitaiki River mouth by carrying out annual cross-section surveys as part of the overall flood risk mitigation strategy as situations may arise following low river flows and westerly drift wherein some excavation could be useful. Provision should be made in future scheme asset management plans to allow for monitoring and possible excavation if required.

Modelling of rivermouth widening excluded global warming effects.

2.2.4 Reid's Central Widening

OPUS (2007) modelling showed that widening of the lower part of Reid's central canal offered the best return on investment and provided benefit to the widest area, both urban and rural.

The lower part of the canal is between 25 and 50 m wide whereas the upper 8 km has a width of 200 m. Water levels were modelled with scenarios of widening the lower section by 20, 50 and 100 m. Without sea level rise, results indicate that widening the canal by 50 m was optimal, doubling the canal capacity and lowering water levels in the Rangitaiki River by 0.5 m in the 100 year flood event.

Modelling of Reid's Central Canal shows substantial benefits to the scheme can be realised by widening the lower 4 km by an additional 50 m. The Rangitaiki-Tarawera FMS therefore supports the canal widening option.

2.2.5 Reid's Central Widening and New Replacement Bridge Options

In 2006 Transit New Zealand commissioned Burnham, Bloxham & Oliver (BBO) and HMS to carry out a capacity review of Reid's Central canal to determine the benefits of a proposed new replacement bridge on State Highway 2 immediately east of Edgecumbe.

Modelling was based on 2004/05 (most current) cross-sections and the previously recommended OPUS scenario whereby the lower section is widened by an additional 50 m. Three bridge options were reviewed and preliminary results showed that Reid's central canal:

- stopbanks continued to overtop under existing cross-section for all flows and bridge options.
- bridges downstream of State Highway 2 bridge are submerged for all flows and bridge options.
- achieved significant flood level reductions if Reid's central canal is widened by 50 m in the lower 4 km of the canal. For example with this widening water levels are kept for the most part within canal banks for all three bridge options during the current canal capacity flow of 110 m^3/s.

Transit New Zealand's consultants BBO recommended that the flood level for the new State Highway 2 bridge design be kept at RL5.0 m plus freeboard. This level will allow flows of up to 200 cumecs to be conveyed within current canal widths and allow for future climate change flows (320 cumecs with sea level rise) to be conveyed *if* canal widening was undertaken (HMS, 2007). In both cases a 'glass wall' has been assumed in the model along the crest of stopbanks and top-ups would be required to keep flood waters within the banks.

Existing bridges in Reid's Central canal including the State Highway 2 Bridge at Edgecumbe create head losses when the canal is operating. As canal flow increases, these head losses increase and stopbank overtopping worsens.

It is recommended that bridges in the Reid's central canal be upgraded to reduce head losses and subsequent flooding onto neighbouring floodplains. Hydraulic requirements for the bridges should be confirmed during next capacity review of Reid's central canal and before design of remedial works commences. The cost of any bridge upgrade would be paid for by Transit New Zealand.

2.2.6 Stopbank Freeboard

Providing stopbank freeboard helps mitigate against the effects of overdesign events. Rural freeboard is currently 300 mm lower than in Edgecumbe urban area (alternatively referred to as differential freeboard). Lower freeboard helps to ensure that overtopping occurs in rural areas before it occurs in urban areas. In addition present water in excess of the Rangitaiki design capacity spills preferentially into Reid's central canal. However since the canal has only a nominal capacity of 110 cumecs within its current banks, for flows greater than Rangitaiki design capacity, extensive flooding will occur as was experienced in 2004. This assumes that the stopbanks at other locations do not fail.

2.3 Overdesign Flood Events

How the flood protection scheme and the communities protected by it would manage an extreme or "overdesign" event is an important issue. The current design standards for the major scheme stopbanks are 100 year for Rangitaiki and Tarawera Rivers and Reid's Central Canal.

The effects of an overdesign flood such as the 300 year flow has been examined for Rangitaiki River that has the largest population at risk in such an event. TransPower have indicated that they require 300 year flood protection around their Edgecumbe substation and will be contributing towards the design and construction cost to increase the level of protection above that already provided (i.e. 100 year)

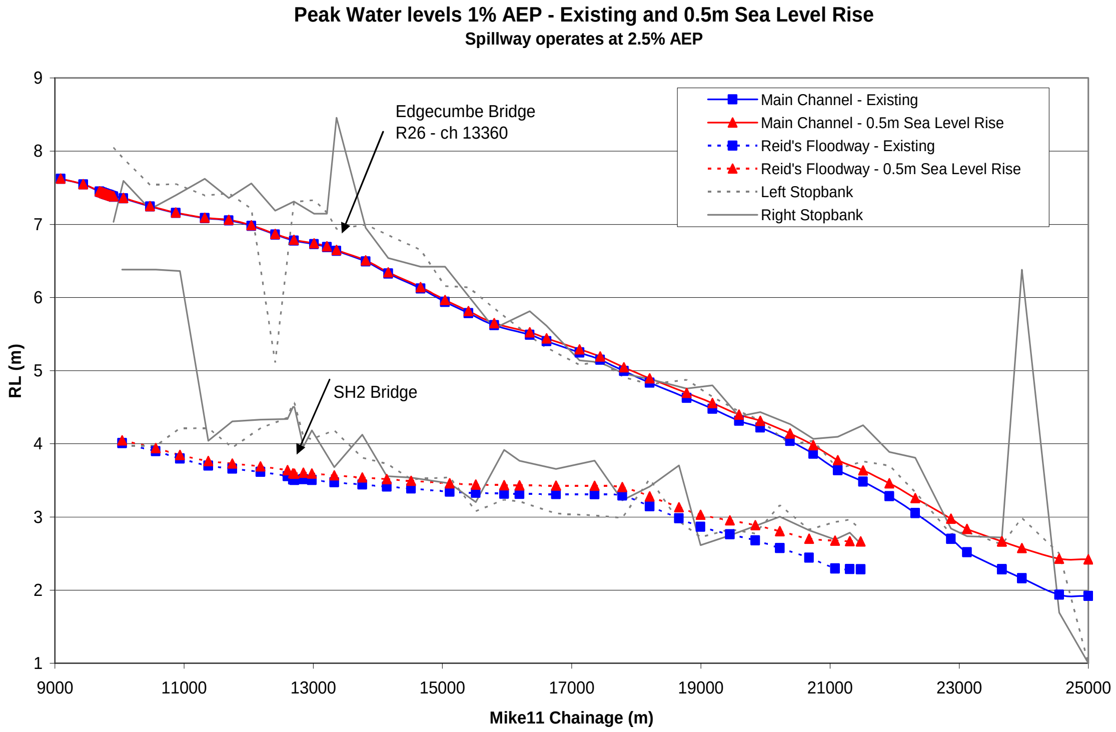


Figure 2.1 Modelled maximum water levels under existing and predicted sea level rise of 0.5 m (from OPUS, 2007)

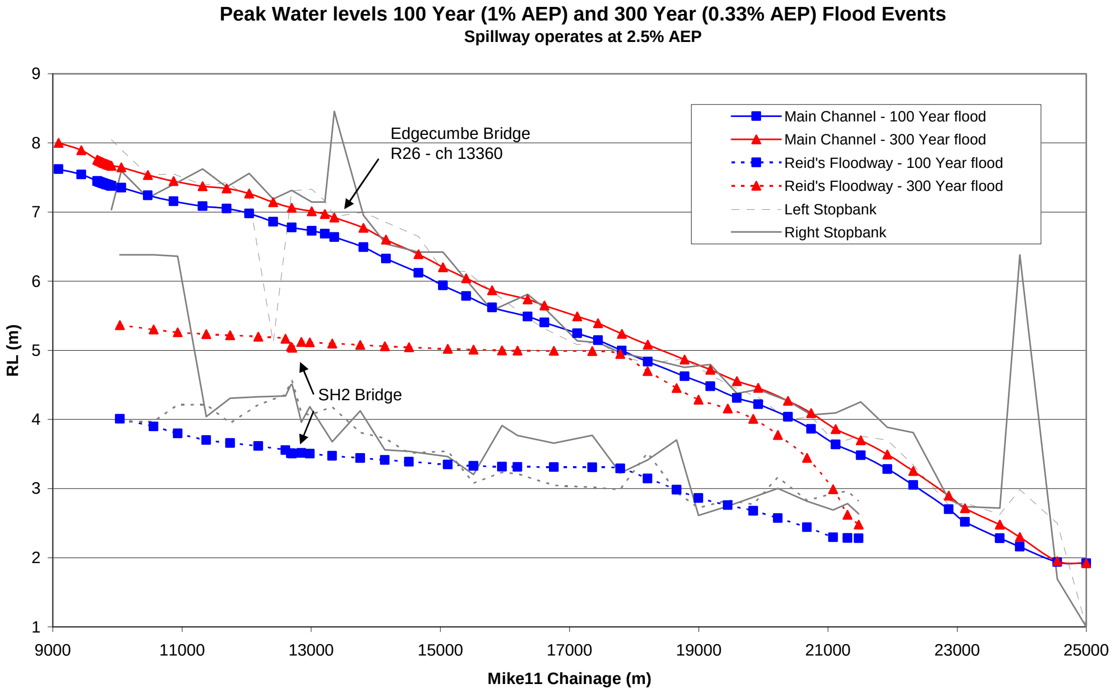


Figure 2.2 Modelled maximum water levels under 100 and 300 year flood events (300 year flood predicted to be future 100 year flood) (from OPUS, 2006)

2.4 Flooding in Tarawera River

A capacity review of the Tarawera River was completed in 2005 (Environment Bay of Plenty, 2005).

Water levels provided in the Environment Bay of Plenty report were also compared to cross-sections surveyed in June 2006 and results reported in the stopbank condition evaluation report (Everitt & Medwin, 2006). A graph showing the comparison of water levels and June 2006 stopbank crest levels are shown in Figure 2.5.

Top-ups are required whenever the stopbank crest level settles to less than half the freeboard requirements. Based on asset management plan criteria top-ups are necessary:

- On the true right stopbank between river distances 200 m and 400 m (near river mouth).
- On the true right stopbank between river distances 1,500 m and 5,500 m (downstream of State Highway 2).
- On the true right stopbank between river distances 700 m and 5,500 m.
- On the true left stopbank between river distances 6,500 m and 7,500 m (just upstream of State Highway 2).
- On the true left stopbank between river distances 6,500 m and 7,500 m (just upstream of State Highway 2).

- On the true left stopbank between river distances 9,300 m and 9,700 m (between State Highway 2 and State Highway 30).

According to the Asset Management Plan Tarawera stopbanks top-ups are due in 2012/13. However the recommendation made at the 2 August 2007 Operations Committee to bring forward Tarawera stopbank top-ups to 2008/09 to is supported.

The effects of an overdesign event should also be assessed for the Tarawera River particularly as it is close to Kawerau township. This should be completed during the next capacity review schedule for 2011/12.

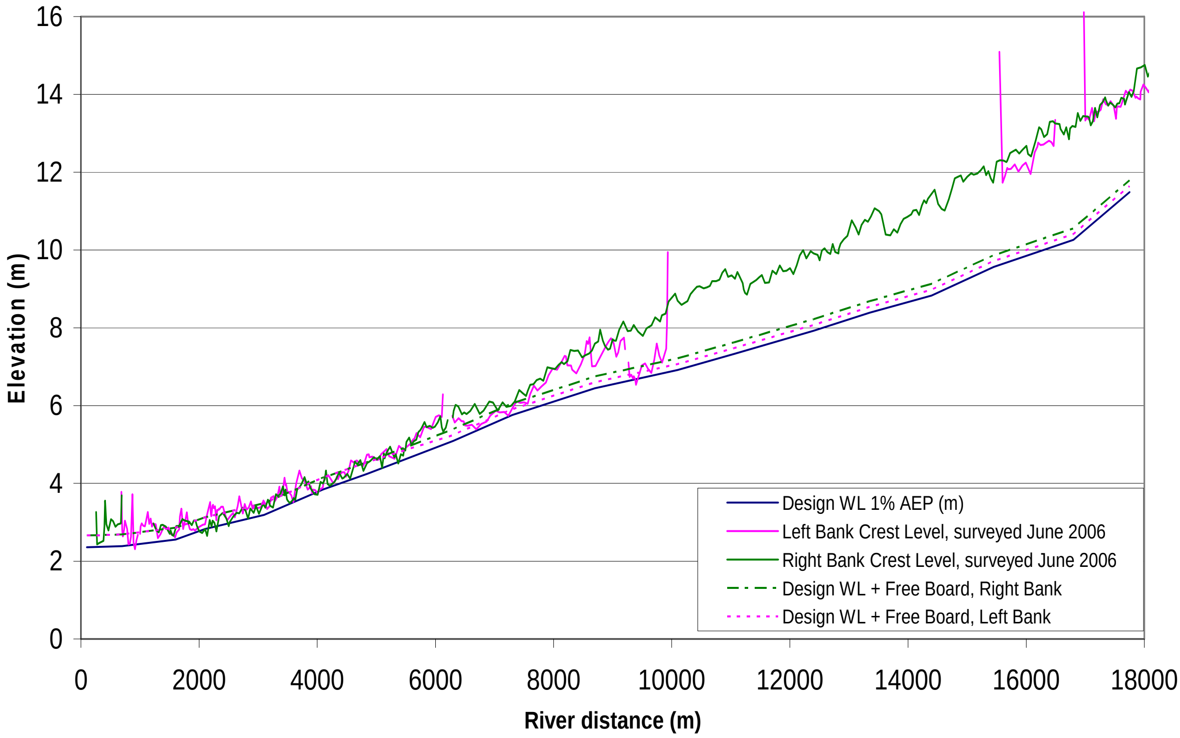


Figure 2.5 Flood levels in Tarawera River below State Highway 30 and stopbank crest levels (from Everitt and Medwin, 2005)

A study on the potential effect of failure of the Rotomahana "plug", that is the isthmus of land separating Lakes Rotomahana and Tarawera, has been completed by OPUS International Consultants (2007). The investigation determined the magnitude and timing of the flood-wave following overtopping erosion of the isthmus at selected locations along the Tarawera River.

The study concluded an overtopping failure of the Lake Rotomahana barrier (isthmus) would require an exceedingly low probability storm event with the annual risk of overflow from Lake Rotomahana being less than a 1000 year flood event. Furthermore 2 m freeboard still exists between the lake level and "plug" crest level in this event.

Because of the significant ponding effect of Lake Tarawera, the dam break flood released from Lake Rotomahana would take 1-4 days to propagate downstream.

Flood hazard maps showing the extent of potential flood inundation resulting from failure of the "plug" indicated that the flood would likely:

- Be confined to a fairly narrow strip along both riverbanks through the upper valley except in the vicinity of the Edwards Road Bridge.

- Inundate low-lying recreational area adjacent to the river through the town of Kawarau but not inundate any residential areas.

- Inundate the floodplain along a narrow strip of the floodplain in places downstream of the State Highway 34 Bridge.

- Extensively inundate the floodplain on both sides of the river downstream of State Highway 30 Bridge as floodwaters spilled over the stopbanks.

