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Floods

Te Rākau Whakamarumaru
Ministry of Civil Defence & Emergency Management

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TEPHRA n . fragmented rock, ash etc ejected by a volcanic eruption, [from the Greek word for ash] Concise Oxford Dictionary.

Cover photo: Volunteers shovel a mountain of sand into waiting sandbags in Helwick Street, Wanaka, as the rising Lake Wanaka floods into the central business area in November 1999. *Photo ODT*
Back cover: A hard row to hoe… a farmer near Kaitangata takes stock of the damage in the flooding of the Otago and Southland region in November 1999. *Photo ODT*.

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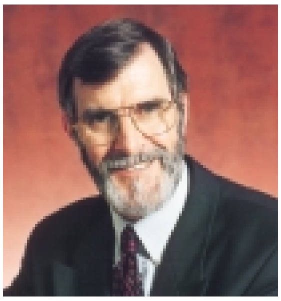

DIRECTOR'S FOREWORD

I am delighted to introduce this volume of TEPHRA which is dedicated to the flood hazard.

The series, focusing on New Zealand's individual hazards, started in 1994 with a national overview of hazards as part of the International Decade of Natural Disaster Reduction (IDNDR). There followed volumes dedicated to volcanoes (1995), storms (1997), earthquakes (1998), and tsunami (1999). Together these volumes represent a significant resource on the natural hazards New Zealand faces - what they are, and what they can do to us.

The 1996 volume was dedicated to the principles of risk management which frame the new environment for civil defence emergency management embodied in the Bill currently before Parliament. The Civil Defence Emergency Management Bill reforms the approach to emergency management in New Zealand with a focus on planning for the possible consequences of hazards across the spectrum of the 4Rs of reduction, readiness, response, and recovery.

Further information on the legislation, as well as copies of the earlier Tephra volumes, can be viewed on the Ministry's website.

This volume on floods deals with New Zealand's most common natural hazard and covers a range of issues from weather trends and prediction, through to floodplain management and includes individual case studies.

While river management is the responsibility of local authorities, the Ministry of Civil Defence and Emergency Management has a strong interest in the potential for flood events to threaten communities, and how this might be mitigated by river management practices, floodplain land use planning or flood response arrangements. These issues are addressed in a recent paper published by the Ministry on *Managing the Flood Hazard*. A summary of the paper is presented in this issue.

I would like to thank all the contributors who have given their time and expertise to make this volume possible.

Coincidentally, with this volume I should note a name change for the Ministry, from the Ministry for Emergency Management to the Ministry of Civil Defence and Emergency Management (MCDEM). This aligns our name with the new Civil Defence Emergency Management Bill.

John Norton
Director
Ministry of Civil Defence and Emergency Management

Peter Sutherland's cows walk across the waterlogged paddocks of his farm at Kaitangata, as the Clutha River spills over its banks in November 1999. *Photo ODT*.

Flood Weather

At Fairlie in 1994, a bridge was swept away and Alpine Timber Ltd's yard was devastated by the flooded Opihi River after 179mm of rain fell in 24 hours. (Photo: The Christchurch Press)

by Erick Brenstrum

a forecaster with MetService and the author of The New Zealand Weather Book, from which part of this article has been taken.

Most floodwater running down rivers in New Zealand comes from the oceans to the north of us. The water evaporates from the sea surface in the tropics or sub-tropics then travels towards New Zealand on winds from the northerly quarter. If the air is caught up in weather systems that cause it to rise, it experiences a rapid decrease in atmospheric pressure, allowing the air to expand rapidly and consequently cool rapidly.

The amount of water vapour air can contain depends on its temperature: warm air is able to contain a lot more water vapour than cold. For example, warm air approaching New Zealand from the north can have almost three times as much water vapour as cold air approaching from the south.

When warm air with abundant water vapour is cooled, some of the vapour changes to tiny liquid droplets that clouds are made of. If cooling continues then some cloud droplets will combine and freeze, growing to form snowflakes and raindrops.

When forecasters are deciding whether to issue a heavy rain warning they have three things to consider - how much water vapour is available in the air moving over New Zealand? - how strong is the upward motion likely to be?- and how long will the upward motion stay over one place?

The upward motion that causes the rain is associated with lows, fronts, and with hills or mountains that force the air to rise.

One of the first steps in forecasting the weather is to gain a good understanding of what is happening now, not only over New Zealand but also over the surrounding parts of the Pacific Ocean as well as Australia and the ocean south of Australia.

Historically, New Zealand forecasters have grappled with the problem of being surrounded by large oceans from which there have been very few weather reports. The introduction and improvement of weather satellites over the last three decades has revolutionised meteorology. Not only do the hourly satellite images show where the major frontal cloud bands and wind shifts approaching New Zealand are located, they have also changed our understanding of how lows and fronts develop and decay.

Fronts show up on satellite images as bands of cloud that often stretch for thousands of kilometres across mid latitudes. Studies of sequences of satellite pictures supplemented by radar images have led to the idea that the cloud bands ahead of fronts are largely caused by long conveyor belts of rising moist air. These conveyor belts originate close to sea level near the tropics and rise steadily as they move towards the pole, reaching altitudes of 10km by the time they reach 50 or 60 South. Once the air has reached this altitude most of the water vapour it had when it left the tropics has fallen out as rain.

A good example of a conveyor belt is shown in the satellite picture taken on 10 March 1990 (Fig 1). A band of cloud can be seen stretching from the tropics, west of Fiji, down over the North Island and on to the Chatham Islands. Heavy rain associated with this front caused one of the worst floods in Taranaki during the twentieth century. The Waitara and Oakura Rivers broke their banks and many people had to be evacuated. Slips closed many roads and a freight train was derailed. The Whanganui River also overflowed its banks, flooding parts of the city and rising to within one metre of the record flood of 1904.

A couple of days later the front produced heavy rain in the Tararua Ranges, causing flooding in Manawatu, Wairarapa, and the Hutt Valley.

On this occasion, the upward motion in the conveyor belt had been increased by the effect of the hills, forcing the air in the northerly airstream to rise. The conveyor belt had a particularly high moisture content - about four times as much as the air lying to the west of the front. This was, in part, because the conveyor belt had its origins so far into the tropics, and also because it had been associated with a Tropical Cyclone which moved large amounts of warm moist air southwards. The remains of the Tropical Cyclone can be seen as the shallow low over the north Tasman in the weather map for 10 March (Fig 1).

The flooding was also made worse by the fact that the front was slow moving, so the heavy rain persisted over the same area for many hours. On the weather map, the fact that the isobars are parallel to the front is characteristic of a slow moving front.

Movie loops of hourly satellite pictures during this situation showed rapid cloud movement down the length of the cloud band, while the front made no progress eastwards across the North Island.

North or northwest airstreams ahead of fronts cause most floods in western areas of New Zealand. Eastern areas, from Gisborne down to Otago, are sheltered from that direction by the mountains, although rivers rising in the mountains can reach flood levels if the rain there is heavy enough.

Floods in eastern areas are usually associated with conveyor belts that approach from the east, so that the upward motion is increased by the air blowing from the sea into the hills.

