*Whakatane District Council & Environment Bay of Plenty*

# Edgecumbe Urban & Rural Flood Hazard

## *Mitigation Options Study*

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# Contents

## EXECUTIVE SUMMARY

Review of the Rangitaiki River Scheme and flood risk to Edgecumbe township and the surrounding rural area identifies that:

(i) The hydraulic conveyance of the design flood event in the river and floodway below Edgecumbe is marginal

(ii) The foundation conditions make the stopbanks prone to piping failures under flood conditions

(iii) Local stormwater is a problem in the Edgecumbe southwest in particular where low lying parts of the urban area are reliant upon a rural standard drainage scheme

A range of approaches are identified to mitigating the resulting flood risk. These range from land use controls, to flood defences of critical areas, to schemes which improve the overall flood carrying capacity of the river system.

Minimum floor levels and restriction on development in high risk areas, as are already applied, are recommended to continue. Managed retreat of the Edgecumbe urban area from the lower lying ground is not considered cost effective or appropriate.

Structural mitigation measures can take two approaches. One is to construct flood defences to protect key infrastructure and the urban area in event of a failure in the stopbanks or an over design event. The second is to upgrade the channel capacity and structural strength of the riverbanks to reduce the risk of a failure or overtopping.

Ideally both approaches would be used to give a “belts and braces” solution. However funding constraints may not allow this. Therefore it will likely be necessary to prioritise works. In this case emphasis should be placed on those measures which improve the overall integrity of the River Scheme and reduce the risk of breaches or overtopping, while also taking specific action to protect key infrastructure such as the Transpower substation.

On this basis the following recommendations are put forward:

**Edgecumbe Urban Area**

**Scheme 1 Edgecumbe South east**: The recommended works consist of raising stopbanks on the western Reids Floodway bank, a new deflector bank by the Transpower substation and provision of an emergency floodpumping location . The works provide protection to properties in Hydro Road area plus the key infrastructure of the Transpower substation and the Fonterra site in the event of a breach upstream. The engineering works are relatively straightforward to implement. Transpower support the works and have agreed to contribute.

**Scheme 2 Edgecumbe North east**:. The works involved are raising of 700 m of the existing Reids Floodway bank, building 500 m of new stopbank and making provision for emergency flood pumping. Fonterra and to a lesser extent Eastpack as the primary beneficiaries need to review the merits of the option.

**Scheme 3 Edgecumbe South west**: The scheme 3a as proposed in 2002 with a low (0.8m approx) stopbank bank on the south and west of Edgecumbe and flood pump station to control local stormwater flooding should proceed. This project is urgently needed to mitigate local stormwater flooding issues which are adversely affecting streets, residential property and the town sewerage system. The current Omeheu rural drainage scheme does not provide adequate stormwater disposal for the low lying parts of Edgecumbe south.

The further lifting of the stopbank to approximately 1.8m height to protect against a river breach (Scheme 3b) does not have local support and is not recommended. This is because a breach into a ring banked area would have much worse consequences than if the outer ring bank was not present.

**Scheme 4 Edgecumbe North west**: A high ring banking option to protect against river breach does not have local support. Smaller scale works of low level banking, ground contouring and flood pumping would improve the performance of the urban stormwater reticulation and are recommended.

**Whole River Scheme Improvement Options**

**Scheme 5 Dredging**

On the basis of the analysis to date dredging is not the preferred option. It has high cost , produces only modest reductions in water level in flood conditions of around 200 mm in a $Q_{100}$ event and it is not clear how long it would remain effective before silting reduced its effect.

**Scheme 6 Improvement to Reids Floodway**

Improvements to the conveyance of Reids floodway offer the best return on investment and provide benefit to the widest area, both urban and rural. The bottom (downstream) 3.7 km of the floodway is between 25 and 50 m wide, whereas the upper 8 km has a width of 200m. Widening the bottom section by 50 m doubles the floodway capacity and lowers water levels in the main river by 0.5 m in a $Q_{100}$ event. This option achieves both key objectives of improving channel conveyance through the lower river system and lowering water levels. The reduction in water levels through Edgecumbe combined with the improved stopbank integrity resulting from the stopbank improvement works in the urban area substantially improves the level of protection to the whole urban area. Priority should be given to this option.

**Scheme 7 Spillway control gates**

The control gated inlet to the Reids floodway is a high cost item. It would be a very useful addition to the river scheme which would complement the Reids floodway improvements and is therefore recommended for inclusion as part of a comprehensive scheme. With floodgates the flow split between the main river and the floodway can be managed to optimise levels and thus minimise stress on stopbanks. It is important to note that with the current overflow weir arrangement almost all flow in excess of the design capacity (ie a flood greater than $Q_{100}$) would tend to spill to the floodway.

**Stopbank and foundation investigation and repair**

Following the 1998 and 2004 floods a number of potentially weak sections of the main river bank over some 5 km have been identified. Environment Bay of Plenty is currently working to investigate and repair these weak areas in the main river stopbanks as a matter of urgency. Critical sections through Edgecumbe have been completed. Following completion of this work a comprehensive investigation of the remaining banks on the main river and Reids floodway will be initiated.

**Overall Flood Mitigation Option**

Funding of all the possible improvement works does not appear viable and therefore priority is recommended to those works which reduce flood risk for the scheme area as a whole. The optimum combination of Schemes in terms of improvement to flood protection for cost is shown in the table below.

Option B is the minimum combination of works recommended. Inclusion of the floodgate (Option C) provides a comprehensive scheme upgrade.

**Table 1 : Edgecumbe Flood Study : Options matrix**

| Scheme | Option A – All works | Option B – Selected Edgecumbe projects + Reids Floodway | Option C - Selected Edgecumbe projects + Reids Floodway + Spillway gates |
|---|---|---|---|
| Scheme 1 - Edgecumbe South East | √ | √ | √ |
| Scheme 2 - Edgecumbe North East | √ | √ | √ |
| Scheme 3a - Edgecumbe South West (low bank) | | √ | √ |
| Scheme 3b - Edgecumbe South West (high bank) | √ | | |
| Scheme 4a - Edgecumbe North West (high bank) | √ | | |
| Scheme 4b Edgecumbe North West (low bank) | | √ | √ |
| Scheme 5 - Rangitaiki River dredging | | | |
| Scheme 6 - Improve Reids Central floodway | √ | √ | √ |
| Scheme 7 - Spillway control gate | √ | | √ |
| Stopbank foundation investigation and repair | √ | √ | √ |
| **Combined Option Cost** | $13,954,000 | $10,243,000 | $13,343,000 |

**Consultation**

Further consultation is now required with the infrastructure asset owners, the scheme community and in particular the farmers and residents potentially affected by any alteration to the Reids floodway and local protection works to Edgecumbe.

**Other Recommendations**

In addition to the recommendations in regards the scheme options, the following further points were identified in the study as requiring further action or noting for future works:

(i) Continue to set minimum floor levels for Edgecumbe and the rural area based upon flood breach levels (Section 3.3.1)

(ii) Assess adequacy of Omeheu and Omeheu Adjunct canal rail bridges in event of a flood breach to west of Edgecumbe (Section 3.4.4)

(iii) Following completion of detailed assessments of the Edgecumbe urban area stopbanks, complete investigations of remaining stopbanks including those on Reids Floodway. (Section 3.5.7)

(iv) Assess capacity of the Edgecumbe stormwater system to remove water flowing from pressure relief trenches (Section 3.5.7)

(v) Ensure any future replacement of the rail bridge over Reids Floodway is not a constriction in event of increasing the design floodway flow (Section 3.5.5)

(vi) Monitor the point bar at the Thornton river mouth to ensure a constriction does not develop (Section 3.5.4)

(vii) Show flood warning levels on the Environment BOP river levels public website and include a site for the Rangitaiki River (Section 4.1.5)

# 1 INTRODUCTION

## 1.1 Background

The township of Edgecumbe lies beside the Rangitaiki River in the centre of the Rangitaiki Plains. The town is home to over 1600 people, the Fonterra dairy factory, a major Transpower substation and several smaller industries.

As with much of the Whakatane District, Edgecumbe has a high level of deprivation, a large number of single parent families, low median incomes and relatively high housing costs. There are few options in the close vicinity for relocation and the town provides full or part time employment for many local residents.

The town is protected from Rangitaiki River flooding by the stopbanks of the Rangitaiki River scheme. The land falls away from the natural levees of the river berms and parts of the town are reliant for stormwater disposal upon the drainage scheme that serves the surrounding rural area.

The Edgecumbe earthquake of 1987 caused up to two metres subsidence of land in the area, particularly to the west of the town and exacerbated drainage issues. Stopbanks and their foundations were damaged by the earthquake. Over the twenty years since the earthquake consolidation of the ground has continued with up to 0.5m of further settlement measured in the southwest corner of Edgecumbe.

Edgecumbe township has thus become increasingly dependent on the performance of the flood protection provided by the wider river and drainage schemes. Low lying areas on the west of the town have on going problems with stormwater ponding on streets and threatening the lowest floor levels in heavy rain.

Potentially far more damaging is the threat to the town in the event of a major failure of the River Scheme stopbanks. In July 2004 an extreme weather event led to very high river levels and surface flooding. A major stopbank breach upstream of Edgecumbe on the east (true right) bank at Sullivans Bend flooded a number of homes in Hydro Road and Konini Place and parts of the Fonterra site. This stopbank failure on the right bank may have spared the main part of the town a major flood, as stopbanks on the left bank within the Edgecumbe urban area were under severe stress in this event. A smaller flood six years earlier in 1998 also necessitated emergency remedial action in the township.

Whakatane District Council (WDC) and Environment Bay of Plenty (Environment BOP) sought financial assistance from Government after the July 2004 flood through the Ministry of Civil Defence and Emergency Management (MCDEM) for the flood response and recovery and for remedial work to prevent a reoccurrence. The response and recovery work has been addressed separately, and the Minister of Civil Defence invited WDC and Environment BOP to submit an integrated cross Council business case for solutions to reduce community risk from the Whakatane and Rangitaiki Rivers. This report examines the engineering options to address community risk from the Rangitaiki River.

## 1.2 Study Brief

The study brief requires that a "*suitable flood protection design for Edgecumbe and its environs be determined. The project will require the identification, consideration and evaluation of options with a sound recommendation for a solution. The project will require integrated interaction between the consultant, Environment Bay of Plenty, Whakatane District Council, Transit New Zealand, Railways Corporation, and other infrastructural asset owners*…"

This report details the options available for flood protection as a basis for input from the community and infrastructure asset owners.

## 1.3 Consultation

A number of organisations and individuals have had input into this study to date.

Environment Bay of Plenty have provided detailed technical information on the Rangitaiki-Tarawera River Scheme and associated drainage works and worked closely with the study team in developing options. The Environment Bay of Plenty "MIKE 11" model of the Rangitaiki River and Reids Floodway was used to evaluate engineering options for improving channel conveyance.

Environment Bay of Plenty staff, their geotechnical consultants (ICE Geo & Civil) and Opus geotechnical engineers have worked closely together on the structural stability of the river scheme stopbanks.

Discussions have been held with the owners of or agents for, the key infrastructural assets including Transit New Zealand, OnTrack, Transpower, Natural Gas Corporation and Fonterra.

The Edgecumbe Community Board has been briefed on the study, outlining the issues and possible flood mitigation options.

Preliminary discussions have been held with rural landowners who would be directly affected by possible options involving new stopbanks for Edgecumbe and the Reids Floodway. Their input in clarifying potential issues with these options was particularly valuable.

# 2 PROBLEM DEFINITION

## 2.1 Flood History

### 2.1.1 Early Drainage Scheme History

The main drainage schemes on the Rangitaiki Plains were completed in the years immediately before and following World War 1. However for many years the Plains continued to be subject to almost annual flooding from the Rangitaiki River. Finally over the period 1971 -80 the Bay of Plenty Catchment Commission completed the Rangitaiki-Tarawera River major scheme (referred to herein as “the Scheme”). The key elements were:

- stopbanking of the main river channel from below Te Teko past Edgecumbe out to the river mouth at Thornton
- construction of the Reids Central Floodway (Figure 1)
- stopbanking of the lower Tarawera River and
- river bank protection works across the whole catchment including the Galatea tributaries.

Reids Floodway leaves the main river 3.5 km upstream of Edgecumbe and rejoins the main river one kilometre above the river mouth at Thornton. The floodway was designed to commence operation at a river flow of 610 $m^3/s$ which is the 40 year return period flood.

For 26 years following the scheme construction there were no large floods in the Rangitaiki river, with the biggest being 372 $m^3/s$ in 1983. The floodway was never used through this period. This period is recognised as being a relatively benign period for flooding in the eastern Bay of Plenty related to the Interdecadal Pacific Oscillation.

### 2.1.2 The 1998 Flood

In 1998 a flow of 464 $m^3/s$ (approximately a 14 year return period flow) severely tested the scheme. This flood had an extended hydrograph lasting over 7 days with a second lower peak. The flood was not large enough to spill into Reids floodway, but came within 0.5m of overtopping in the lower river downstream of Edgecumbe, highlighting a lack of channel capacity in the lower reach. This flood also showed up several weak spots in the stopbank foundations, including immediately behind the Transpower substation.

Following the 1998 flood a number of stopbank improvement works were undertaken including:

- Toe loading and relief drainage at the Transpower site
- Relief drainage and cribwalling at the Fonterra site

- Improvements to stability and drainage of stopbanks and floodwall at College road in Edgecumbe

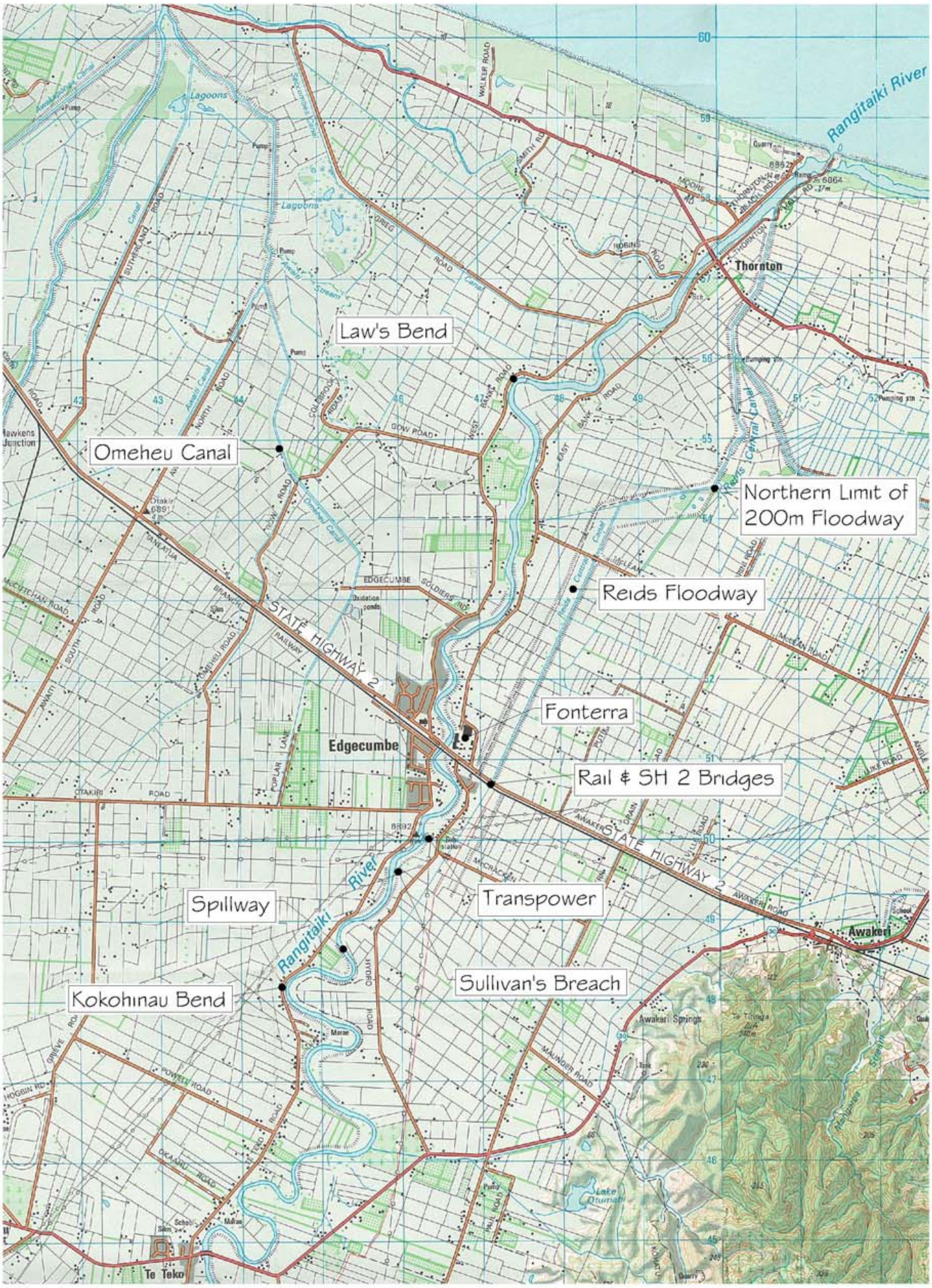
These works appear to have improved the stopbank structural stability of the treated sites as no problems were observed at these locations in the July 2004 flood.

A review of the lower river hydraulics (Environment BOP 2000) found that in flood conditions dunes in the river bed were causing higher roughness than the original design had allowed for, leading to the higher than expected water levels. To counter this, stopbanks were raised at a number of vulnerable locations where the banks had been close to overtopping. A decision was made to raise the banks in the lower river to restore them to a 50 year standard rather than the scheme standard of 100 year. This was accepted as a temporary situation for the reach from Edgecumbe to Thornton. The Asset Management Plan (AMP) documents this and notes that the channel capacity was to be reviewed after 5 years and if necessary the channel would be dredged to restore $Q_{100}$ conveyance (note this refers to the main channel component of the $Q_{100}$ flow after allowing for the design flow down Reids floodway). The dredging is programmed for 2008/09 in the AMP and this is further discussed in Section 3.5.4 of this report.

### 2.1.3 The 2004 Flood

The 2004 flood was a 100 year flow of approximately 760 $m^3$/s. This was the largest flow since 1944 (784 $m^3$/s). The stopbank breached at Sullivans bend (450 m upstream of the Transpower substation) on the rising limb of the flood, shortly after the spillway to Reids floodway had commenced operation. Stopbanks at several spots within Edgecumbe were under severe stress and the Sullivans breach may well have prevented a breach within the Edgecumbe urban area by diverting water out of the main channel and immediately reducing water levels.

The breach rapidly developed to 150 m width and spilled a flow of approximately 250 $m^3$/s into Reids Floodway, well over 2 times its design capacity. The Rail bridge and the western approach to the State Highway 2 bridge over Reids floodway washed out, the floodway filled to overtopping and the Reids Floodway bank washed out downstream of Mclean Rd (Figure 1).




RANGITAIKI PLAINS FROM TE TEKO - THORNTON

FIGURE 1

Upstream of the railway embankment water was dammed by the constriction formed by the existing rail and road bridges and reached a level of 4.84 m. This was high enough to cause water to flow along Hydro Rd and through the subway into the Fonterra site. (Figure 2). A number of houses in Konini Place and some in Hydro road were flooded. Water entered the Transpower site but fortunately did not result in a power outage. The State Highway 2 bridge approach washed out and this relieved the water level preventing further rise into the substation.

