



MANAWATU RIVER AT RUAHINE ST CARPARK—FEB '04

This is landscape architects jargon for collection of features such as viewing platforms, sculptures, and planting.

While much of the enhancement work does not contribute directly to improving flood protection, it certainly will not negate any flood protection work, and it is practical to carry out both projects in parallel.

The provisional estimate for the enhancement works is \$2.75 million.

Peer Review of Design

The new design stopbank levels have been subjected to a peer review. The peer review team consisted of two engineers with long experience in different aspects of river management and flood control schemes, and computer simulation of river flows.

Calculation of levels for such a large flood is a very challenging task, given that the flood is much larger than any flood in living memory. Experienced judgement is an important part of the computer simulation, it is not simply a matter of feeding in numbers and accepting the result uncritically.

The peer review has been thorough, has included a number of meeting and discussions between Council design staff and the peer review team, and has resulted in a consensus about the design stopbank levels.

Project Cost and Sequencing of the Works

The project is expected to cost \$11.5 million, and the work will be spread over a seven year period, starting in 2007-08, and finishing in 2013-14. A small amount of stopbanking in the worst location will be upgraded in 2006-07. That work has already commenced.

It would be desirable to do the work faster than this, but unfortunately that is not realistic. There are difficulties associated with doing work in private residential properties, in close proximity to urban infrastructure, and in places readily accessible to the public. There will be high levels of demand placed on staff time. Given that a major upgrade of the Lower Manawatu Scheme is already taking place in rural areas, and placing heavy demands on staff resources, it would not be realistic to attempt to resource the City Reach project in a period shorter than seven years.

The seven year programme has been planned on the basis of priorities. Stopbanks with the most serious height deficiency will be upgraded first. The priorities determine that stopbank raising work will mostly start at the upstream end and progress in the downstream direction. Rock lining construction has been programmed according to the risk of lateral erosion, and therefore the risk of undermining failure of stopbanks.

A consequence of carrying out the work in descending priority order is that the first year of work will improve the flood protection much more than the seventh year.

The river realignment at Anzac Park cliff will take place over the summer of 2008-09, which is the earliest practicable time, given the need for investigations, design, consents, and sourcing of rock. The contribution from the developer is dependant on the work being done early, because the benefits of the work reduce as the cliff continues to erode. A considerable reduction in the cost of the project results from carrying out this item of the works programme sooner rather than later. It is also desirable to mitigate the safety hazard as soon as practicable.

Funding

The works carried out in 1995-2001 were funded by a special targeted rate, and an associated loan that will be completely paid back in June 2009. The original intention was that the special targeted rate should be terminated in June 2009.

It is now proposed that the rate should not be terminated, but that the loan should be extended for a further 15 years, and the rate increased from the current \$12.11 for every \$100,000 of capital value to about \$20 for every \$100,000 of capital value. This increase would be introduced gradually over a period of three years.

Consultation

A "City Reach Upgrade Working Party" was formed late in 2006. It comprises councillors and officers from Horizons and Palmerston North City Council. The working party is fully supportive of the project, and has specifically approved the 4500 cumec design standard, as well as being supportive of the various elements of the project described above.

Palmerston North City ratepayers have an opportunity to make submissions on this proposed project during Horizons' Draft Annual Plan consultation process. Written and oral submissions can be made from 3 April 2007 until 5pm 4 May 2007. Submissions will be heard on 21 and 23 May 2007.

FREEPOST 374
Horizons Regional Council
City Reach Submissions
Private Bag 11025
PALMERSTON NORTH

KEEPING PEOPLE SAFE

March 2007

Keeping Palmerston North Dry (Long Version)



HOKOWHITU SCHOOL—MAY 1941

Introduction

On 16 February 2004 many Palmerston North residents witnessed the power of the Manawatu River as it carried its largest flood since 14 June 1902. The flow was high, powerful and turbulent, but was successfully contained by stopbanks, those earth embankments that have been built to keep the water out of Palmerston North. In places the water was more than two metres higher than the ground on the City side of the stopbank.

Had the stopbanks collapsed, it is likely that between 1000 and 2000 houses would have had water through them. Had it happened without warning, lives could have been lost.

The 16 February 2004 flood is not the largest flood on record. Floods in 1880 and in 1902 were definitely larger, and the flood of 1897 might have been larger. Much is at stake, and while we received some reassurance on that day, we need to plan for floods larger than the February 2004 flood.