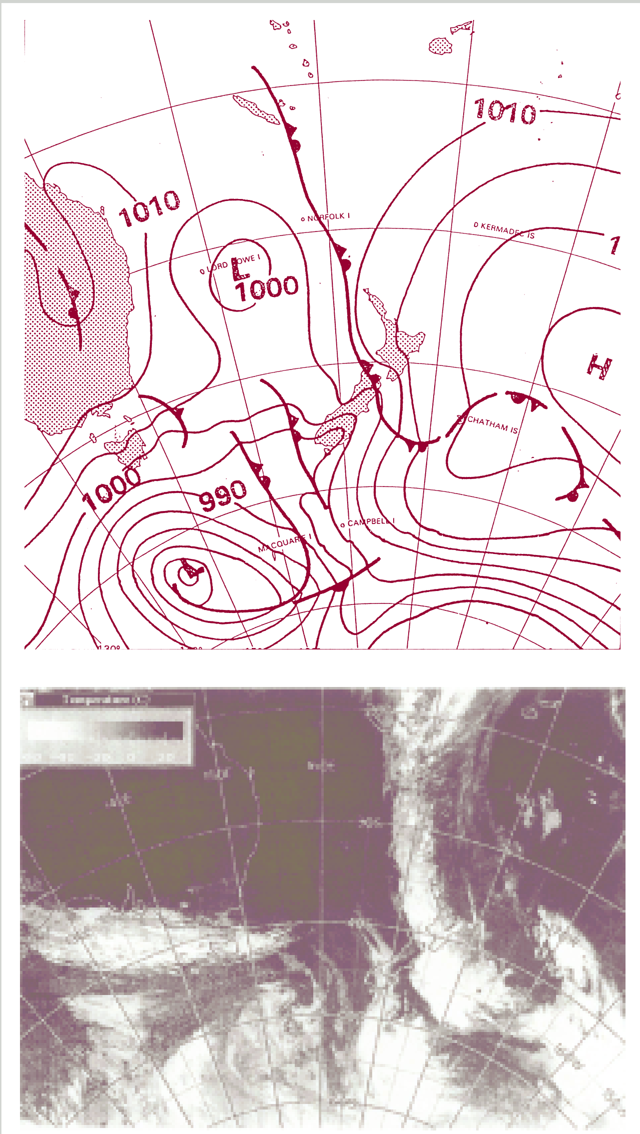

FIG 1: Weather map and satellite photo for 10 March 1990 showing conveyor belt of cloud and rain extending from the tropics to Taranaki.

An example of this occurred on 18 March 1994, flooding parts of South Canterbury and Otago. A low centre was situated west of Buller while a front became

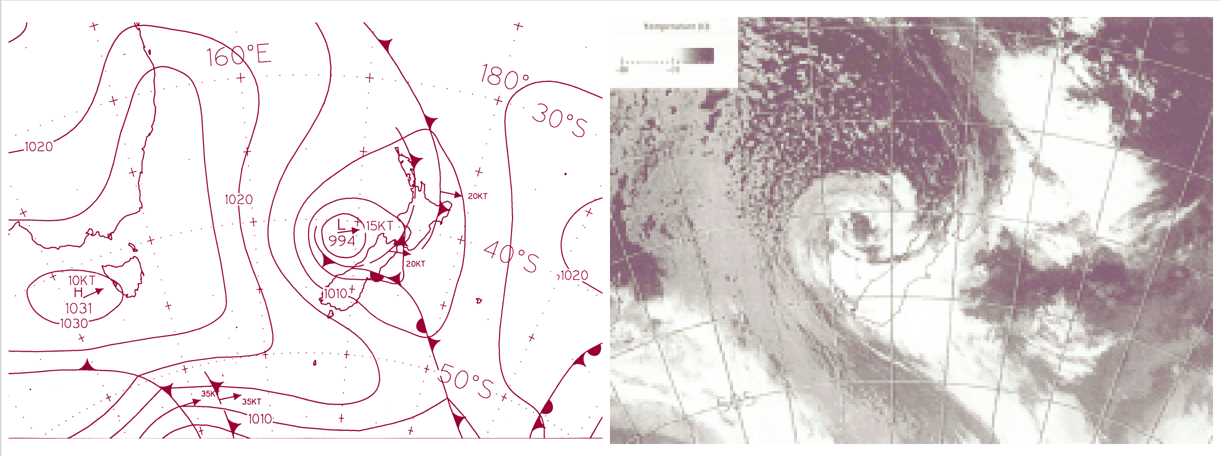

FIG 2: Floods in South Canterbury and Otago. Weather map and satellite photo for 18 March 1994.

slow moving near Banks Peninsula (Fig 2). In the satellite picture the cloud associated with the warm conveyor belt can be seen east of the Kaikoura Coast, while the cloud with the slow moving front stretches away to the southeast of Otago. As the warm conveyor belt swung round over South Canterbury and wrapped itself around the low centre, it rose abruptly over the cold air west of the stationary front. This, combined with the uplift caused by rising over the hills, caused prolonged heavy rain.

On the 19th, 179mm of rain fell in 24 hours on the town of Fairlie. The bridge over the Opihi River was destroyed and a $2.5 million timber business on the river bank was wiped out when the river swept through taking tractors, trucks, timber and sawmilling buildings with it. Over 100mm of rain fell over much of Otago. Roads were washed out or blocked by slips, water entered many homes and one man was drowned when his trail bike was washed away as he tried to cross a swollen stream. Up to 160 residents were evacuated from low-lying areas near the Opihi River and there were serious stock losses in the Hakataramea Valley.

The global scale computer models that are used in weather forecasting now handle the broad outlines of these situations very well a day or two in advance but do not always capture the fine detail. They may over or under estimate the rainfall by a factor of two, or make an error of 100 km in predicting the location of the heavy rain. To improve these predictions meso-scale computer models are being developed which operate over a small fraction of the Earth's surface - such as the Tasman Sea and New Zealand - but which have a much higher density of data points and a more accurate depiction of New Zealand's terrain.

Better meso-scale models should also improve our ability to forecast features that are much smaller than lows and conveyor belts, such as convergence lines of heavy showers. These can also produce devastating floods, although usually only over a small fraction of a province. One of the worst cases of this occurred on 20 December 1976 when extremely heavy rain fell from a convergence zone that ran along the hills west of Wellington City and stretched up over the Hutt Valley. More than 300 mm was recorded in 24 hours over much of this area - something expected, on average, only once every 100 years or more. Much of the rain actually fell in less than 12 hours, making it more like a once-in-700 year event.

Flash floods roared down steep gullies where, ordinarily, ankle-deep creeks trickled into the harbour. Miraculously, no one was killed by these, despite the Hutt motorway being cut off and hundreds of workers having to be rescued by helicopter from the roof of a factory surrounded by fast moving flood waters from the Korokoro stream. Many vehicles were destroyed, some crushed almost beyond recognition.

The torrential rain caused landslips in many places, tragically taking the life of a three year old boy when the side of a hall in Crofton Downs collapsed under a slide of rocks and earth. A number of houses in Stokes Valley were crushed by slips or driven from their foundations. In the Hutt Valley, a state of emergency was declared with many people having to be evacuated. After the floodwaters receded, damage was estimated at $30 million.