The next phase is to prepare an Emergency Action Plan which is due for completion in 2008.

2.5 Flooding in the Rangitaiki Plains

A two dimensional hydraulic model (MIKE FLOOD) of the Rangitaiki Plains between Rangitaiki and Tarawera Rivers was used to evaluate flood levels and develop flood hazard maps that could result from normal catchment rainfall or breaches of the Rangitaiki River stopbanks (Wallace, 2006). Flood levels were modelled in this catchment for the 100 year flood event (100 year flood levels are equivalent to 50 year flood levels expected in 50 years time. Refer s1.12.1d).

The five flood scenarios modelled comprised:

- a breach at Laws Bend, Rangitaiki River (left bank), with 100 year tide level and 20 year flow in the Rangitaiki River.

- a breach at Laws Bend, Rangitaiki River (left bank), with 20 year tide level and 100 year flow in the Rangitaiki River.

- a breach downstream of Thornton Road, Rangitaiki River (left bank), with 100 year tide level and 20 year flow in the Rangitaiki River.

- a breach downstream of Thornton Road, Rangitaiki River (left bank), with 100 year tide level and 20 year flow in the Tarawera River.

- 100 year rainfall on the Rangitaiki Plains and 20 year tide level.

Flood inundation maps for each of the five scenarios above are shown as Figures A3.1 to A3.5 in Appendix 3.

Breach scenarios are discussed in s2.6 but a combined flood map showing the maximum flood levels for each of the five scenarios is reproduced as Figures A2.1 and A2.2 in Appendix 2. Both figures include a 500 mm freeboard allowance. Figures A2.1 and A2.2 also includes an insert with results from a breach scenario at Kokohinau Bend on the left bank of the Rangitaiki River. The Kokohinau breach scenario was the subject of a separate modelling exercise (Environment Bay of Plenty, 2006). In all maps, flooding to depths less than 50 mm are not shown.

Modelling results indicate:

- All scenarios cause extensive flooding in the area bounded by the two major rivers, State Highway 2 and the raised coastal sand dunes north of Thornton Road.

- Flood depths exceed 2 m in the area to the north of Laws Bend and west of Rangitaiki River.

- All scenarios cut-off Thornton Road access between Matata and the Rangitaiki Plains.

Assumptions for the Rangitaiki Plains model are detailed in Wallace's (2006) report however the major assumptions and recommendations are as follows:

- Use of 1987 photogrammetric data in establishing ground levels in the Rangitaiki Plains. Some settlement of the plains is known to have occurred since 1987 so flood levels are considered conservative. Using recently available LIDAR data in the next model update is recommended.
- Use of 1997 canal stopbank data. Stopbank crest levels are known to have settled since 1997 so flood levels are considered conservative. Use of updated canal cross-sectional data (with additional sections and confirmation of relevant culvert dimensions) is recommended.
- Use of limited flood event data. Installing additional water level recorders, undertaking flow gauging and recording debris mark levels are recommended. Flood levels obtain in the July 2004 should also be used when calibrating future floodplain models.

2.6 Future Development and Flood Mitigation in the Rangitaiki Tarawera Catchment

Urban growth and development of additional hardstand surface areas within the catchment is inevitable with the possible result of increasing run-off. Potential flood level rises must therefore be avoided, mitigated or reduced so that others are not adversely affected.

To reduce the flood effects of future development Environment Bay of Plenty will continue to provide Whakatane District Council with floodmaps of the catchment. Floodmaps will help Whakatane District Council avoid building in flood prone areas and mitigate against the effects as required.

Further floodplain scenario mapping to complete coverage of the Rangitaiki Tarawera catchment is planned in 2007/08 as follows:

- east of the Rangitaiki River right bank to the Kope Orini catchment plus interior drains.
- west of the Tarawera River left bank plus interior drains.
- breach scenarios at selected locations on Rangitaiki and Tarawera Rivers.

Future modelling will establish flood levels arising from the maximum envelope of the above scenarios for the 50 year (at 2055) and 100 year (at 2080) flood events. It will also indicate flood depths over roads that provide access to buildings and subdivisions.

The impacts of floodplain infilling must be considered on a case by case basis so that it does not adversely affect others. Whilst these may be small on their own, they do add up cumulatively particularly where there is significant ongoing development potential e.g. the Kope Orini basin. However, a particularly minor effect from an area with non-cumulative potential may be acceptable occasionally, say up to 15 mm maximum, or where there are no affected houses.

It is recommended that:

- Provision of 100% mitigation where infilling occurs within the catchment at locations where significant ongoing development is expected. 100% mitigation should be applied to post development effects which might otherwise increase the flood risk to neighbouring properties. Mitigation options would be reviewed on a case-by-case basis however they might include provision of culverts and/or bridges to preserve overland flow paths, retention ponds, compensatory lowering of land and pumping equivalent volume of additional run off and lost storage e.g. Carter Holt Harvey/The Hub site.

- Adequate access and egress be provided to new buildings and subdivisions before resource consent is granted. In this regard New Zealand S4404:2004 Land Development and Subdivision Engineering states in clause commentary C4.3.2.4 that the "*the standard recommended for ponding or secondary flow on roads is that they are passable to light vehicles in the 2% AEP event and to 4WD in the 1 % AEP event*".

- All flood maps produced from modelling be given to Whakatane District Council to help them identify flood prone areas and plan future development in such a way that reduces, mitigates or avoids these floodable areas.

2.7 Stopbank Security

No stopbank is failsafe and some possibility of a breach does exist. Stopbank breaches might occur as a result of:

- Overtopping and subsequent scour of the stopbank's landward slope.

- Seepage under or through the stopbank leading to piping or heave failures.

- Erosion of the stopbank by the river.

- Stopbank slope instability.

Another issue threatening stopbanks is rabbit hole/warren weaknesses. Environment Bay of Plenty has employed contractors to eradicate rabbits on both Rangitaiki and Tarawera Rivers, however the hole/warrens are difficult to backfill.

Maintenance and repairs to flood protection assets are completed based on the outcome of condition assessments, capacity assessments, geotechnical investigations, flood damage and programmed maintenance according to the asset management plan.

Since completion of the river scheme flood defences the only natural major stopbank breach that has occurred was at Sullivan's Bend on the Rangitaiki River. In July 2004 the Rangitaiki was subject to a flood in excess of its design capacity and a breach occurred as a result of piping failure through the stopbank foundation.

Sections 1.10.2 and 1.10.3 outline studies related to stopbank capacity and condition that have been completed or are still in progress. For example at the time of writing this report geotechnical studies were underway at potential breach sites; Laws Bend, downstream of Thornton Road (Rangitaiki River site) and at Kokohinau Bend.

Remedial works implemented or proposed to increase the factor of safety against stopbank failure include:

- Rock protection on the riverbank or berm to reduce erosion.
- Fill overlays on landward toe of stopbanks to increase seepage paths.
- Pressure relief trenches and subsoil drains to intercept seepage under stopbanks.

2.7.1 Tarawera Stopbank Failure

The stopbank condition monitoring report noted that “potential for under-seepage will always exist due to the permeable nature of the foundations” (Everitt & Medwin, 2006). On this basis Everitt selected five sites that would be suitable for further geotechnical investigation and seepage and stability assessment. Selection criteria was based on the likely high permeability of foundation materials, previous remedial work carried out on the stopbanks (toe loading), obvious wet land on landward side at some locations and of course experience with the breach at Sullivan’s Bend stopbanks /foundations which were constructed of similar materials (Everitt, 2007). Breach scenarios will also be examined to assess the effect of flooding on the adjacent floodplain. Sites are summarised and location shown in Table A3.1 and Figure A3.6 in Appendix 3.

Geotechnical investigations, seepage and stability analysis and breach flood maps are programmed for 2007/08.

2.7.2 Rangitaiki Stopbank Failure

As mentioned in s2.6 breach scenarios have already been modelled at locations along the true left Rangitaiki stopbanks. Resulting flood level information was used to help create flood maps to the east of the river. In 2007/08 breach scenarios are to be modelled at locations along the true right stopbank to assess flood levels to the east of the Rangitaiki River. The breach at Sullivan’s bend near Reid’s Central spillway gives some idea of the devastation that can result from a true right breach site. Three sites have been selected for breach evaluation and these are summarised and location shown in Table A3.1 and Figure A3.6 in Appendix 3.

At the time of writing geotechnical engineering firm Ice Construction Ltd is investigating one of the three sites namely Langdons.

2.7.3 Probability of Stopbank Breaching

For a full analysis of the Rangitaiki Tarawera Rivers flood hazard, some assessment of the likelihood of stopbank breaches could be undertaken. Environment Bay of Plenty may undertake a risk assessment for the Tarawera and Rangitaiki River stopbanks depending on the outcome of seepage and stability analysis (geotechnical investigations) recommended in s2.6.1 and s2.6.2.

Probability of Rangitaiki and/or Tarawera stopbank breaching could be calculated separately for left and right stopbanks of the respective main rivers. Probabilities would be assessed for the design service level and “overdesign” flood events. The assessment would take into account current stopbank condition assessments, protection measures already in place and the results of current capacity reviews and geotechnical investigations.

A probability assessment of Rangitaiki/Tarawera stopbank breaching is only recommended if some doubt arises as to whether remedial works should be implemented in response to engineering assessments completed. Results would be reported in the Stage 2 report.

2.7.4 Residual Risk

As with any protection system a certain amount of risk will always be inherent at some point in the life cycle of any flood management system. The flood risk remaining after implementation of risk treatment, for example, the risk of flooding that still exists despite protection provided by say stopbanks is defined "residual risk".

Residual risks in Rangitaiki-Tarawera River scheme catchment include:

- Overdesign events. The historical experience in flood management is that design standards are regularly exceeded in nature and it is not common practice to at least counter the effects of maximum credible events, rare though they might be.

- Stopbank stability. Implicit in the understanding that stopbanks meet design standards is the assumption that adequate factors of safety exist for geotechnical stability. Environment Bay of Plenty is assessing stability of Edgecumbe stopbanks to check if acceptable factors of safety exist against failure modes mentioned in s2.7. If factors of safety are inadequate then remedial work will be implemented to restore them to acceptable standards.

- Prolonged steady state seepage conditions. Traditionally stopbanks are designed as water retaining embankments that experience bank full conditions for relatively short periods of time, not extending over more than 12 hours and often less than six hours (pg 130, Atcheson, 1968). As such stopbanks may not be designed to handle prolonged seepage flows and pressures. Threat of failure under these conditions was very real in the case of Edgecumbe following the July 1998 floods. Refer s1.10.2 for further detail. Risk of failure can be reduced by implementing remedial works that result from an adverse seepage and stability assessment. However that being said there are approximately 109 km of stopbanks within the Rangitaiki Tarawera rivers scheme so some residual risk will always be present.

2.8 The Flood Hazard

The flood hazard is the potential for damage to property or people due to flooding and associated erosion due to say, stopbank and floodwall overtopping or stopbank breaching. Environment Bay of Plenty has a very good database of information regarding the magnitude of historical floods, the most recent notable event being the July 2004 flood. Local councils and utilities record the impact of floods such as the extent of urban flooding and disruption to services.

In July 2004 regional and territorial councils, the community and utility providers got some indication of the risks associated with severe flooding. Descriptions of the impact the July 2004 flood had on the region are documented below.

2.8.1 Community at Risk

Fortunately no lives were lost in the Rangitaiki-Tarawera catchment during the July 2004 floods. However widespread flooding in the catchment did give rise to many people being evacuated from their homes. By 30 July 2004 a maximum of 326 people were registered as being evacuated at Edgecumbe Town Hall (Environment Bay of Plenty RO[14] Recovery Report No. 8, 6/08/04).

2.8.2 Built Assets at Risk

Public and private utilities are impacted by large flood events in the Rangitaiki Plains. In general:

- Flood protection assets including stopbanks, edge protections, buffer land, floodgates and pump stations may be damaged due to high scouring flows and water levels.
- Rural dwellings and farm facilities might be flood damaged at locations where stopbanks breach or overtop.
- Commercial, industrial and private buildings might be flood damaged where stopbanks breach or overtop.

(a) Flood Protection Assets

The 2004 July floods caused significant damage to Environment Bay of Plenty's infrastructural assets.

The extent of damage outlined in Table 2.3 is described in terms of the nature of the repair work carried out.

Table 2.2 Description of repair works to flood protection assets in 2004.

River	**July 2004***
Rangitaiki River	10.2 km of rock placement
	5.65 km of vegetation protection planted
	Stopbank reinstatement at Sullivan's Breach plus other manmade breach sites
Whirinaki River	150 m of rock protection (lining)
	2.3 km of vegetation protection planted
Tarawera River	850 m of rock placement

Source: Appendix 2 Bay of Plenty Region Operations Report 2005/06 Final Claim, August 2006

[14] Environment Bay of Plenty RO = Eastern Bay of Plenty Recovery Office. Recovery reports were sent frequently to the Director MCDEM during and after the flood event.

(b) Rural Dwellings and Farm Facilities

In July 2004 a total of 75 dairy farms were badly affected (Whakatane District Council Press Release, 22/7/04).

The costs of lost production and re-establishing production on flood damaged Eastern Bay of Plenty rural properties was assessed at about $50 million. However the assessment did not include the costs of re-establishing buildings, cow sheds, lost supplements, long term production losses, and continuing costs after the first year of the July 2004 floods (Beacon 14/9/04).

Several unfortunate circumstances were evident at the time of the floods. Firstly, since the autumn of 2004 was dry and pasture cover depleted farmers were forced to feed extra supplements during the early winter (May/June) leaving farmers short of supplements at about the time of the flood. Secondly, farmers who took on stock for short term grazing from their flood-affected neighbours reduced their own grass and supplement levels. (Beacon, 14/9/04).

The Ministry of Agriculture and Fisheries (MAF) added in their review of the 2004 floods (MAF, 2007).

This event affected a greater proportion of dairy farms and because it hit so close to calving, many cows had to be moved out of the region. The Government paid for one way stock transport costs.

(c) Buildings

In July 2004 floodwaters damaged dwellings in Edgecumbe due to the breach of the Rangitaiki River stopbank at Sullivan's bend on the true right. A number of homes were flooded in Hydro Road and Konini Place and parts of the Fonterra site. OPUS state in their Edgecumbe urban and rural flood hazard report (OPUS, 2006)

Stopbanks on the left bank within Edgecumbe urban area were also under severe stress in this event and the main part of the town may have only been spared a major flood by the failure on the right bank at Sullivan's Bend. Six years earlier in 1998 a smaller flood also necessitated emergency remedial action.

2.8.3 Utility Vulnerability

To provide some idea of how vulnerable utilities are in the event of severe flooding a brief description of damage incurred in the catchment during the 2004 July floods is outlined below.

(a) Roading and Bridges

During the July 2004 floods widespread damage occurred to rural properties and roading throughout the Whakatane District. The worst areas hit included the Rangitaiki Plains due to the breaching of the Rangitaiki River at Sullivan's Bend. Roads owned and managed by Whakatane District Council that suffered flood damage included State Highway 2 west of Rangitaiki River Bridge, Waiohau and Troutbeck Roads, Black Road, Pikowai, Herepuru and Manawahe Roads. Approaches to several road bridges were washed away including a 70-80 m approach to Horomanga Bridge (Whakatane District Council, 2004).