The Proposed Upgrade of Palmerston North's Flood Protection

In December 2006 Horizons Regional Council resolved to include in its 2007-08 Draft Annual Plan a proposal to spend \$11.5 million over a period of seven years to upgrade the city's protection against being flooded by the Manawatu River.

The proposal is to provide protection against a flood larger than any experienced since records began in 1880. This newsletter sets out details of the proposal, and explains your opportunities to provide your input.

Early History of Flood Protection Works

The threat of flooding from the Manawatu River has always been apparent.

Much of the residential development of early European times did not occur on low-lying ground, and was not seriously at risk from Manawatu River floods. Our earliest aerial photographs, taken in 1942, show that much of the area at risk from the Manawatu River was occupied by low density rural-residential properties. Five and ten acre blocks were common.

In May 1941 the river flooded about 250 hectares of the city. Much of that area was rural-residential, but some of it was relatively high density residential development. The water travelled some distance away from the river, and reached the intersection of Ferguson and Albert Streets. The flow in the river was quite large, but not exceptional.

Sometime before 1941, the Palmerston North River Board had constructed stop banking between Fitzroy Street and Jickell Street, but it proved to be inadequate during the 1941 flood. After 1941 the height of the stopbanks was increased. When a larger flood occurred in January 1953, most of the stopbanking was effective, and flooding of the city was limited to a much smaller area around Manawatu St and the south end of Albert Street. The safety margin was however worryingly small.

The Lower Manawatu Flood Control Scheme

Between 1959 and 1965, an ambitious project called "The Lower Manawatu Flood Control Scheme" was constructed. The Scheme protects 280 square kilometres of pastoral, horticultural and urban land from flooding by the Manawatu River and its major tributaries between Ashhurst and the sea.

The Lower Manawatu Scheme (LMS) boundaries are legally defined on a map, and all property owners within the scheme boundary pay rates according to the degree of benefit they receive. The rate payable is a proportion of the capital value of the property.

The Scheme relies mainly on stopbanks to contain the water. A total length of 250 kilometres of stopbanking was constructed, with 150 kilometres containing the Manawatu River, and a further 100 kilometres containing the major tributaries.

Other works include riverbank protection in the form of linings made of rock or concrete rubble, and live willow protection. The purpose is to prevent the river from eroding the ground out from underneath the stopbanks.

The Moutoa Sluiceways, near Shannon, divert excess flood flows through the Moutoa Floodway, which bypasses a low capacity, flat-graded, winding reach of river. The Floodway returns the water to the river near Foxton, where the river is once again large enough to carry major flood flows. Despite a popular misconception, operation of the Moutoa Sluiceways has no effect on river levels at Palmerston North, because the gates are too far away.

Palmerston North's flood protection is provided entirely by 8 km of stop banking, and associated riverbank protection works to prevent the stopbanks from being undermined. The intention of the Lower Manawatu Scheme was to provide protection against the "100 year flood", with a generous safety margin at Palmerston North, and, for economic reasons, a somewhat less generous safety margin in the rural areas.

The “100 Year Flood”

The “100 year flood” is a colourful, much used term. While it is graphically illustrative, it can also be confusing because sometimes it is used wrongly or inaccurately. Sometimes people mean only that the flood in question was very large.

The term has a technical basis. Regional Councils keep records of the size of floods in their important rivers, and estimate the size of a 100 year flood by applying a statistical process to those records. Being statistical, the estimate is always approximate, and the shorter the period of record, the less accurate the estimate.

There are some things the term does not mean. It does not mean that if we have a 100 year flood now, 100 years will elapse before the next such a flood. It is quite possible to have two 100 year floods close together.

Other factors add to the difficulties in being precise about a 100 year flood. Unless we have a very long period of record, the 100 year flood estimate will change appreciably each time we have a very large flood. This is inevitable. A return period estimate is a statement about the past. It is based on floods known to have occurred in the past. Floods that are yet to occur in the future can not be included, because we do not know when they will occur, or how large they will be.

Climate change causes 100 year flood estimates to be something of a moving target. The 100 year flood will become larger and larger as time goes by.

The 100 years is known as the “return period”. It implies that over a very long period of time, on average 100 years will elapse between floods of this size. The definition is not particularly helpful, because it assumes that the overall climate does not change, and we now know that to be untrue.

A more helpful definition refers to the probability of the flood being equalled or exceeded in any given year, rather than the average interval between the floods. Thus a 100 year flood is also known as a “1% Annual Exceedance Probability” flood, or a 1% AEP flood.

How Likely is it that a House will be Flooded if it has 100 Year Protection?