The causes of this convergence can be understood by looking at the large-scale situation. The weather map for 20 December 1976 (Fig 3) shows a low east of Cook Strait with a shallow trough of low pressure extending across Wellington to another low northwest of Auckland. The second isobar around the low bends across the South Island from Kaikoura to Hokitika, then loops back onto the North Island near Wanganui. The large gap between it and the central isobar of the low where they both bracket the Wellington region indicates very light winds for the Wellington area.

The mountain ranges block most airstreams crossing the country so that through the narrow gap of Cook Strait, the wind is almost always funnelled directly from high to low pressure rather than blowing parallel to the isobars. On this occasion, a light southerly was blowing along the Kaikoura coast towards the middle of the trough over Wellington while, at the same time, a light northerly was blowing down the Kapiti coast towards Cook Strait. These two low-level winds, blowing from opposite directions, met in a convergence zone over the Hutt Valley and the hills west of Wellington City.

The air in the trough of low pressure was very unstable and so deep cumulonimbus shower clouds were already mushrooming up. Once the convergence zone was established, the upward air motion driving the cumulonimbus clouds increased dramatically and heavy rain commenced.

The upward air motion within the clouds helped to sustain and reinforce the inflow of air at the base - thereby setting up a feedback mechanism between the clouds and the convergence zone, which served to maintain and intensify them both. Furthermore, the way in which the heaviest rain followed the line of the hills suggests that the cumulonimbus became anchored over them for a time, perhaps because the surface northerlies on one side and the southerlies on the other were partially deflected upwards by the rising ground, helping to focus the upward air motion near the ridge line.

Eventually, the trough over Wellington moved slowly to the east allowing the southerly winds to prevail, and the convergence line broke up. The cumulonimbus began to dissipate and the heavy rain eased off.

More recently, another dramatic example of this type of weather occurred over the Hokianga on 21 January 1999. Thunderstorms forming over a low-level convergence line gave Oponini 211mm of rain in less than five hours, and the nearby hills are estimated to have had over 300 mm. Flash floods swept out of these hills and poured across farmland, bouncing 1.5 metre-diameter boulders around like tennis balls, according to one eyewitness. Large trees, stripped of their bark and branches, were carried for kilometres by the floods and turned into battering rams, tearing through fences, smashing cars and shunting houses off their foundations.

In Panguru, the river changed course and flowed through the school. People were rescued from rooftops, and 73-year-old Agnes Wake was up to her neck in floodwater in her lounge before she abandoned her house and swam for safety. Thirty people sheltered upstairs in a two-story building as floodwater swept through the ground floor. Bridges were washed out and slips cut many roads, so that medical supplies and food had to be dropped by helicopter. Miraculously no one was killed in this area, but downpours along the same convergence line also caused flooding in Pukekohe, where one man was drowned, and at Kaiwaka, where a young girl was washed into a culvert and died several days later from the injuries she received.

As computer power increases both meso-scale models and global scale models are expected to improve. In addition, improvements are expected as better information gathering systems come on line.

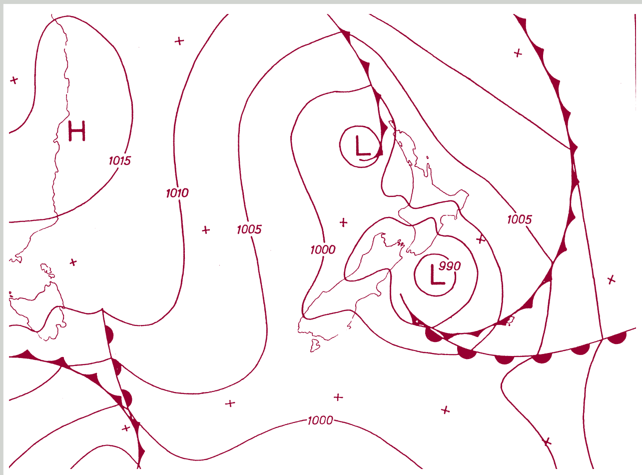

FIG 3: Wellington/Hutt Valley flood, 20 December 1976.

One of the traditional problems for Southern Hemisphere meteorology has been the lack of weather information over the vast areas of ocean that cover most of the hemisphere. New technology is changing this. There are satellites now that can measure the wind speed over the ocean surface by sending down a pulse of microwave energy. The fraction of energy that bounces back to the satellite from the sea-surface depends on the size of the capillary wave, which in turn depends on the strength of the wind at the surface. The satellite makes thousands of these measurements every day over areas where there may have been only a handful of ship reports. These extra wind reports give a much more complete picture of the pattern of the wind over the oceans and therefore of the distribution of highs and lows and the isobars

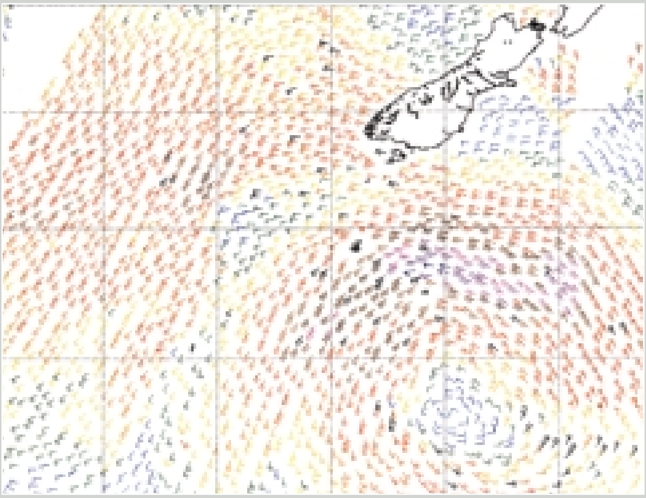

FIG 4: Surface winds on the afternoon of 16 Oct. 2000 as measured by a satellite satterometer. These represent a massive increase in our knowledge of current weather condidions over the oceans around New Zealand.

between them. (Fig 4)

Increasingly, this new information is being incorporated into the computer models that are trying to analyse and forecast the state of the atmosphere, leading to improvements in their depiction of the future positions of highs and lows and gales and rain-bands.

Improvements are also expected in the use of weather radar. Techniques are now being developed to turn radar measurements of the rain as it is falling into detailed predictions of river levels many hours ahead.

On longer time scales, our understanding of climate variability is also improving and we have learned more about the El Niño Southern Oscillation (ENSO) weather pattern. Since the late 70s we have experienced a regime where El Niños have occurred much more frequently than La Niñas. Indeed the two strongest El Niños of the last hundred years (1982-83 and 1997-98) have occurred during this period. However, studies of long-term trends, based on palaeoclimatological evidence, such as records of tree rings extending back hundreds of years, have shown a tendency for ENSO to change every twenty or thirty years from a period when El Niño dominates to one where El Niño and La Niña occur with about equal frequency.