(b) Aerodrome

Whakatane Airport was not damaged during the major July floods.

(c) Sewerage Network

In July 2004 a power outage occurred in Edgecumbe at the Hydro Road pump station for three days. Hydro Rd and Milk products stations were flooded. Tawhara, Kowhai and Kauri/Kowhai stations were overwhelmed. Overflows occurred in numerous locations.

No service issues were reported in Murupara and Te Mahoe. However in Murupara, the Whirinaki River overflowed into and silted the No 2 pond. (Whakatane District Council, 2004).

(d) Stormwater Network

In July 2004 Edgecumbe urban areas namely Hydro Road, Ngaio Place and Totara Street were flooded (Whakatane District Council, 2004).

(e) Water Supply

Public water supplies for Edgecumbe were maintained during the July 2004 apart from flooded areas in Hydro Road. Supply was cut off for 5-6 days to approximately eight properties in Hydro Road, the Fire Station and New Zealand Milk Products, while the water main was isolated and repaired.

(f) Electricity

In July 2004 many power poles were swept away by floods and slips (Ian Robinson, Horizons, 21/9/04).

TransPower's Edgecumbe substation was very nearly lost to floodwaters that rose almost to the level of the transformers, which could have caused an outage covering a large area of Eastern Bay of Plenty

(g) Gas

In July 2004 a high pressure gas delivery station and two pipelines were damaged close to State Highway 2 in Edgecumbe. Floodwaters almost reached critical instrumentation at the station and stopbank erosion exposed the pipelines one of which was a 100 mm diameter high pressure line. Vector needed to carry out weekly inspections of the assets. Pipeline remedial repairs were estimated to be in the order of $0.5M (Vector, 2007).

(h) Telecommunications

According to Telecom no obvious damage to telecommunications network within the catchment was evident in July 2004. In July 2004 (email from Daryl May, Telecom, 26/06/07).

2.8.4 Flood Damage Costs

The Eastern Bay of Plenty Disaster Recovery Office estimated that the July 2004 floods would end up costing the eastern Bay of Plenty region which includes the Rangitaiki Tarawera catchment more than $100M. This estimate included $50M for agricultural losses, $10M for roads and $10M in damage to river scheme assets. It did not include loses that were covered by insurance (Beacon, 11/8/04).

Flood damage costs can be calculated for the following:

- Loss of productive land (temporary loss due to silt coverage and permanent loss due to river bank erosion).
- Damage to infrastructure and utilities.
- Damage to urban property.

(a) Loss of Productive Land

Table 2.2 shows the reinstatement cost for productive land in the Rangitaiki Tarawera catchment following the July 2004. These figures are based on MAF data assessed in September 2004. Costs exclude re-establishing buildings, cowsheds, lost supplements, long-term production losses and continuing costs after the first year of the July 2004 floods. Most of the catchment was affected by excess water with slips and erosion affecting production on unsilted land.

Table 2.3 Reinstatement costs of productive land that flooded in July 2004 (Beacon, 14 September 2004).

Silt Deposits	Area (ha)	Reinstatement Cost per hectare* $/ha)	Reinstatement Cost ($)
Lost land (to river)	110	N/A	N/A
Severe (Silt > 150 mm)	3,500	2,500+	8,750,000
Moderate (Silt 50 – 150 mm)	9,100	1,500	13,650,000
Light (Silt < 50 mm)	14,660	500	7,330,000
Totals	27,370 ha		$29,730,000

* these are July 2004 rates

MAF's assessment of the catchment areas inundated by floodwaters during July 2004 were:

- Galatea 1336 ha
- Waiohau 336 ha
- Rangitaiki Plains 6847 ha

In September 2004 MAF estimated production losses at 6.4-7.5 million kg milk solids. At a rate of $3.80/kg this is equivalent to $24-$29 million in lost production. Hence the overall damage costs for reinstatement and lost production were estimated in September 2004 to range between $53.7M - $58.7M.

(b) Damage to Infrastructure and Utilities

The cost of flood damage to infrastructure and utilities in the Rangitaiki and Tarawera catchments for July 2004 floods is summarised in Table 2.3. Costs of damage are taken from Environment Bay of Plenty and Whakatane District Council files and correspondence from various utility providers as indicated.

Table 2.4 Estimated repair costs of infrastructure and utilities damaged in July 2004

Infrastructure and Utility	***Brief Description***	***2004 Estimated Cost ($)***
Roading and Bridges	Repair of road surfaces, slips, repair of revoked State Highway 38 and Troutbeck Road Bridge etc.	1,501,065[α]
Sewerage	Reinstate Edgecumbe and Murupara ponds, Edgecumbe pump station repair.	167,000[α]
Water Supply	Repair Te Teko reservoir and pump station facilities and Thornton reticulation, reinstate access to Matata reservoir etc.	52,970[α]
Stormwater	Desilt drains, provide bunding and pumping in Edgecumbe and Matata.	1,520,000[α]
Flood Protection	Repair of flood protection assets, flood monitoring and emergency response and contract work.	8,440,746[#]
Electricity	Replace several power poles and lines, which were swept away in floods and slips. Use of generators, some switchgear blown.	100,000[+]
Gas	Repair of gas pipeline near Edgecumbe/Reid's Central Canal (Source: Hugh Driver, Vector, email 12/6/07).	500,000
Telecommunications	Nil.	0
	Total Estimate of Damage Costs	$12,281,781

\# From Environment Bay of Plenty (B Crabbe, 2006). Estimate includes response and recovery costs.

\+ From Horizons. Phone discussion with Ian Robinson (21/6/07).

α From Whakatane District Council report, 2004, Appendix 2

Ψ From Telecom (D May, 26/106/07)

(c) Damage to Urban Property

As at 8 October 2004, in the Whakatane district, district inspectors inspected a total of 370 homes for flood and landslip damage. Fortunately no houses were condemned. The inspectors found that 118 of these homes did not have house contents insurance (Environment Bay of Plenty RO Recovery Report No. 12, 8/10/04). It is uncertain how many of these houses were within the Rangitaiki Tarawera catchment.

2.8.5 Social Impact

In the event of major flooding much of the focus is on the tangible losses such as loss of assets, property, infrastructure and business. Of less focus are the intangible damages, which include the social and psychological impacts that result from community disruption during and after the major flood. Intangible losses may effect people when:

- Flooded residential areas have resulted in the emergency evacuation of people to safe and dry shelter.
- Essential services such as potable water supplies and waste disposal services are cut-off thus increasing health risk.
- Personal possessions are lost which may result in emotional trauma.

(a) Emergency Evacuations

At the peak of the July 2004 floods several thousand people throughout the Eastern Bay were evacuated from their homes and relocated in temporary accommodation. In the Rangitaiki-Tarawera catchment a maximum of 326 people registered as evacuees at Edgecumbe Hall. (Source: Eastern BOPRO, Recovery Report#8, 6/8/04).

On the western side of the Rangitaiki River in Edgecumbe floodwaters affected 98 homes, requiring 205 people to be evacuated. On the eastern side, the comparative figures were 31 and 98 respectively, and on both sides of the river there were many others left isolated until floodwaters receded. (WDC Flood Event Report, 2004)

(b) Health Risks

No serious illnesses due to the failing potable water supply or sewerage reticulation were reported in the catchment as a result of the floods.

(c) Medical Services

Very little was reported at the time of the July 2004 floods or subsequent to it of any medical emergencies that arose as a direct result of the floods.

(d) Emotional Trauma

The psychological impact of the July 2004 flood was better recorded then the July 1998 floods. After the July 2004 flood there was great demand for support services such as Victim Support, Women's Refuge and Social Workers. Whakatane District Council even arranged to engage a psychologist to assist its ratepayer's work through their loss (Eastern BOPRO, Recovery Report#11, 3/9/04). In late September 2004 Dr Rob Gordon, the clinical psychologist involved in the 2004 Manawatu-Wanganui floods, facilitated a series of workshops on stress in the community.

The responsibility for coordinating counselling requests was passed from the Eastern BOPRO to Victim Support on 3 September 2004 after the office was disestablished. Victim Support indicated that due to the demand they had to refer people out of the area to connect with counsellors although it was hoped that counsellors might come into the region.

Victim Support employed four field workers to work directly with groups and affected areas throughout the wider Eastern Bay of Plenty region. Stresses in the community also manifest itself in an increase in family violence following the floods. The Police indicated that family violence rose in late August 2004 with nine instances reported. There was an increase in self-referrals to Women's Refuge, which put substantial pressure on the service and caused them to seek additional accommodation.

Schools faced considerable challenges to meet the extra social, physical, psychological and educational needs of pupils who were evacuated and/or are in temporary accommodation. The Ministry of Education and Child, Youth and Family therefore prepared a proposal for an emergency Social Worker in Schools (SWIS) in the Eastern Bay of Plenty.

2.8.6 Community Resilience

Recent flood events have impacted and will continue to impact the Rangitaiki-Tarawera community and their ability to pay for future flood protection. The community's ability to pay for flood protection is limited owing to the high level of socio-economic deprivation in the district and anticipated population trends. Offsetting these observations however is the community's positive community spirit that has shown historically that it can rise above natural disasters and will no doubt continue to do so in the future.

(a) Socio-Economic Deprivation

The Index of Deprivation, NZDep01 is an integration of nine variables from the 2001 census, reflecting eight dimensions of deprivation. Variables include income, employment, telephone access, qualifications and home ownership. The following facts help to provide a picture of the community's limited ability to fund future flood protection.

- Of the 16 regions in New Zealand, the regions that have relatively more areas of deprivation include Northland, Gisborne and the Bay of Plenty.
- 40% of the Bay of Plenty population are in the more deprived deciles (8-10) compared with New Zealand as a whole (30%).
- The Eastern Bay of Plenty has higher proportions of its population in the more deprived deciles (8-10) than other parts of the region.
- Whakatane District has 25% of its population in the most deprived decile (10).

(i) Employment

The Eastern Bay of Plenty has a high level of unemployment, particularly in the areas that have been most severely impacted on by the floods. According to the 2001 census 8% of Whakatane District was unemployed compared with 6% for the region and a national average of 5%. Since 2001 unemployment has dropped to 3.9% for the Bay of Plenty and to 3.8% for New Zealand as a whole (September 2006).

(ii) Income

Family incomes in the Eastern Bay of Plenty are low compared to New Zealand as a whole. In Whakatane 32% of families have a combined income below $30,001, which compares to a national average of 27%. When combined with the low levels of insurance in the affected community, these incomes are likely to hinder the ability of the wider catchment to meet the costs of increased rates to fund infrastructure restoration works.

(iii) Qualifications

Whakatane District has a high percentage of youth between the ages of zero and 24 years at 39%. This figure compares with the national average of 36%.

61.8% of Whakatane schools are classified as decile 3 or lower when, by definition, only 30% of New Zealand schools have these rankings. Furthermore 24% of people aged 15 years or over in Whakatane District have post-school qualifications, which compares with 27.7% for New Zealand as a whole.

(iv) Telecommunications

In 2001 92% of New Zealand households had access to a telephone and 36% had access to the internet. The Eastern Bay of Plenty, being thinly populated and relatively remote with a largely poor population, had proportionately fewer households with telephone access and or internet access. 86% of households in Whakatane District has a working telephone in their household while 27% had access to the internet.

(v) Industry – Primary Production

The community's resilience was impacted by the July 2004 floods because it reduced the primary industry's productivity and hence financial capacity to help pay for flood recovery and protection.

At the time of the 2001 census primary industry (agriculture, forestry and fishing) accounted for 17.6% of full-time equivalent employment in the Eastern Bay of Plenty. The primary industry's contribution to the local economy (Gross Domestic Product) was an average of nearly 17% over the five years to March 2003.

Each year MAF carries out an economic appraisal of rural regions throughout New Zealand and the Whakatane catchment is assessed as part of the Waikato/Bay of Plenty region (MAF, 2006). In 2005/06 MAF's assessment of dairy farms showed:

- an increase in income (due largely to increased milk solids production) *but* continuing cost rises.
- an overall financial loss, a continuation of recent years.
- ongoing financial loss in 2006/07 indicating the difficulty for the average farm to operate profitably on a $4.05 payout.

Similarly for dry stock farms MAF analysis show:

- steady farm productivity *but* produce prices fell between 15 and 25%.
- net trading profit fell by 25%.
- continued increases in production costs.
- capital purchase have halved.

According to Mark McIntosh, AgFirst's Whakatane based agricultural consultant, the current ability of farmers to cover significant capital costs is limited by their constrained cash flows. Although dairy farmers are able to borrow based on their high levels of equity with low payouts the constraint then becomes their ability to service the debt in their cash flows (especially given the high interest rates) (McIntosh, 2006).

Miles Mander, rural banker based at Whakatane's National Bank agrees with McIntosh's view of the rural economy. Miles says that although the value of established farms has increased (due to say purchase of other farms) cash flow has become tighter. Currently dairy farm operational costs are $0.60 per kg but if this is compared with a payout of $4.05 per kg of milk solids then one can see that margins are indeed slim (Mander, 2006).

The National Bank which produces a general nationwide rural report based on various economic factors comments on rural profitability (National Bank, December 2006):

Discretionary expenditure is expected to be constrained at least until March/April 2007 when a better fix on actual revenue is obtained. A cash deficit before capital expenditure was a common outcome in most agricultural sectors for year end June 2006. The positive outlook for unit prices for sheep meat, beef, venison and apples will boost revenue. Revenue for dairy and kiwifruit is forecast to be similar to 2006. However all sectors face increased unit costs. The hard winter will exacerbate absolute expenditure on many pastoral farms *in 2006/07 as they try to rebuild conserved feed reserves.*

(b) Anticipated Population Trends

The Rangitaiki-Tarawera catchment's ability to pay for flood protection schemes is dependent in part on its rating base and thus population size.

In 2001 the total Whakatane District population was approximately 32,800 (rural and urban) and the medium projected population for the district (rural and urban) from 1996-2016 anticipates a rise until 2006, before decreasing to about 1996 levels. The combined urban population in Edgecumbe and Murupara was 3,600. In the same period the urban population of Kawerau was approximately 6,900.

While population increases in the coastal townships will continue, changes in the nature of farming and other rural-based activities make predicting rural population growth difficult. It is likely that communities that were reliant on the forestry sector for employment opportunities such as Galatea and Murupara will continue to diminish in the foreseeable future (Proposed Whakatane District Plan, 2004).

(c) Community Spirit

During and following the July 2004 floods various reports revealed a strong and supportive spirit in the eastern Bay of Plenty, which helped it recover from the immediate community trauma. On 20 July 2004 the New Zealand Herald reported:

Many people had been traumatised by the floods, made worst by the series of earthquakes which hit the area (New Zealand Herald, 20/7/04) However despite the tragedy Deputy Whakatane Mayor Brian Birkett told the New Zealand Herald, “That was the last thing we need,” he said. “But there is a real strength of spirit in this community. We will get through this.”