Downstream of State Highway 2 water ponded between the main river levee and the Reids Floodway to a level of 3.89 m at the Fonterra site. The Fonterra transport garage was flooded to a depth of around 1.0 m and water entered the administration buildings and lipid plant. The main processing and store areas are elevated and were not affected.

Extensive surface flooding occurred over farmland west and east of Reids Floodway.

Controlled breaches of the stopbanks were made at three locations to return water to the main river and it was only after two weeks of pumping that the bulk of the water was removed.

## 2.2 Edgecumbe Stormwater

The layout of Edgecumbe is shown on Figure 2. The east side of Edgecumbe, ie Hydro Rd, Konini Place and the Fonterra site are mainly located on relatively high ground (at around RL 5.0 m) on the natural river levee. Consequently these areas have good natural stormwater drainage out to the rural scheme drains (Reids central canal) but as demonstrated by the 2004 flood are still vulnerable in event of a major river breach upstream.


EDGECUMBE TOWNSHIP

FIGURE 2

However on the west of Edgecumbe the urban area has been developed on lower lying land. The 1987 earthquake substantially worsened this situation with a drop in the ground level of up to 2m. Areas that had previously been able to drain by gravity dropped to around 2.5 m RL and now have to be pumped. Pump stations were constructed at the Omeheu Adjunct canal and Omeheu east. Over the 20 years since the earthquake the ground has continued to consolidate and a recent survey (Opus 2002) indicates up to 0.5 m of additional settlement has occurred in the southwest corner of Edgecumbe.

Edgecumbe west of the Rangitaiki river is thus reliant on the rural drainage scheme of the Omeheu canal system. However the Omeheu drainage is designed to a rural standard (to remove 28 mm/day, equivalent to the runoff from a 5 year return period 3 day duration storm). Under the rural standard some flooding of the rural land is acceptable (more so for pasture than for horticultural use), whereas ponding of this duration and frequency is clearly not acceptable for urban roads and properties.

The Omeheu Canal system has a current design capacity for a 20 % AEP (5 yr) storm. Events greater than this will result in the canal overtopping and the pump stations being unable to remove surface water. Water will pond on the farmland and back up in the outlet drains towards Edgecumbe, leading to surface flooding in the lower streets such as Totara Street.

Surface flooding of streets from local rainfall in the southwest quadrant of Edgecumbe is a regular (say 1-2 times per year) event, with the potential to cause flood damage to a number of houses in a larger event. The lowest floor level is at 2.24 m RL. The north west quadrant (Puriri Crescent area) is less frequently affected but would still be subject to extensive ponding in a larger event that exceeded the capacity of the Omeheu system.

Concern with the stormwater disposal in the southwest of Edgecumbe led to an investigation of options for improvement (Opus 2002). This study recommended the construction of a low stopbank to RL 2.5m and a floodpump to isolate the urban area from the adjoining rural land. Note that the study was solely focussed on local stormwater and did not require consideration of protection in case of a breach of the main river stopbanks.

In the event of a breach to the west (true left bank) of the main river banks upstream of Edgecumbe (for example at Kokohinau), the urban area would be subject to extensive inundation, especially the areas south of the rail embankment. A breach on the west would see lower parts of the urban area under up to 1.5m of water. Should a stopbank breach occur within the urban area itself then the potential for damage would be very severe with high water velocity and scour for several hundred metres out from the breach location.

## 2.3 Channel Conveyance

It has been apparent from both the 1998 and 2004 floods that the lower river channel has insufficient conveyance to pass the design flows. The lowest sections of stopbank were raised after the 1998 flood to restore a 100 year capacity for the urban area, but the scheme currently has only a 50 year capacity below Edgecumbe (Section 2.1.2).

To restore the scheme to 100 year standard over the lower river the conveyance will have to be increased. Possible measures include, singly or in combination, dredging, stopbank raising and altering the split of flow between the main channel and the floodway. These options are further developed in Section 3 below.

### 2.4 Structural Strength of Stopbanks

There are two aspects to ensuring the performance of the river scheme to a design standard. One is to provide sufficient conveyance (waterway area), the other is to ensure the stopbanks and their foundations are structurally sound enough to retain the floodwaters for the duration of the flood. Historical and recent scheme experience is that there are substantial issues around the structural strength of the banks and foundations.

Several features of the Rangitaiki Scheme combine to make containing floodwater through stopbanks a difficult engineering task:

(i) The underlying soils are a mix of peats, estuarine silts and recent pumice alluvium. In places the pumice sand and gravel layers extend from the river bed out beneath the stopbanks into the adjacent country. This provides high potential for piping failures, and the scheme has a history of these (eg Reynolds in May 1962, Sullivans bend 2004). Figure 3 (taken from the original scheme drawings) illustrates a typical problem area with pumice sands extending under the stopbanks.

(ii) The stopbanks were constructed from locally available soils and are thus built of relatively permeable sand and silt materials rather than lower permeability clays.

(iii) Apart from one or two locations the stopbanks were constructed on top of existing ground and did not include specific foundation treatments such as cutoff trenches, toe loading or relief drainage.

(iv) Soft foundations lead to on going settlement of stopbanks which hence need to be topped up. This is provided for in the Asset Management Plan.

(v) The river is perched above the surrounding plain on a natural levee, with a ground level difference of up to 2m within 200-300 m of the river berm. This generates a high differential head of water in floods and exacerbates the risk of a piping failure

(vi) The original scheme stopbanks were placed to closely follow the river course, due to the constraints of existing houses, land tenure and roads. In a number of places the banks are therefore squeezed between the road and the river. On the outside of major bends (eg Kokohinau) this leads to a high potential for river erosion to damage the stopbank in floods.

As a consequence of the above factors the potential for failure of the banks, most likely due to piping of the foundations, is high and the options to address the risk are limited and expensive. Following review of the whole length of the main river stopbanks, a number of sites of higher risk have been identified and treated since 1998, and this work is continuing. However there are 35 km of banks on the main river and a further 20 km on Reids

Floodway, of which 6 km of the main river banks have so far been, or are in the process of being, investigated in detail and remediated (Section 3.5.7).

Earthquakes and land development activities can alter subsurface flow paths. The 1987 earthquake is identified as a factor in the weakening of stopbanks (ICE Geo & Civil, 2005). A total of 5.9 km of the Rangitaiki River stopbanks were damaged in the 1987 earthquake and required repair. Damage included stopbank cracking and loss of strength of foundations. It was noted that there was a correlation between loss of strength of the stopbank foundations and the need for placement of toe loading and surcharges.

Ground conditions are highly variable and there is some residual risk of seepage (piping) erosion in the embankment foundations, even with rigorous investigations.

## 2.5 Climate change and extreme events

### 2.5.1 Sea level rise

Environment Bay of Plenty has adopted a policy of designing flood control assets to accommodate a sea level rise of 0.5m over the next 50 years. Environment Bay of Plenty and MfE Climate Change Office (2004) consider this to be a mid range prediction.

The effect of sea level rise will be to raise the water level at the river mouth and so raise the flood profile over the lower river. Progressively with time therefore sea level rise can be anticipated to reduce the scheme freeboard over the lower river (ie below Edgecumbe). Modelling has been carried out to assess the impact of this (Appendix 1).

### 2.5.2 Global warming and storm intensity

Global warming is predicted to result in an increasing frequency and severity of storms. This is because warmer air can hold more moisture, and so the potential to generate intense and sustained rainfall increases. Environment Bay of Plenty have made a detailed assessment of the potential increase in flooding by 2080 based on the Climate Change Office midrange 2$^{o}$C temperature increase for the Bay of Plenty (MfE 2004) and are working on a tripling in flood frequency. Under this scenario by 2080 the 100 year flood for the Rangitaiki river may be more the size of what would be currently assessed as a 300 year flood (ie the $Q_{100}$ will be around 1,000 $m^3/s$ instead of 780 $m^3/s$). The capacity of the existing river channel under this event is evaluated in Appendix 1.

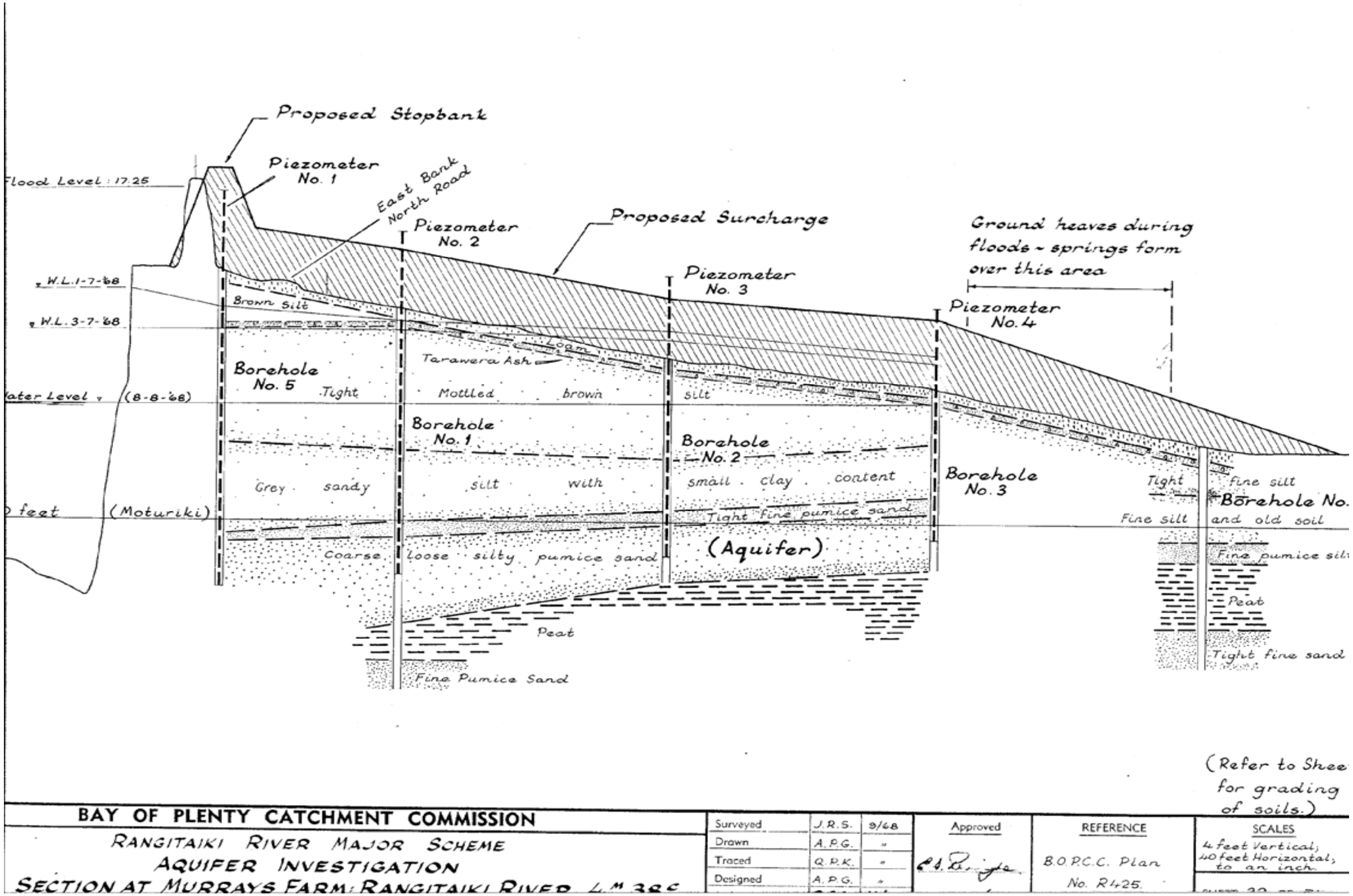



**Figure 3 : Example of Stopbank Foundation Condition**

### 2.5.3 The "Overdesign Event"

A consideration closely related to that of increased storm intensity is that of the "overdesign event". The scheme is currently designed for a $Q_{100}$ flow (780 $m^3/s$) with freeboard. Design freeboards are 300 mm for the Rangitaiki River rural area banks, 250 mm for Reids Floodway and 600 mm for the reach through Edgecumbe. (EBOP 2004). Freeboards provide a safety margin and do not provide extra capacity. However higher flows than 780 $m^3/s$ are always possible, albeit being very rare events.

How the scheme and the communities protected by it would manage the risk of an overdesign event is an important issue, and needs to be considered in relation to the wider civil defence strategies of flood risk management  A 100 year (1%AEP) design event is not a high level of protection for important infrastructure assets. There is a 40% chance of exceeding this flood level in 50 years.  Standards for buildings require a higher level of protection against other hazards, for example, a 450 year return period (10% chance of exceedance in 50 years) is a common standard for design earthquake loads for typical residential structures.

Transpower have advised that they are working to a higher return period (300 year or greater) for their key assets at the Edgecumbe substation.

With the current configuration of an uncontrolled overflow weir into Reids Floodway, the water slopes in high flood conditions are such that most water in excess of scheme design capacity will spill preferentially into the Reids Floodway. As the floodway has only a nominal 110 $m^3/s$ capacity within the current banks, then for a flow greater than $Q_{100}$ extensive flooding as was experienced in the 2004 event would be expected. This assumes that the stopbanks at other locations do not fail. Differential freeboard on stopbanks to flood one area first in event of overtopping is one way to manage the overdesign flood as discussed in Section 3.7.

## 2.6 Infrastructural assets

As well as the Edgecumbe urban area and the high producing lands of the Rangitaiki Plains, the flood control Scheme provides protection and interacts with several important infrastructural assets.

### 2.6.1 Transpower Edgecumbe Substation

The Transpower substation is a major substation which provides electricity distribution to all the Eastern Bay from Edgecumbe through to Cape Runaway. As such it is a vital piece of community infrastructure, and especially so in times of flood. If the substation were to fail in a flood then most sewer and stormwater pumping in both Whakatane and Opotiki Districts would be lost. As the Whakatane and Waioeka rivers commonly flood when the Rangitaiki river does, then the potential consequential damage from such an outage is very large.

The substation is sited on the river levee beside Hydro Rd at a ground level of around 5.0 m RL.

### 2.6.2 State Highway 2

State Highway 2 crosses the Rangitaiki river and the Reids Floodway at Edgecumbe. The Rangitaiki river bridge is structurally sound, well clear of maximum flood levels and has no waterway issues.

The Reids Floodway bridge is a three span structure of 20 m over the Reids Canal. The bridge is narrow and has traffic safety issues. The western (Edgecumbe side) approach washed out in the 2004 flood. Transit New Zealand recognise the deficiencies of the bridge and have included its replacement in the capital works programme. It has a high priority and replacement is likely over the next 2-3 years subject to funding. Budget provision has been made for a longer and higher structure to accommodate greater floodway flows without damage.

While State Highway 2 is a key transport route for the Bay of Plenty and Gisborne, loss of the route for a short period at Edgecumbe is not critical. Two other alternative routes are available to cross the Rangitaiki Plains.

### 2.6.3 Railway line

The Taneatua branch railway through Awakeri crosses the Rangitaiki plains. Built many years ago when the drainage and flooding problems were much more frequent, the rail was constructed on an embankment typically 2-3 m above the surrounding ground. The embankment forms an effective dam across the plains for any flood flow that breaks out of the main river and floodway.

The line east of the Kawerau branch is no longer used. A span of the bridge at Reids Floodway washed out in 2004 and has not been repaired. It is understood from OnTrack that there are no immediate plans to reinstate rail services on the route or reconstruct the bridge. If the bridge is to be replaced then through the resource consent process Environment BOP would require a longer structure consistent with an increased floodway flow to be built.

### 2.6.4 Fonterra Site

The Edgecumbe manufacturing site is one of Fonterra’s large milk processing sites, servicing farms in the eastern bay and Galatea. Wastewater from the site is irrigated to large areas of the dairy land on the Plains. This disposal is adversely affected by flooding.

Most of the key manufacturing and energy plant at the site is above likely flood levels and was not affected by the 2004 flood. There was damage to the administration, transport garage and the lipids plant (a relatively small processing unit). The main dry store (finished product awaiting shipment) was within 100 mm of flooding. The timing of the flood, coming in July when most manufacturing operations are shut down for maintenance was fortuitous. A flood in peak processing season would have been much more disruptive.

The Fonterra site is located against a meander bend below the SH bridge over the Rangitaiki River. The river bank is steep from the stopbank crest to the river bed along this bend and there is very limited room on the landward side. Any erosion or piping failure of the bank at the site would result in major damage to the factory. Environment Bay of Plenty have recently completed work on this reach to strengthen the bank with rock protection.

#### 2.6.5 Natural gas pipeline

The natural gas line to Gisborne runs through Edgecumbe and there is a compressor station close to the Fonterra site. Two gas lines cross Reids Floodway at State Highway 2. This infrastructure will need to be accommodated by the replacement of the SH2 bridge.

# 3 OPTIONS FOR MITIGATING FLOOD RISK

## 3.1 Comprehensive Flood Risk Management

Mitigation of flood risk requires a comprehensive flood management strategy. Civil Defence planning requires consideration of flood risk within a broader context encompassed by the "Four Rs" of disaster management:

- Risk **R**eduction
- **R**eadiness
- **R**esponse
- **R**ecovery

Primarily this study is focussed on Risk **R**eduction. Risk Reduction can be achieved through several paths. Development in at risk areas can be controlled through the planning process to limit the exposure of dwellings and infrastructure to flooding. Where development has already taken place and flood protection is now found to be unsustainable then a managed retreat from the flood prone areas may be an option. Alternatively, engineered solutions such as stopbanks, river control works and pump schemes can be constructed to protect otherwise flood prone land.

Options for risk reduction are considered in Sections 3.2 -3.7 below. **R**eadiness, **R**esponse and **R**ecovery are covered in Section 4.

## 3.2 Retain existing level of flood protection

Acceptance of the current flood risk is always an option. However it is one that carries a high risk of future flood damage. Low lying areas of Edgecumbe will continue to be affected on a regular (more or less annual) basis by local stormwater flooding. This flooding has adverse effects including temporary road closures, flooding of yards and even houses if the rain is severe enough. Surface flooding, particularly in Edgecumbe south, is a major source of infiltration to the sewer system. This results in overloading of the pumpstations and oxidation ponds and spillage of sewage to town streets and to farmland adjacent the ponds creating health and environmental risks.

With the current level of flood protection the risk of a major flood breach remains undiminished. This has the potential to cause major disruption and damage to both the rural land and the urban area. Assigning a return period or likelihood of occurrence for a breach is difficult. While the return period of high flows is well defined, there is uncertainty about the structural capacity of the stopbanks. Experience from the last 10 years (the 1998 and 2004 flood events) would lead to the conclusion that at present any flood greater than the $Q_{40}$ level poses a major threat.

The status quo or "do nothing" option has been taken as the base case against which to assess the economics of possible upgrading options.

The social impacts of retaining the current level of flood protection also need to be considered. The flood risk would inevitably depress the attractiveness of Edgecumbe as a place to live, limiting further investment in existing residential properties and the commercial area. Living in a flood prone area is a stress factor for the residents who are understandably anxious about the consequences for their homes and community should another flood occur.

## 3.3 Flood Risk Avoidance Strategies

### 3.3.1 Minimum Floor levels and Limitations on development

Lessening of exposure to flood damage through appropriate siting of residential development and setting of minimum floor levels is a key strategy in limiting future flood damage.