A 1% AEP flood has a 1% chance of being equalled or exceeded this year. It also has a 1% chance next year, and again the year after. Over a long period, the 1%’s accumulate, and so a 100 year protection standard is not quite as reassuring as it initially seems.

The typical lifetime of a house in New Zealand is variable, but many houses reach an age of 80 to 100 years before they need an overhaul so major that demolition is a serious alternative. If, for example, a period of 80 years is considered, there is a 55% chance that the 100 year flood will be equalled or exceeded during the lifetime of the house. There is also an 80% chance that the 50 year flood will be equalled or exceeded, and a 15% chance that the 500 year flood will be equalled or exceeded.

During the lifetime of a typical New Zealand house, it is more likely than not that the 100 year flood will occur. However the house has a very good chance of not experiencing a 500 year flood.

Standards of Flood Protection Higher than the “100 Year Flood”

For many years the traditional practice was to provide residential development with flood protection to resist a 100 year flood.

In more recent years, both in New Zealand and overseas, there has been a trend to provide higher levels of protection to major urban areas. Flood protection of higher than 100 year standard is planned or in place for Upper and Lower Hutt, Christchurch, Ashburton, and Papamoa (Tauranga) as well as Palmerston North.

A very high standard of flood protection is partly a matter of economics. The cost of the damage cause by extreme floods can be weighed against the likelihood of the floods occurring, and the cost of works to prevent or minimise flood damage. This is a type of cost/benefit analysis, and usually shows that a very high standard of flood protection, frequently much larger than the 100 year flood, can be justified.

As well as pure economic considerations, the social consequences of large scale flooding need to be considered, as was demonstrated in New Orleans in August 2005. Palmerston North does not face a flood hazard on quite that scale, but it could potentially experience a disaster much larger than any Civil Defence emergency experienced to date in New Zealand.

During an extreme flood in the Manawatu River, if flood protection works fail the number of houses flooded could number in the thousands, and if there is no warning there could be fatalities. The scale of the potential catastrophe would have devastating and far reaching consequences for the community in many ways.

The Size of Large Floods in the Manawatu River

The Manawatu River has one of the longest hydrological records in the country. An automatic water level recorder was installed near the Fitzherbert Bridge in 1929, and river levels have been recorded continuously since then. Before that, records were kept of the highest flood in each year from 1902 to 1929. Reasonably reliable information also exists about very large floods in 1880 and 1897.

Floods can be compared by comparing river levels, but frequently it is more convenient to compare rates of flow, or “discharge”, which is measured in “cubic metres per second”, usually abbreviated to “cumecs”. Frequent measurements made by the Horizons Hydrology team mean that for all of our major rivers, if we know the river level at any recorder site, we know the discharge.

Thus we know that on 16 February 2004, between noon and 9.00pm, 3500 cubic metres of water flowed under the Fitzherbert bridge every second. The discharge was 3500 cumecs.

The table below gives the discharges for the ten largest known floods since 1880.

RANK	YEAR	DISCHARGE (CUMECs)
1	1880	4000
2	1902	3800
3	2004	3500
4	1907	3340
5	1897	3300
6	1953	3175
7	1992	2830
8	1965	2745
9	1906	2615
10	1941	2605

Upgrade Works Needed to Provide Protection Against 4500 cumecs

All of the 8 kilometres of existing stopbanks will have to be raised. The worst location is just upstream of Ruamahanga Crescent, where the stopbank will be built up by nearly 1.6 metres. That work is in progress at the time of writing this newsletter. The amount of fill that has to be added to the stopbank decreases in the downstream direction, until at the end of Albert Street only about 300mm needs to be added.

From Sharon Place (off Buick Cres) downstream the amount of fill that has to be added to the stopbank again increases. At the worst location near the sewage treatment plant, just over a metre has to be added to the stopbank height.

Some properties in Buick Crescent currently have no stopbank, but will need to have a stopbank or floodwall if full protection is to be provided to the city. There will be a number of ways of achieving our objectives in each case. Each property will be inspected, and the issues discussed with the property owner. Every endeavour will be made to find a way to achieve the necessary flood protection in a way that minimises the impact on individual properties.

New rock linings will be placed, with a total length of 2.1 kilometres. The first of these rock linings will be placed at Dittmer Drive, between the two rock linings already in existence. The next will be placed upstream of the Fitzherbert Bridge, and a third will be placed between the Napier Road drain and the upstream end of the Palmerston North Golf Course.

Realignment of the Manawatu River at Anzac Park Cliff

The largest single item of work in the proposed project is a realignment of the river adjacent to the Anzac Park cliff.