Known as the Pacific Decadal Oscillation, this switch is expected to occur again soon. In fact, it may already have done so in light of the persistent La Niña conditions that occurred through the summers of 1999 and 2000. If La Niñas do become as frequent as El Niños during the next few decades, we can expect floods to become more frequent in eastern areas of New Zealand than they have been over the last twenty years, while floods in western districts should become less frequent.

But as weather predictions improve on all time scales we still have to guard against the human tendency for complacency. As predictions become more successful, loss of life and damage to property are minimised, and this increases the risk that people may under-rate weather hazards.

Factors causing flooding to be New Zealand's

Number One Hazard

Alistair I. McKerchar and Charles P. Pearson

National Institute of Water & Atmospheric Research (NIWA)

When rainfall over a river catchment area is exceptionally large, the resulting river discharge can exceed the capacity of the usual river channel, and flooding of land adjacent to the channel occurs. When exceptional tides combine with storm surges, flooding of low lying coastal regions occurs. Such flooding is a naturally occurring hazard.

Flooding has always been a hazard in New Zealand. Insurance industry records show that flooding is the largest source of claims for damage due to natural hazards. Given the many other natural hazards faced in the New Zealand landscape, especially its vulnerability to earthquakes, this article explores some of the reasons why flooding remains a pre-eminent hazard.

ATTRACTIVENESS OF FLOOD PRONE LAND

At the time of European settlement in New Zealand in the middle and late 19th Century, shipping provided the major transport links and flat land near rivers and harbours was naturally favoured for settlement. Many towns and cities were located in areas prone to flooding. The attractiveness of some locations, for example in the Hutt Valley, at Queenstown and Blenheim, was enhanced by the scarcity of suitable land away from the river valley.

In addition, river valleys were favoured for settlement because soils were well watered and naturally fertile, making it easy for agricultural and horticultural development to take place. Flooding is often accompanied by extensive stock losses.

HISTORICAL LACK OF DEFINITION OF FLOOD HAZARD

With hindsight, it is easy to question the wisdom of establishing settlements in their chosen locations. In the context of the times however, there was a lack of knowledge of the landscape that was being settled. For settlers from the gentle landscape of the British Isles, the early geophysical events experienced in New Zealand, for example the Wellington earthquake of 1855, the flooding of Christchurch by the Waimakariri River in 1868, the Tarawera eruption of 1886, must have been shocking surprises. Who of the early Wellington settlers, for example, was aware that they had chosen to locate their new settlement atop one of the world's major fault lines where severe tremors could happen at any time? Who in the Canterbury settlement in the 1850s would have appreciated that much of the area of the new city of Christchurch was part of the active fan of a major river and that periodic shifts in the river channel should be expected? Even today, how many people

LAND LINE
Harold Ulrikson of Queenstown braves the wet and cold to make a call in Earnslaw Park, Queenstown in November 1999.

FIGURE 1: Rees Street, Queenstown, New Zealand, on 29 September 1878 (above), and 16 November 1999 (below). In both cases, the water level nearly reached the window sills of the hotel in the centre of the photographs. (Photographs: Hocken Library and Otago Daily Times.)

know of the vulnerability of Auckland to volcanic action, and that Rangitoto Island is only a few hundred years old?

UNDERSTANDING FLOOD HAZARD

The accumulation of knowledge and data about vulnerability of the country to flooding has been a slow process. Rainfall data is available for the main centres from the mid-19th Century, but comprehensive monitoring of rainfall over the country, and information about rainfall intensities has been achieved only in recent years. The information gathered distinguishes New Zealand in a hydrological sense in having virtually a continental range of variability. The influence of mountain ranges is fundamental to understanding the hydrology of the country. The mountains intercept moist maritime winds, and heavy rainfall occurs on the windward slopes, and rain-shadows occur in the lee.

The intensity of storms, integrated over a year, gives annual rainfall. The distribution of mean annual rainfall is a useful index to understanding flood hazard. Mean annual rainfall in parts of the Southern Alps is known to exceed 12 m/yr, but is less than 0.4 m/yr in Central Otago. This variation is crucial for understanding the flood regime of rivers all over the country. For example, the Hutt River rises in the Tararua Ranges in the southern North Island where annual rainfall exceeds 6 m/yr, but is a flood hazard in the Hutt Valley where annual rainfall typically is less than 1.4 m/yr.

Observations of early flood levels are available in many instances. This information is always valuable, but changes in river channels can mean that it is difficult to estimate the flows that corresponded to the maximum levels, and systematic data is essential to fully define flood hazard. Early information has not always been well used. For example, after a succession of severe storms in September 1878, Lake Wakatipu rose to extreme levels and inundated the parts of the fledgling township of Queenstown adjacent to the lake (Fig 1). Unfortunately, the fact that the attractive flat land adjacent to the lake was flood-prone did not deter development. Consequently, when a similar level was reached in November 1999 (Fig 1), severe flood damage occurred. Not many locations have evidence of early flooding as clear as that presented in Fig 1.

In contrast to the inherent simplicity of rainfall measurement, systematic collection of river flow records is a major undertaking requiring the resources of an organisation rather than an individual. It requires regular measurement of water levels, and the establishment and maintenance of a hydraulic relationship, known as a rating curve, that gives streamflow corresponding to a given water level. The establishment of the rating curve depends on a series of measurements of discharge, usually undertaken with a current meter, for the river in different states of flow. The measurements are difficult to make in the conditions illustrated in Fig 2. Movement of sediment in a river is a complication which calls for regular checking of the applicability of the rating curve.

When assessing flood hazard, rating curves are needed to convert peak flow rates to corresponding levels. Often this is achieved with the aid of detailed hydraulic models.

Systematic monitoring of rivers commenced early in the 20th Century to enable hydroelectric potential to be defined. Almost invariably, these records were the outflows of the large lakes that had potential for hydroelectric development. The resulting records, for example for Lake Taupo and the southern lakes of the South Island, comprise the longest continuous hydrological records available for the country, and are invaluable for investigation of long-term changes in flows. (Processing and storing the records is a computationally intensive task which was one of the first applications of electronic computers in the early 1960s.)

FIGURE 2: Tengawai River, South Canterbury, in flood. (Photo: Environment Canterbury.)

Most records for rivers where extreme flows are not moderated by lakes commence much later than the hydroelectric records, in the 1950s or 1960s. The adoption of a UNESCO promoted International Hydrological Decade programme for 1965-1974 as a mechanism for a country-wide systematic approach to hydrological data collection was a major step forward. Under this programme, more than 90 hydrological regions were defined on the basis of precipitation, geology, and overland slope, and detailed hydrological measurements were made at basins considered to be representative of many of these regions. The data collected under this programme, and in many cases continuing to be collected, are an important component

FIGURE 3: The Otira River, 22 May, 1980, after scour during a sustained flood destroyed the railway embankment. A locomotive driver was killed. (Photo: The Christchurch Press.)

of the present National Hydrometric Network (Pearson, 1998). With the benefit of the archive of data gathered over the years from this network, and complementary networks operated by regional and district councils, the flood regime, and hence the flood hazard, of rivers and streams around the country can be better defined. For example we (McKerchar and Pearson, 1989) carried out a national assessment of river flooding probabilities using data up to 1987. An update is overdue!