WDC and Environment BOP already have policies in place to control development in flood prone areas through the subdivisional consent process and the setting of minimum floor levels for new residential construction. All building permit applications for the Rangitaiki Plains received by WDC are referred to Environment BOP for review of floor levels. For areas of the Plains within the Rangitaiki flood control scheme boundary Environment BOP currently provide two minimum floor levels. One is defined in terms of the $Q_{100}$ flood level from local stormwater plus freeboard. In areas within the flood spread of a major river breach a level based on the breach level plus 500 mm of freeboard is also given. The location will determine which level is higher. For areas outside of the scheme boundary landowners are required to obtain independent professional advice to set a floor level.

The minimum floor levels are then carried through to the building consent process with the higher level set. As a result new dwellings on the Plains are (and have for a number of years) being built on substantially elevated platforms. The setting of minimum floor levels minimises the future cost of damage to property.

New residential building is not allowed in areas of high risk flood such as the floodway or the low lying pumped basins.

Within the Edgecumbe urban area there are a number of streets which are below the flood breach level (Section 3.4). While there is no requirement to retrospectively raise floor levels of properties, major additions or new dwellings will have floor levels set which will be high relative to existing dwellings – possibly up to 1.5 metre in some streets. This is a significant constraint on any further development in these areas due to the cost of building well above ground level.

It is recommended that minimum floor levels continue to be set based upon flood breach levels. Even following a substantial upgrade of the overall river scheme high floor levels would be a prudent measure to retain as they minimise damage in the event of climate change or “overdesign” events (Section 2.5.3).

### 3.3.2 Managed Retreat from flood prone areas

With hindsight, development of the lower lying land areas in Edgecumbe township and in particular the low basin of Edgecumbe south including Totara Street and Kanuka Place may not have been an appropriate land use decision. This situation was exacerbated by the 1987 earthquake and associated land subsidence. A managed retreat from the low lying areas is an option. However this would entail a massive disruption to a long established community.

The combined capital value of those properties (180 approximately) below the flood breach level (Section 3.4.4) is $34M. This figure greatly exceeds the cost of improved flood protection and on that basis retreat of the urban area is not justified.

A wholesale retreat from this part of the town would cause major social impacts. There are no suitable vacant areas of high land in Edgecumbe where dwellings could be relocated to and therefore the dwellings would have to be relocated elsewhere in the District. This in turn would impact upon the sustainability of the workforce for the local businesses and on the viability of schools and services if residents moved away.

The cost to relocate an individual house (on a piled foundation) would be of the order of $20,000. However to this must then be added the cost of land purchase for the new section, reconnection of services, reestablishment of grounds, garaging and outbuildings and temporary accommodation. The overall cost of the relocation would then approach the cost to build anew..

Houses on the higher ground closer to the river which are only marginally below the flood breach level (say by up to 0.5 m) could be raised to minimise property damage in event of a breach. The cost to raise a house on a piled foundation is typically $15-20,000. To this is added reconnection of services, restoring access and temporary accommodation, putting an overall cost at around $30,000.

The major disadvantage of this approach is that the investment made is purely defensive – ie it does nothing to reduce the risk of the flood breach occurring. Further it provides no benefit to the wider rural area or other parts of the town.

## 3.4 Flood Defences for Edgecumbe Town

### 3.4.1 Omeheu Canal System

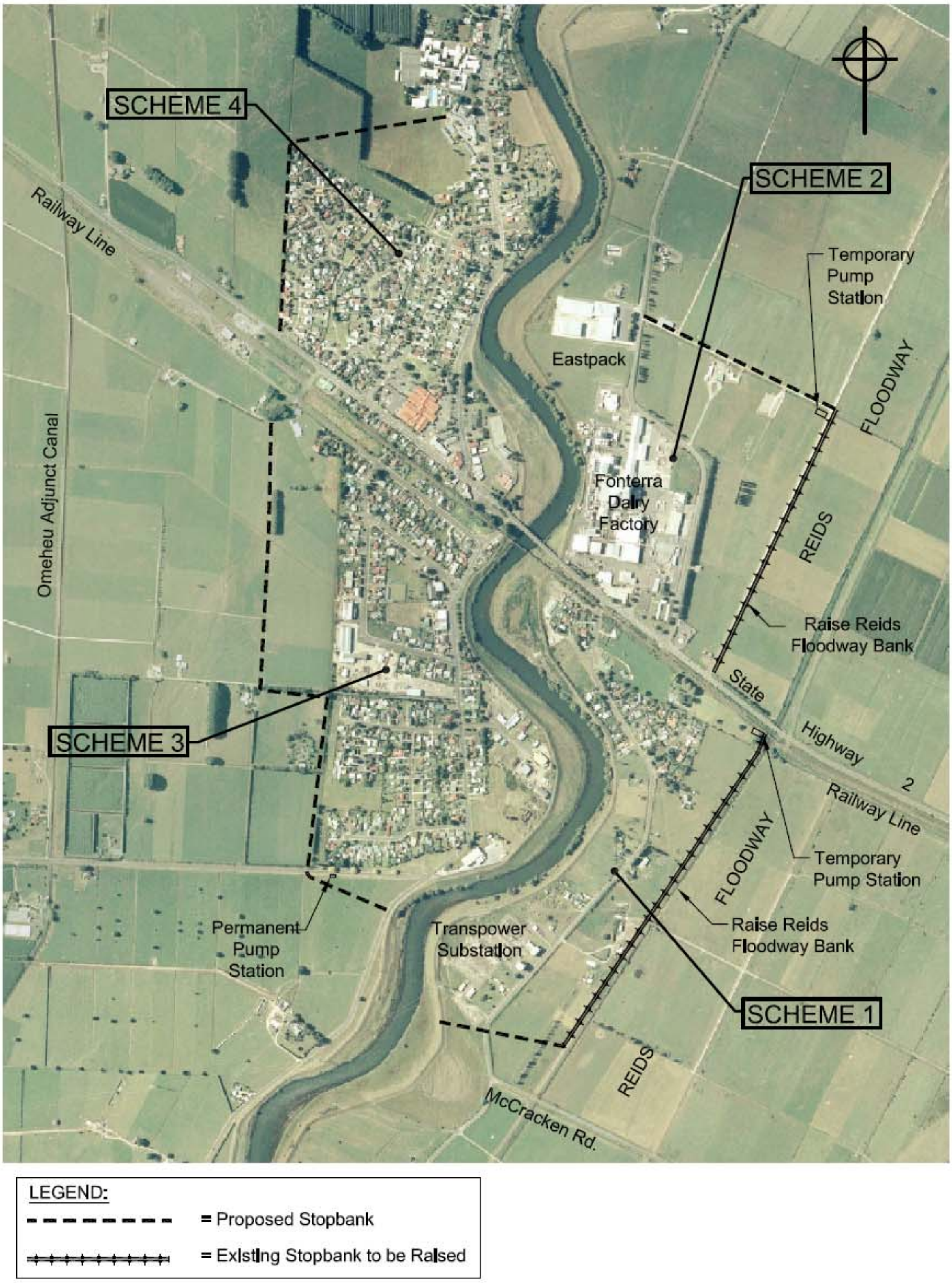
One possible solution to the stormwater problems in the west of Edgecumbe would be to increase the capacity of the Omeheu canal system to convey water out to the Tarawera river. However as the Omeheu canal only has a 5-10 year capacity (Environment BOP 2005) the canal capacity would need to be increased to achieve a significant improvement to the level of service for Edgecumbe. Similarly the pump stations that service Edgecumbe (Omeheu Adjunct and Omeheu East) would need to be upgraded.

This option is not considered worth pursuing at this stage. The main drawback is that an upgrade based only upon pumping to the Omeheu canal will not provide any degree of protection to the urban area in the river breach situation as there is simply too much water to pump. However in the longer term there may be merit in increasing capacity of the Omeheu system and this is being explored through the Environment BOP Flood Plain Management Strategy (FPMS) currently in preparation.

### 3.4.2 South East Edgecumbe (Scheme 1)

The south east quadrant of Edgecumbe includes the Transpower substation and the residential areas of Hydro Road and Konini Place. On the river side of Hydro Road this area is relatively high at RL 5.0 m. East of Hydro Road the land is lower at RL 3.5 – 4.0 m but still has good fall out to Reids canal for normal stormwater flows.

The principal risk to be mitigated against for this area is of flooding from the river or Reids Floodway, particularly in the case of a river breach as in 2004. The main river stopbanks over this reach already include an additional 300 mm freeboard (ie 600 in total) for the urban area so overtopping through this reach is unlikely. Some improvement works to stopbanks and foundations on 300 m of the bend behind the Transpower substation have already been undertaken after the 1998 flood .




# EDGECUMBE FLOOD DEFENCE OPTIONS

FIGURE 4

The recommended mitigation measure for Edgecumbe south east is a combination of upgraded stopbanks and foundations and floodpumping as follows (Figure 4):

- Raise the left bank on the Reids Floodway from just north of McCracken Rd to the rail embankment by approximately 0.6 m to RL 4.8m.
- Further stopbank toe loading and relief drain works on the main river stopbank
- Construct a new deflector stopbank from the Reids bank back across to high ground immediately upstream of the substation
- Have provision for a tractor mounted flood pump to be set up to drain seepage water from within the ring banked area.

The direct area of benefit of these works is the Transpower site, the 45 dwellings in Hydro Road & Konini Place, plus Fonterra (as the bank protects against water flowing north through the subway)

There is a further and very substantial benefit to whole of the Eastern Bay by improving security of power supply and hence flood pumping in flood emergencies.

The estimated cost of these works is $381,000 (excluding any allowance for stopbank improvements). Detailed estimates are included as Appendix 3. Stopbank investigations are still underway in this area. Stopbank improvements are discussed in Section 3.5.7.

The Scheme 1 works can stand alone from any other scheme works.

The level of stopbanking on which the cost estimate is based is to protect against an event similar to the 2004 breach, which reached a level of 4.84 m in this area. This is therefore greater than a 100 year standard. Transpower have indicated they will adopt a higher standard than $Q_{100}$ for protection of the substation given its regional significance. Transpower have confirmed they will contribute to the scheme and integrate works specific to their site with the wider scheme. With additional works to specifically protect the Transpower site the cost of the works is $690,000, of which the Transpower contribution is $409,000.

### 3.4.3 North East Edgecumbe – Scheme 2

The north east quadrant includes the Fonterra site, the Awaroa demonstration farm, the fire station, the natural gas pumpstation, Eastpack, the State Highway 2 bridge and the rail bridge.

Stormwater drainage is generally adequate in this area (apart from some localised problems on East Bank Rd outside Eastpack) and the risk to be mitigated against is river or floodway stopbank overtopping or breach.

The specific flood protection works recommended to protect against a river breach are (Scheme 2):

- Raise the left bank on the Reids floodway from SH 2 for 700m north by 0.5 m to 4.5 m RL.
- Construct 500m of new stopbank 2m high to RL 4.5 m from the Reids bank west to high ground immediately downstream of Eastpack
- Have provision for a tractor mounted flood pump(s) to be set up to drain seepage water from within the ring banked area.
- Investigate, assess and if necessary extend stopbank toe loading and relief drain works on the main river stopbank (these works are now substantially complete)
- Investigate and assess any improvement works which may be needed on the Reids bank and foundations. Under this scheme the bank would be required to withstand a large differential head (which it was not tested under in the 2004 flood as there was water on both sides).

The direct area of benefit of this scheme is the Fonterra site and the Awaroa Demonstration farm (also owned by Fonterra ) plus Eastpack (Kiwifruit packhouse). These are the major employers for the Edgecumbe area and make a substantial contribution to the economic well being of the area.

This scheme is dependent upon completing Scheme 1, as otherwise the area remains vulnerable to flooding from upstream through the subway. Note that flooding south through the floodway from the Fonterra site is very unlikely due to the levels.

The estimated cost of the works is $809,000. This does not allow for any foundation improvement to the Reids Canal or main river stopbanks. Some stopbank improvements have already been carried out on the cribwall at the Fonterra site. Observations from the 1998 and 2004 floods have not identified specific areas of concern with the river stopbank between Fonterra and Eastpack (500 m of bank). Stopbank repairs are discussed in Section 3.5.7.

### 3.4.4 South West Edgecumbe – Scheme 3

The south west quadrant includes a large portion of the Edgecumbe residential area and several commercial premises. In particular it includes the low areas of Kanuka, Totara, and Kowhai streets.

This area has existing problems with local stormwater disposal. Flooding on streets is a regular (several times per year) occurrence. Stormwater ponding in heavy rain in this area is a major source of inflow to the Edgecumbe sewerage system, leading to pump station and treatment pond overflows.

Edgecumbe southwest would be inundated to over 1 m depth (approx RL 3.4 m) by any river breach on the west bank upstream of Edgecumbe

Given the low lying ground in part of this area (lowest floor levels at RL 2.24) and the current reliance on the Omeheu canal system the only feasible way to increase the level of flood protection to this area is through a combination of ringbanking and floodpumping. The recommended works are to (Figure 4):

- Construct a new stopbank across the existing drainage reserve and farmland immediately to the west of the township. The height of this bank depends upon the objective; for local stormwater a low bank of around 0.7 m height max would suffice (Scheme 3a). If it is desired to protect against a river breach flood from upstream then the bank has to be much higher at 1.6m or more (Scheme 3b).
- Construct a new permanent electric powered flood pumping station (plus backup generator) to drain water from within the ringbanked area back to the Rangitaiki river.
- Continue stopbank toe loading and/or relief drain works on the main river stopbank (Section 3.5.7).

This is similar in concept to the scheme proposed in 2002 to address stormwater and related sewerage system issues. For Scheme 3b the stopbank height has been increased to provide protection against a river breach flood.

Primarily the scheme would be protecting against the localised stormwater flooding. It would also address the additional drainage needs which will arise from the stopbank toe drainage works on the main river stopbanks. As the pumps would be expected to be used 2-3 times per year the recommendation is for a permanent pump installation. The pumpstation controls would be set clear of the flood breach water level.

Scheme 3 logically combines with that for the Edgecumbe north west.

Further detailed design is needed to clarify the flood level in a breach situation for the Edgecumbe south west. Modelling of river breach scenarios for Environment BOP (1995) indicated a maximum level of RL 3.0-3.3 in this basin. However the same study substantially underestimated the ponding depths for a breach on the south east as happened in 2004. Unlike the south east where the high ground of the earthquake scarp confines flooding, in the south west river flood waters can spread very extensively to the west. The Omeheu and Omeheu Adjunct Canal banks at around RL 3.4 m would set a minimum level for any pond. However the rail embankment does form a substantial barrier to northward flow of a flood. It is recommended that a new flood breach model study be carried out using a breach flow similar to 2004. It is likely that an increase to the waterway area at the Omeheu and Omeheu Adjunct Rail bridges will be needed to avoid excessive pond depths in the south west basin. If increased water way is not provided then it is likely that one or both of the Omeheu rail bridges would wash out under a major flood.

Main river stopbank improvements are required to provide surety against a river breach into this area. Seepage in 1998 around the Environment BOP works yard (Ngaio Place) raised concerns over piping potential in this area. This area is one of the sites under current investigation and repair (Section 3.5.7)

The estimated cost for Scheme 3a (low bank) is $818,000.

The estimated cost of the works for Scheme 3b is $1.27M (excluding rail bridge and stopbank improvement work).

### 3.4.5 North West Edgecumbe – Scheme 4

The Edgecumbe north west quadrant includes the lower lying residential areas of Puriri, Matipo, Tawhara, Titoki, Rata, Hinau streets, the commercial area of Riverslea Mall, Edgecumbe College and Primary school.

These lower lying areas are at risk of ponding from larger local rainfall events. Much of the area is sufficiently low to be at risk from flooding in a river breach situation with a level in the flood pond of 2.9 m RL predicted (Environment BOP 1995). The area is reliant on the Omeheu pump stations and canals for drainage.

If positive exclusion of river breach floodwaters was set as an objective then a high ring banking scheme would be needed (Scheme 4a):

- 790 m of new stopbank up to 1.6 m high across the farmland immediately to the west of the township (Figure 4)
- New permanent flood pumping station
- Continue stopbank toe loading and relief drain works on the main river stopbank

The estimated cost of the works is $1.05M (excluding main river stopbank improvements).

As with the Southwest, a low bank option to improve the drainage in localised heavy rain would provide substantial benefit to the street flooding and sewer infiltration (Scheme 4b). The estimated cost of this work is $891,000.

This reach includes several areas of concern in the main river stopbanks which are part of the current investigations and improvement works.

#### 3.4.6 Drawbacks of Ring banking Options

For the river breach situation the ring banking options are in effect “flood defences” – ie they protect key infrastructure and urban areas in the event of a flood breaking out of the river outside of the protected area, but they do not in themselves reduce the risk of a breach.

Options for ring banking parts of Edgecumbe share a common weakness – in the event that the river stopbank within the ring banked area fails then flood water would be trapped by the new outer bank – creating a bathtub effect. Flood waters would quickly rise to the level of the ring bank crest and would likely be up to 1 m deeper than would be the case without the ring bank.

The emergency response to a stopbank breach flowing into a ring banked area would be to breach the ring bank to allow the water to flow out onto the surrounding plain, however whether the bank could be breached quickly enough to avoid severe flood depths would be doubtful.

Options involving high ring banks are not supported by the community due to the perceived risk of a river breach or overtopping into the protected area. The low bank options do have general community support as they are seen to address the regular stormwater related flooding issues.

### 3.5 Options to Improve Whole of Scheme Performance

#### 3.5.1 Objectives

The main objective for the river scheme as a whole must be to pass flood water through the combined main channel and floodway system at the lowest possible level. If this can be done then the risks of overtopping of banks and of piping failure will be kept to the minimum, to the overall benefit of all the scheme community and the District as a whole. In this sense the whole scheme options are primary “flood prevention” works as opposed to the ring bank options which are secondary “flood defences”.

#### 3.5.2 Raising of Stopbanks

In other situations raising stopbanks to increase channel capacity and freeboard would be a preferred option. However for the Rangitaiki scheme this is not preferred, for the reasons set out in Section 2.4 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.

#### 3.5.3 Relocating Stopbanks

In principle there would be benefit in widening the stopbanked river floodplain in some reaches, so stopbanks do not follow the meander loops so closely. Advantages would be a shorter length of stopbanks, increased hydraulic capacity/storage and provision of a buffer zone between the main river channel and the stopbanks. However existing roads, houses, land tenure and ground contour, the constraints that led to the original stopbank locations, preclude this.

### 3.5.4 Dredging of Lower River – Scheme 5

The lower river has been observed to have below scheme design capacity (Section 2.1.2). One possibility to restore the channel capacity to $Q_{100}$ standard in the main river below Edgecumbe is by dredging of the river bed (the Asset Management Plan currently provides for this in 2008/09).

The Environment BOP Rangitaiki MIKE 11 model was run to analyse the effect of dredging the lower channel (Appendix 1). Three options were evaluated:

- Dredging of 1m from the bed over a 10 km reach from Edgecumbe down to Thornton
- Dredging of 0.5 m over 10 km
- Selective dredging from the narrower and shallower cross sections from Edgecumbe down to Thornton Road bridge

The selective dredging option was found to give the best return in terms of water level drop /$m^3$ of material shifted, lowering water level immediately downstream of Edgecumbe by around 200 mm in a $Q_{100}$ event (Refer Figure 3.3 Appendix1). To achieve this some 280,000 $m^3$ of material (assumed mainly coarse pumice sand) would need to be removed. It was assumed for costing purposes that this would be deposited to adjacent low lying farm land after first stripping topsoil, thereby deriving a benefit of raising poorly drained and flood prone land.