During the July 2004 flood volunteers and Environment Bay of Plenty and Whakatane District Council staff worked around the clock to:

- sandbag and protect the Edgecumbe substation from being inundated with water;
- pump water off affected farms;
- deliver rubbish skips for flood rubbish and debris; and
- clear roads of debris and slip material.

After the July 2004 floods a positive spirit prevailed in the community. Teams of workers called “Task Force Green” travelled through the rural communities including Galatea/Waiohau and Rangitaiki Plains. The teams assisted in the clean up. Priority works included desilting, cleaning and refilling water troughs, picking up debris in paddocks and reinstating fences.

In August 2004 many kilometres of fencing were repaired and reinstated, troughs were recommissioned and tons of destroyed haybales were removed from farms. Task Force Green was also responsible for helping remove slip debris, revegetating, fencing off slip faces and work in the urban area by reinstating walkways and playgrounds contaminated by floodwaters. (Eastern BOPRO, Recovery Report 11, 3/9/04).

(d) Community Outlook

Despite the positive spirit of the local community to rise above the ‘floodwaters’ other factors appear to make flood protection difficult to sustain financially in the future. The level of socio-economic deprivation, the vulnerability of the primary industry to help pay for protection works and predictions of future population size collaborate to make funding of flood protection works questionable.

These issues have implications for the resilience of the community and its ability to cope with future flood events. Based on current observations:

- there will be limitations on the community in paying for mitigation programmes, works etc;
- some residents will be vulnerable to flood damage as a result of underinsurance; and
- recovery in the event of a future flood may be slow.

Ongoing issues with stock created higher then normal stress levels for farmers in the area.

2.9 Estimated Potential Damages

Results of flood modelling can be used to provide estimates of potential damage, provided reasonable information about the value of the floodplain asset or property, and its distribution is available. Having estimates of flood damage information can help decision makers determine benefit cost ratios for different scenarios and help prioritise the order of remedial works. The benefit in this sense is equivalent to the damage prevented by investing in remedial works (i.e. the cost). In the Edgecumbe flood hazard study OPUS Consultants calculated benefit cost ratios for several schemes that offer protection to the township as well as the wider Rangitaiki Plains (refer s1.9.2b).

Further potential flood damage costs can be assessed catchment wide for a number of *hypothetical scenarios* that include stopbank overtopping and breaching for the locations discussed in sections 2.6.1 and 2.6.2 above.

A flood damage cost assessment is only recommended if some doubt arises as to whether remedial works should be implemented in response to engineering assessments completed. Results would be reported in the Stage 2 report.

Part 3: Key Issues and Recommendations

The underlying aim of floodplain management planning is to reduce the susceptibility/exposure to flooding to property and persons that live within the scheme catchment. This Floodplain Management Strategy (FMS) comprises three stages. The aim of this Stage 1 report is to identify and describe existing flood issues within the Rangitaiki and Tarawera catchments, outline existing flood protection measures, identify potential hazards and elements at risk and identify what mitigation options are needed. Stage 2 identifies flood mitigation options and Stage 3 will provide further detail on how the selected options will be implemented.

Table 3.1 summarises all the recommendations made in this Stage 1 report; it nominates the stakeholder responsible, the output required and timeframe.

This Stage 1 study has revealed that flood protection provided in the Rangitaiki Tarawera catchment requires further work to fully meet service level requirements as set out in the scheme asset management plan. However in saying that, Environment Bay of Plenty is generally aware of the challenges and has commenced a number of measures that will ultimately reduce, mitigate or avoid identified flood risks. This FMS captures most measures currently being undertaken and adds further recommendations that will reduce risk further. To restore flood design service levels the most pressing structural measures required includes stopbank top-ups (or renewals) on the Tarawera and Rangitaiki Rivers and Reid's Central Canal. The main question for stakeholders will be whether they are prepared to bring forward and implement some important renewal items earlier than anticipated?

The *main* ***structural*** *recommendations* are summarised briefly below with a proposed modified Long Term Council Community Plan (LTCCP) time schedule shown in Table 3.1 (refer to Part 3 of this report).

1 Tarawera River stopbanks require top-ups to achieve 100 year protection. The recommendation made at the 2 August 2007 Operations Committee was that this renewal work be brought forward from 2012/13 to 2008/09 to restore service level requirements.

2 Stopbank top-ups are also required along the lower Rangitaiki River reach (which starts just downstream of Edgecumbe township and extends to the river mouth) to achieve the 100 year protection service level. Protection for the lower reach is currently provided for the 50 year flood event with 300 mm freeboard. The temporary 50 year protection was agreed to by the scheme liaison group and formalised as part of the June 2004 Rangitaiki Tarawera Asset Management Plan (Environment Bay of Plenty, 2004). Before topping up lower Rangitaiki stopbanks it is recommended that geotechnical stability be assessed and climate change effects be considered to 2030 and 2080 through updated modelling. Effects of a new Reid's Central spillway structure should also be considered in the modelling. Since Rangitaiki stopbank top-ups are not scheduled to commence until 2010/11 it is recommended that these additional studies commence in 2008/09.

3 Reid's Central Canal is narrow at some places greatly restricting its capacity. Studies carried out since July 2004 indicate water levels would be reduced significantly in the canal and Rangitaiki River if the canal were to be widened by 20 to 50 m in the lower reach. Since Reid's Central canal top-ups are planned for 2009/10 it is recommended that geotechnical stability be assessed and climate change effects to 2030 and 2080 respectively be included 2030 in updated modelling. These studies need to commence in 2008/09 in order to meet the stopbank top-up renewals programme.

The *most significant* ***non-structural*** recommendations include:

4 Updating floodmaps of the Rangitaiki Plains as new catchment information on becomes available. Updated floodmaps will help Whakatane District Council better plan for future development by keeping floodwaters away from development and development away from floodwaters. Flood risk maps for the area west of the Tarawera River and east of the Rangitaiki River to the Whakatane River will be produced by Environment Bay of Plenty in 2007/08.

5 The requirement for land developers to mitigate 100% the additional run-off generated by their developments so that the effects are less than or equal to existing (pre-development) levels. Mitigation should be applied to post development effects which might otherwise increase the flood risk to neighbouring properties. Mitigation options would be reviewed on a case-by-case basis however they might include provision of culverts and/or bridges to preserve overland flow paths, retention ponds, compensatory lowering of land and pumping equivalent volume of additional run off and lost storage e.g. Carter Holt Harvey/The Hub site. In floodplain management terminology 'structural measures' refers to a specific group of flood protection structural assets such as stopbanks, floodwalls, riprap etc. Culverts and bridges are structural assets but in this context they are used to help achieve the non-structural measure of providing 100% mitigation of post-development effects.

6 This FMS supports in principle the recommendations made by OPUS (2007) in their Edgecumbe flood mitigation study especially those related to the river scheme as a whole. Briefly these include constructing several low level stopbanks and pump stations around Edgecumbe township, completing stability assessment of rural stopbanks and implementing measures to restore factors of safety to accepted engineering levels, widening Reid's Central Canal (refer point 3 above) and constructing a spillway/control structure at Reid's Central Canal.

The decision making process will take place at the end of each of the three stages when Environment Bay of Plenty's Strategic Policy Committee and key stakeholders are invited to review results of the strategy as it unfolds, assess the risks presented, provide feedback, approve or make alternative recommendations to those made by Council Officers.

In the Stage 2 report Environment Bay of Plenty will:

- report on the outcome of recommended tasks made in this Stage 1 report.
- identify the flood mitigation options that are available to reduce the flood risks identified.
- if necessary, provide an economic and environmental evaluation of the options.

In Stage 3, the Strategic Policy Committee will confirm the stakeholders' choice of mitigation options, prioritise strategies and set in place a programme to implement the choices made.

Table 3.1 Current LTCCP major renewals programme (in black) and proposed changes (in black) and design timetable (in blue)

LTCCP Year	Tarawera River Assets	Rangitaiki River Assets	Reid's Central Canal Assets
2007/08		Ongoing stopbank stability assessment and remedial works at Edgecumbe	
2008/09		Complete update of hydraulic model Complete stopbank stability assessment and remedial works at Edgecumbe Dredge lower Rangitaiki River – recommend cancelling this task[15].	Complete update of hydraulic model Complete stopbank stability assessment (other than widened section) Commence stopbank widening design and geotechnical investigations Complete design of new spillway structure Complete design and reconstruction of other Reach 10 canal stopbanks e.g. Awakaponga etc
2009/10	Complete stability assessment of stopbanks Complete stopbank design and contract documents	Complete stopbank stability assessment (over balance of stopbanks) [16]	Continue stopbank widening construction Commence construction of spillway structure
2010/11	Tarawera stopbank reconstruction, Reach 8 ↑	Complete stopbank design and contract documents Rangitaiki stopbank reconstruction, Reach 1 – mouth to Edgecumbe	Complete stopbank widening construction Complete construction of spillway structure
2011/12	↑	Rangitaiki stopbank reconstruction, Reach 2 – Edgecumbe to Te Teko plus ORC Pump (major maintenance)	
2012/13	Tarawera stopbank reconstruction, Reach 8[17]		

[15] This option not recommended. Refer to s2.2.2. OPUS (2007) estimate dredging cost at $7M
[16] Geotechnical consultant recommends limiting investigations to places where top-ups are required. Investigations need not be carried out at locations where there is no record of historical problems.
[17] Reach 8 comprises Tarawera River reach between State Highway 30 and the river mouth.

Table 3.2 Recommended tasks to identify mitigation options for Rangitaiki Tarawera Floodplain Management Strategy for Stage 2

Task No.	Recommendation	Stakeholder Responsible	Output for Stage 2 Report	Completion Date
1	Text related to Matahina Dam in the Environment Bay of Plenty Flood Warning manual should be cross-checked against TrustPower's Matahina dam EAP and flood procedures. The Matahina dambreak flood map should also be appended to the Flood Warning Manual. (Report reference 1.9.2)	Environment Bay of Plenty	EAP confirmed as being compatible with Flood Manual. Inclusion of Matahina dam break flood map in Flood Manual.	30 December 2008
2	This FMS supports in principle the recommendations made by OPUS in their Edgecumbe flood mitigation study especially those related to river scheme as a whole. (Report reference: 1.9.2)	Whakatane District Council/ Environment Bay of Plenty	-	-
3	Complete detailed inspection of Tarawera stopbanks during raised river levels particularly of the landward toe of the banks and beyond (Report reference: 1.9.3)	Environment Bay of Plenty	Prepare inspection report	30 June 2008
4	Geotechnical investigations should be carried out on the remaining 29km of Rangitaiki stopbank and 20km of Reid's Central stopbank not already assessed as part of Edgecumbe stopbank stability project. Investigations should confirm adequate stability exists and commence before top-ups are implemented. Reid's Central stopbank top-ups are scheduled for 2009/10. Rangitaiki stopbank top-ups between the river mouth and Edgecumbe are scheduled for 2010/11 and between Edgecumbe and Te Teko in 2011/12. (Report reference: 1.9.3)	Environment Bay of Plenty	Undertake geotechnical investigations on Rangitaiki and Reid's Central Canal stopbanks	Complete Reid's Central Canal geotechnical investigation report before 30 June 2009 Complete Rangitaiki geotechnical investigation report before 30 June 2010
5	Should there be a lack of demand to extract gravel from areas where it needs to be removed then Environment Bay of Plenty should consider removing a defined quantity each year. This might be implemented by offering a subsidy to contractors to remove the gravel. In any case an item for gravel extractions should be added to the maintenance budget of the scheme asset management plan (Report reference 1.10.3)	Environment Bay of Plenty	Consider adding gravel extraction as an annual maintenance item in the scheme asset management plan.	30 June 2008

Task No.	Recommendation	Stakeholder Responsible	Output for Stage 2 Report	Completion Date
6	A cross-section survey and assessment of gravel volumes should be undertaken on the Rangitaiki River upstream of Aniwhenua to determine the extent to which flooding has worsened as a result of gravel build up. Removal of gravel build up will reduce flood risk and increase storage capacity for Aniwhenua hydroelectric dam. (Rep reference 1.10.3)	Environment Bay of Plenty/ Bay of Plenty Electricity	Prepare an assessment report outlining how gravel upstream of Aniwhenua has worsened flooding.	31 December 2009
7	The bed level of the lower reaches of the Horomanga River should be lowered initially by an average of 0.5m over the 70m design fairway width. Recommendation carries over from the 2006 NERMN report (Report reference: 1.10.3)	Environment Bay of Plenty	Complete gravel extraction to lower Horomanga River by 0.5 m	31 December 2008
8	The Ruarepuae River bed is aggrading in the lower reaches (cross-sections 1 to 3) and degrading in the upper reaches (cross-sections 4 to 6). It is therefore recommended that extraction concentrate in the lower reaches. Recommendation carries over from the 2006 NERMN report. (Report reference: 1.10.3)	Environment Bay of Plenty	Complete gravel extraction to lower Ruarepuae River in lower reaches	31 December 2008
9	A detailed design should be undertaken to define desirable bed levels at each cross-section of the Whirinaki River. Extraction should be encouraged at the aggrading reaches around cross-sections 4 and 5. Recommendation carries over from the 2006 NERMN report (Report reference: 1.10.3)	Environment Bay of Plenty	Complete detailed design of Whirinaki River that defines desirable bed levels. Encourage extraction as cross-sections 4 and 5.	31 December 2009
10	It is recommended that Whakatane District Council consider placing a note on LIM reports that confirms stopbank bylaw compliance (or otherwise). (Report reference: 1.11.1)	Whakatane District Council	Report back on progress placing notes on Whakatane District Council LIM reports	Ongoing

Task No.	Recommendation	Stakeholder Responsible	Output for Stage 2 Report	Completion Date
11	Undertake study to determine effect of land use changes in catchment. (Report reference 1.11.2)	Environment Bay of Plenty	Report on potential impacts arising from changes in catchment land use.	20 February 2013
12	Climate change scenarios for 2030 and 2080 and outlined in Table 2.1 should be modelled in future capacity reviews of scheme rivers, streams and drains. This will help Council decide what future proofing could be done today. These scenarios should be modelled before detail design commences of the remedial works proposed for Edgecumbe and the wider Rangitaiki River scheme works (Report reference: 2.2.1)	Environment Bay of Plenty	Confirm climate change scenarios are modelled adequately in future capacity reviews.	Ongoing
13	Dredging of the Lower Rangitaiki is scheduled in the Rangitaiki Tarawera Asset Management Plan for 2008/09. Given the cost/benefit is likely to be low this activity is no longer recommended. (Report reference: 2.2.2)	Environment Bay of Plenty	Remove Rangitaiki River dredging item from AMP and LTCCP.	N/A
14	The Rangitaiki river mouth cross-section should be monitored as part of the overall flood risk mitigation strategy since situations may arise following low river flows and westerly drift wherein some excavation could be useful. (Report reference: 2.2.3)	Environment Bay of Plenty	Add maintenance item to RT AMP for monitoring and excavation (if required) of river mouth.	31 July 2008
15	Modelling of Reid's Central Canal shows substantial benefits to the scheme can be realised by widening the lower 4km by an additional 50m. The Rangitaiki Tarawera FMS therefore supports the canal widening option. (Report reference: 2.2.4)	Environment Bay of Plenty	Confirm Reid's Central canal is to be widened in the lower reach	To be confirmed
16	It is recommended that bridges in the Reid's central canal be upgraded to reduce head losses and subsequent flooding onto neighbouring floodplains. Hydraulic requirements for the bridges should be confirmed in the next capacity review of Reid's central canal and before design of remedial works commences. (Report reference: 2.2.5)	Environment Bay of Plenty	Confirm optimal hydraulic requirements for bridges in canal during next capacity review of Reid's Central canal.	Before 30 June 2009