The Anzac Park Cliff is the 50 metre high cliff 700 metres downstream of Albert Street. The river hits the cliff, and turns a sharp right angle to the right. The river has been eroding the cliff for many years, and the cliff was retreating at a rate of one metre per year for a number of years preceding 2004. Since February 2004 the rate of retreat has increased.

One effect of the very sharp turn in river direction is that flood levels are elevated upstream of the cliff for some distance. Another effect is that eventually the river will start to attack the river bank on the city side of the river downstream of the cliff. The nearby stopbank would ultimately be endangered, and another expensive rock lining would probably be needed.

If the effects of the cliff on the flood protection scheme were the only effects to be considered, it would be less expensive to raise the stopbanks and construct the rock lining than it would be to realign the river. However other factors also need to be taken into account.

Land near the top of the cliff is being progressively subdivided, and high value housing developments are occurring. There is currently a building line which prevents houses being built within 150 metres of the most actively eroding section of the cliff. At the time of deciding the building line location (in 1993) it was conservatively estimated that the cliff top could reach the building line about 100 years later.

The proposal is therefore that further erosion of the cliff be prevented by excavating a new channel to move the river away

from the cliff, and make the sharp river bend much more gradual. Erosion of the cliff would be prevented. The project would have similarities with the Fitzroy Bend realignment carried out in 1996-97. However the realigned length would be a little shorter, and the new alignment would be held in place by a rock lining rather than heavy rock groynes.

A proposal has been discussed whereby Horizons will carry out the river alignment, and the developer will lower the height of the cliff, flatten its slope, and plant trees on it. Since the realignment provides a benefit to the developer, he has indicated a preparedness make a substantial contribution to the cost of the realignment.

The Mangaone Stream

The Mangaone Stream has a 180 square kilometre catchment, with its headwaters in the hills between Cheltenham and Pohangina township. It flows into the Manawatu River near the Awapuni landfill, and is contained by stopbanks for most of its course through Palmerston North. The stopbanks are maintained as part of the Lower Manawatu Scheme.

The stream is obviously much smaller than the Manawatu River, but nonetheless is able to carry enough water to cause serious flooding in Palmerston North. If a stopbank failed, it could flood hundreds of houses and cause tens of millions of dollars worth of damage.

The stream is not able to carry more than a ten year flood in its channel through Palmerston North. Flood carrying capacity could not be increased without spending unaffordable sums of money on lengthening ten bridges, and buying and relocating a large number of houses.

The extra water is therefore allowed to spill out of the stream at two spillway locations, near Robert’s Line and Flyger’s Line. The water flows across farmland in a westerly direction, to the north of the city. It has always done this, and although some reduction in frequency of flooding has been achieved, it is likely that this land will always be floodable.

Stopbanking near Flyger’s Line and Benmore Ave prevent this water from entering the city. Some of this stopbanking has been found to be inadequate, and will be upgraded as part of the project. A return stopbank on the tributary adjacent to the airport will also be upgraded.