The cost of this operation would be at least $7 million. There is a large uncertainty associated with dredging costs.

The area of benefit would be to all rural land downstream of Edgecumbe, the Edgecumbe urban area and the infrastructural assets, through reduced water levels under flood conditions and through restoration of the scheme design standard.

As an option dredging has several limitations:

- It is not a permanent solution – the time before the river fills in again with movement of sand from upstream is uncertain. In this regard it should be observed that the twin peak operation of the Matahina power station affects riverbank stability and hence sediment inputs to the river.
- Dredging as above would only return the channel to Scheme design standard, ie it provides no additional margin for overdesign (ie> $Q_{100}$) events or future more intense storms.
- The gain is likely to be lost over time due to sea level rise

- A large quantity of material has to be shifted to effect a relatively small drop in water level

For these reasons dredging is not recommended. The modifications proposed to Reids Floodway (Section 3.5.5) achieve a better reduction in water level in the main river for less cost.

**River Mouth**

A related issue to dredging is the river mouth. At the Thornton river mouth the cross section tends to narrow due to the formation of a sandbar on the western side. Under normal flow conditions this restricts the outlet width to around 50 m, considerably less than the upstream river width. Under high flood conditions this sandbar will scour. However there have been concerns expressed that until this happens the narrow cross section could hold up water level in the river. The Environment BOP River model was used to assess the extent of this constriction effect.

Modelling shows (Appendix1) that under full flood conditions of the design $Q_{100}$ flow, if the mouth did not scour water levels would be some 200 mm higher than for a scoured cross section. This effect would extend upstream for 4km.

However observation from past floods is that the sandbar does scour relatively quickly on the rising limb of the flood, and is highly unlikely to be intact by the time of peak flow. This is supported by the model calibration, which requires a wider (scoured) cross section to obtain a match with the 2004 flood profile.

It is concluded therefore that permanent works to widen the mouth section are not necessary. Nonetheless the “spit fuse” is an important part of the overall lower river system. It is recommended that the mouth cross section be monitored as part of the overall flood management as there may be situations after prolonged low river flows and westerly drift when some excavation could be useful.

**Laws Bend**

There is a large meander bend in the Rangitaiki River at Laws corner 5 km upstream from Thornton. Approximately 100 mm of superelevation of flow was observed at this bend in 2004 and the river was on the point of overtopping to the west before the breach at Sullivan’s reduced water levels.

The Environment BOP river model was used to assess the sensitivity of the flood profile to the energy losses at this bend (Appendix1). However the gain from easing the bend is predicted to be small (less than 100 mm). A house has recently been constructed on the east bank close to the stopbank and this now reduces the options for easing the bend.

Environment BOP have reinforced the river bank protection works and raised the stopbank on the outside of the bend since 2004. No further works are proposed for this location.

### 3.5.5 Reids Floodway – Scheme 6

The current configuration of the Reids Floodway is hydraulically inefficient. From the start of the Floodway at the spillway downstream for 8 km it has a width of 200 m (designed to 10 chain) but over the lower 3.7 km this narrows down to an average width of 44 m (Figure 5) and at the narrowest point is only 25 m wide. It is understood that land owners in the area at the time the scheme was designed in the 1960's were unwilling to have land incorporated into the floodway.

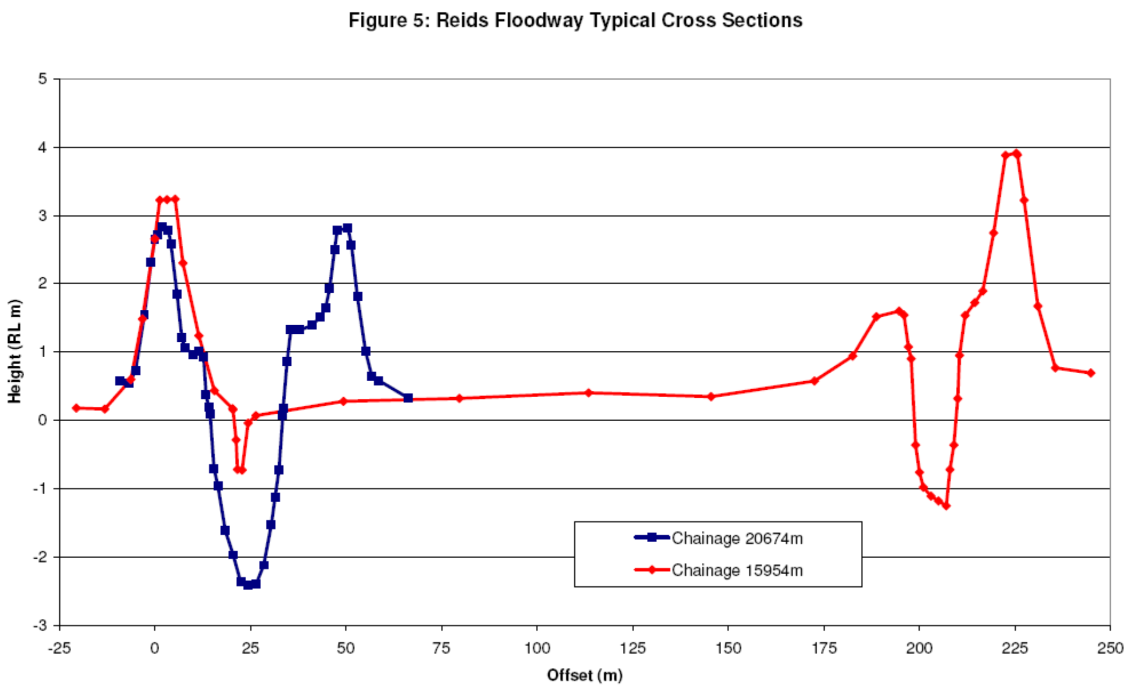



**Figure 5: Cross sections at Mclean rd (15954m) and section 20674**

Modelling of the floodway (Appendix1) clearly shows the effect of this constriction, with 900 mm of head lost over the first 3.7 km from the Rangitaiki River up to Langdons boundary and then only 200 mm lost over the next 5 km up to SH 2 (Figure 6).

The River Scheme would benefit greatly by widening the lower 3.7 km of the floodway thereby removing the constriction and increasing the conveyance. Three options were modelled to assess the benefits of this, a widening of the floodway to 200 m over the lower narrow reach, a widening by 50 m and by 20m. As expected, widening gives a very substantial improvement; increasing capacity of the floodway by up to 100 $m^3/s$ (ie doubles) and lowering water level in main river by 0.5 m in the $Q_{100}$ flood. A 50 m floodway width appears to be optimal (Figure 6).

The works required are to relocate/reconstruct the west Reids stopbank approx 50 m further out (ie 3.7 km of new bank). There are impacts on other infrastructure such as farm races, fencing and drainage which would need to be addressed.

The estimated cost of the works is $5.54M. This allows for the stopbank construction, relocation of farm assets and compensation to landowners as per Environment BOP normal practice. The area of benefit would be all rural land on both sides of the Rangitaiki River downstream of the floodway weir, the Edgecumbe urban area and infrastructure through reduced river water levels under flood conditions, reduced risk of a river breach and through restoration of the scheme design standard.

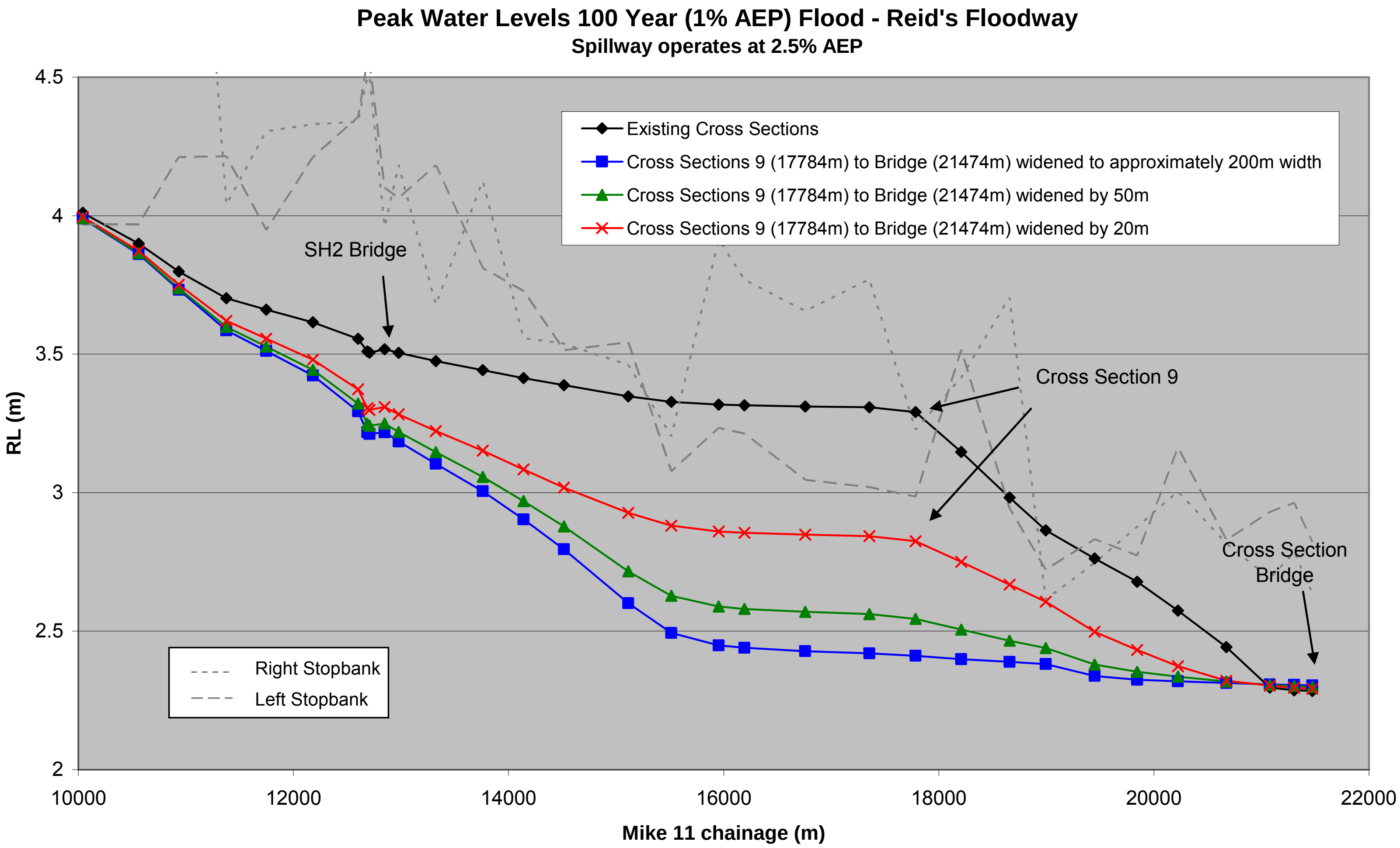



**Figure 6: Modelled maximum water levels in Reids Floodway under cross section widening scenarios for 100 year flood**

Unlike dredging the main river channel, providing increased capacity in the floodway:

- Provides a margin for an overdesign event (as more can be spilled from the main river)
- Provides a margin for climate change
- Is a permanent improvement

To get the full benefit from a widened floodway would ideally require a gated control structure on the floodway entrance as discussed below.

It is important to note that under this option change to the frequency of flow in the floodway is not proposed, ie the floodway would still commence operation at around the $Q_{40}$.

### 3.5.6 Control gates to Floodway – Scheme 7

Under the current weir spillway arrangement there is no ability to control the timing or amount of water which spills to the floodway. Very importantly, because of the levels, the spillway will preferentially take flow once it starts to operate. In overdesign events almost all flow greater than $Q_{100}$ will flow down Reids Central and result in widespread overtopping and probable bank failure as in the 2004 flood spread.

A solution is to provide a gated control structure for part or all of the floodway design flow. Other major river schemes such as the lower Manawatu (Moutoa gates) and the Ruamahunga include such structures.

The advantages of a control gate are:

- It provides positive control over the diversion of floodwater to Reids floodway
- The split of water between the floodway and the main channel can be managed in real time to optimise levels in both the main river and the floodway with downstream tidal conditions and upstream inputs from Matahina dam.

A practical example of how a control gate could be used to improve the overall scheme reliability is that currently there is no ability to divert water into Reids floodway at flows less than $Q_{40}$. A possible situation where it would be desirable to do this would be a flood with a low peak but extended hydrograph (similar to 1998) which lasted long enough to cause significant problems with stability in the lower river stopbanks. With a gate in place flow could be diverted to the floodway to relieve pressure.

A design option may be to control say ½ to 2/3 of the design flow and allow weir flow for the balance with a reduced cost for the gate and still achieve substantially improved flow control.

The estimated cost for control gates is $3.1m.

The area of benefit is the whole scheme through optimised levels in the floodway and main river and hence reduced risk of bank failure.

A control gate is compatible with a widened floodway.

Concern has been expressed by landowners adjoining the floodway that control gates would result in more frequent use of the floodway, to the detriment of the land within the floodway and the adjoining land that drains into it. It is not proposed to alter the frequency at which the flow would enter the floodway, unless to relieve an emergency and imminent failure on the main river. A clear set of operating rules governing the floodway operation will be set out as part of the resource consent process for the floodway upgrade.

### 3.5.7 Stopbank Repair and Upgrading

Following the 2004 flood Environment BOP commissioned a geotechnical review of the Scheme stopbanks by ICE Geo & Civil Ltd. This identified 12 sites (totalling some 5km of bank) where ground conditions, observations or past history suggest there are weaknesses in the foundations which need to be addressed. Investigation and repair has proceeded on these sites and most are now completed or underway. Assessment of the sites completed to date has confirmed the presence of highly permeable pumice sand and gravel layers extending beneath the stopbanks at these locations with consequent high risk of piping failure.

Observations of stopbank or foundation distress during previous floods highlight obviously at risk sections of bank and identify immediate priorities for repair. However this approach does not provide a comprehensive assessment of the condition of the banks. For example the Sullivans breach in 2004 immediately lowered water levels in the lower river and reduced seepage gradients. Had this not happened then it is probable further weak spots would have been observed later in the flood hydrograph. Similarly the Reids floodway banks were not fully tested under the design differential head as they were overtopped with floodwater on both sides.

Following review of findings from the first sites it was decided to extend the investigations to include all the stopbanks within the Edgecumbe urban area.

On the basis of the investigation work to date it appears prudent to allow for remedial works (either toe loading or relief drainage) for the full length of the urban banks. Several sites within Edgecumbe itself are relatively expensive to treat due to limited room to work between the stopbank and houses. Based upon costs from sections already completed the estimated cost of the works within the Edgecumbe urban area is $1.5M.

The extensive lengths of relief drains which are required to increase the factor of safety of the Edgecumbe urban area stopbanks will result in some additional inflows of water during flood conditions.This increases the importance of stormwater improvements in the southwest quadrant.

This is remedial work which is required to ensure the scheme can perform structurally to the current design standard of $Q_{100}$ level. Ground conditions are highly variable and there will remain some risk of seepage (piping) erosion in the embankment foundations, even with rigorous investigations. Earthquakes and land development activities have potential to alter subsurface seepage paths.

The area of benefit is to the whole scheme through reduced risk of stopbank breach.

### 3.6 Role of Matahina and Aniwhenua Dams in Flood Mitigation

The Rangitaiki river system includes the two hydro lakes of Matahina and Aniwhenua. The role of these lakes in mitigating floods in the lower river is often questioned by those on the river scheme. The Hydro lakes do have an important role to play in the management of floods through the lower river, but that role is subject to significant limitations and is not the sole answer to future flood protection needs for the reasons as set out below.

Matahina is designed and built as a hydroelectric reservoir and not as a flood detention dam. The penstock intakes and spillway are configured to maximize the head of water over the turbines. The lake has an effective operating range of 5.2 m from a minimum level of RL 71.6m to a maximum design flood level of 76.8 m. The minimum level is set by the intake to the penstocks, at lake levels below this water cannot be discharged through the turbines without drawing in air and causing cavitation damage to the machines. The lake does have a low level sluice outlet as was used to dewater the lake for repair following the 1987 earthquake, but this is not designed for routine use.

The effective storage between minimum and maximum levels is 10.4 million $m^3$. This is a large amount of water, but in actual fact relatively small compared with the total volume of water which passes through the lake in a major flood. For example in July 2004 the total volume of flood water was 155 million $m^3$ (counting only the period when flow was above 300 $m^3/s$). Matahina lake is long and relatively narrow and so does not provide a large increase in storage volume as level rises.

In contrast to the above a reservoir designed specifically for flood detention would be normally kept at a low level, have outlets at a low level, and have a large surface area so that a small rise in water level will store a large volume of water.

Matahina Lake (and the same goes for a lesser extent to Aniwhenua upstream) can be used to modify the hydrograph of a flood. It must be realized however that the effect of using the storage is to reduce the flood peak at the expense of making the duration of the flood in the lower river longer. This is a very important point as discussed again below.

There are established rules for operation of the lake as set out in the Resource Consent held by Trustpower. These are set to protect both the dam stability and the lower river.

Matahina is an earth core dam and as such is designed to operate over a narrow range of water level – wide and rapid fluctuations are not desirable for an earth dam. Secondly, large releases of water from the dam in a short period have the effect of generating an artificial flood in the lower river, causing scour of the banks and damage to the scheme river protection assets and for this reason the rate at which water can be released is limited by the operating rules. Importantly, if releases were at a high enough level they would contribute to increased seepage pressures in the stopbank foundations.

The operating rules can be used to mitigate a flood peak in the following manner:

- In advance of a possible flood (say an incoming cyclonic system) the lake would be lowered to minimum level within the constraints of the operating rules
- If the flood eventuates the lake will refill and discharge would be through the turbines at maximum generation until spillway level was reached
- In a large flood the storage will be used up on the rising limb of the hydrograph and normal spillway operation would take place

The effect of this is to "clip" the top off the hydrograph, but extend the period of high flow. Figure 7 shows how this would have worked in the July 2004 event, with peak flow in the lower river potentially reduced to around 600 $m^3$/s.

Analysis of the timing of floods over the last 40 years shows that there are two periods most likely to produce a major flood in the Rangitaiki River. February when tropical cyclones hit has produced several very large floods (1965 and 1967). However these events do come with usually over a weeks warning as the storm develops and tracks down from the tropics. This allows adequate time to draw the reservoir down in advance. The other high risk period is July and early August (eg 1970, 1998 and 2004) when winter low pressure systems track over the Bay of Plenty. The behaviour of these storms is more difficult to predict. The low pressure systems can move relatively quickly across the region, delivering intense rainfall but for short duration. Dangerous situations arise, as in 2004, when systems meet a southerly front moving up the north island and stall over the Eastern Bay, delivering sustained heavy rain over 2-3 days. A modification to the operating rules to maintain the reservoirs at low levels for the duration of this high risk window is a possibility.

Certainly management of the dams to reduce flood peaks is very helpful in managing floodwaters through the lower river. However there are drawbacks:

Firstly even with the peak removed the flows in the lower river are still large enough to place the stopbank foundations under severe stress. The Sullivan's breach occurred at a discharge of around 600 $m^3/s$, well before the peak discharge of 780 $m^3/s$.