Task No.	Recommendation	Stakeholder Responsible	Output for Stage 2 Report	Completion Date
17	According to the asset management plan Tarawera stopbanks top-ups are due in 1012/13. However if funding and other resources permitted it is recommended Tarawera stopbank top-ups be bought forward as early as 2008/09 to reduce the risk of stopbank failure during the 100 year design event. (Report reference: 2.4)	Environment Bay of Plenty	Confirmation that Tarawera stopbank top-up design will commenced early in 2008/09	Complete Tarawera stopbank top-ups before 30 June 2009
18	The effects of an overdesign event should also be assessed for the Tarawera River particularly as it is close to Kawerau township. This should be completed during the next capacity review scheduled for 2011/12. (Report reference: 2.4)	Environment Bay of Plenty	N/A	30 June 2012
19	Update existing floodmaps between Rangitaiki and Tarawera Rivers using newly available data e.g. LIDAR, latest stopbank crest levels, actual July 2004 flood level data etc (Report reference: 2.5)	Environment Bay of Plenty	Provision in 2008/09 Annual Plan to update existing flood maps between Rangitaiki and Tarawera Rivers	30 June 2009
20	Prepare new floodmap for area west of Tarawera and east of Rangitaiki River. Use any new flow and level data made available since previous modelling e.g. LIDAR data. (Report reference: 2.6)	Environment Bay of Plenty	Provide WDC with new or updated floodmaps as they come available	30 June 2008.
21	Where infilling occurs within the catchment measures should be taken to mitigate 100% the post development effects that might otherwise increase the flood risk to neighbouring properties. (Report reference: 2.6)	Whakatane District Council	Confirmation that Council will consider the effects of infilling when assessing resource consent applications	Ongoing.
22	Adequate access and egress should be provided to new buildings and subdivisions before resource consent is granted. Due regard should be given clause commentary C4.3.2.4 of NZS4404:2004 Land Development & Subdivision Engineering which states that the "*the standard recommended for ponding or secondary flow on roads is that they are passable to light*	Whakatane District Council	Confirmation that Council will take into account flood depths over access & egress routes to proposed buildings and subdivisions when	Ongoing.

Task No.	Recommendation	Stakeholder Responsible	Output for Stage 2 Report	Completion Date
	vehicles in the 2% AEP event and to 4WD in the 1 %AEP event". (Report reference: 2.6)		assessing resource consent applications	
23	All relevant flood maps produced by modelling shall be given to Whakatane District Council to help them identify flood prone areas and plan future development in such a way that reduces, mitigates or avoids the flood hazard. (Report reference: 2.6)	Environment Bay of Plenty	New and updated floodmaps to be sent to WDC as they come available.	To be confirmed
24	A probability assessment of Rangitaiki/Tarawera stopbank breaching is only recommended if some doubt arises as to whether remedial works should be implemented in response to engineering assessments completed. (Report reference: 2.7.3)	Environment Bay of Plenty	If required – report risk assessment results in Stage 2 report.	30 June 2008
25	A flood damage cost assessment is only recommended if some doubt arises as to whether remedial works should be implemented in response to engineering assessments completed. (Report reference: 2.9)	Environment Bay of Plenty	If required – report risk assessment results in Stage 2 report.	30 June 2008
26	Publish Stage 2 report-outlining outcomes of Stage 1 recommendations and mitigation options available.	Environment Bay of Plenty	RTFMS Stage 2 Report	30 June 2008

Part 4: Appendices

Appendix 1 – Summary of Rangitaiki Tarawera Rivers Scheme Assets and Capacity Reviews

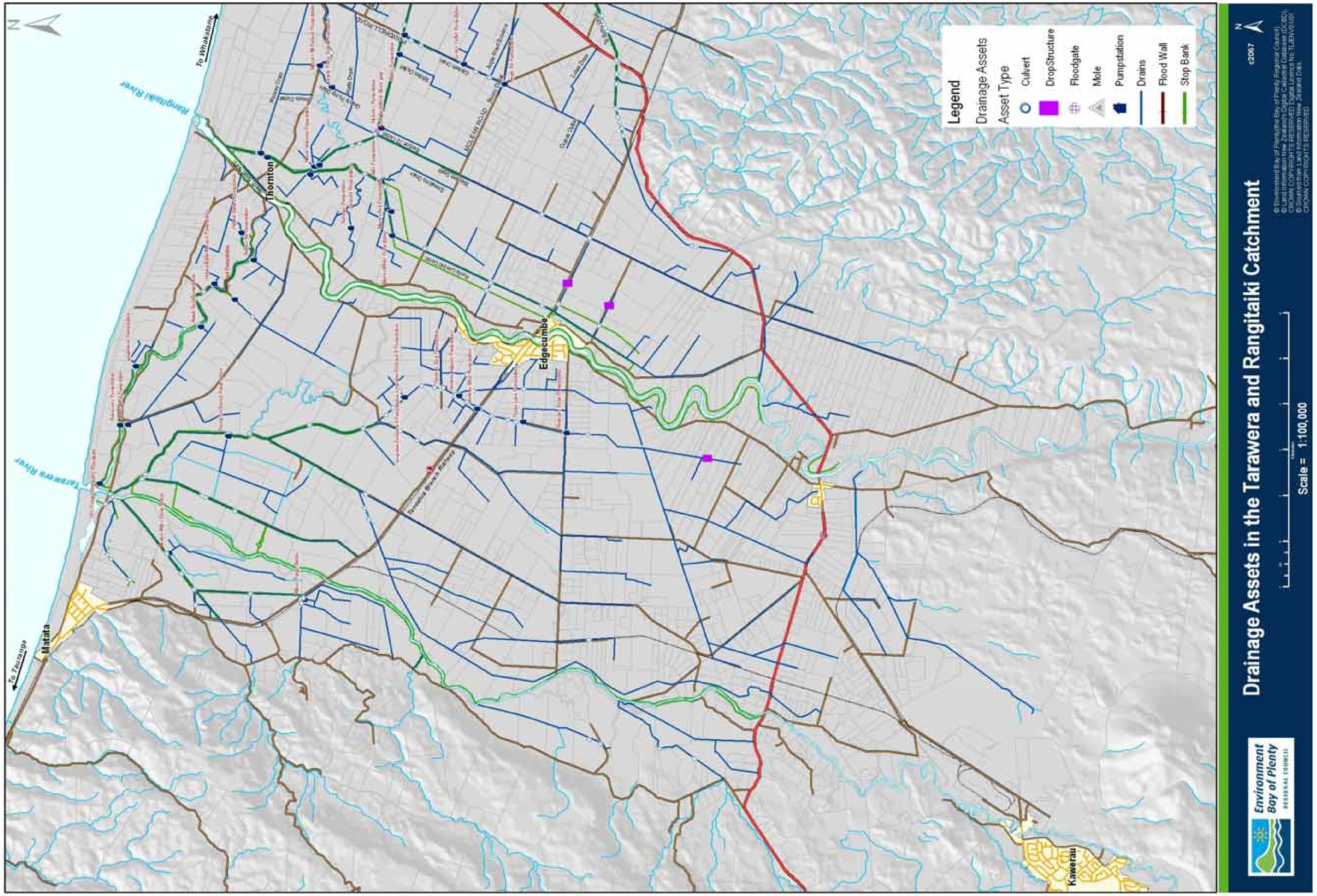


Figure A1.1 Location plan of flood protection assets in Rangitaiki River Scheme.

Table A1.1 Summary of capacity reviews undertaken

Report Date	Location	Model Used & Reviewer
February 2007	Reid's Central Canal	MIKE 11 by Grant (HMSL) for Transit New Zealand
December 2006	Rangitaiki Plains between Rangitaiki and Tarawera Rivers	MIKE FLOOD by Wallace
March 2006	Rangitaiki River & Reid's Central Canal	MIKE 11 by Harkness (OPUS)
2005	Lower Tarawera	MIKE11 by Arts/Pak
May 2002	Awaiti Omehu canal	MIKE 11 by Wallace
October 2000	Rangitaiki River below Edgecumbe	MIKE 11 by Blackwood
June 1995	Rangitaiki flood hazard	By Barnett Consultants Ltd
October 1988	Rangitaiki River (post 1987 earthquake)	By P. Dine & P. Journeaux
April 1986	Lower Tarawera	By G Pemberton

Appendix 2 – Rangitaiki Plains Flood Maps

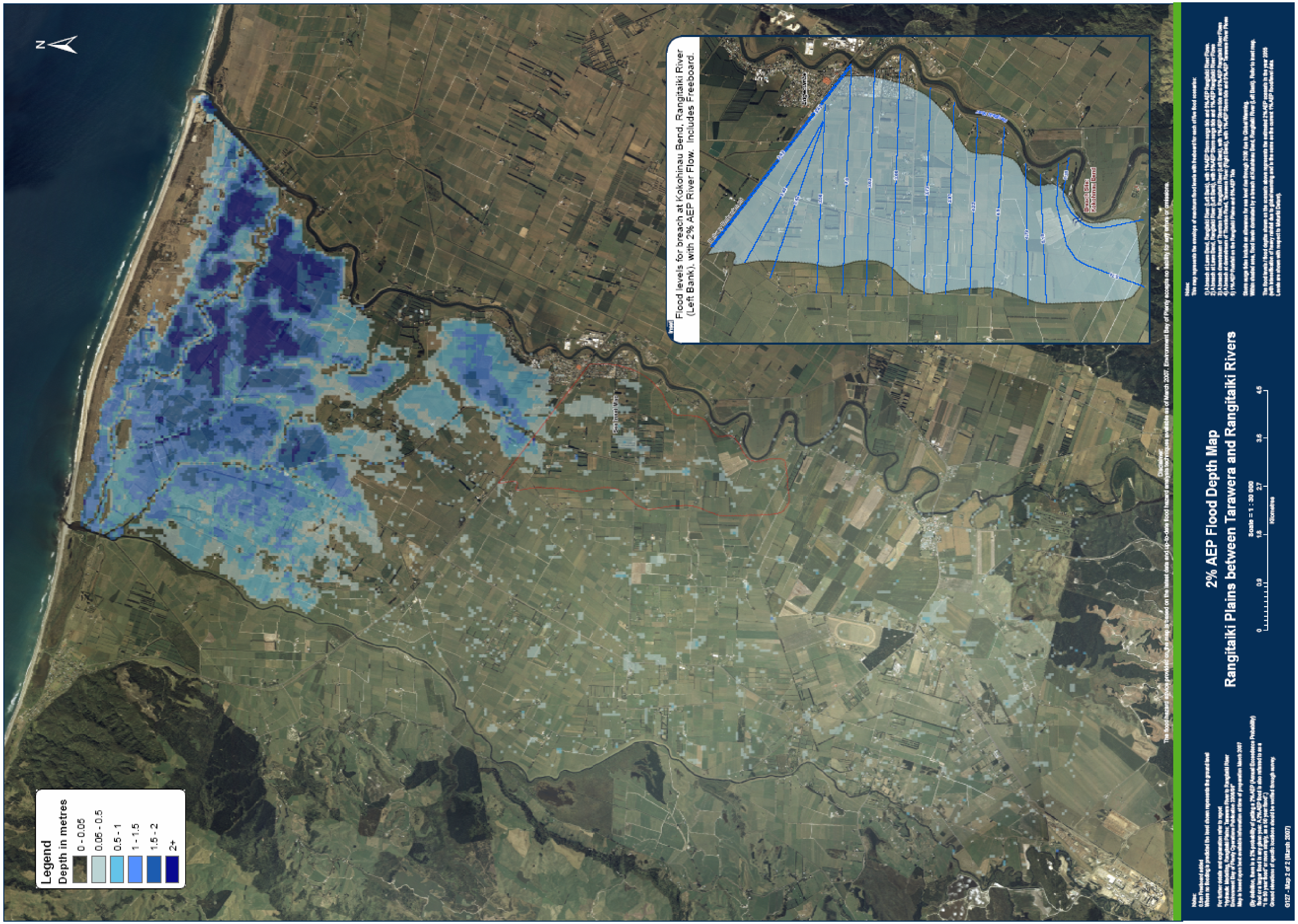


Figure A2.1 Flood depth and extent in Rangitaiki floodplain during a 50 year flood event (based on 2055 rainfall figures an envelope of maximum flood levels from five scenarios).

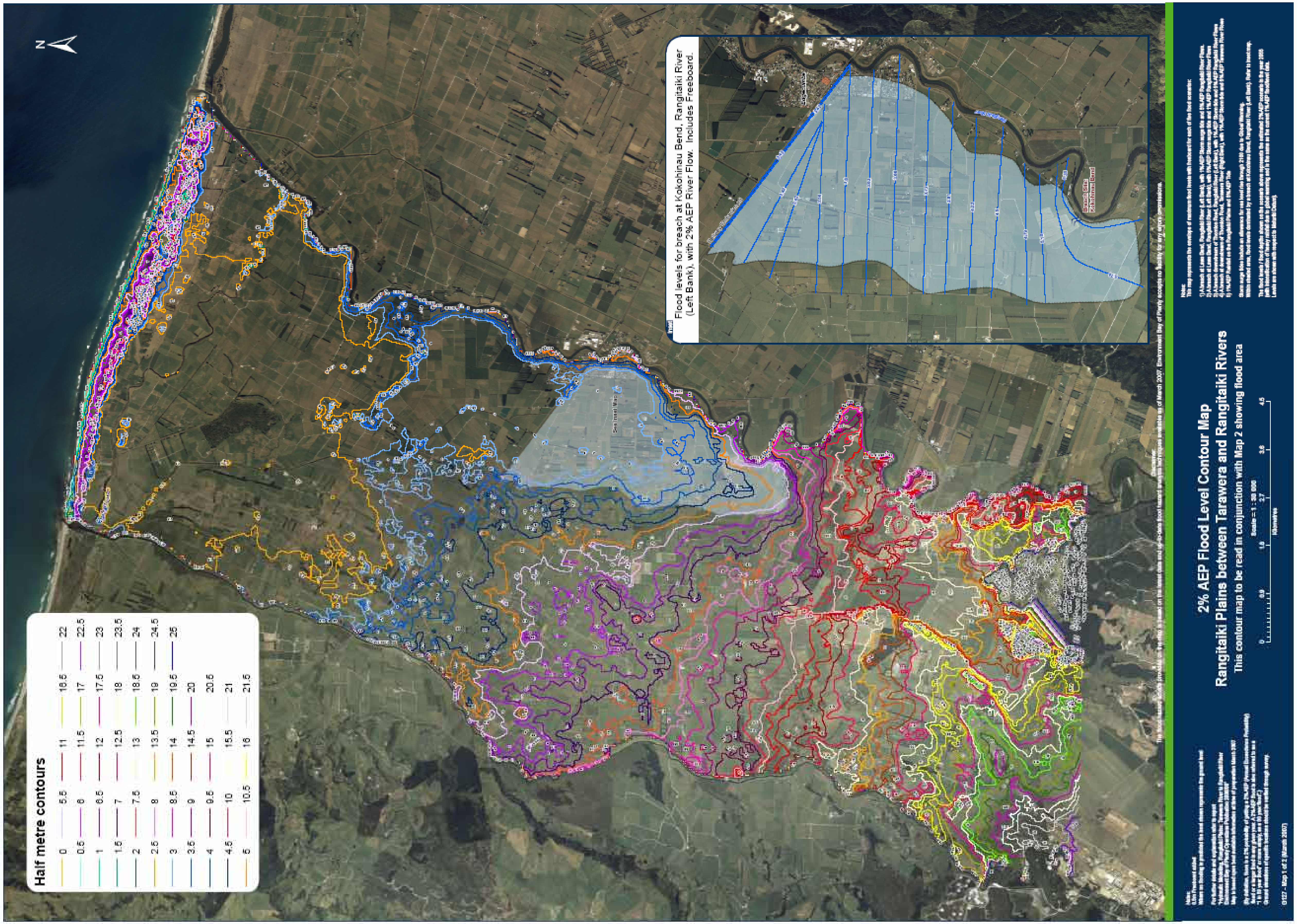


Figure A2.2 Flood level contours and extent in Rangitaiki floodplain during a 50 year flood event (based on 2055 rainfall figures an envelope of maximum flood levels from five scenarios).