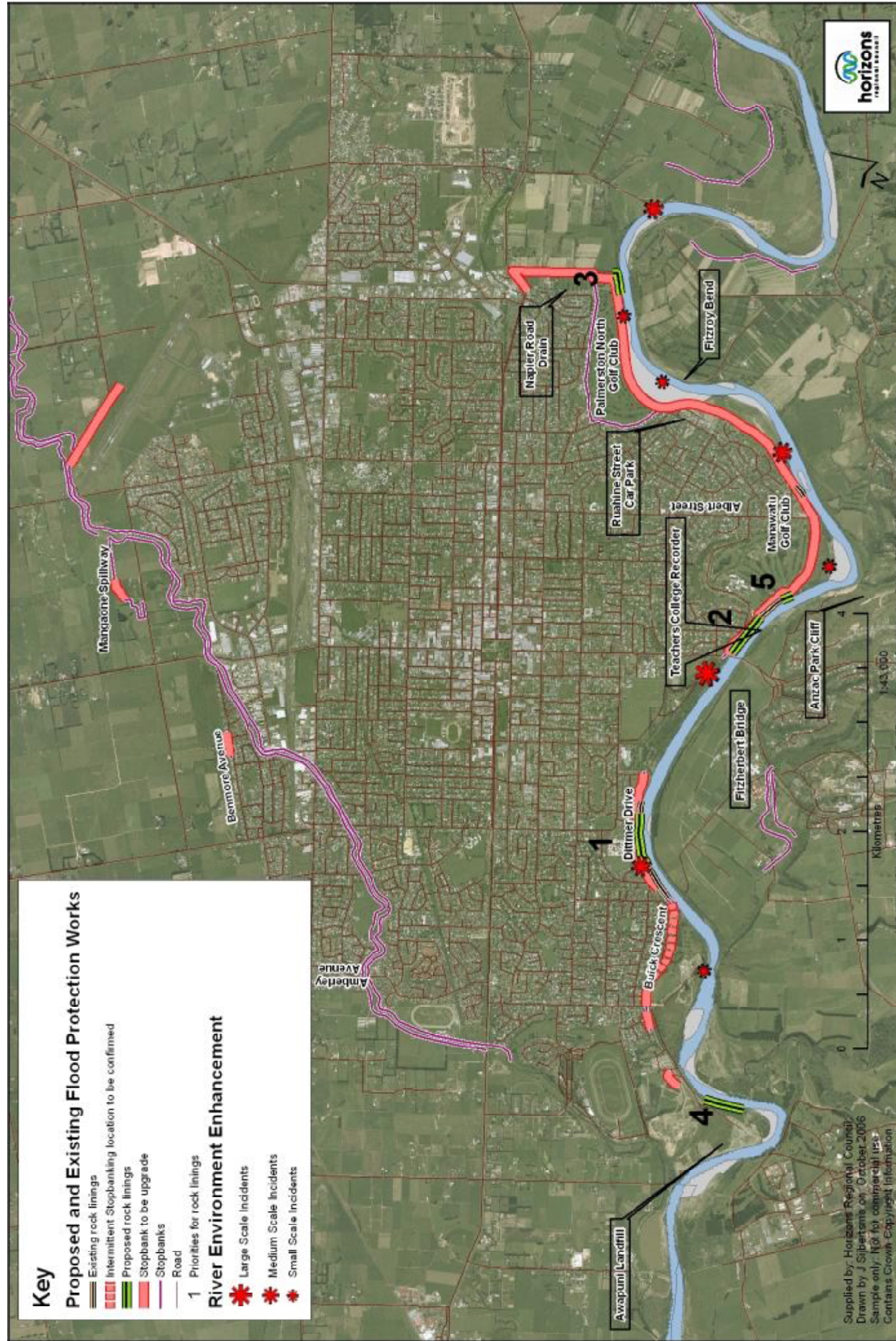
Other work is already being carried out in the Mangaone Stream, although it is not part of this project. Rock linings are being placed where erosion has occurred. Concrete block retaining structures are being built where stopbanks are too close to the stream channel, and there is a risk of slumping causing the stopbanks to be undermined.

River Environment Enhancement

The Manawatu River is a major natural feature on the City’s doorstep, and not much has been done in the past to develop the recreational and visual possibilities presented by this natural feature. Horizons Councillors, supported by City Councillors, are determined to remedy this.

A significant component of the project is therefore enhancement of the river environment for recreational purposes, and to improve visual amenity values. Artist’s concept drawings can be viewed at Horizons Regional Council, 11-15 Victoria Avenue, Palmerston North. The map showing the location of flood protection works also shows where the river environment will be enhanced. The red asterisks are called large, medium or small scale ‘incidents’.

Manawatu River at Palmerston North Proposed Upgrade of Flood Protection



Before the 2004 flood occurred, a statistical analysis of the flood flows concluded that a 100 year flood had a discharge of 3450 cumecs. After 2004 that figure was revised upwards to 3700 cumecs.

The Flood of 16 February 2004

The February 2004 flood is probably the third largest flood on record, but it might be the fourth largest. There is some uncertainty about the 1897 flood, that flood was higher at the upstream end of the gorge than was the 2004 flood. Certainly the 2004 was the largest flood since 1902.

Before 2004, the statistics said that a 3500 cumec flood would have a return period of 110 years. The statistics have since been revised, and it is now assessed to have a return period of 70 years.



The largest known flood, the 4000 cumec flood of 1880, is estimated to have a return period of 200 years.