Secondly by releasing water early in advance of a flood the duration of high flows is lengthened. For the Rangitaiki River this has two potentially serious downsides:

(i) scour damage to the banks will be worse. Bends such as at Kokohinau and Fonterra where the river runs hard under the stopbanks are vulnerable to scour (note both these sites have been reinforced post 2004)

(ii) the time available for increased seepage pressures in the foundations and piping to develop is increased. As an example the 1998 flood was considerably less in peak flow than July 2004, but extended for longer and showed up a number of seepage areas.

There is also an economic cost, in that release of water specifically for flood mitigation purposes may not be optimum for power generation. There is no certainty that a flood will eventuate from a predicted weather system – the lake may well be drawn down unnecessarily. This in fact happened shortly after the Matahina Dam's construction when the lake was drawn down in advance of a predicted storm which didn't eventuate – the resulting high flows in the lower river caused substantial damage to the banks.

To utilize the dams in this manner requires an element of foresight and considerable judgement of what would be an uncertain and rapidly changing situation – there is potential to make calls which hindsight would prove wrong. An example is the July 2004 flood, where if the dam water had been released earlier then the Sullivans breach may well also have occurred earlier – in the dark of the storm on the Saturday night and not in daylight.

These reservations aside, the dams have an important role in mitigating floods and as part of the overall flood risk mitigation strategy their use is optimized. Following the 2004 flood, Environment BOP and Trustpower have reviewed flood forecasting and communication to ensure this happens. In future as the record of river flows lengthens and the sophistication of weather forecasts increases (more gauges in the catchments, possibly weather radar in the Bay of Plenty) reliability of flood warning should improve. Currently a predictive model of the catchment which can provide advance warning of flood flows in the lower river based upon raingauge records and weather forecasts is under development as a joint Environment BOP and TrustPower project.

### 3.7 Overdesign Events

As identified above, overdesign events will preferentially flow to the Reids Floodway. Stopbank freeboards are currently 300mm lower in the rural area than in the Edgecumbe urban area, ensuring overtopping would occur to rural land. Currently both banks of the River and floodway are set to the same nominal design level. A differential freeboard could be used to direct floodwaters first to one area in event of an overdesign flood, as is currently done on the Whakatane Scheme. This could limit spread of floodwaters. The implications of this would need to be worked through with the affected landowners. Construction of differential freeboards is not part of the works proposed herein.

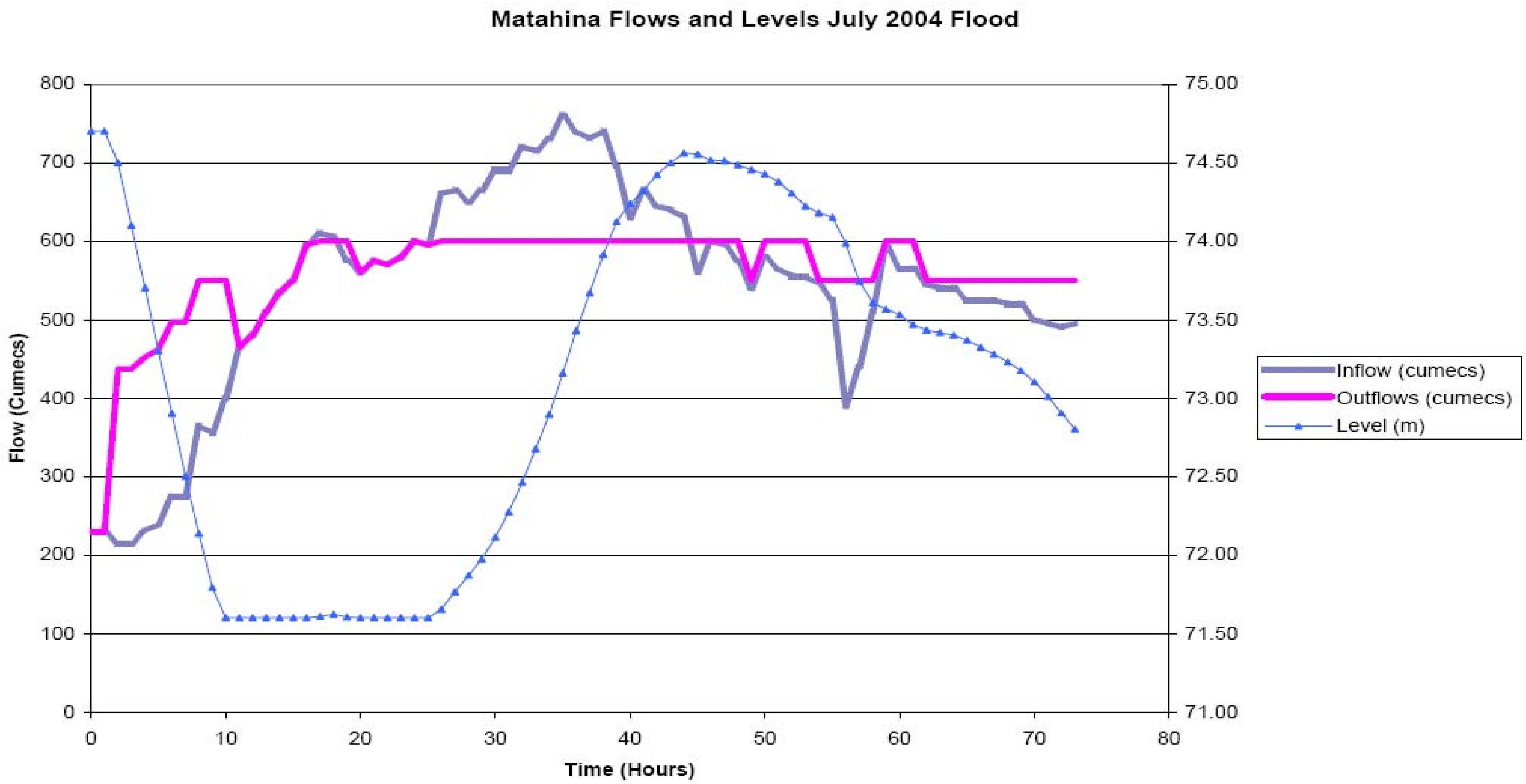



**Figure 7: Simulation of effect lowering of Matahina lake could have had on the 2004 flood hydrograph (EBOP 2004)**

# 4 READINESS, RESPONSE AND RECOVERY

Section 3 has discussed the options available to **R**educe risk of flood damage occurring. The other components of comprehensive flood management are **R**eadiness, **R**esponse and **R**ecovery:

## 4.1 Readiness

The Bay of Plenty Civil Defence Emergency Management (CDEM) Group Plan sets out how the Bay of Plenty will ensure a state of readiness and lists specific steps to be taken by agencies and the community to be ready to respond to an emergency.

### 4.1.1 Planning

As part of the CDEM Group the Whakatane District Council (WDC) and Environment BOP have agreed Standard Operating Procedures (SOPs) and Contingency Plans that detail how the consequences of an emergency event will be managed at a local level and how response arrangements can be escalated.

The Whakatane District Councils SOPs are:

| | |
|---|---|
| SOP 4 | EOC/Headquarters Activation |
| SOP 12 | Communications |
| SOP 31 | Warning Systems |
| SOP 36 | Disaster Recovery |
| SOP 37 | Welfare Centre Establishment Procedures |
| SOP 38 | Public Information |

These SOPs are progressively being updated by the WDC Emergency Management Officer.

The Whakatane District Council has also been working with local communities to develop Community Response Plans (CRP's) for communities that could be isolated by an event:

- Matata – completed 2006
- Te Urewera (Ruatoki, Waimana, Waiohou, Ruatahuna) – completed 2006
- Galatea – proposed
- Murupara Community Self-help Programme

Planning is also a critical part of the flood defence assets managed by EBOP.

The Rangitaiki – Tarawera Rivers Scheme Asset Management Plan (AMP) details how the River Scheme assets will be managed. This ongoing management is necessary to ensure the scheme flood defences are in a state of readiness for any emergency event. This AMP includes planned maintenance and capital activities and details of how these are funded.

### 4.1.2 Public Education

Environment BOP as the regional planning group has a Civil Defence link on their website www.ebop.govt.nz. This contains information for the public including:

- Be Prepared (how to prepare your home and family for emergency)
- Regional Hazards, and the
- CDEM Group Plan

The WDC Recovery Office was established following the 2004 flood event. Their website for recovery activities is www.easternboprecovery.org.nz. This contains information for people affected by disasters and provides an umbrella site for the Whakatane District Council's Recovery Team and the supporting agencies involved in the recovery process.

### 4.1.3 Training

The WDC has programmed training for WDC staff who will work in the Local Emergency Operations Centre.

The Group Warning Plan contains information on how warnings are received, transmitted and used. There are a number of agencies involved in the surveillance, monitoring and assessment of hazards. In a number of cases these agencies are also responsible for issuing warnings under the National Civil Defence Plan.

### 4.1.4 Flood forecasting

Environment BOP and Trustpower are cooperating to maintain an effective flood forecasting model. This will assist with the optimisation of releases from Matahina Dam and in warning the community.

Environment Bay of Plenty issues warnings of a threat of flooding.

Met Service issue special bulletins on heavy rain and other severe weather conditions.

### 4.1.5 Flood warning systems

Environment Bay of Plenty monitors rivers, rainfall and meteorological sites throughout the Bay of Plenty. Thirty of these sites are telemetered, i.e. the data from them is transmitted back to base via a radio and phone network. Some of this information is included on the regional councils public website www.envbop.govt.nz.

Information obtained from telemetered and private rainfall and river gauging sites is used in flood models to assist in issuing accurate warnings to landowners and Civil Defence controllers. The guidance to the operation of this warning system is contained within the EBOP 'Flood Warning Manual'.

#### 4.1.6 Communications

Environment BOP publishes some of the rainfall and river gauging information on its public website. Suggested improvements to this include:

- Include flood warnings for all major rivers including the Rangitaiki. This could specify the level of warning eg. Level 1, level 2 etc.

- Inclusion of a river level monitoring site on the Rangitaiki River into the public website. This could indicate the level of a 1, 5, 20 year flood to assist the public with assessing the significance of the river levels.

The WDC Special Operating Procedure 12 details the CD Communication actions at a local level.

The Group Emergency Office Centre (GEOC) level communications are detailed in the BOP CDEM Group EOC SOPs.

The WDC Emergency Management Officer is investigating installing a resource management database (RMD) system for use in the Emergency Operating Centre. This database is used by many local authorities. This would ensure easy access to the information currently contained within the SOPs.

Suggested improvements to the system are updating the WDC website to include emergency notices and providing a link to the EBOP website for flood warnings.

It is recommended that Environment BOP explore the use of text messaging to improve the effectiveness of warning systems and communication with the river scheme landowners during flood emergencies.

### 4.2 Response

Response activities are those actions taken immediately before, during or directly after an emergency event to save lives, limit extent of damage to property and infrastructure, and restrict the impact of a hazard. Response activities include

- Formal declaration of local emergency
- Activation of Emergency Operations Centres (EOCs)
- Issuing Warnings
- Establishing response priorities
- Deployment of resources
- Collection and dissemination of information

Prior to escalation to an emergency event the initial response will be guided by the WDC Utilities Incident Response Plan. This plan provides information to assist WDC staff and contractors in managing an event, such as minor flooding on residential property, prior to escalation to a Civil Defence Emergency. It provides details of responsibility, actions, communications and escalation. This document is currently in draft form.

An evacuation plan for Edgecumbe needs to be developed. The township has limited areas of elevated ground, especially in event of a breach upstream of the township on the west bank.

Environment BOP manages the Flood Warning System in the Bay of Plenty. The details of actions and responsibilities for this system are contained in the 'Flood Warning Manual' an internal document for use by the nominated EBOP Flood Managers and EBOP staff. The manual contains information on:

- Monitoring sites
- Responsibilities
- Contact details for observers (to assist with predicting flood levels for issuing warnings),
- Contact details of landowners in the Rangitaiki floodway (to warn to move stock),
- Contact details for District Council, police and road controlling authorities

It would be valuable to extend the number of people included in the warning to include people living immediately beside the main river and Reids Floodway stopbanks. Observations of residents, such as spongy ground, are very valuable in both managing flood response and also in planning future improvements.

### 4.3 Recovery

The WDC Recovery Office was established following the 2004 flood event. The purpose of the Recovery Office is to co-ordinate support for the community affected by the storm in July 2004, and most recently, the disaster at Matata in May 2005. The Recovery Office can support and help people, families and communities get their lives back together after a disaster, by providing specialist services and resources.

# 5 RECOMMENDATIONS

## 5.1 Discussion

The above review of the Rangitaiki River scheme and Edgecumbe flood risk identifies that there are problems with:

(i) The hydraulic conveyance of the Rangitaiki river and Reids Floodway below Edgecumbe

(ii) The structural strength of the stopbanks and foundations which make them prone to piping failures

(iii) Local stormwater flooding in the west of Edgecumbe

A range of flood mitigation options are identified. These range from land use controls, to flood defences of critical areas, to schemes which improve the overall flood carrying capacity of the river system.

Ideally all approaches would be used. However funding constraints may not allow this. Therefore it will be necessary to prioritise works. In this case emphasis should be placed on those measures which improve the overall integrity of the scheme and reduce the risk of breaches or overtopping, while also taking specific action to protect key infrastructure. On this basis the following recommendations are put forward:

## 5.2 Edgecumbe Urban Area

**Scheme 1 South east**: It is recommended this scheme proceed. The works provide protection to the houses in the Hydro Road area plus key infrastructure of the Transpower substation and the Fonterra site in the event of a breach upstream. The engineering works are relatively straightforward to implement . Transpower have confirmed their support for the proposed works and that they will contribute towards them.

**Scheme 2 North east**: This scheme involves stopbanking and is relatively straightforward to implement. Fonterra and to a lesser extent Eastpack as the primary beneficiaries need to review the merits of the option.

**Scheme 3 South west**: The scheme as proposed in 2002 with a low bank and flood pump station to control local stormwater flooding and inflow to the sewerage system. (Scheme 3a) should proceed as a high priority. This work is urgently required.

The further lifting of the proposed ring bank to protect against river breach (Scheme 3b) does not have local support and is not recommended.

**Scheme 4 North West**: A high ring banking option (Scheme 4a) to protect against river breach does not have local support. Smaller scale works of low level banks, ground contouring and flood pumping (Scheme 4b) would improve the performance of the urban stormwater reticulation and are recommended.

**Consultation**

Consultation is required with landowners affected by stopbank works and with the community.

## 5.3 River Scheme

**Dredging**

On the basis of the analysis to date dredging is not the preferred option for improving the lower river flood conveyance. It has a large cost uncertainty, produces only modest reductions in water level in flood conditions and is of uncertain duration of effect. A very large quantity of dredge spoil would have to be disposed of.

**Improvement to Reids Floodway**

Improvements to the conveyance of Reids floodway offer the best return on investment and provide benefit to the widest area, both urban and rural. This option achieves both key objectives of improving channel conveyance through the lower river system and lowering water levels. The reduction in water levels through Edgecumbe combined with the improved stopbank integrity resulting from the stopbank improvement works in the urban area substantially improves the level of protection to the whole urban area. Priority should be given to this option.

**Spillway control gates**

The control gated inlet to the Reids floodway is a high cost item. It would be a very useful addition to the river scheme which would complement the Reids floodway improvements and is therefore recommended.

**Stopbank and foundation investigation and repair**

Current work to investigate and repair the weak areas in the main river stopbanks is essential and is proceeding as rapidly as possible. Following completion of this work a comprehensive investigation of the remaining banks on the main river and Reids floodway should be initiated.

## 5.4 Combined Schemes

Table 1 below shows how the various schemes could be combined into an overall flood mitigation option.

The Reids Floodway improvements combined with the Edgecumbe Schemes 1, 2, 3a and 4b constitute the minimum combination (Option B)

Addition of the Spillway control gate for the full flow (Option C) provides a comprehensive scheme.

**Table 1: Edgecumbe Flood Study: Options matrix**

| Scheme | Option A – All works | Option B – Selected Edgecumbe projects + Reids Floodway | Option C - Selected Edgecumbe projects + Reids Floodway + Spillway gates |
|---|---|---|---|
| Scheme 1 - Edgecumbe South East | √ | √ | √ |
| Scheme 2 - Edgecumbe North East | √ | √ | √ |
| Scheme 3a - Edgecumbe South West (low bank) | | √ | √ |
| Scheme 3b - Edgecumbe South West (high bank) | √ | | |
| Scheme 4a - Edgecumbe North West (high bank) | √ | | |
| Scheme 4b Edgecumbe North West (low bank) | | √ | √ |
| Scheme 5 - Rangitaiki River dredging | | | |
| Scheme 6 - Improve Reids Central floodway | √ | √ | √ |
| Scheme 7 - Spillway control gate | √ | | √ |
| Stopbank foundation investigation and repair | √ | √ | √ |
| **Combined Option Cost** | $13,954,000 | $10,243,000 | $13,343,000 |

### 5.5 Consultation

Further consultation is now required with the scheme users, infrastructure owners and in particular the farmers potentially affected by any alteration to the Reids floodway.

## 5.6 Other Recommendations Arising

In addition to the recommendations in regards the scheme options, the following further points were identified in the study as requiring further action or noting for future works:

(i) Continue to set minimum floor levels for Edgecumbe and the rural area based upon flood breach levels (Section 3.3.1)

(ii) Assess adequacy of Omeheu and Omeheu Adjunct canal rail bridges in event of a flood breach to west of Edgecumbe (Section 3.4.4)

(iii) Following completion of detailed assessments of the Edgecumbe urban area stopbanks, complete investigations of remaining stopbanks including those on Reids Floodway. (Section 3.5.7)

(iv) Assess capacity of the Edgecumbe stormwater system to remove water flowing from pressure relief trenches (Section 3.5.7)

(v) Ensure any future replacement of the rail bridge over Reids Floodway is not a constriction in event of increasing the design floodway flow (Section 3.5.5)

(vi) Monitor the point bar at the Thornton river mouth to ensure a constriction does not develop (Section 3.5.4)

(vii) Show flood warning levels on the Environment BOP river levels site and include a site for the Rangitaiki River (Section 4.1.5)

## References

Bay of Plenty Catchment Commission (1968) ; "*Rangitaiki River Major Scheme – Volume 4 Plans"*

Environment Bay of Plenty (2002): "*Review of the Flood Carrying capacity of the Rangitaiki River below Edgecumbe*" Operations report 2000/09

Environment Bay of Plenty (2002): "*Awaiti Omeheu Canal Modelling Study*" Operations report 2000/03

Environment Bay of Plenty (2004): "*Rangitaiki – Tarawera Rivers Scheme Asset Management Plan*" Operations report 2004/02

Environment Bay of Plenty (2004): "*Development of a Mathematical Model for the Forecast of Flood Flows in the Lower Rangitaiki River*" Operations report 2004/07

Gibbons, W. (1990) : "*Settlement and Drainage on the Rangitaiki 1890 -1990*"

Opus Consultants (2000) : "*Stopbank Assessment Rangitaiki River, Edgecumbe"* Geotechnical report 2069 for Environment Bay of Plenty

ICE Geo & Civil (2005): *"Rangitaiki River Stopbanks – Review of Stability"* Report prepared for Environment Bay of Plenty.

Opus Consultants (2002) : "*Edgecumbe South Stormwater Study"* Report 2-89153.00 for Whakatane District Council

Wallace, P. (2005): "*Hydraulic Modelling of Rangitaiki Plains Tarawera River to Rangitaiki River"* Report prepared for Environment Bay of Plenty

# Appendix 1 : Rangitaiki River and Reids Floodway Modelling

Mike11 models of the Rangitaiki River main channel and Reid's floodway have been set up by Environment BOP. The main channel has been calibrated with 1998 and 2004 flood levels. Reid's floodway has not been calibrated.