Figure A2.3 Flood depth and extent in Kope Orini Basin during a 50 year flood event (based on 2055 rainfall figures an envelope of maximum flood levels from five scenarios) (Plan R745).

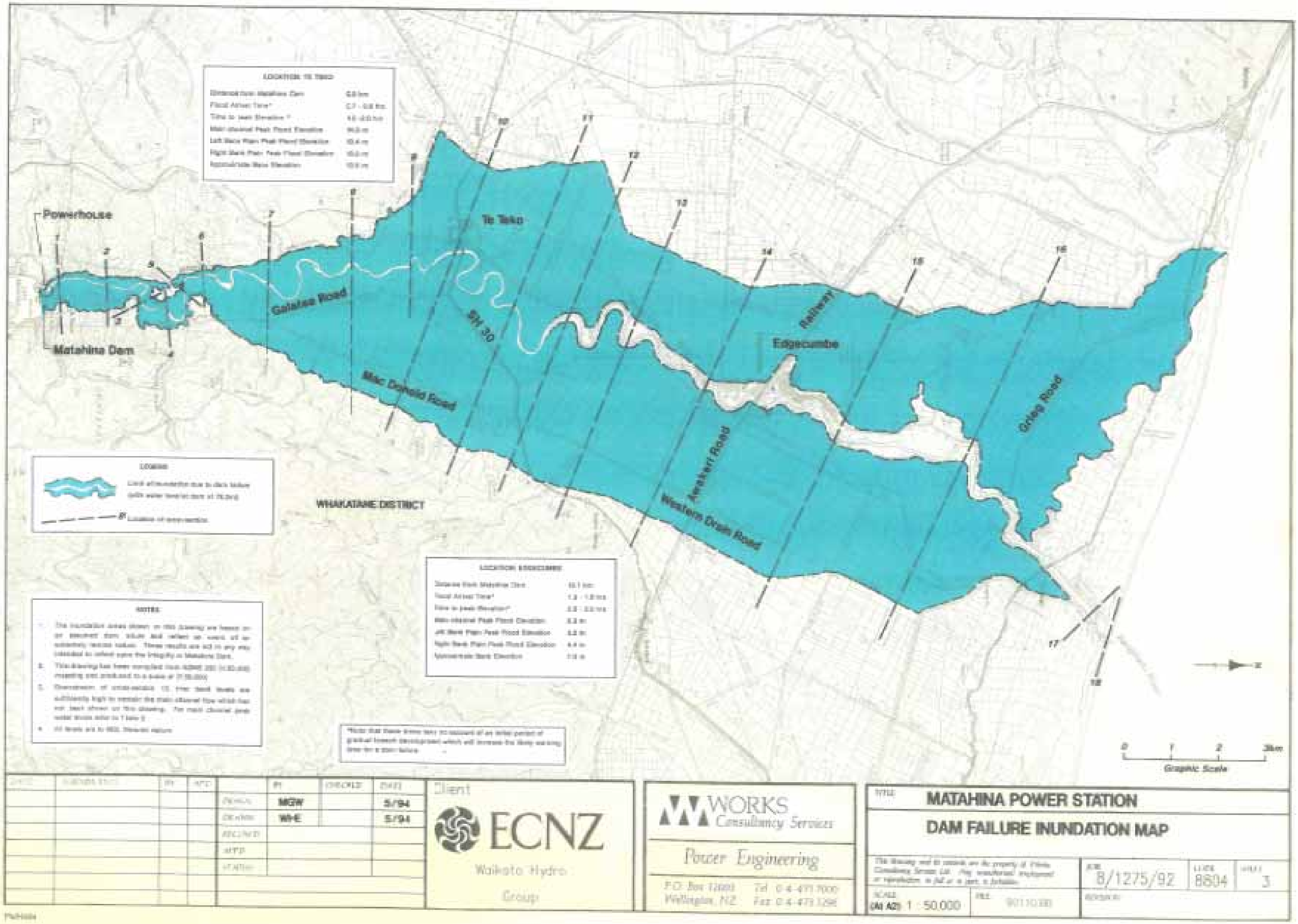


Figure A2.4 *Flood water time and peak water level following sudden dam break at Matahina (TrustPower, 2006).*

Appendix 3 – Potential Stopbank Breach Flood Maps

Inundation from a breach at Laws Bend, Rangitaiki River
1% AEP Tide

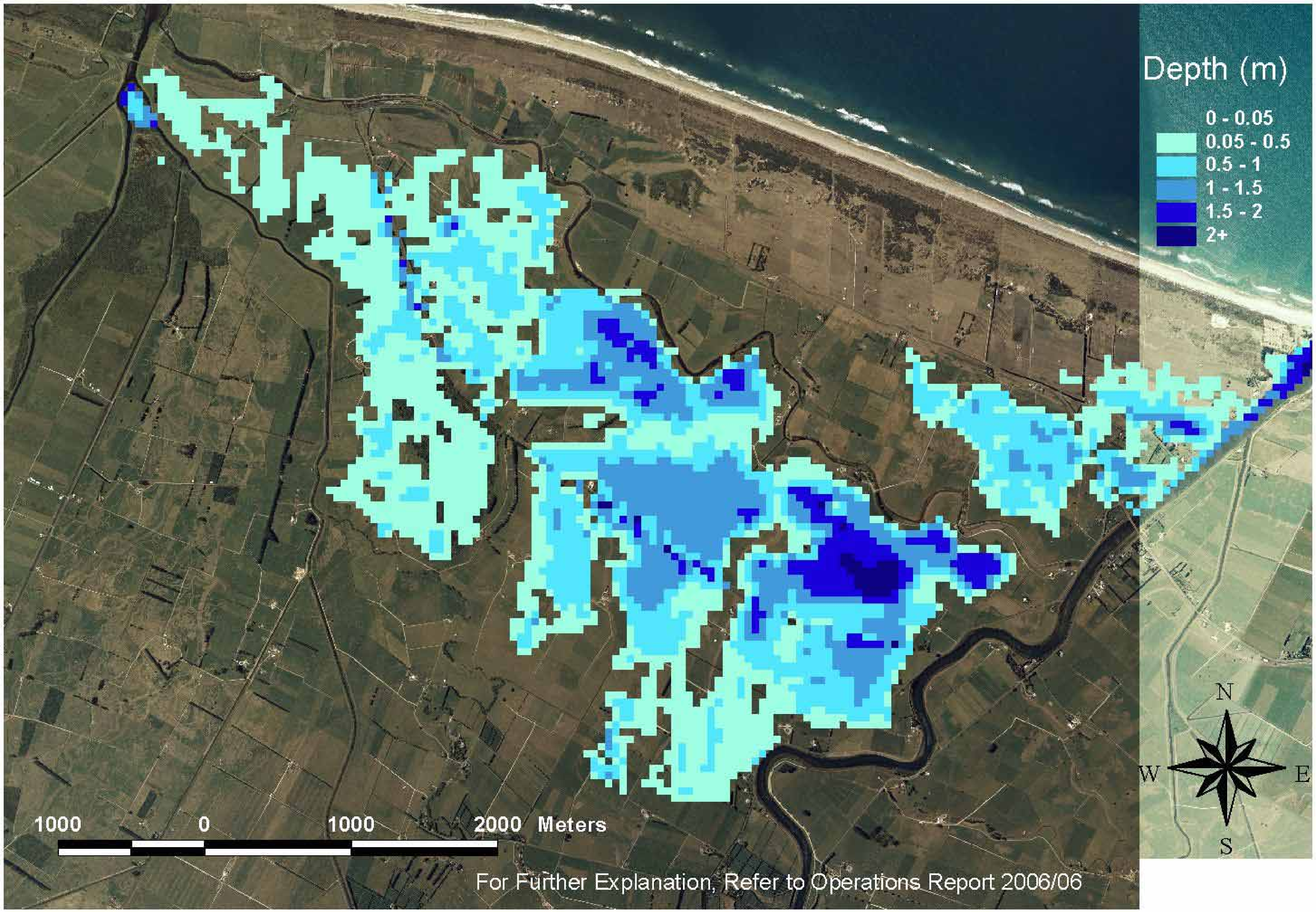


Figure A3.1 Maximum flood depths and extent resulting from a stopbank breach at Laws Bend during a 100 year tide and 20 year flood event in the Rangitaiki River (Scenario 1). No Freeboard included.

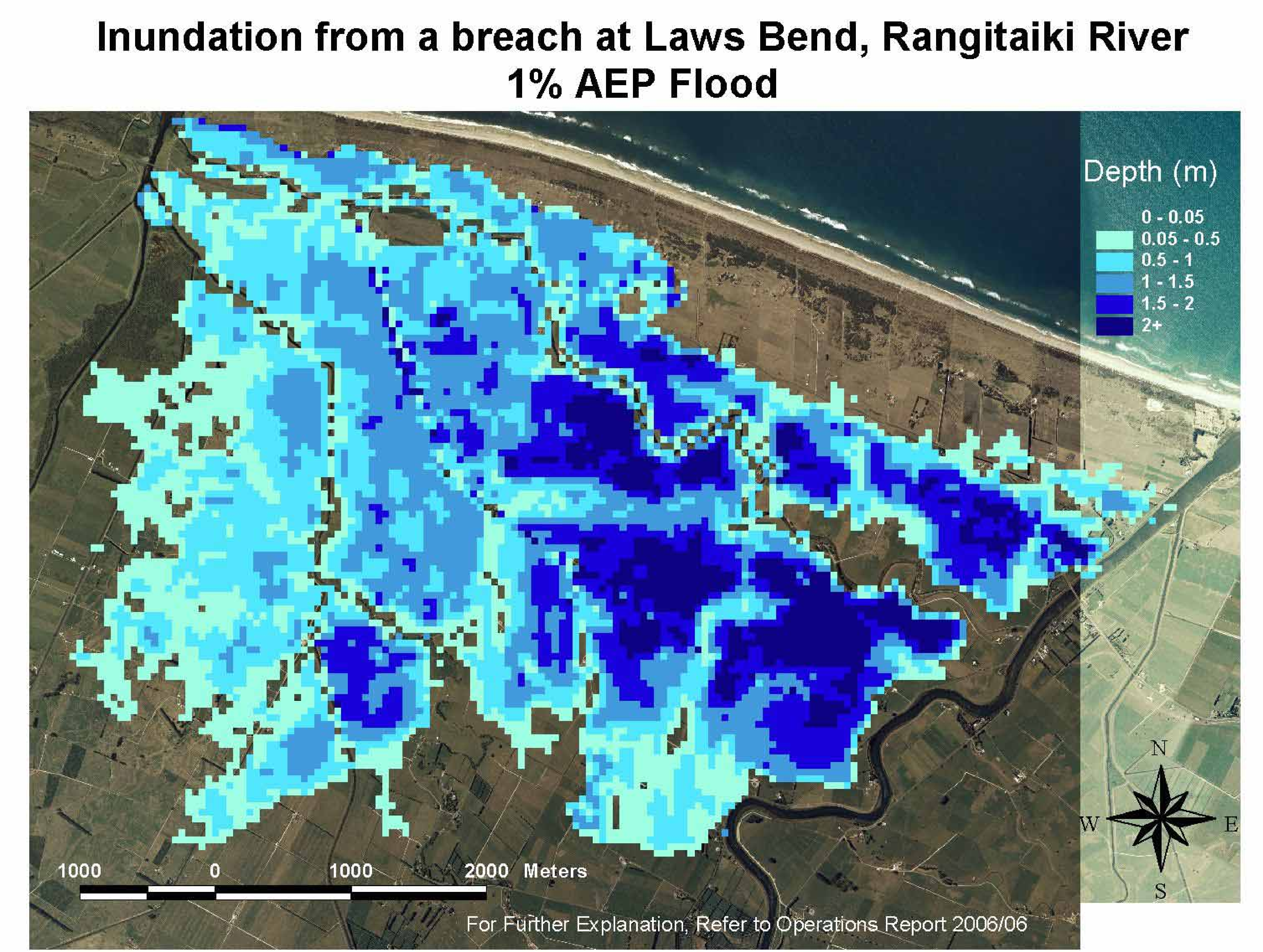


Figure A3.2 Maximum flood depths and extent resulting from a stopbank breach at Laws Bend during a 20 year tide and 100 year flood event in the Rangitaiki River (Scenario 2). No Freeboard included.