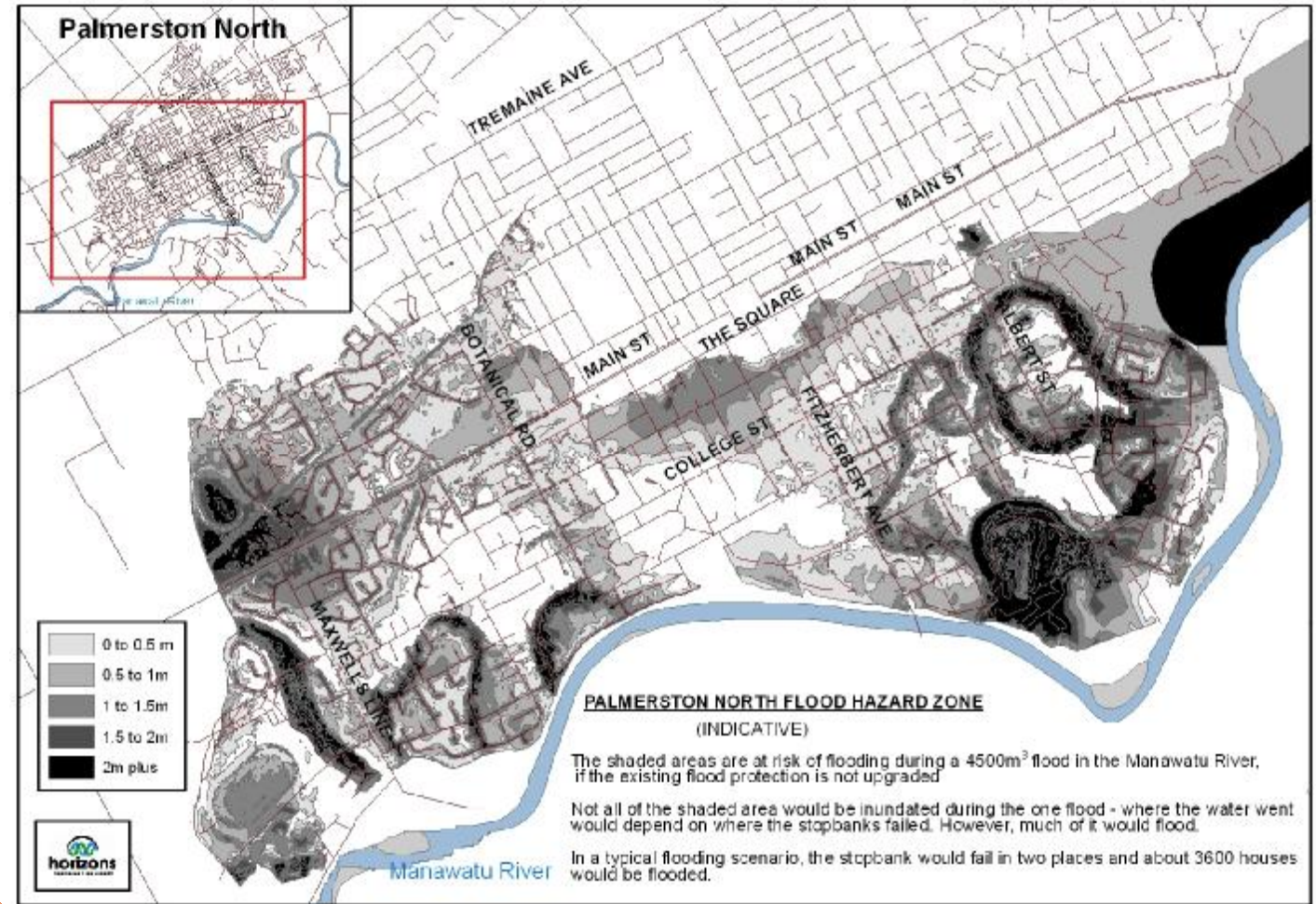
Upgrade of Flood Protection Works at Palmerston North 1995 to 2001

In June 1994 Council recognised the scale of Palmerston North's flood hazard, and adopted a proposal to spend \$7.5 million upgrading the city's flood protection to guard against a flood larger than any previously known flood.

Council decided to provide protection against a 4500 cumec flood. While not the largest possible flood, this is a flood significantly larger than the largest known flood, the 4000 cumec event of 1880. The statistical analysis at the time suggested that a 4500 cumec flood was a 2000 year flood. This meant it would have a one in 2000 chance of occurring in any given year, or a 1% chance of occurring during a 20 year period.

After the February 2004 flood, the statistics were revised, and the flood is now regarded as a 500 year flood. This represents a very large reduction, but is still a very high standard of flood protection.

These very large return period estimates are rather tentative. The period of record is much less than 500 years, which means that the margin of error is large, and global warming adds further uncertainty.



How Much Flooding Could a 4500 cumec Flood Cause if Stopbanks Failed?

The area that would flood can not be precisely predicted, because it is not known exactly where or when stopbanks would fail. However the 1994 study suggested that it was certain that some failures would occur. A useful way to deal with this type of uncertainty is to consider a range of feasible scenarios, and this was done.