DEFINING FLOOD HAZARD

The usual hydrological practice to assess flood hazard from rivers is to estimate a design flood flow and an associated maximum water level. Where long-term records are available for the river in question, statistical frequency analysis methods are used to determine a flood size with a given probability of exceedence. Typically, a flood with an annual exceedence probability of 1 in 200 is adopted as a design criterion for protection works and establishing minimum floor levels. More, or less, stringent standards are applied depending upon the value of assets to be protected. The analysis of long records, many of which commence in the 1950s or 1960s, has only been possible in recent decades.

Faced with a lack of flood records, past practice has been to assess the frequency of storm rainfall for the catchment of the river in question, and then apply a rainfall to runoff transformation to estimate the flood flow corresponding to the peak rainfall. Before the advent of the major hydrometric programmes of the 1960s and later, this approach was logical since rainfall records were generally longer than flood records. This approach was used in assessing the flood design criteria for many flood protection schemes, bridges and culverts designed and constructed until quite recently. The approach suffers two main deficiencies: the knowledge of the rainfall distribution is inadequate in many cases, and significant error is encountered in the rainfall to runoff transformation process.

As an example of the limitations of the

FIGURE 4: Flooding of suburban Invercargill, 27 January, 1984. (Photo: The Southland Times.)

SUBMARINE PARK?
The Barker family of Frankton takes a look at the Queenstown-Lakes District Council's "full" $4 million Church St underground car park – which was filled with water from Lake Wakatipu in 1999. (Photo: ODT)

knowledge of storm rainfall, the main source of rainfall frequency information until 1980 was Robertson (1963). The highest 24 hour duration rainfall with a 1 in 20 annual exceedence probability (AEP) in this publication is 518 mm (20.4 inches) for Milford Sound. It is now known that there is a band in the Southern Alps where the 1 in 20 AEP 24 hour rainfall is substantially in excess of this value.

Further, recent work has shown that the storm rainfall frequency - runoff transformation is generally inferior to direct analysis of flood records for nearby river basins, and then preparing an estimate of the design flood for the site in question. Thus the level of protection provided by some older flood protection schemes, may in fact be less than planned for in the original design. Fortunately, regional councils responsible for flood protection schemes, which include stopbanks and flood detention dams, are aware of the limitations of early hydrological designs, and initiate periodic scheme reviews where more recent methods and data are used to reassess the level of hazard.

Limitations of knowledge also apply to understanding the extent of scour and sediment movement that accompanies flooding in gravel bed rivers. Failure of embankments or protection works is often a consequence of fast flowing water scouring away unconsolidated material. Where the embankment carries a transport route, the results can be tragic (Fig 3).

CHANGING LAND USE

Many flood protection schemes on rivers and around the coast in New Zealand have been designed to supply a relatively low level of protection for rural land, perhaps up to a one in ten AEP flood. Expansion of urban boundaries and the proliferation of lifestyle blocks in some cases has seen development taking place on rural land without recognition of the low level of protection provided for flooding. Such was the case around Invercargill when a storm occurred on 26-27 January 1984 which gave a 24 hour rainfall of 134 mm - more than twice any other daily rainfall recorded since recording began in 1939. Devastating flooding occurred of urban and light industrial development on land adjacent to streams whose stopbanks offered only a low level of protection (Fig 4). Insurance industry payouts for damages incurred totalled $100 million (1997 dollars), making it probably the most damaging flood in New Zealand's history. Eriksen (1986) described changing land use without regard for flood hazard as "Creating flood disasters".

The Invercargill catastrophe is a hard lesson on the need for community awareness, to be reflected in regional, city and district plans, that land adjacent to rivers, and low lying land on coastal margins, is at risk of inundation. If development is to occur, it needs to be of a nature that recognises the hazard.

CHANGING HYDROLOGICAL REGIME

The term "climate change" is widely recognised, and in the New Zealand context is evident as an increase in temperatures for the 20th century, with mean temperatures for the latter part of the century typically 0.5°C higher than temperatures for the early part of the century. Some of the change is thought to be naturally occurring, but part is attributed to enhanced production of greenhouse gases such as carbon dioxide and methane. Climate change as a

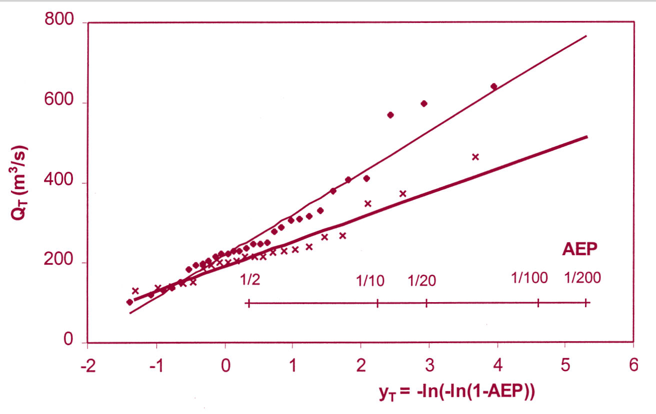

FIGURE 5: Frequency analysis plot of the annual maximum flood peaks for the Rangitaiki River at Te Teko for 1949-1977 (¨) and 1978-1999 (´). The vertical axis of the plot is the flood values (Q_T) and the horizontal axis relates to the annual exceedance probabilities (AEP). The straight lines are the fitted Extreme Value Type 1 (Gumbel) probability distributions. The 1 in 100 AEP estimate for the first period of record is 710 m³/s (standard error ±11%), is significantly greater than the estimate from the second period of 470 m³/s (standard error ±12%). (Data supplied by Environment Bay of Plenty).

consequence of the greenhouse gas effect is predicted to bring more frequent and more intense storm rainfalls.

Some of the changes in hydrological regime occur as abrupt shifts at time intervals of decades and appear to be part of the natural variability of climate. Much of the 20th century temperature increase occurred quite suddenly, at about 1950 when prevailing westerly and southwesterly winds weakened. Another shift at about 1977 saw a strengthening of westerlies in central and southern New Zealand. The west and south of the South Island became wetter and cloudier, and the north and east of the North Island became drier and sunnier. This change coincided with an eastward movement of the South Pacific Convergence Zone, a subtropical band of increased cloudiness that brings rainfall to islands in the Southwest Pacific. The movement is part of a Pacific-wide natural fluctuation called the Interdecadal Pacific Oscillation (IPO). Shifts in the IPO occurred around 1925,1947 and 1977. It is strongest in the North Pacific where it relates to variations in northern Pacific salmon stocks, but it also influences sea temperatures in the equatorial tropical Pacific which closely relate to the status of the El Niño Southern Oscillation (ENSO) phenomenon. An El Niño event is warmer than usual water in the eastern equatorial Pacific Ocean, and its opposite, a La Niña, has cooler water there. More La Niña episodes occurred in the interval 1947-1977, and more El Niño episodes have occurred since 1977. Thus in areas of the New Zealand where the climate is affected by the ENSO phenomenon, we might expect to see a shift at about 1977.