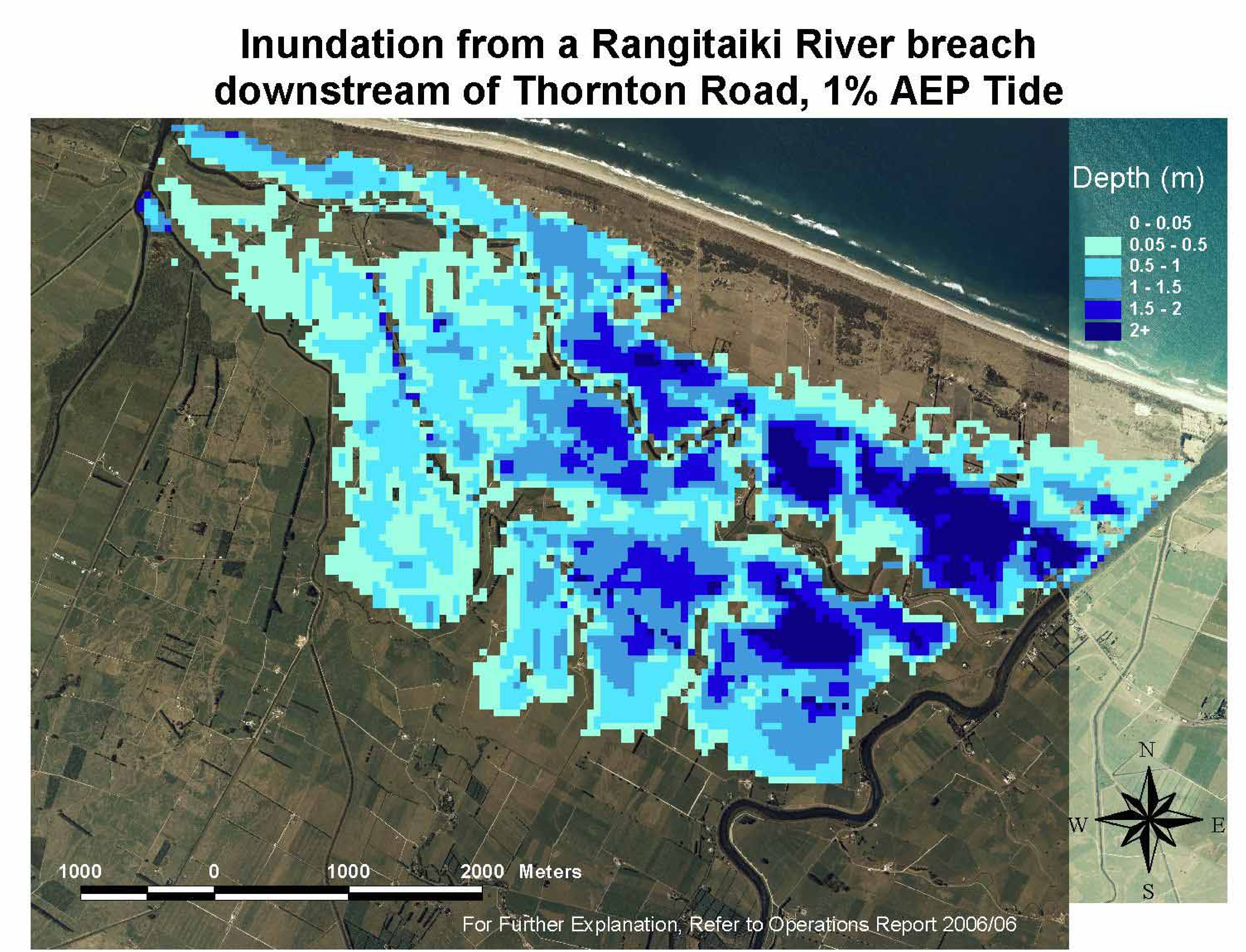


Figure A3.3 Maximum flood depths and extent resulting from a stopbank breach at Rangitaiki River, below Thornton Road during a 100 year tide and 20 year flood event in the Rangitaiki River (Scenario 3). No Freeboard included.

Inundation from a Tarawera River breach downstream of Thornton Road, 1% AEP Tide

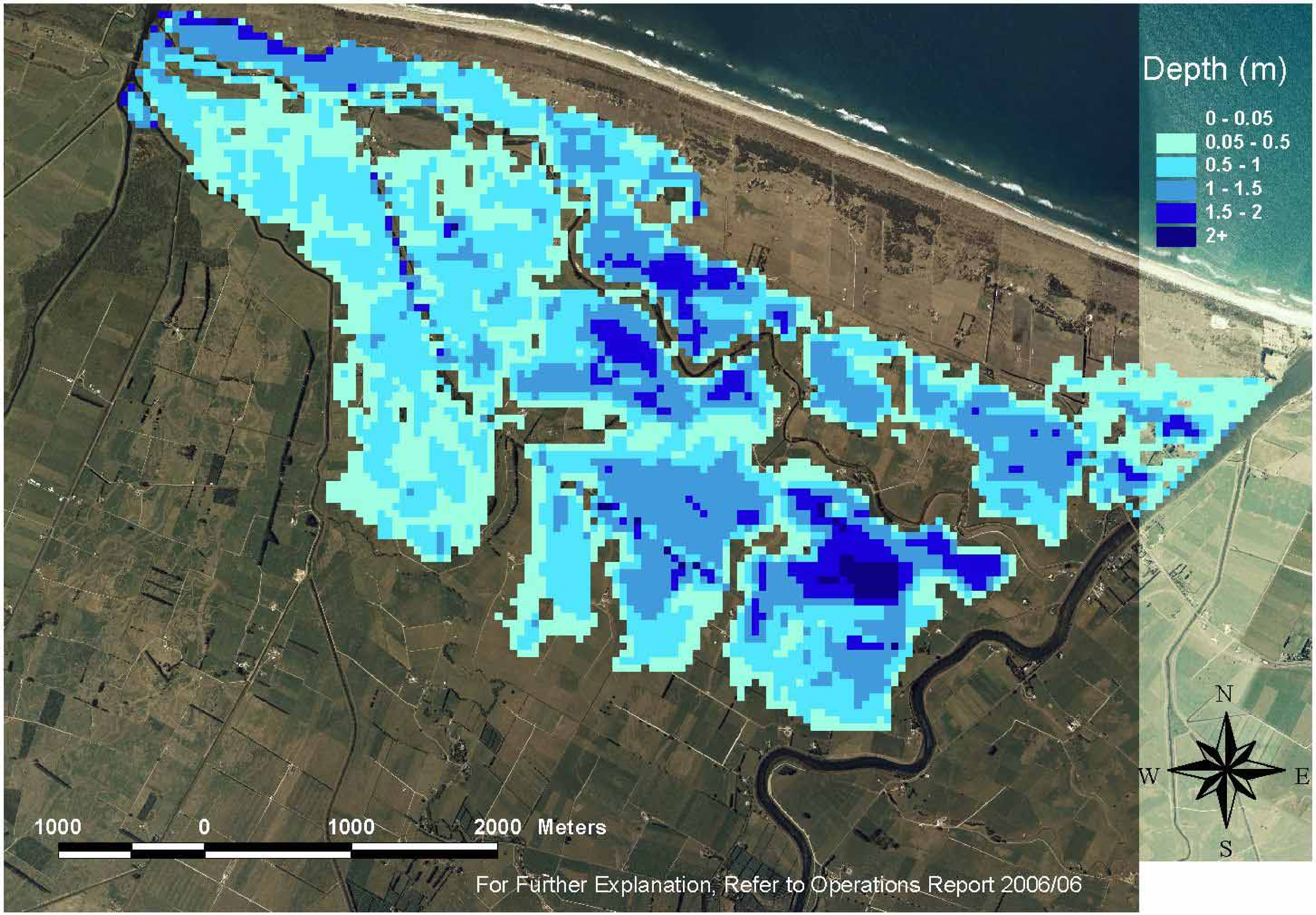


Figure A3.4 Maximum flood depths and extent resulting from a stopbank breach at Tarawera River, below Thornton Road during a 100 year tide and 20 year flood event in the Tarawera River (Scenario 4). No Freeboard included.

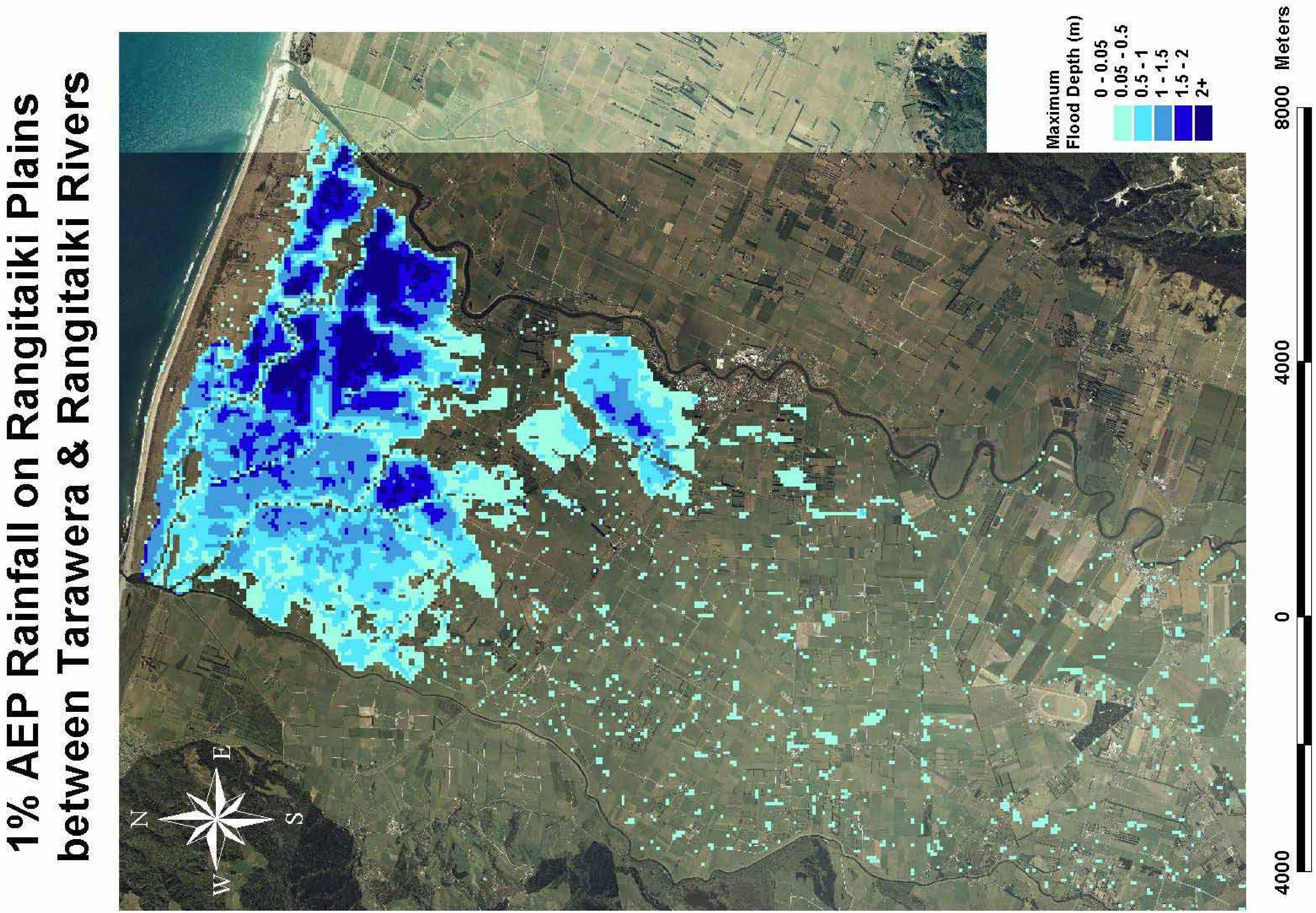


Figure A3.5 Maximum flood depths and extent resulting from 100 year rainfall on the Rangitaiki Plains (Scenario 5). No Freeboard include.

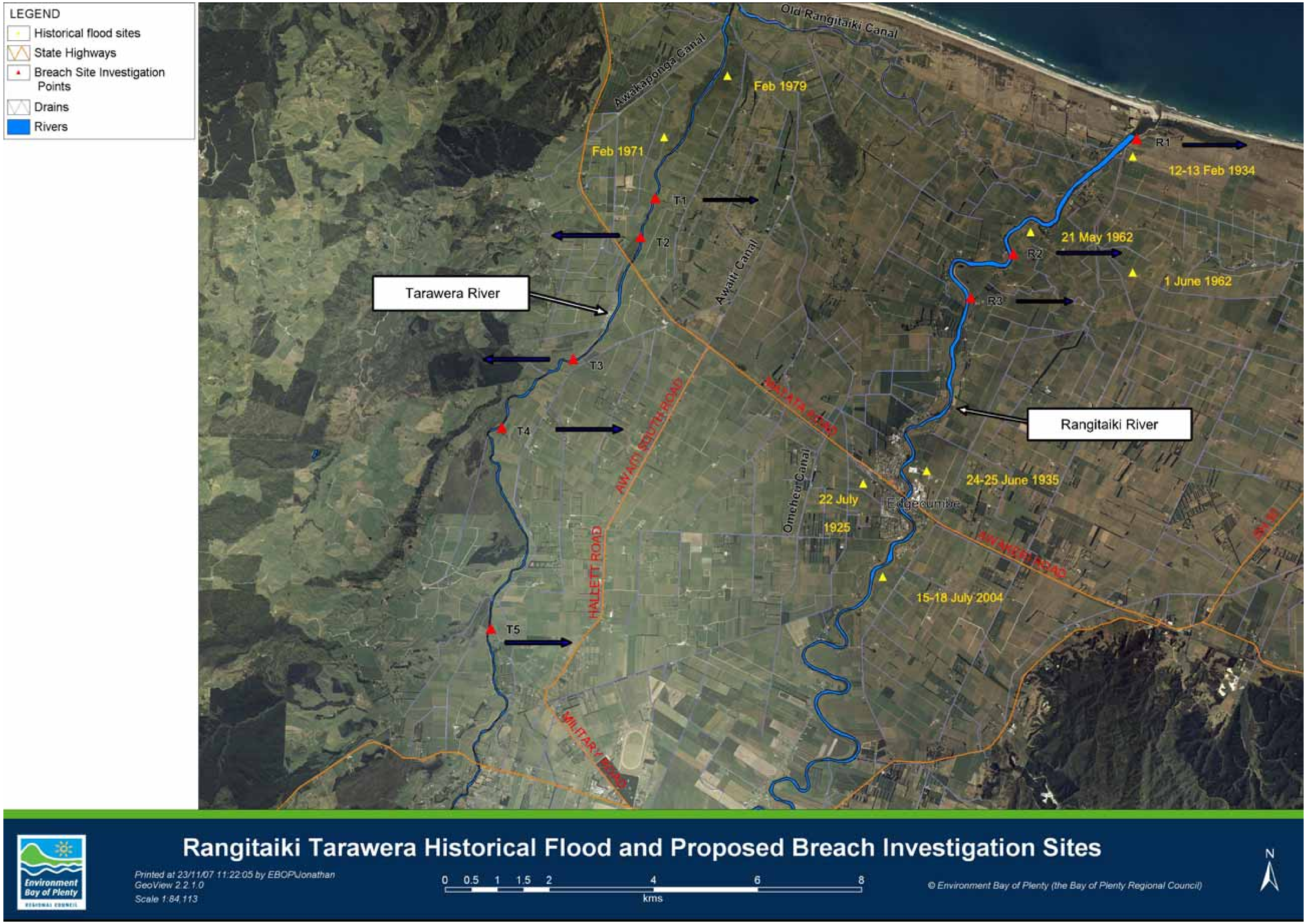


Figure A3.6 Potential urban stopbank breach sites in Tarawera River and Rangitaiki River stopbanks.

Table A3.1 Summary of stopbank sites requiring seepage and stability assessments in Tarawera River and Rangitaiki Rivers.