The map shown on the previous page is a combination of scenarios, and gives a reasonable overview of areas at risk. Not all of the shaded area would be inundated in any one flood, but all of it is at risk in one scenario or another. Some unshaded areas around the periphery of the shaded area could also be at risk.

It was estimated that between 12% and 20% of the city could flood if the Manawatu River carried 4500 cumecs, and the proposed flood protection works had not been constructed. Between 2800 and 5300 houses would have been flooded, and direct damage costs would have been between \$190 million and \$365 million (in 1994 dollars).

The direct damage costs are effectively what insurance companies would pay out if all damage was insured. Indirect and intangible damage costs would be over and above the direct damage costs. The calculated damage costs did not include the costs of damage to and failure of infrastructure.

Loss of infrastructure would be a major issue. Many roads, workplaces and schools would be flooded. Electric power and telephones would be partially or completely non-functioning. In some scenarios the sewage treatment plant would be inundated, and might not be functional for quite some time.

Flood Protection Works Carried Out Between 1995 and 2001

Construction of the flood protection work was carried out between 1995 and 2001:

- Massive rock linings were placed on the riverbanks to prevent any erosion that might undermine the stopbanks. These can be seen upstream of the Fitzherbert bridge, and adjacent to Dittmer Drive;
- Much of the eight kilometres of stop banking protecting the city was raised in height;
- New stopbanks were constructed between the Manawatu River and the Palmerston North Golf Course, and adjacent to the Awapuni Sewage Treatment plant; and
- More than a kilometre of river was realigned near the downstream end of the Palmerston North Golf Course. The river now flows around a more gently curved bend, and is much further away from the Roxburgh Cres stopbank than it used to be.

Funding of the 1995-2001 Flood Protection Upgrade

The project cost \$7.5 million, and the cost was met with a targeted rate levied on all properties in the Palmerston North urban area. A loan was taken out for a 15 year period. The work was completed in 2001, and the targeted rate is now used solely to pay back the loan, which will be completely paid back in June 2009. The rate is the same for all properties, and last year amounted to \$12.11 for every \$100,000 of capital value.

All properties pay the same whether or not they are at risk of flooding. This is because flooding on this scale would have a serious effect on everybody in Palmerston North, even those who do not experience flooding.

Although a case could be made for having some properties pay more than others, the reduction in rates for non-floodable properties would not be large, and it was considered more sensible to keep the rating system simple, rather than adopt a very purist user-pays system.

You can see how much you pay in LMS rates by looking at your Horizons Regional Council rate demand. You will see two lines, both starting with "LMS". For most Palmerston North residential properties, the two lines total between \$20 and \$70. Payment of this modest sum minimises the hazard presented by a major force of nature.

The first line is for the basic Lower Manawatu Scheme, which is paid by all protected properties between Ashhurst and Foxton Beach. This rate contributes towards the provision of 100 year protection for the entire LMS area.

The second line shows the rate paid for the additional work needed to provide a higher level of protection than the 100 year flood. This rate is paid only by property owners in Palmerston North.

Performance of the Flood Protection Works During the February 2004 Flood

The flood protection works were successful during the flood of February 2004. The river did not enter the city, and damage to major works was minor in relation to the size of the flood.

- The floodwater was entirely contained by the stopbanks.
- The heavy rock linings were virtually undisturbed.
- At Fitzroy bend, the heavy rock groynes suffered only minor damage, the steel pile permeable groynes were undamaged, and two of the embankments adjacent to the rock groynes suffered some repairable damage.
- Tree edge protection was quite severely damaged in some places, particularly at Dittmer Drive.

However the safety margin was less than expected. It had been anticipated that there should have been 1.5 metres of freeboard during a 3500 cumec flood. Freeboard is the vertical height of the top of the stopbank above the water surface. Freeboard is built into the design in the same way as a bridge or building has a safety factor, in both cases it is a way to allow for uncertainties.

Much of the actual freeboard was slightly more than a metre, but in the worst place, on the new stopbank adjacent to Ruamahanga crescent, the freeboard was only 450mm.

The freeboard problem arose because insufficient allowance was made for channel roughness in the 1994 design. Channel roughness is a measure of resistance to the flow created by various features of the river, such the shape of the river bed, vegetation on the riverbanks, and turbulence in the flow. The greater the roughness, the slower and deeper the river flow. Roughness appears in calculations as a set of numbers that are input into the computer simulation of flood flows. In this case the numbers were calculated from the known discharge and levels of the flood of July 1992. It was assumed that the roughness experienced by the river would be the same in larger floods as it was in July 1992. The assumption has often been made for similar projects in the past, but it is evidently inaccurate.