The implications of these changes for flood hydrology can be seen by examining long-term flood records. For example, the Bay of Plenty region has been recognised as being "flood rich" until 1977, and "flood poor" since then. Estimates of flood frequency depend upon which period of record is analysed. The Rangitaiki River at Te Teko in the Bay of Plenty drains 2893 km² and has records since 1949. The Matahina Dam constructed in the 1970s has little influence on flood flows. Standard flood frequency of the annual maximum flood series for Te Teko for two periods of record, (1949-1977, and 1978-1999, Fig 5) shows a decrease of 240 m³/s (34%) in the 1 in 100 AEP flood estimate. Changes as large as this are of serious concern for hazard mitigation.

If only the post-1977 data was available, a design flood estimate for this region would be too low if a shift of the IPO back to the pre-1978 conditions occurs. Flood protection works would be more vulnerable to overtopping than planned, and damages incurred would be greater than expected. The Bay of Plenty is fortunate that there are a number of long records in the region that encompass the pre-1978 flood–rich period. On the other hand, there may be other parts of the country where the opposite effect is apparent, with the pre-1978 period flood-sparse and the period from 1978 flood-rich. The implication is that there could be flood protection works installed that offer a lesser standard of protection than is intended. If this is the case, it could be a contributing cause to high levels of flood damage. The extent of shifts in flood records and the impact on design flood estimates is a topic worthy of investigation.

CONCLUSION

Many towns and cities in New Zealand regions are at risk of flooding. Understanding and experience of the extent of the flood hazard has grown from the time of European settlement, and an awareness has developed of features of New Zealand rivers that are not commonly encountered elsewhere. However, the record of assimilating and applying that understanding and experience has been patchy.

The susceptibility of river valley land to flooding by rivers and of low-lying coastal land to inundation by the sea is a feature that must be incorporated into land planning and management strategies promoted by regional, city and district councils. Where development of hazard prone areas is proposed, the development needs to be of a nature that recognises the hazard, for example by using floor levels that are well above anticipated flood levels. In the long term, the aim is to reduce the likelihood of a repetition of the disastrous Invercargill-type flooding.

Challenges are to be faced in assessing how flood risk is changed as a consequence of climate change. Some preliminary information suggests that a shift occurred in 1977 or 1978 as a consequence of a shift in the Interdecadal Pacific Oscillation which has affected the frequency of occurrence of El Niño and La Niña events. Certainly, there has been a significant reduction in the number of floods in Bay of Plenty rivers during the period 1978-1999. The topic needs further investigation to define the wider pattern.

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THE 'Big One' OF '98

Linda Thompson
Environment Waikato

"We have a problem" were the words from Environment Waikato's Flood Duty officer on 9 July, 1998.

They initiated a major and sustained effort to manage the massive flood event which followed. It was an event expected only once in 100 years, and the lessons learned have enhanced flood management in the Waikato Region for the future.

It wasn't just one flood, but three in a row. Very high river levels were experienced over the whole Region during the period 9 – 20 July, 1998, after sustained, widespread and, in places, record rainfalls. The weather pattern repeated itself at about one week intervals, resulting in three major events.

The flood protection schemes worked well and as designed. Effects and damage were substantially less than the previous major flood event in 1958 – beyond the memories of many of those working to manage the event - even with more water passing through the catchment in 1998. In all, about 25,000 hectares of valuable farmland, agricultural and horticultural production and residential communities were protected. But it wasn't an easy job.

The confluence of the Waikato and Waipa rivers in flood graphically shows the mixing of the two sources.

SETTING THE SCENE

The Waikato is the fourth largest region in New Zealand, covering most of the central North Island and the Coromandel.

Environment Waikato, the Waikato Regional Council, manages natural and physical resources within the 25,000 km^2 area of its jurisdiction. It represents 366,800 people who live in the central North Island, and its role is to help communities, industry and other groups to live and work with natural resources – water, soil, air, geothermal areas and coasts.

The Council's Asset Management group looks after flood control, land drainage and catchment protection schemes. Millions of dollars of public money are invested in these assets which provide security for the community in floods and protect valuable soil from erosion. The Council's Natural Hazard Programme gathers information to help minimise the effects of natural hazards such as volcanic eruptions, floods, landslides and earthquakes.

A detailed Flood Warning Manual provides processes to be followed if high rainfall or river level alarms are activated for all catchments in the Region. The manual ensures the Council works closely with the owners of the eight Waikato hydro stations (now two different companies) using the lake storage facilities to help lessen flooding downstream in the vulnerable Lower Waikato area.

At Environment Waikato, a 24-hour roster ensures immediate response to any developing weather situation or any other natural hazard, and the Flood Operation Centre can be established and be fully operational immediately. Technology provides for the automatic transmittal of rainfall and river level information from remote sites via telephone lines. Alarm messages are received by pager and e-mail.

When this drama first began, the magnitude and duration of the events to come were unpredictable. It was just raining – a lot.

BALANCING THE WATER

It was the nature of the back-to-back deluges which meant the ground became saturated, and river levels couldn't return to normal in between. After the first downpour, the upper catchment rivers reacted very quickly when the second arrived. Most of the rainfall fell between 9 - 11 July, with Ngaroma (near Te Kuiti) receiving its July normal in less than two days. Other sites also recorded well above normal rainfall for July (between 51 and 167 percent).

The Waikato River system also stayed very high for longer, much longer than the great flood of 1958, as rivers were already swollen and successive rainfall storms arrived after the main event on 9 July. At its peak, the Waipa River contributed over half of the flood flow recorded below the confluence with the Waikato River at Ngaruawahia.

Just before the storm began, Lake Taupo's level was 356.94 metres (still 0.31 metres below the winter maximum control level (MCL) of 357.25 metres). The lake rose 0.85 metres (a total of 520 million cubic metres) from record inflows over the first three weeks of July - the highest flows since 1905. Environment Waikato instructed the then-ECNZ to control flows from the Taupo Gates and store water in the hydro dams to help lessen the effects of flooding in the Lower Waikato River. Between 9 - 20 July, a total of 340 million cubic metres of water was stored in Lake Taupo.

Environment Waikato and ECNZ worked constantly together to ensure that the Karapiro Hydro Dam was used to the best advantage to minimise flooding downstream. The cascade effect and uncontrolled tributary inflows through the already full dams made this process difficult. It became clear that to effectively manage flood flows through the lower Waikato system, Environment Waikato flood managers needed the lowest possible flow downstream of Karapiro to allow the Waipa River peak to pass through.

Three flood peaks hit Ngaruawahia. The first

Huntly College under water at the height of the flood.

was the initial high tributary inflows into the Waikato River which were not able to be held in Karapiro (plus the tributary inflows below Karapiro and the Waipa flows). The second peak was the arrival of the Waipa peak (which was long and flat), and the third peak represented the second Waikato peak caused by the second storm on 14 and 15 July.

The Waikato River flood wave grew rapidly as it moved downstream as the third storm hit, mainly on the lower Waikato tributaries. This meant the tributaries in this area peaked as the main Waikato River peak was passing through. The Waipa River flood wave also grew as it moved downstream towards Ngaruawahia because of the flooded lower tributaries, and was the largest recorded between Otorohanga and Ngaruawahia since the flood of '58.