No	Location	Closest Cross-Section	Photo [18]	River Distance (m)	Left or Right Bank	Justification
Tarawera River						
T1	Bench mark T5 (Site R6)	T6R	RB6	4700	Right	Freeboard is less than design minimum
T2	Upstream end Wetland to State Highway 2 (Site L6)[19]	T6L	LB13	5500	Left	Freeboard is less than design minimum
T3	Bench mark T8 to 8400 (Site L8)	T8L	LB17	8400	Left	Bend erosion
T4	Braemar water supply (Site R12)	T10R	RB14	10600	Right	Typical representative stopbank cross-section
T5	State Highway 30 (Site R15)	T14R	RB20	15100	Right	Typical representative stopbank cross-section
Rangitaiki River						
R1	Thornton Hall Rd	R2R		900	Right	Floodwater would pond between sand dunes and Thornton Road. Breach could occur from high river flows and/or storm surge effects.
R2	Reynolds Bend	R11R		4500	Right	Erosion damaged the bend in July 2004. In 1962 there was a breach. Ground levels are very low compared with the stopbank crest height.
R3	Langdon's	R16R		6000	Right	Geotechnical investigations completed by Ice Construction Ltd have identified large differential height between ground and stopbank crest height.

[18] Refers to photo number listed in Everitt & Medwin's stopbank condition evaluation report (2006).
[19] Refers to inspection site number in Tarawera River Stopbanks Condition Evaluation Report (Everitt & Medwin, 2006)

Part 5: References

Atcheson, A.R. (1968); River Control and Drainage in New Zealand, Soil Conservation and Rivers Control Council, Ministry of Works.

Barnett Consultants Ltd. (1995); Rangitaiki River Flood Hazard Study. Draft Report. June 1995.

Beacon (2004) newspaper article: Flood Damage Assessed at $50M, Keith Melville quoting Pat Kilgarriff, 14 September 2004

Beacon (2004) newspaper article dated 11 August 2004

Blackwood, P.L. (2006); Email Peter Blackwood to Robbin Britton: Meeting with David Bewley, WDC, Peter Blackwood, 27 October 2006, File Ref 5810 02 R01

Blackwood, P.L. (2005); Power Point Presentation to Whakatane District Council – 'Bay of Plenty Regional Council River & Drainage Schemes: Provision of Global Warming Draft Policy', 25 October 2005

Blackwood, P.L. (2000); Review of the Flood Carrying Capacity of the Rangitaiki River Below Edgecumbe, Environment Bay of Plenty. (In press).

Crabbe, B.K (2007) Potential Stopbank Breach Sites along the Rangitaiki River, Email correspondence 7 June 2007

Cowie, C.A (1957) Floods in New Zealand 1920 – 1953 with Notes on Earlier Floods Wellington: The Soil Conservation & Rivers Control Council

Dine, P. D. and Journeaux, P. (1988); Rangitaiki River Scheme Post 1987 Earthquake. Bay of Plenty Catchment Board and Regional Water Board, October 1988.

Environment Bay of Plenty/WDC (2007) Improved Hazard Mitigation in Whakatane District: Business Case, in response to the invitation to jointly present an integrated cross-council business case for solutions to reduce community risk from the Whakatane and Rangitaiki Rivers, August 2007, Ref: CBC (Min (05) 7/20).

Environment Bay of Plenty/Whakatane District Council (2007) Improved Hazard Mitigation in Whakatane District, Report to MCDEM, Draft v2.01, July 2007

Environment Bay of Plenty (2006); Rangitaiki River – Kokohinau breach scenario. Memorandum from Ingrid Pak to Peter Blackwood, 26 June 2006, File 5680 05

Environment Bay of Plenty (2006); Bay of Plenty Region July 2004 and December 2004 Flood Events: Final Claim from Environment Bay of Plenty for Government Assistance towards Response Costs and Costs of Reinstatement of Damaged River and Drainage Scheme Infrastructural Assets, Operations Publication 2005/06, August 2006, ISSN 1176 – 5550

Environment Bay of Plenty (2006) NERMN River and Stream Channel Monitoring Programme – 2002 to 2006, I Pak, Environmental Publication 2006/15, Sept 2006 (ISSN 1175 – 9372)

Environment Bay of Plenty (2005); Review of the Flood Carrying Capacity of the Tarawera River Downstream of State Highway 30, Draft Operations Report (2005/03)

Environment Bay of Plenty (2004) Application to Government for Financial Assistance July 2004, Operations Publication 2004/04, ISSN 1176 – 5550

Environment Bay of Plenty (2004) Rangitaiki-Tarawera Rivers Scheme Asset Management Plan, June 2004, Operations Publication 2004/02, ISSN 1176 – 5550

Everitt, S (2007) Tarawera Stopbank Condition Assessment (Email S Everitt to R Britton, 9 March 2007)

Everitt, S and Medwin, R (2006) Tarawera River Stopbank Condition Evaluation Draft Report, Internal Report 2006/06, December 2006

HMS (2007) Email: Reid's Central Canal – testing 50m widening, sent by Duncan Grant to Robbin Britton dated 8 March 2007, (included plots)

Jones, J. A. (1987); Report on the Earthquake of 2 March, 1987 and its Effect on Bay of Plenty Catchment Commission and Rangitaiki Drainage Board River and Drainage Schemes, Functions and Responsibilities. Bay of Plenty Catchment Commission and Rangitaiki Drainage Board, 13 March 1987.

MAF (2007) RMupdate "The Floods of 2004 – Looking Back" RM 16, Web page:

MAF (2004) email from Pat Kilgarriff to R Britton dated September 2004

MetService (2007) Press Release, New Public Good Forecast and Warning Services, Peter Kreft, Manager, National Forecast Centre, 6 July 2007

http://www.maf.govt.nz/mafnet/publications/rmupdate/rm16/rm16-02.htm

Ministry for the Environment (MfE) (2007) Adapting to the impacts of Climate Change (Road show information brochure), October 2007

Ministry for the Environment (MfE) (2004) Preparing for Climate Change – A Guide for Local Government in New Zealand, New Zealand Climate Change Office, July 2004 (ISBN: 0-478-189511-6, ME Number: 534)

Mullholland, M (2006) *The Effect of Land Use Change on the Hydrology of Pumice Catchments,* Environment Waikato, Technical Report 2006/35

OPUS (2007) *Edgecumbe Urban & Rural Flood Hazard, Mitigation Options Study* by Askey, Wiles & Dennison, OPUS International Consultants Ltd November 2006

OPUS (2007) *Lake Rotomahana Dam Break Flood Hazard Assessment and Emergency Action Plan* by A Pepper and G Webby, OPUS International Consultants Ltd, December 2007

OPUS (2001); *Floodplain Management Planning Guidelines*, OPUS International Consultants Ltd

OPUS (2000) *Stopbank Assessment Rangitaiki River, Edgecumbe* by David Dennison, OPUS International Consultants Ltd June 2000

Pemberton, G. (1986); Lower Tarawera River Stopbank Seepage. Bay of Plenty Catchment Commission, April 1986.

Titchmarsh, R. (1996); Rangitaiki-Tarawera River Scheme Maintenance Review. Environment Bay of Plenty, March 1996.

TrustPower Ltd (2006): Matahina Flood Management Procedure, Revision 4, 3rd November 2006.

Vector (2007) PowerPoint Presentation: Vector High Pressure Gas Transmission System, Flooding Impact at Edgecumbe/Reid's Central Canal, attached to email sent by Hugh Driver, Vector, 12 June 2007

Wallace, P (2006); Hydraulic Modelling of Rangitaiki Plains Tarawera River to Rangitaiki River. December 2006

Wallace, P. (2002); Awaiti Omeheu Canal Modelling Study. Environment Bay of Plenty. May 2002. Operations Report 2002/03

Wallace, P. (1999); File note: Rangitaiki Tarawera River Stopbank Inspection, Phil Wallace, 20 September 1999, File 5810 02 R01

Whakatane District Council (2004); Proposed Whakatane District Plan, Updated November 2004

Whakatane District Council (2004); Report on July 2004 Storm, Flood and Earthquake Event, September 2004

Williams, A.L. (1992); geotechnical Investigation – Thornton Seepage Problem, BECA's, November 1992

Glossary of Terms

Aggradation – The build up of gravels and other materials deposited by flowing water in the bed of a river over a moderate to long period of time.

Annual Plan – A document produced annually by local authorities to inform stakeholders of its objectives, intended activities and expenditure required for a period of one financial year.

Asset – A physical facility of value which enables services to be provided and has an economic life of greater than 12 months.

Asset Management (AM) – The combination of management, financial, economic, engineering and other practices applied to physical assets with the objective of providing the required level of service in the most cost effective manner.

Average Recurrence Interval (ARI) – The long-term average number of years between the occurrence of a flood as big as (or larger than) the selected event. For example, floods with a discharge as great as (or greater than) the 20 year ARI design flood will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event. (see also annual exceedance probability).

Batter – Sloped sides of a stopbank, minimum 1V:3H.

Berms – Low-lying flat land adjacent to the riverbank. Berms are a natural extension of the main channel, and carry water during floods.

Berm Protection – The land area between the river edge and the stopbanks provides river berm protection. It combines with edge protection to provide security for stopbanks.

Breaching – Breaching occurs when flood waters attack and erode stopbanks and floodwalls, eventually breaking through to flow through previously protected floodplain areas.

Condition Monitoring – Continuous or periodic inspection, assessment, measurement and interpretation of resulting data, to indicate the condition of a specific component so as to determine the need for some preventive or remedial action.

Cumec – A cumec measures water flow. 1 cumec equals 1 cubic metres of water passing a given point every second (1 m^3/sec).

Cusec – The imperial unit for flow namely cubic feet per second.

Cut-off trenches – Trench filled with permeable material and designed to collect seepage under stopbank and remove it safely thus reducing the risk of bank failure due to say piping.

Design Flood – A hypothetical flood representing a specific likelihood of occurrence (for example the 100 year or 1% probability flood). The design flood may comprise two or more single source dominated floods.

Design Standard (Or Service Level) – The standard of the flood mitigation methods designed to contain a flood of a certain size.

Development – Erecting a building, carrying out excavations, using land or a building, or subdividing land. *Infill* development refers to developing vacant blocks of land that are generally surrounded by developed properties. Greenfield development refers to developing properties in previously underdeveloped areas, e.g. the urban subdivision of an area previously used for rural purposes (see non structural measures).

Effects – See adverse effect or flood hazard effects.

Emergency Management Measures – See non-structural measures.

Flood – A relatively high river flow that overtops the natural or artificial banks in any part of a watercourse (see cumec).

Flood Defences – Physical structures that keep floodwaters in the river corridor. They include stopbanks and flood walls (see structural measures).

Flood Hazard – The potential for damage to property or people due to flooding and associated erosion.

Flood Hazard Effects – The negative impacts of flooding caused by fast flowing or deep ponded flood waters. Fast flowing or ponded flood waters are dangerous for people, becoming more severe where floods affect urban areas. These effects also include damage to the flood protection system. And other structures and building by water and debris, or by erosion.

Floodplain – The low-lying portion of a river valley, adjacent to the river corridor, which is covered with water when the river overflows during floods.

Flood Warning – The process used to warn a community of an impending flood. Warnings to the general public may be provided by methods such as local radio stations and street alarm systems (see emergency management measures).

Freeboard – A factor of safety usually expressed as a height above the adopted flood level thus determining the flood planning level. Freeboard tends to compensate for factors such as wave action, localised hydraulic effects and uncertainties in the design flood levels.

Geomorphology – The landform and landscape of a particular place, shaped by physical processes.

Gravel Extraction – The selective removal of surplus gravel from the riverbed. Extraction has two main purposes: (1) to maintain optimum flood capacity without worsening bank erosion; (2) to correct misalignments and ease flow pressure against eroding banks. Extraction occurs on the beaches in the riverbed and, excluding river crossings, usually does not involve work in flowing water.

Infrastructure – Networks, links and parts of facility systems, e.g. transport infrastructure (roads, rail, parking) of water system infrastructure (pipes, pumps and treatment works).

Land Information Memorandum (Lim)/ Project Information Memorandum (PIM) – They contain a wide range of information about a chosen parcel of land, such as the presence of natural hazards, access easements, services such as stormwater drains, or resource consents issued on the property. Including all publicly available hazard information in a LIM or a PIM is a statutory requirement under section 31 of the Building Act section 44 of the Local Government and Official Information and Meetings Acts, respectively. Guidance may be given for the way this information is interpreted and presented.

Layering – When willows along channel banks are five years old they are lopped and layered i.e. the upper trunks are partially severed and the stems are left to lie generally across the river banks to re-sprout into the bank.

Level of Service – The definition of service quality for a particular activity (i.e. roading) or service area (i.e. street lighting) against which the service performance may be measured. Service levels usually relate to quality, quantity, reliability, responsiveness, environmental acceptability and cost.

Meander – The natural wave-line pattern of a river on a floodplain.

Mitigation – For this plan, the act of moderating or reducing the effects of the flood hazard or flood protection works (see flood hazard effects and adverse effects).

Non-Structural Measures – Non-structural measures mainly deal with the residual risk of flooding. These measures keep people away from floodwaters and help the community cope when flooding occurs. *Land-use measures* influence the way land is used and buildings are constructed. They include *regulatory methods* (policies and rules in district plans) and *voluntary actions* (information and advice to help people to make their own decisions). *Emergency management measures* seek to improve the community's preparedness and response to flooding. Non-structural measures are the most cost-effective flood mitigation approach.

Overtopping – The process of floodwaters flowing over the top of stopbanks and floodwalls (see breaching).

Piping failure – Development of erosion to the extent that a hole develops through a water retaining embankment, with rapid loss of water from the water source.

Relief drainage – Similar to toe drains.

Renewal – Works to upgrade refurbish or replace existing facilities with facilities of equivalent capacity or performance capability.

Riprap – Rock specifically designed and placed against water retaining banks in order to protect the slope from erosion.

Runoff – The amount of rainfall from a catchment that actually ends up as flowing water in the river or creek stage.

Seepage cut-off walls – An impermeable barrier placed in the bank beside a waterway to lengthen the seepage path and thus reduce the risk of bank failure due to say piping.

Service – As in *utility service,* is a system and its network infrastructure that supply a community need.

Stopbanks – Banks aligned beside the river to prevent floodwaters flowing into floodplain areas. They are also known as *flood defences.*

Structural Measures – Structural measures are structures or other physical works designed to keep floodwaters away from existing development. Stopbanks and floodwalls are obvious examples of structural works. Channel works include bank edge works and channel management. Rock linings, vegetation buffers and groynes are bank edge works, which protect flood defences like stopbanks and maintain the channel's position. Other active channel management methods include bed and beach re-contouring and gravel extraction. They are used occasionally to reduce the opportunity for the river to erode its banks and damage structural works.

Toe drains – A drain installed at the bottom (toe) of the landward side of a water retaining embankment. The drain comprises a granular fill material and acts to control seepage discharges from within and below the embankment.

Toe loading – Laying extra fill material adjacent to the bottom of a stopbank structure. The extra fill material provides additional weight to resist upward seepage pressure.