There are several factors that could have resulted in higher roughness in February 2004 than in July 1992. The larger and deeper flows would have built larger dunes on the gravel bed. The deeper flows would have generated larger turbulence cells, which in turn would increase flow resistance. The riparian willow growth was higher and more bulky in most places, which would have added resistance both to flow in the downstream direction, and to flow interchange between off-channel floodplain areas and the main channel. It may even have been a factor that the trees were in leaf.

The freeboard during the February flood should have been at least 1.5 metres throughout the city. It reached this in some places but was mostly somewhat less. The worst locations were right at the upstream end and right at the downstream end of the city. The very tight "U" bend adjacent to the Awapuni landfill evidently caused a very high energy loss, which meant that locally the river level was 900mm above the calculated level.

Standard of Flood Protection Currently Provided

The stopbanks will clearly contain a 3500 cumec flood, such as that of February 2004. A 100 year flood (3700 cumecs) should also be contained, albeit with less freeboard.

If however we experienced a 4000 cumec flood, such as happened in 1880, the stopbanks would not be high enough at one location near Ruamahunga Crescent. Water would flow over the stopbank at depths of up to 250mm, for a length between 50 and 200 metres. Freeboard would also be marginal for the stopbank adjacent to the sewage treatment plant. If emergency response was effective, the necessary extra height could be provided by sandbagging. The situation would however be marginal. At the time of writing this, the stopbank at Ruamahanga Crescent is being upgraded.

What Standard of Protection Should be Provided?

Council decided at its December 2006 meeting that the 4500 cumec standard adopted in June 1994 should be confirmed.

In 1994 it was concluded that this standard was the optimum in terms of cost / benefit. Three broad groups of factors were weighed up:

- the cost of damage that could be caused by extreme floods;
- the likelihood of the damage occurring; and
- the cost of providing flood protection.

A wide range of large floods, and a number of different standards of flood protection were considered in this way. The 4500 cumec standard was found to be the optimum. A lesser standard would have left the city exposed to too great a risk. A higher standard would have meant spending very large sums of money in providing protection against floods with very low probabilities.

When the community has many competing claims on its funds, it becomes difficult to justify spending huge sums when there are such diminishing returns. The community is very unlikely to agree to the expenditure that would be required to completely eliminate flood risk (if indeed that is possible), so people need to understand that there will always be some residual risk.

A revised cost / benefit analysis has not been carried out for the project currently proposed, but it seems likely that a new analysis would give a similar answer to that of 1994. While more money

needs to be spent to achieve the 4500 cumec standard, a reassessment of probabilities suggests that the flood is four times as likely to occur as was expected in 1994. The extra cost over and above the 1994 proposal would be more than offset by the extra benefit of the current proposal.

Any proposal to construct flood protection to a higher standard would come up against a substantial obstacle, that obstacle being the Fitzherbert bridge. A larger flood could only be conveyed under the bridge if the bridge was lifted and lengthened. No cost estimate has been prepared for this, but it is likely that the cost of the proposed upgrade project might have to be doubled or trebled to achieve even a modest increase in flood carrying capacity. Thus the Fitzherbert bridge determines the upper level of affordable flood protection.

Climate Change

The size of 100 year floods can be expected to increase continuously in the future, due to global warming. Expected increases in rainfall have been assessed by the Ministry for the Environment. Three global warming scenarios are considered. The scenarios are based on a range of assumptions, and are termed Low, Medium and High.

The table below shows the MfE predictions for the decrease in the return period of a 4500 cumec flood in the Manawatu River as time goes by

Global Warming Scenario	Future return period for flood of 4500 cumecs		
	2030	2060	2100
Year	2030	2060	2100
Low amount of warming	450	400	370
Medium amount of warming	320	180	110
High amount of warming	230	80	30

The "medium" scenario is regarded as the most appropriate scenario for design purposes, although the consequences of the "high" scenario need to be born in mind.

It can be seen that by the year 2060, the return period of a 4500 cumec flood is expected to be reduced to 180 years. This is still a reasonably high standard, although it clearly represents an erosion of the protection standard.

Calculations based on the above assumptions suggest that the probability of a 4500 cumec flood occurring between 2007 and 2030 is about 7%, and between 2007 and 2060 is about 20%. For the "high" scenario, those probabilities are 10% and 30% respectively.

The implications for flood protection further into the future are serious. At this stage not enough is known to allow detailed planning, but it will be important to monitor new findings about climate change projections as they become available, and to respond decisively to those findings.