The river protection systems did exactly what they were designed to do. The impact and damage from this flood was substantially less than in 1958, with protection of approximately 25,000 hectares and property damage substantially reduced. However, a large chunk of the Region was still very significantly affected, with some 11,350 hectares of farmland flooded. Damage to river protection systems and other community facilities and private property has been high, with total damage assessed at around $17.5 million.

WHERE DID THE RAIN COME FROM?

As July began, a repetitive weather pattern was established over the Tasman Sea and central New Zealand - a slow moving high pressure system to the east of the country, and a low pressure system occupying the Tasman Sea.

The MetService issued a number of heavy rain warnings. On 1 July, 100 – 150mm was forecast for Lake Taupo's catchment. Ahead of the low, an active front was preceded by a strong northerly flow bringing mild humid air in a deep layer down from the subtropics onto the North Island. As the front passed over the North Island in the early morning of 2 July, widespread rain followed.

On 7 and 8 July, an intense high moved slowly away, while a shallow complex low over central and eastern Tasman approached the country. Forecasts issued for the South Waikato and Taupo Regions predicted up to 100 mm in the hills and 40 to 60 mm in lower lying areas over the period from midnight, 8 July. The timing and duration were about right, but the amounts in the high country were under forecast.

During 14 July, a low which had developed north of New Zealand moved quickly southeast over the upper North Island bringing a brief period of widespread rain in an easterly flow ahead of the low. An alert was issued at 11am on 13 July for the Waikato Basin and Taupo areas with about 30 mm forecast in a 12 hour period from about midday the next day. This was upgraded to a full warning in the morning with 30-40 mm predicted in the eastern parts of the catchment and lesser amounts farther west.

MEASURING THE WATER

Both rainfall and water levels are measured automatically in real-time at 41 recorders strategically located throughout the Waikato Region. These form part of Environment Waikato's overall telemetry network, with four of these recorders owned and operated by the National Institute of Water and Atmospheric Research (NIWA). The telemetry system has been upgraded in recent years as part of the operational improvement programme.

The Rangariri spillway across State Highway One which closed the road at the height of the flood.

The first storm on 2 July on the Tongariro River was not noticed, other than by those people who were alerted on Awamate and Grace Roads.

On 9 July the Tongariro River was rising noticeably throughout the day. A number of large logs collected against the piers under the State Highway 1 Bridge, creating a backwater upstream from the bridge, and a standing wave effect next to the underside of the bridge superstructure. The Tongariro River continued to rise through the day and by late afternoon Transit New Zealand had to clear flood debris from beneath the bridge, closing it. Flood debris was continuing to jam against the bridge piers and south of Turangi, at the red hut pool, a fishing bach subsided into the river and was completely demolished.

Flood waters over-topped the river bank, five or six mostly unoccupied houses close to the Tongariro Lodge were evacuated, and a sewage pump station also had to be closed.

Under the Tongariro Offset Works Agreement, ECNZ is required to stop diverting water from the Moawhanga, Whangaehu, and Whanganui River catchments when the level of Lake Taupo is at, or is expected to reach, 357.25 metres. At 5am on Sunday 12 July, the TPD operators were advised that the lake was nearing this level, diversion ceased – and did not begin again until 3 August when the level of Lake Taupo fell below 357.25 metres.

Early in the flood event, the Taupo gates restricted the outflow – described later as like emptying a swimming pool through a straw. With the Taupo outflow severely restricted above large inflows running into Lake Taupo (above 500 cumecs on 16 July) the level of the lake continued to rise, swelling to its highest level in 40 years (357.49 metres).

River levels generally declined on 16 and 17 July. On 17 July, Lake Taupo control gates were opened and flows through the Waikato hydro system were increased to reduce lake levels. The control gates were maintained at their maximum setting until the level of lake fell significantly below the MCL of 357.25 metres - on Monday, 3 August - more than two weeks after the gates were set to maximum opening.

But if the Taupo gates had been fully opened throughout this event, peak flood levels at Hamilton, Huntly, and Mercer would have been 1 metre, 0.5 metres, and 0.1 metres higher than they actually were.

IN THE CITY

The flood peak level recorded at Bridge Street in Hamilton City (16.71 metres) was 1.57 metres below the peak level recorded in the 1958 flood. In the city, various sections of the community paths were closed, Grantham Street car park was inaccessible, and some low-lying streets were inundated, flooding basements and causing electrical problems.

Hamilton City Council Emergency Management staff used sandbags in critical areas to combat the high levels through the city. Many sections of the community paths that flank the river, including the Grantham Street car park, were cordoned off for safety.

At Ngaruawahia, when the main storm struck on 9 July, the river level at Ngaruawahia was already above normal due to an earlier event less than a week before. About 55 percent of the peak flow recorded at Ngaruawahia came from the Waipa River, which drains only 30 percent of the total Waikato catchment, while the Waikato River contributed 45 percent of the flow from as much as 70 percent of the catchment.

At Huntly, before the event, there was no telemetry available on the Huntly water level recorder, which meant that warnings could only be issued based on the situation upstream at Ngaruawahia. Due to both deteriorating conditions and the threat to some Huntly residents and property such as Huntly College, it was decided by Environment Waikato flood managers to install a temporary telemetry unit on the recorder to enable predictions more specific for Huntly. The telemetry system became so essential during the flood event that it has now become a permanent feature of the site.

This was the third major flood event experienced in the Mercer area since 1995. Local stopbank failure is common in this reach of the river when the river level exceeds about five metres.

Flood flows above Ngaruawahia on the Waikato River have been assessed as being between a 20-30 year event. Flood flows below Ngaruawahia increased to a 70-100 year event.

It took about 17 hours for the Waipa flood wave to travel from Whatawhata to Ngaruawahia, but it only took about 9 hours for the Karapiro releases to reach Ngaruawahia (and about five hours to reach Hamilton). This is due to the confined Waikato River channel between Karapiro and Ngaruawahia, which pushes the water through at higher velocities than that on the Waipa River between Otorohanga and Ngaruawahia, where there are ponding areas.

The Waikato River flood wave increased in magnitude as it moved downstream (below Ngaruawahia) due mainly to the arrival of the third rainfall event, which mainly concentrated itself on the lower Waikato tributaries. This in effect caused the tributaries in this area to peak during the time when the main Waikato River peak was passing through.

Data from the Waipa River recorders indicates that the relative size of the flood wave increased as it moved downstream towards Ngaruawahia, and was the largest recorded between Otorohanga and Ngaruawahia since the 1958 flood. It is estimated that it took 77 hrs for the main flood wave to travel between Otorohanga and Ngaruawahia. Major channel works, such as the removal of willows, have taken place since the 1970s meaning that peak river levels are now significantly reduced due to the reduction in obstructions.

The Mangatangi (Maramarua) River also flows into the Whangamarino Swamp. During the flood, the river experienced about four different peaks due to multiple storms in the Hunua Ranges, with the maximum flow recorded being 117 cumecs (four metres above normal) on 15 July.

Many farms that fringe this river system were inundated as the flood waters left the main channel, flowing over the berms. When the Whangamarino Control gates were closed, flood waters quickly accumulated in the wetland, resulting in the highest level recorded since 1958, only just below the design level.