The model files, as provided by EBOP, were run with the 100 year design hydrograph. The results were the same as those obtained by EBOP and confirmed our setting up of the files and later version of the Mike11 software produced the same outputs.

## 1 Sea Level Rise

The model was run with the existing 2004 cross sections and the 100 year flood hydrograph (peak flow 780 $m^3/s$). The existing tidal boundary condition dataset (as provided by EBOP) was increased by 0.5m to simulate future sea level rise.

Figure 1.1 shows the maximum water levels reached during the 100 year flood event in the Rangitaiki main channel below the Edgecumbe bridge and in Reid's Floodway. The blue line shows the maximum water levels under the existing tidal conditions, - the solid line detailing the main river channel and the dashed line denoting Reid's Floodway.

The red line details the maximum water levels reached during the 100 year flood with an increase in sea level of 0.5m.

The 0.5m increase in sea level results in a rise in maximum water levels of 0.5m at the river mouth and 0.012m (12mm) upstream at the Edgecumbe Bridge. In Reid's Floodway the increase in maximum water levels is more noticeable with a rise of 0.381m (381mm) at the confluence with the main channel and 0.086m (86mm) at the SH2 Bridge.

## 2 300 Year Flood Event

A result of future climate change is expected to be a change in the return period of flood events. For example, what is now considered a 100 year flood event by 2080 may become a 50 year event.

It is estimated that in the future a 100 year return period flood event will be of a magnitude that is equivalent to the current 300 year return period flood. The current 300 year flood is estimated to be approximately 1000 $m^3/s$.

The current 100 year flood hydrograph, provided in the modelling files by EBOP, has been scaled up by the ratio of 1000/780 (1.282) to derive a 300 year flood hydrograph as an input to the modelling.

Model results for maximum water levels from the 300 year flood are shown in Figure 2.1 in comparison to those of the 100 year flood event. The existing 2004 cross sections were used for the modelling runs.

Maximum water levels increase along the entire length of river and floodway with the most significant increases occurring within Reid's Floodway. An increase of 0.279m at Edgecumbe Bridge and 0.195m near the mouth are predicted in the main channel. In Reid's Floodway a relatively constant increase of about 1.6m is expected from SH2 Bridge to chainage 17784m before decreasing down to the confluence.

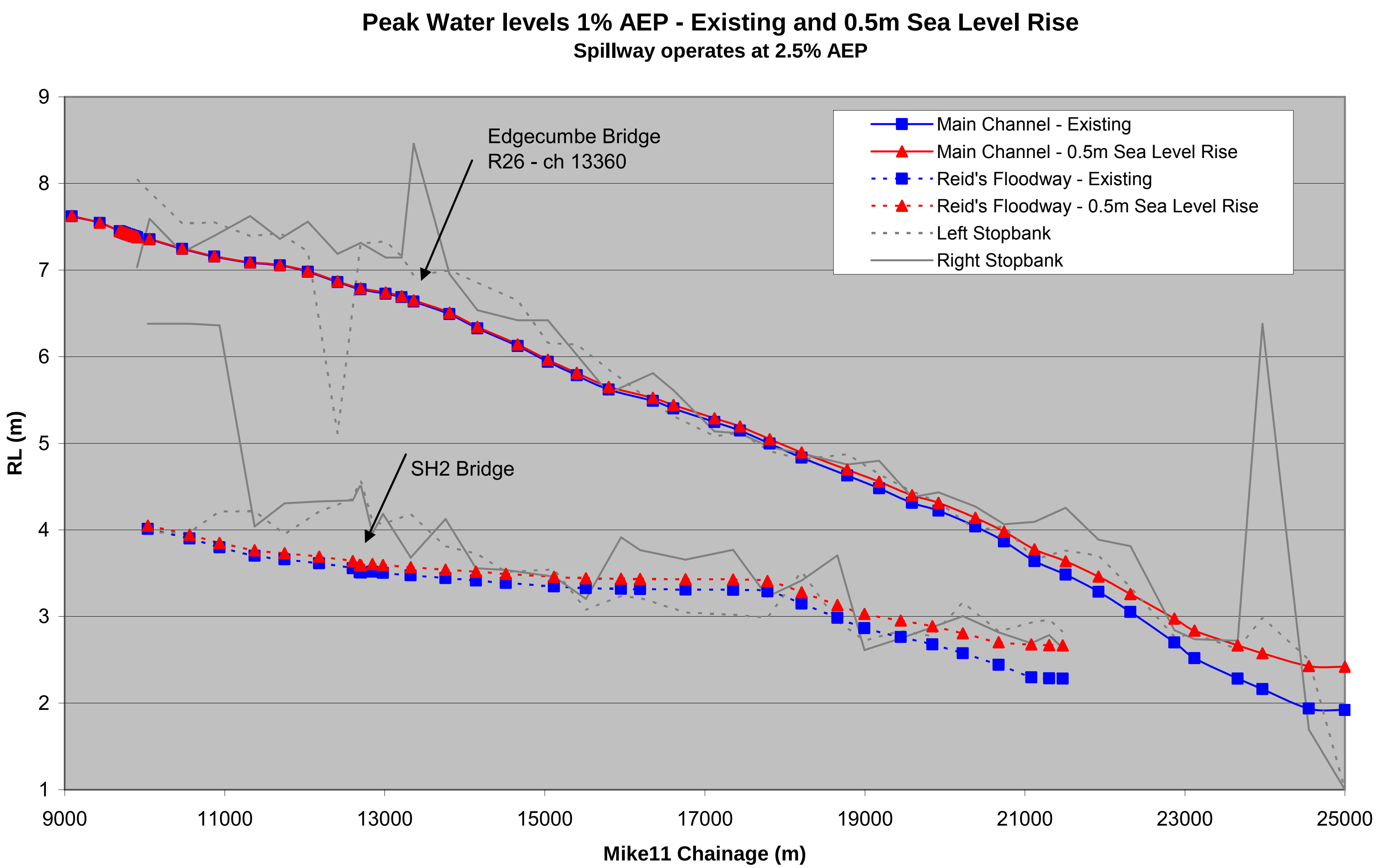



**Figure 1.1** **Modelled maximum water levels under existing and predicted sea level rise of 0.5m**

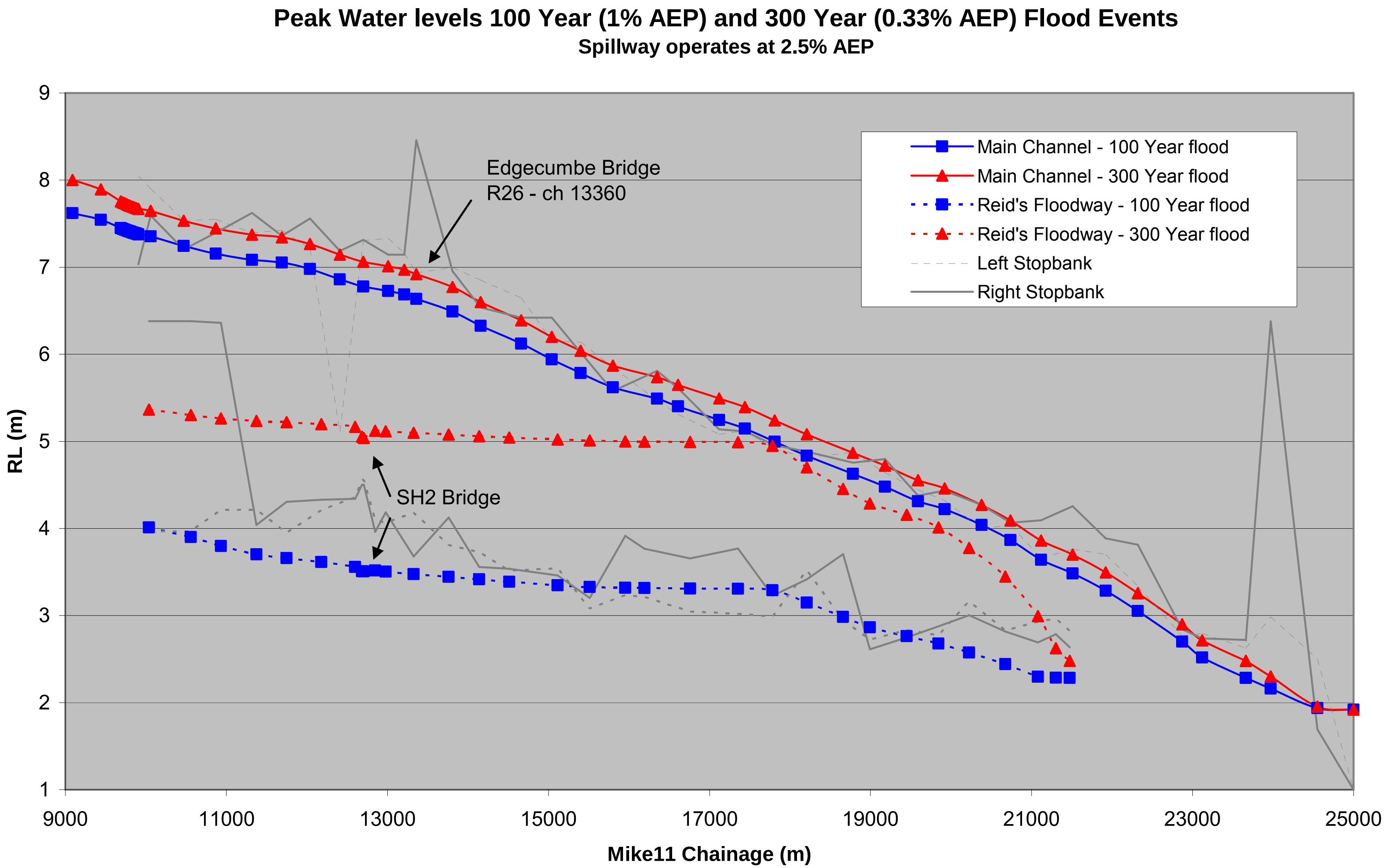



**Figure 2.1** **Modelled Maximum Water Levels Under 100 and 300 Year Flood Events. (300 Year Flood Predicted to be Future 100 Year Flood)**

# 3 Assessment of Dredging in Main Channel

A number of dredging scenarios have been investigated by amending cross sections of the main channel to simulate dredging and lowering of the river bed. Care has been taken not to undermine the stability of stopbanks.

## 3.1 Dredge 0.5m

Cross sections from R26, below Edgecumbe Bridge, to R1 (chainage 13810m to 23970m) inclusive have been lowered by 0.5m.

Model results of the maximum water levels from the 100 year flood with the dredged cross sections are compared to the existing cross sections in Figure 3.3. Results from other dredging scenarios below (Sections 3.2 to 3.5) are also plotted.

## 3.2 Dredge 1.0m

Cross sections R26 to R1 have been lowered by 1.0m from their existing profiles (i.e. an additional 0.5m to Section 3.1).

Results are plotted in Figure 3.3.

## 3.3 Specific Dredging

The cross sectional areas of R26 to R1 were plotted and compared, and those with relatively smaller areas were picked for dredging to increase their areas to a comparable size to the others.

Figure 3.2 show the cross sectional areas (at the 100 year flood level) of each cross section from R26 to R1. The cross sections selected for dredging are: R25, R23, R22, R21, R16, R15, R10, R9, R8, R6, R5 and R4.

Results are plotted in Figure 3.3.

## 3.4 Specific Dredging and Laws Bend Widening

Two cross sections at Laws Bend (R13 and R14) have been investigated as to whether the channel can be widened. Two scenarios have been modelled. The first uses the specific dredging as detailed in Section 3.3 and also widens the flood channel at R14 by offsetting the stopbank by 50m. The second does the same but also adds an offset of 20m to the stopbank at R13.

The modelled maximum water level results are detailed in Figure 3.3.

## 3.5 Increase Outlet

The outlet section of the Rangitaiki River mouth has been widened to assess whether the existing cross section is constricting flow and causing higher water levels in the lower reaches of the river.

Figure 3.1 details the existing cross section profile of the outlet as well as that of the dredged cross section and the 1987 profile (Section 3.6).

Model results are detailed in Figure 3.3.

### 3.6 Model Outlet with 1987 Cross Section

The outlet section of the Rangitaiki River mouth has been modelled with the 1987 cross section profile to simulate the mouth of the river with a spit fuse before scour occurred leading to the current cross section profile.

Model results are detailed in Figure 3.3.

### 3.7 Dredging Summary

All dredging scenarios make a noticeable improvement to maximum water levels with the exception of dredging the outlet (Section 3.5) which provides only a 30 to 40mm lowering of maximum water levels at the mouth and immediately upstream.

The dredging of 0.5m and 1.0m from all cross sections between R26 to R1 results in consistent lowering of the maximum water levels. The dredging of 1.0m provides the best result of all dredging options.

The three specific dredging options (Sections 3.3 and 3.4) including the offsetting of the stopbank at Laws Bend produce similar results. The two involving Laws Bend (Section 3.4) show slightly lower water levels upstream of Laws Bend (for approximately 3.5km). All three specific dredging options mirror the 0.5m dredging option until Laws Bend where the specific dredging results in lower water levels down towards the mouth.

Applying the 1987 cross section of the river mouth to the model (with existing 2004 cross sections for all others) results in higher water levels a reasonable distance back up the main channel as flow is constricted through the outlet to the sea.

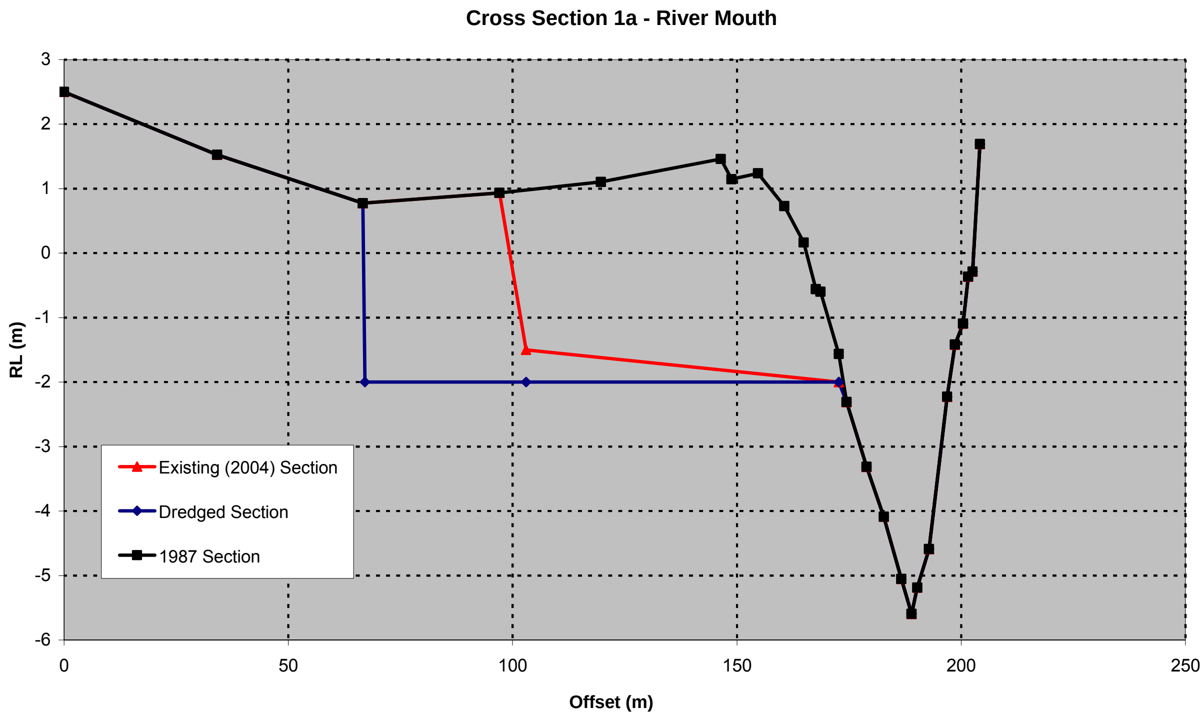



**Figure 3.1 Rangitaiki River Mouth Cross Section – Existing, Dredged and 1987 Profiles**

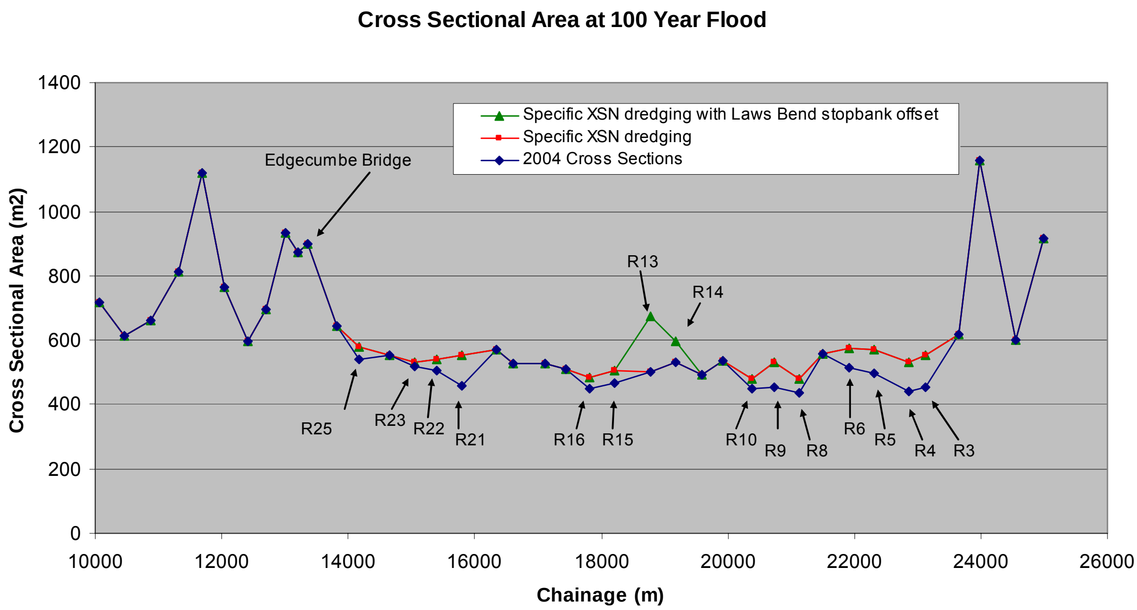



**Figure 3.2 Rangitaiki River Cross Sectional Area ($m^3$) at 100 Year Flood Level – Existing and Dredged Scenarios**

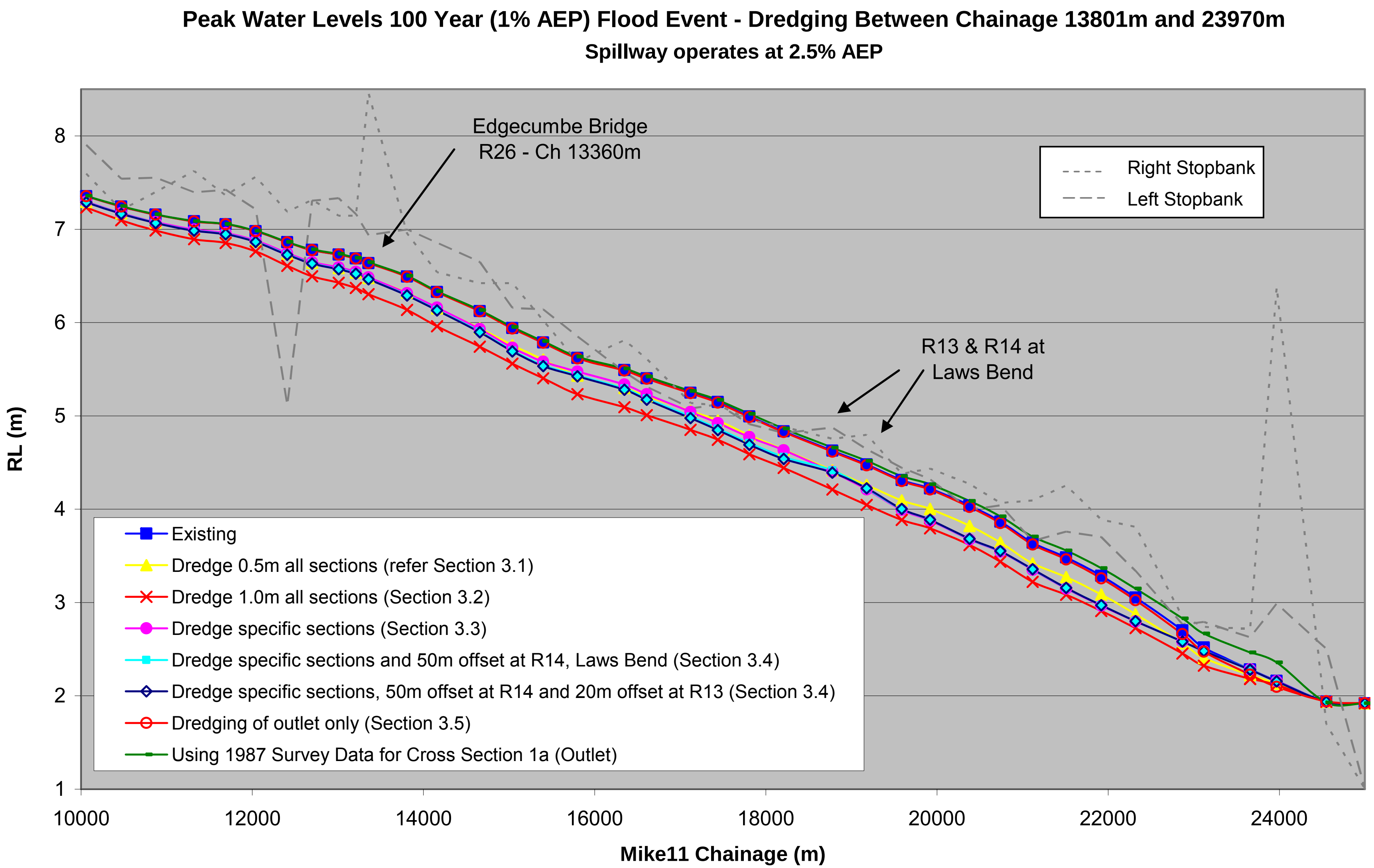



**Figure 3.3 Modelled Maximum Water Levels Under Dredging Scenarios for 100 Year Flood Event**

# 4 Reid's Floodway

The lower 4 kilometres of Reid's Floodway is very narrow and constricted relative to upstream cross sections. Cross section 9 (chainage 17784m) to the Bridge cross section (chainage 21474m) have been widened and modelled with the following three scenarios to assess the impact of widening this lower reach of the floodway:

- Widened the cross sections to make them approximately 200m wide to be consistent with upstream cross sections.
- Widened the cross sections by 50m
- Widened the cross sections by 20m

Figure 4.1 details the modelled maximum water levels from a 100 year flood in Reid's Floodway for the three scenarios as well as for the existing cross sections.

Widening the cross sections to a width of 200m to be consistent with upstream sections reduces the maximum water levels significantly, particularly from the SH2 Bridge to upstream of the confluence with the main river channel. At cross section 9 the water level drops 0.88m from 3.29m to 2.41m.

The levels between cross section 9 (chainage 17784m) and cross section 13 (chainage 15514m) are much lower after the existing constriction below cross section 9 is widened.

The widening of the cross sections by 20m and 50m shows similar patterns of reduction in peak water levels but not to the same extent. Widening by 20m still produces a significant reduction in water levels along the length of Reid's Floodway.

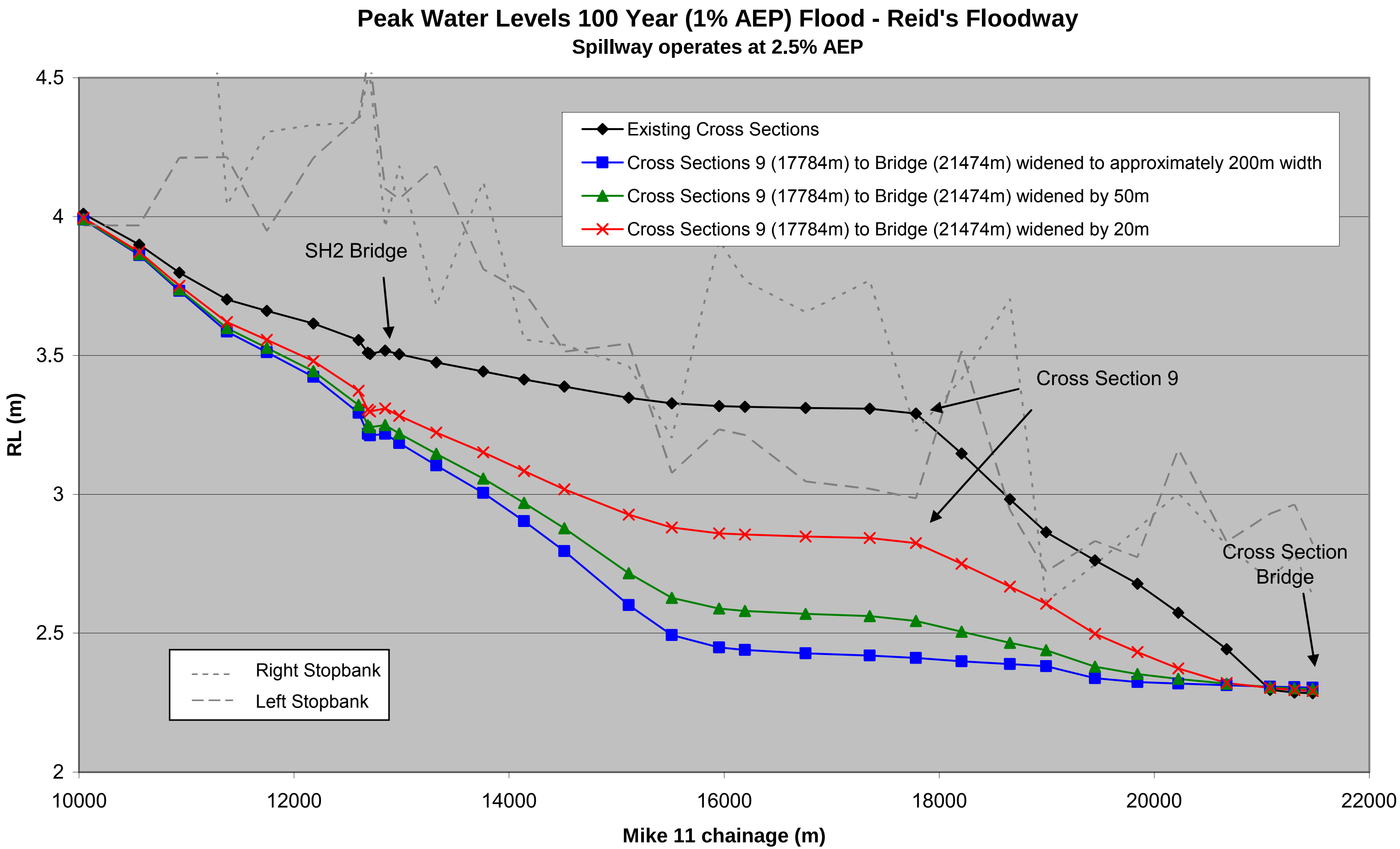



**Figure 4.1 Modelled Maximum Water Levels In Reid's Floodway Under Cross Section Widening Scenarios for 100 Year Flood Event**

In addition to widening the lower reaches of Reid's Floodway, a model scenario was developed to pass a flow of 200 $m^3/s$ from the main channel down the floodway during the 100 year flood. Essentially leaving 580 $m^3/s$ flowing down the main channel.

This was modelled for all three widening options.

Figure 4.2 shows the modelled levels in Reid's Floodway. The black line is the existing maximum levels reached in the 100 year flood event with the spillway operating at 2.5% AEP. The brown line shows no spill into the floodway.

The green, red and blue lines show the maximum levels for the three widening scenarios of 20m, 50m and 200m respectively.

Widening by 20m and passing 200 $m^3/s$ down the floodway shows no improvement over the existing situation. Widening by 50m and up to 200m show lower levels in the lower half to two thirds of the floodway.

All scenarios indicate higher levels at the top of the floodway than the existing situation.

Figure 4.3 shows the modelled levels in the main channel. All three scenarios of passing 200 $m^3/s$ down Reid's over plot each other (580 $m^3/s$ in the main channel) and are 0.48m lower than the existing situation at Edgecumbe Bridge.

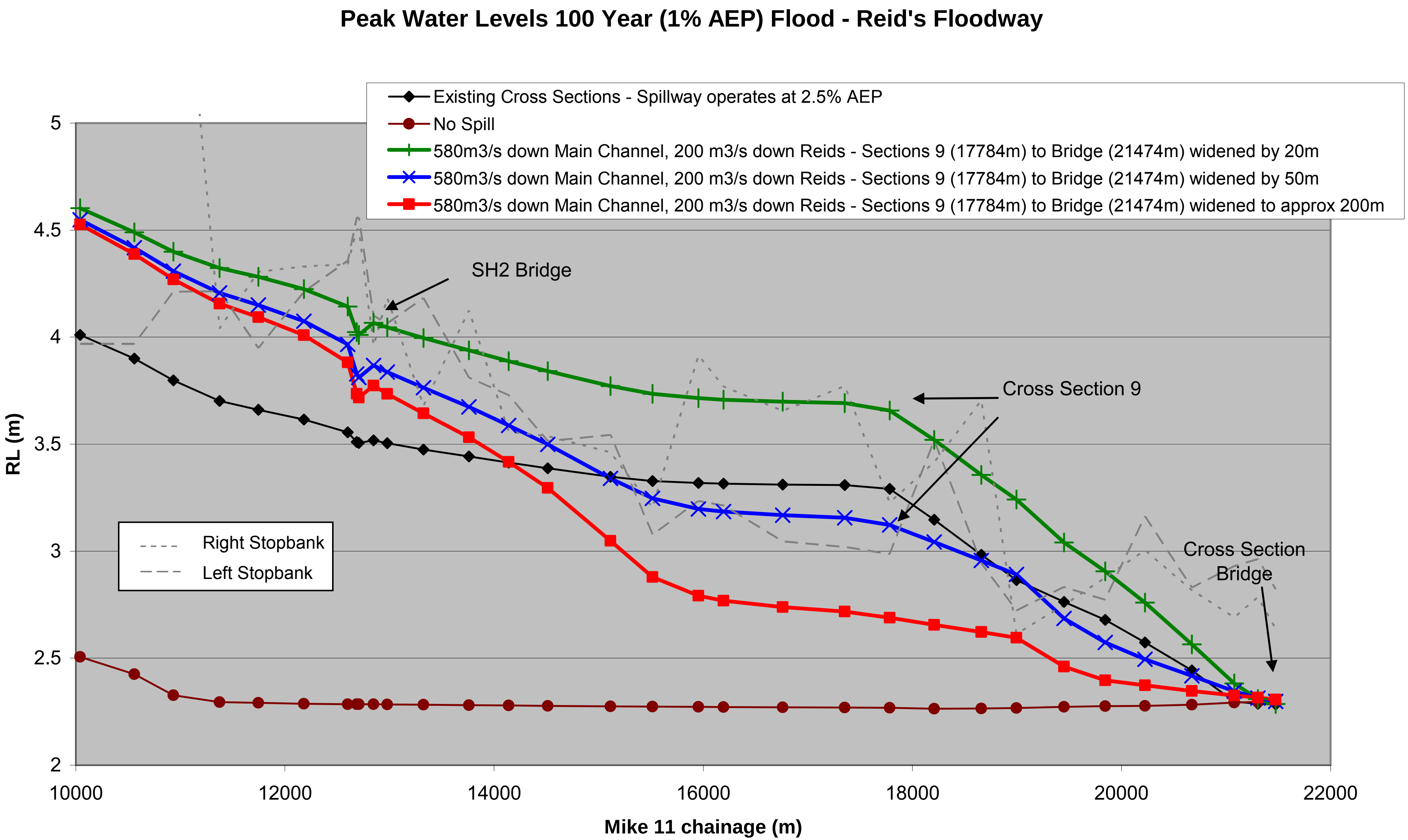

Peak Water Levels 100 Year (1% AEP) Flood - Reid's Floodway
Existing Cross Sections - Spillway operates at 2.5% AEP
No Spill
580m3/s down Main Channel, 200 m3/s down Reids - Sections 9 (17784m) to Bridge (21474m) widened by 20m
580m3/s down Main Channel, 200 m3/s down Reids - Sections 9 (17784m) to Bridge (21474m) widened by 50m
580m3/s down Main Channel, 200 m3/s down Reids - Sections 9 (17784m) to Bridge (21474m) widened to approx 200m
SH2 Bridge
Cross Section 9
Cross Section Bridge
Right Stopbank
Left Stopbank
RL (m)
Mike 11 chainage (m)
5
4.5
4
3.5
3
2.5
2
10000
12000
14000
16000
18000
20000
22000

**Figure 4.2 Modelled Maximum Water Levels In Reid's Floodway with Cross Section Widening Scenarios and Passing 200 $m^3/s$**

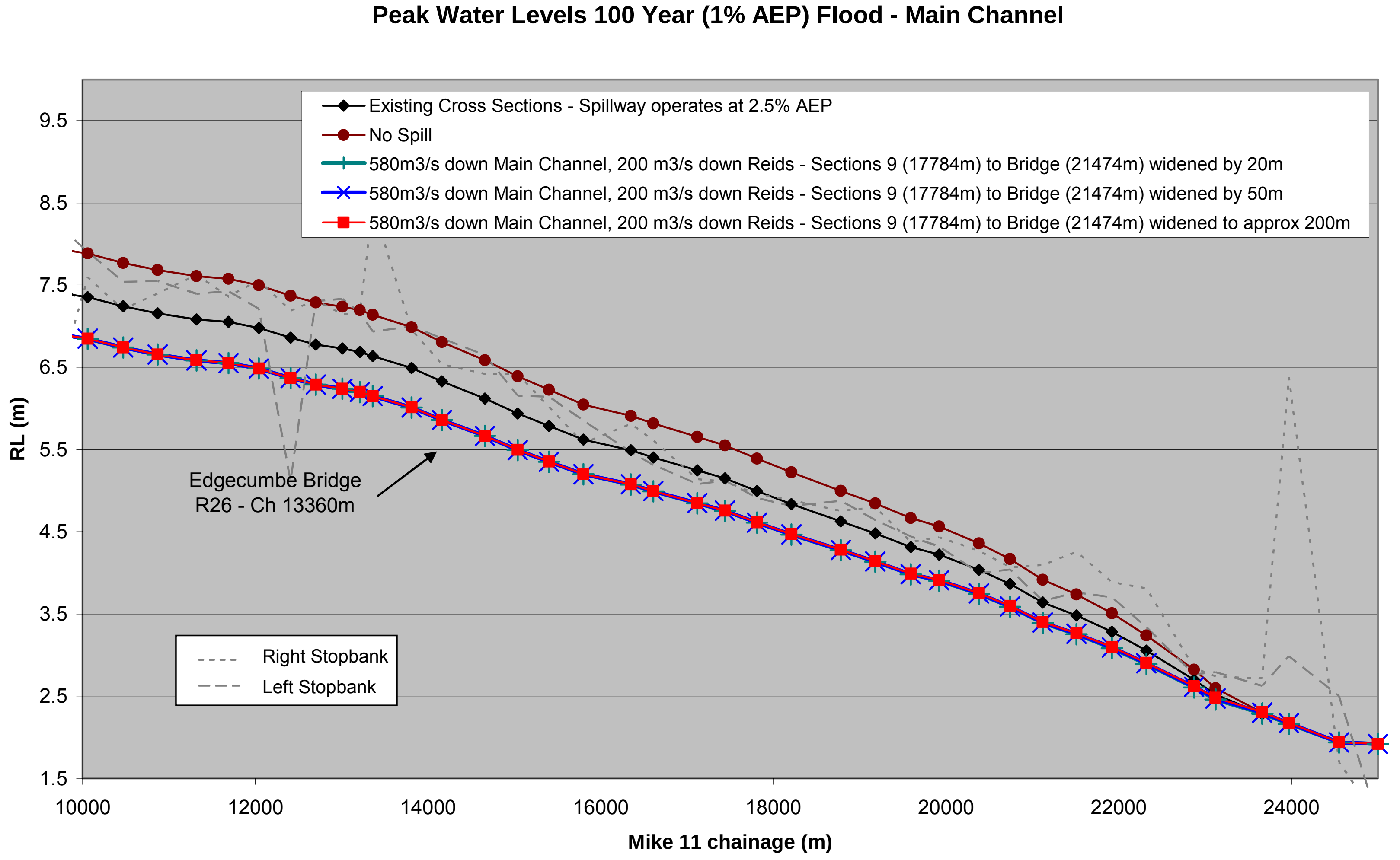



**Figure 4.3 Modelled Maximum Water Levels In Main Channel after 200 $m^3/s$ passed to Reid's Floodway**

## Appendix 2: Review of Repairs Following 2004 Flood

Several sections of the stopbank suffered erosion or slips on the riverside of the stopbank. Seepage pressures towards the river, caused by rapid drawdown as the river level subsided, likely contributed to these slips.

Detailed as-built records of repair measures at each site are not available as works were carried out on an urgent basis to restore the integrity of the system as soon as possible. Our understanding of the repairs is based an interview with Environment BoP Works Engineer, Tony Dunlop, and on photographs of the works.

The sketch below shows the repair works carried out on the left bank of the river near Eruera's Corner and is considered typical of the repair works.

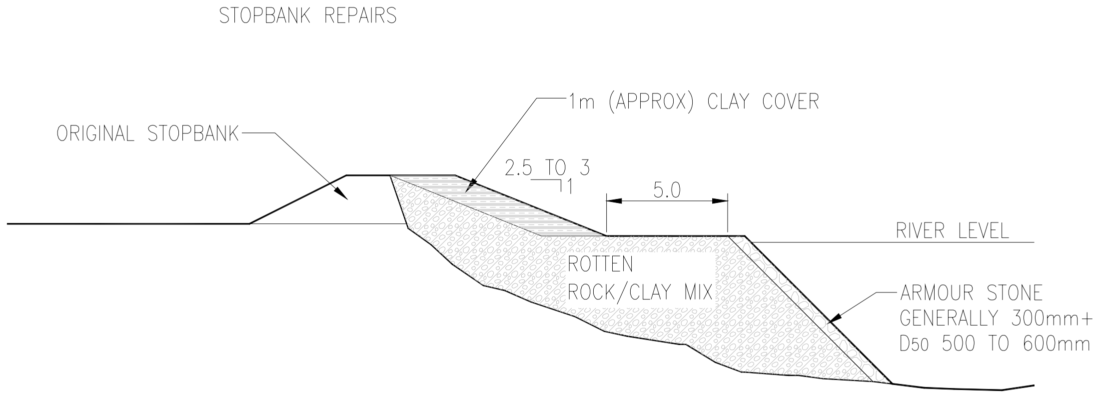
The berm and shell of the stopbank were reinstated using a mixture of "rotten" rock and clay. Material was placed up to river level by end tipping. Above the river level, nominal compaction was achieved by track-rolling only. The batter slope of the fill is uncontrolled below river, likely at or near its natural angle of repose. Above the berm, the finished batter slope is about (2.5 to 3) H:1V.

A layer of clay was placed on the inner surface of the stopbank, above the berm, to act as a seepage barrier. Armour stone, consisting of rock armour stone was placed on the underwater slope of the rotten-rock fill. Rock size was generally bigger than about 300mm, with an estimated median size of around 500 or 600mm.

In our opinion, this type of repair is appropriate for the circumstances after last year's flooding. Costs for temporary cofferdams and dewatering each site, to enable rebuilding the berm and underwater parts of the river bank with compacted material, would be prohibitive. There is no practicable alternative to end-tipping a rocky material into the river. It is expected that segregation during filling into the water may have removed some of the clay in the fill mixture, but the resulting fill is expected to have permeability as low or lower than the sand and silt layers that are typical of the plains in this area.

We suggest that the clay cover on the inner face of the repaired stopbank should be extended to cover the surface of the berm as well. This would increase the travel path for any seepage through the berm material.

Filling into the river has the potential to alter the patterns of erosion and deposition within the river channel. As the underwater part of the berm is uncompacted and is likely to have a steep slope there is some potential for erosion in the repair area, despite the layer of armour stone. We recommend that stream cross sections should be taken at regular intervals to give early warning of any erosion.


STOPBANK REPAIRS
1m (APPROX) CLAY COVER
ORIGINAL STOPBANK
2.5 TO 3
1
5.0
RIVER LEVEL
ROTTEN
ROCK/CLAY MIX
ARMOUR STONE
GENERALLY 300mm+
D50 500 TO 600mm

## Appendix 3: Scheme Estimates

TOP

**Opus International Consultants Ltd**

| ESTIMATE | | | | | |
|---|---|---|---|---|---|
| Name Of Work: | | Estimate Status: | | Funding Approval | |
| | Edgecumbe Flood Study | Prepared by: | | P Askey | |
| | | Quantities: | | PA | 7-Jul-07 |
| | Scheme 1 : | Rates: | | PA | May 07 |
| | Edgecumbe South East | Checked: | | LA | July 07 |
| | Increased std to transpower | | | | |
| | | Approved: | | PA | July 07 |
| File: | | | | | |
| Item | Description | Unit | Qty | Rate | Amount |
| | | | | | |
| | PRELIMINARY & GENERAL | | | | 20,000.00 |
| | | | | | |
| 1 | STOPBANKING | | | | |
| 1.1 | Easements | LS | 1 | 5000.00 | 5,000.00 |
| 1.2 | Survey | LS | 1 | 5000.00 | 5,000.00 |
| 1.3 | Geotechnical investigations | LS | 1 | 10000.00 | 10,000.00 |
| 1.4 | Foundations | | | | |
| 1.4.1 | Undercut | m3 | 1650 | 5.00 | 8,250.00 |
| 1.4.2 | Backfill with imported fill | m3 | 1650 | 28.00 | 46,200.00 |
| 1.4.3 | Cutoff | m | 1290 | 25.00 | 32,250.00 |
| | | | | | |
| 1.5 | STOPBANK CONSTRUCTION WITH IMPORTED FILL | | | | |
| 1.5.1 | Base case raise by 0.6 m | m3 | 3950 | 28.00 | 110,600.00 |
| 1.5.2 | Additional 0.5 m to reids bank over 200m | m3 | 1650 | 28.00 | 46,200.00 |
| 1.5.3 | Raise Upstream bank to RL 5.8 m | m3 | 3150 | 28.00 | 88,200.00 |
| 1.5.4 | new downstream bank to RL 5.5m | m3 | 708 | 28.00 | 19,824.00 |
| 1.5.5 | Raise tanker access road | m3 | 150 | 50.00 | 7,500.00 |
| 1.5.6 | Rock armour to upstream bank | m3 | 480 | 70.00 | 33,600.00 |
| | | | | | |
| 2 | ROAD RECONSTRUCTION | | | | |
| 2.1 | Raise and resurface | m2 | 800 | 30.00 | 24,000.00 |
| 2.2 | Stoplogs | m3 | 4 | 500.00 | 2,000.00 |
| | | | | | |
| 3 | FLOOD PUMPING | | | | |
| 3.1 | Access | LS | 1 | 3000.00 | 3,000.00 |
| 3.2 | Hardstand | LS | 1 | 1000.00 | 1,000.00 |
| 3.3 | Concrete discharge sluice | LS | 1 | 2000.00 | 2,000.00 |
| 3.4 | Pump unit | ea | 1 | 15000.00 | 15,000.00 |
| | | | | | |
| 4.0 | DRAINAGE | | | | |
| 4.1 | Low level outlet already in place | | | | 0.00 |
| | | | | | |
| 5.0 | REINSTATEMENT & COMPENSATION | m | 900 | 25.00 | 22,500.00 |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | SUBTOTAL | | | | 502,124.00 |
| | | | | | |
| | RESOURCE CONSENTS | | | | 20,000.00 |
| | | | | | |
| | ENGINEERING @ 8% | | | | 17,000.00 |
| | | | | | |
| | CONTINGENCY @ 30% | | | | 150,637.20 |
| | | | | | |
| | **Estimate Total** (excl. GST) | | | | $689,761.20 |

TOP

**Opus International Consultants Ltd**

# ESTIMATE

| | | | | | |
|---|---|---|---|---|---|
| Name Of Work: | | Estimate Status: | | Funding Approval | |
| | Edgecumbe Flood Study | Prepared by: | | P Askey | |
| | | Quantities: | | PM | 1/06 |
| | Scheme 2 : | Rates: | | PA | May 07 |
| | Edgecumbe North East | Checked: | | LA | May 07 |
| | | | | | |
| | | Approved: | | PA | May 07 |
| File: | | | | | |

| Item | Description | Unit | Qty | Rate | Amount |
|---|---|---|---|---|---|
| | | | | | |
| | PRELIMINARY & GENERAL | | | | 10,000.00 |
| | | | | | |
| 1 | STOPBANKING | | | | |
| 1.1 | Easements | LS | 1 | 5000.00 | 5,000.00 |
| 1.2 | Survey | LS | 1 | 5000.00 | 5,000.00 |
| 1.3 | Geotechnical investigations | LS | 1 | 10000.00 | 10,000.00 |
| 1.4 | Foundations - Bank top up | | | | |
| 1.4.1 | Undercut | m3 | 1050 | 5.00 | 5,250.00 |
| 1.4.2 | Backfill with imported fill | m3 | 1050 | 28.00 | 29,400.00 |
| 1.4.3 | Cutoff | m | 700 | 25.00 | 17,500.00 |
| 1.5 | Foundations - new bank | | | | |
| 1.5.1 | Undercut | m3 | 2250 | 5.00 | 11,250.00 |
| 1.5.2 | Backfill with imported fill | m3 | 2250 | 28.00 | 63,000.00 |
| 1.5.3 | Cutoff | m | 500 | 25.00 | 12,500.00 |
| | | | | | |
| 1.6 | Stopbank Construction with imported fill | | | | |
| 1.6.1 | Top up existing reids bank | m3 | 3990 | 28.00 | 111,720.00 |
| 1.6.2 | new return bank to eastbank Rd | m3 | 9500 | 28.00 | 266,000.00 |
| | | | | | |
| 2 | ROAD RECONSTRUCTION | | | | |
| 2.1 | Raise and resurface Eastbank rd 200 m | m2 | 1200 | 10.00 | 12,000.00 |
| 2.2 | Raise and resurface SH 2 - assume part of reids bridge replacement | | | | |
| | | | | | |
| 3 | FLOOD PUMPING | | | | |
| 3.1 | Access - Existing | | | | nil |
| 3.2 | Hardstand | LS | 1 | 1000.00 | 1,000.00 |
| 3.3 | Concrete discharge sluice | LS | 1 | 2000.00 | 2,000.00 |
| | | | | | |
| 4.0 | DRAINAGE | | | | |
| 4.1 | Low level outlet | m | 12 | 300.00 | 3,600.00 |
| 4.2 | Flapgate | ea | 1 | 3000.00 | 3,000.00 |
| | | | | | |
| 5.0 | REINSTATEMENT & COMPENSATION | m | 900 | 25.00 | 22,500.00 |
| | | | | | |
| | SUBTOTAL | | | | 590,720.00 |
| | | | | | |
| | RESOURCE CONSENTS | | | | 5,000.00 |
| | | | | | |
| | ENGINEERING @ 8% | | | | 36,000.00 |
| | | | | | |
| | CONTINGENCY @ 30% | | | | 177,216.00 |
| | | | | | |
| **Estimate Total** (excl. GST) | | | | | $808,936.00 |

TOP

**Opus International Consultants Ltd**

# ESTIMATE

| | | | | | |
|---|---|---|---|---|---|
| Name Of Work: | | Estimate Status: | | Funding Approval | |
| | Edgecumbe Flood Study | Prepared by: | | P Askey | |
| | | Quantities: | PDA | PM | Feb 06 |
| | | Rates: | PDA | PA | May 07 |
| | Edgecumbe South West | Checked: | LA | LA | May 07 |
| | Scheme 3a - Low banks | | | | |
| | | Approved: | PDA | PA | May 07 |
| File: | | | | | |

| Item | Description | Unit | Qty | Rate | Amount |
|---|---|---|---|---|---|
| | | | | | |
| | PRELIMINARY & GENERAL | | | | 50,000.00 |
| | | | | | |
| 1 | STOPBANKING | | | | |
| 1.1 | Easements | LS | 1 | 20000.00 | 20,000.00 |
| 1.2 | Survey | LS | 1 | 8000.00 | 8,000.00 |
| 1.3 | Geotechnical investigations | LS | 1 | 15000.00 | 15,000.00 |
| 1.4 | Foundations to new bank | | | | |
| 1.4.1 | Undercut & backfill | m3 | 1200 | 28.00 | 33,600.00 |
| | | | | | |
| 1.5 | Stopbank Construction with imported fill | | | | |
| 1.5.1 | Construct new Bank | m3 | 5600 | 28.00 | 156,800.00 |
| | | | | | |
| | | | | | |
| 2 | FLOOD PUMPING | | | | |
| 2.1 | Access | LS | 1 | 2000.00 | 2,000.00 |
| 2.2 | Pump station civil works | LS | 1 | 48000.00 | 48,000.00 |
| 2.3 | Pump & Electrical | LS | 1 | 60500.00 | 60,500.00 |
| 2.4 | Generator unit & Housing | ea | 1 | 60000.00 | 60,000.00 |
| 2.5 | Power supply | LS | 1 | 30000.00 | 30,000.00 |
| 2.6 | Discharge line to River | m | 300 | 250.00 | 75,000.00 |
| 2.7 | Discharge outlet | LS | 1 | 1000.00 | 1,000.00 |
| | | | | | |
| 3.0 | DRAINAGE | | | | |
| 3.1 | Low level outlet 900 mm RCRRJ | m | 12 | 400.00 | 4,800.00 |
| 3.2 | Headwall & Flapgate | LS | 1 | 7500.00 | 7,500.00 |
| | | | | | |
| 4.0 | REINSTATEMENT & COMPENSATION | m | 750 | 25.00 | 18,750.00 |
| | | | | | |
| | | | | | |
| | | | | | |
| | SUBTOTAL | | | | 590,950.00 |
| | | | | | |
| | RESOURCE CONSENTS | | | | 10,000.00 |
| | | | | | |
| | ENGINEERING @ 8% | | | | 40,000.00 |
| | | | | | |
| | CONTINGENCY @ 30% | | | | 177,285.00 |
| | | | | | |

**Estimate Total (excl. GST)** $818,235.00

TOP

**Opus International Consultants Ltd**

# ESTIMATE

| | | | | | |
|---|---|---|---|---|---|
| Name Of Work: | | Estimate Status: | | Funding Approval | |
| | Edgecumbe Flood Study | Prepared by: | | P Askey | |
| | | Quantities: | | PM | Feb 06 |
| | | Rates: | | PA | May-07 |
| | Edgecumbe North West | Checked: | | LA | May 07 |
| | Scheme 4b - Low Bank | | | | |
| | | Approved: | | PA | Sep-07 |
| File: | | | | | |
| **Item** | **Description** | **Unit** | **Qty** | **Rate** | **Amount** |
| | | | | | |
| | PRELIMINARY & GENERAL | | | | 50,000.00 |
| | | | | | |
| 1 | STOPBANKING | | | | |
| 1.1 | Easements | LS | 1 | 20000.00 | 20,000.00 |
| 1.2 | Survey | LS | 1 | 8000.00 | 8,000.00 |
| 1.3 | Geotechnical investigations | LS | 1 | 15000.00 | 15,000.00 |
| 1.4 | Foundations to new bank | | | | |
| 1.4.1 | Undercut | m3 | 650 | 5.00 | 3,250.00 |
| 1.4.2 | Backfill with imported fill | m3 | 650 | 28.00 | 18,200.00 |
| 1.4.3 | Cutoff | m | 0 | 25.00 | 0.00 |
| | | | | | |
| 1.5 | Stopbank Construction with imported fill | | | | |
| 1.5.1 | Construct new Bank | m3 | 4830 | 28.00 | 135,240.00 |
| | | | | | |
| | | | | | |
| 2 | FLOOD PUMPING | | | | |
| 2.1 | Access | LS | 1 | 5000.00 | 5,000.00 |
| 2.2 | Pump station civil works | LS | 1 | 48000.00 | 48,000.00 |
| 2.3 | Pump & Electrical | LS | 1 | 61000.00 | 61,000.00 |
| 2.4 | Generator unit | ea | 1 | 60000.00 | 60,000.00 |
| 2.5 | Power supply | LS | 1 | 30000.00 | 30,000.00 |
| | | | | | |
| 3.0 | DRAINAGE | | | | |
| 3.1 | Low level outlet 900 mm RCRRJ | m | 12 | 400.00 | 4,800.00 |
| 3.2 | Headwall & Flapgate | LS | 1 | 7500.00 | 7,500.00 |
| 3.3 | Redirect farm drain | m | 160 | 20.00 | 3,200.00 |
| | | | | | |
| 4.0 | REINSTATEMENT & COMPENSATION | m | 790 | 31.00 | 24,490.00 |
| | | | | | |
| 5.0 | SOLDIERS RD PUMP STATION UPGRADE | LS | 1 | 115000.00 | 115,000.00 |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | SUBTOTAL | | | | 608,680.00 |
| | | | | | |
| | RESOURCE CONSENTS | | | | 50,000.00 |
| | | | | | |
| | ENGINEERING @ 8% | | | | 50,000.00 |
| | | | | | |
| | CONTINGENCY @ 30% | | | | 182,604.00 |
| | | | | | |
| | **Estimate Total (excl. GST)** | | | | $891,284.00 |

TOP

**Opus International Consultants Ltd**

# ESTIMATE

| | | | | | |
|---|---|---|---|---|---|
| Name Of Work: | | Estimate Status: | | Rough Order | |
| | Edgecumbe Flood Study | Prepared by: | | P Askey | |
| | | Quantities: | | PM | 1/06 |
| | Scheme 5 | Rates: | | PA | May 07 |
| | Lower Channel dredging | Checked: | | LA | May 07 |
| | | | | | |
| | | Approved: | | PA | May 07 |
| File: | | | | | |
| **Item** | **Description** | **Unit** | **Qty** | **Rate** | **Amount** |
| | | | | | |
| | PRELIMINARY & GENERAL | | | | 500,000.00 |
| | | | | | |
| 1 | DREDGING | | | | |
| 1.1 | Dredging of river bed | m3 | 286000 | 8.00 | 2,288,000.00 |
| 1.2 | Resurvey | LS | 1 | 16000.00 | 16,000.00 |
| | | | | | |
| 2 | DUMPSITE (Assumed to 1.5m depth) | | | | |
| 2.1 | Strip topsoil | ha | 20 | 6000.00 | 120,000.00 |
| 2.2 | cart in dredge spoil | m3 | 286000 | 5.00 | 1,430,000.00 |
| 2.3 | Uplift and respread topsoil | ha | 20 | 6000.00 | 120,000.00 |
| 2.4 | Regrassing | ha | 20 | 1200.00 | 24,000.00 |
| | | | | | |
| | SUBTOTAL | | | | 4,498,000.00 |
| | | | | | |
| | RESOURCE CONSENTS | | | | 100,000.00 |
| | | | | | |
| | ENGINEERING @ 5% | | | | 224,900.00 |
| | | | | | |
| | CONTINGENCY @ 50% | | | | 2,249,000.00 |
| | | | | | |
| | **Estimate Total (excl. GST)** | | | | $7,071,900.00 |

TOP

**Opus International Consultants Ltd**

# ESTIMATE

| | | | | | |
|---|---|---|---|---|---|
| Name Of Work: | | Estimate Status: | | Funding Approval | |
| | Edgecumbe Flood Study | Prepared by: | | PA | |
| | | Quantities: | | PM | Sept 06 |
| | Scheme 6 : | Rates: | | PA | May 07 |
| | Reids Floodway Widening | Checked: | | LA | May 07 |
| | | | | | |
| | | Approved: | | | May 07 |
| File: | | | | | |
| **Item** | **Description** | **Unit** | **Qty** | **Rate** | **Amount** |
| | | | | | |
| | PRELIMINARY & GENERAL | | | | 50,000.00 |
| | | | | | |
| 1 | STOPBANKING | | | | |
| 1.1 | Easements | LS | 1 | 20000.00 | 20,000.00 |
| 1.2 | Survey | LS | 1 | 16000.00 | 16,000.00 |
| 1.3 | Geotechnical investigations | LS | 1 | 40000.00 | 40,000.00 |
| 1.4 | Foundations to new bank | | | | |
| 1.4.1 | Undercut | m3 | 16650 | 5.00 | 83,250.00 |
| 1.4.2 | Backfill with imported fill | m3 | 16650 | 28.00 | 466,200.00 |
| 1.4.3 | Cutoff | m | 3700 | 25.00 | 92,500.00 |
| | | | | | |
| 1.5 | Stopbank Construction with imported fill | | | | |
| 1.5.1 | Construct new Bank | m3 | 107650 | 28.00 | 3,014,200.00 |
| | | | | | |
| 2 | ANCILLARY WORKS | LS | 1 | 234000.00 | 234,000.00 |
| | | | | | |
| 3 | COMPENSATION & RESTORATION | m | 3700 | 30.00 | 111,000.00 |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | SUBTOTAL | | | | 4,127,150.00 |
| | | | | | |
| | RESOURCE CONSENTS | | | | 20,000.00 |
| | | | | | |
| | ENGINEERING @ 5% | | | | 150,000.00 |
| | (note /m3 rate includes supervision) | | | | |
| | CONTINGENCY @ 30% | | | | 1,238,145.00 |
| | | | | | |
| | **Estimate Total** (excl. GST) | | | | $5,535,295.00 |