The major river systems in the Hauraki Basin and the Coromandel Ranges were less affected than the Waikato / Taupo river systems. The peak flow in the Piako River is assessed at a 12 percent (eight year return period) event. Flood flows in the Waihou River system were generally relatively small, except in the upper tributaries. The flood in the Hauraki Basin Rivers was also small.

However, in Awakino, SH3 was closed for almost a week when a major slip at Mahoenui inflicted severe damage. Minor slips within the Awakino Gorge also caused some disruption.

Control gates at Te Onetea, Lake Waikare, and Whangamarino were opened and closed under flood rule guidelines. The Lake Waikare (northern outlet) and Whangamarino gates are closed when the level of the Waikato River is greater than the water level in the Whangamarino Wetland. Closing the gates prevents backflow from the river into the wetland. Under 'normal' flow conditions, when the river level is below the wetland level, the gates remain open and natural through flow occurs between Lake Waikare, the Whangamarino and the Waikato River. The Lake Waikare and Whangamarino gates are always closed together.

Many farms that fringe the lake were inevitably flooded as the local private stopbanks were overtopped. Farms that fringe the Whangamarino wetland were also flooded due to the swollen Maramarua and

Whangamarino Rivers which continued to infill the wetland above private stopbanks levels while the gates remained closed.

The Whangamarino Wetland area swelled from its normal 17 km^2 to 67 km^2, as opposed to 126 km^2 in the 1958 flood. Without the gates, the wetland level would have been equal to the Waikato River level of 6.11m, and an extra 73 km^2 of land would have been underwater.

The Rangiriri Spillway is designed to flow water from the river over State Highway One into Lake

Huntly under water, with the college at its centre.

Waikare. About 200 cumecs of water flowed across the spillway when the river peaked on 12 July.

HOW THE FLOOD WARNING SYSTEMS WORK

Rainfall and water levels are measured automatically at 41 different strategically located recorders that are linked to Environment Waikato's recently upgraded flood warning computer system (*HydroTel™*) based in Hamilton. This data is used in conjunction with MetService bulletins and, if required, information by ECNZ on flows through the Waikato hydro-electric system.

An "alarm" is triggered automatically when a predetermined rainfall intensity or water level is exceeded at a particular recording site. The system then notifies Environment Waikato's rostered Emergency Management Officer (EMO) automatically by pager. The EMO then acts according to a set of procedures contained within Environment Waikato's flood manual, and in the Flood Management Rules (ECNZ).

The first flood warning for this event was issued about 11pm on 9 July. Between Thursday 9 July and Monday 20 July, over 1,780 high river level and/or heavy rainfall warnings were issued from Environment Waikato's monitoring system to both internal and external contacts via pager, fax, and/or email messages. The busiest day was Friday, 10 July when about 475 individual flood warning messages were released.

During the event, there was a 335 percent increase in the use of Environment Waikato's 0832 Infoline for the Waipa/Waikato River system.

One of the problems facing the technical staff supervising the telemetry system was that the majority of the recorder sites located between Otorohanga and Ngaruawahia on the Waipa River, and between Ngaruawahia and Mercer on the Waikato River, had all their six pre-determined alarm trigger points exceeded. This meant that as the river levels continued to rise, new alarm settings had to be entered during the event.

The centre's phones, faxes, email and computer facilities were active 24 hours per day for almost two weeks. As the event grew in stature, the number of staff involved swelled to about fifty (from the normal four), each six person team doing twelve hour shifts, ensuring information, resources and field assistance were coordinated as efficiently as possible.

Various whiteboards and message sheets conveyed constantly changing information such as calculations on predictions, phone numbers, rosters, incoming river information, and requests for sandbags and other resources.

THE AFTERMATH

Transit NZ suffered the largest damage cost - damage to state highways was about $14.853 million, including $5 million to repair the Mahoenui land slip. District Councils suffered the second highest cost, with damage to local roads, stopbanks, infrastructure and road closure. Damage to local roads generated a large proportion of the cost for councils. In addition the Franklin District Council incurred large costs ($1.18 million) resulting from damage to flood protection works.

Damage costs to farmland were also significant and estimated at $1.784 million, with the average damage cost per hectare for the Lower Waikato area $515. Approximately 11,000 hectares of farmland were flooded, with water staying in the Lower Waikato about 25 days.

Environment Waikato incurred $1.683 million in costs for damage to flood protection works (stopbanks, floodgates, pump stations, drainage ways) which comprise the LWWCS. The damage cost incurred by Huntly College was approximately $1.06 million. This is a substantial cost for an individual organisation and reflects the large amount of damage, which occurred within a relatively small area.

The costs to Environment Waikato, District Councils, Transit NZ, the Department of Conservation and Huntly College are approximately $25 million. The cost to farmland is approximately $1.7 million.

In total an area of about 11,350 hectares of productive land was inundated. The extent of damage was substantially less than in 1958, where approximately 37,000 hectares were inundated in the lower Waikato and Waipa Rivers alone, and extensive inundation and damage occurred to housing in areas such as Otorohanga, Te Kuiti and Turangi.

KEEPING THE COMMUNITY INFORMED

Environment Waikato's Regional Civil Defence Controller convened daily debrief meetings in Hamilton to update the key agencies of the current situation and the likely scenario for the next 24 hours, while providing an opportunity to hear feedback and concerns from those agencies representing the flood affected areas.

The meetings were attended by Emergency Services (Fire Service, Police, and Ambulance), ECNZ, Ministry of Civil Defence, Tranzrail, Transit New Zealand, Ministry of Agriculture, Automobile Association, Federated Farmers (Waikato and Hauraki branches), New Zealand Insurance Council, Taranaki Regional Council, Taupo District Council, Waikato District Council, Waipa District Council, Hamilton City Council, Franklin District Council, Waitomo District Council, and Otorohanga District Council.

Various post-event debrief meetings were held at both an internal and external level. All agencies involved in the flood were invited to attend a one-off meeting at Environment Waikato to exchange ideas, information, and impressions on how the event was managed.

Community meetings were held during October at Te Kauwhata, Huntly, Te Kohanga, and Mercer to provide an opportunity to review the flood event and how it was managed with the affected communities, to disseminate information on the event, and to identify issues of concern, and opportunities for future improvement.

Lake Taupo rose a total of 0.85 metres, or 10 cm above the compensation level during the July flood. Taupo residents were warned via a newspaper advertisement about possible erosion and flooding problems, especially if the wind picked up and drove water into foreshore communities.

Post flood, the community needed to know what happened and why. Communications tools included:

- A special one page *Taupo Times* advertising feature (explaining the effect and reasons for the high lake levels, and options for mitigation)
- School visits in the flood-affected areas
- Post-event community debrief meetings in the affected areas to hear, and where necessary, address concerns
- Shortly after the event, a special issue of the Council's quarterly magazine EnviroCare (titled *"The Big Wet"*) was produced and distributed region-wide.

WHAT WE CAN LEARN

Tighter land-use controls on flood prone properties by District Councils will be encouraged and supported by Environment Waikato (for both existing buildings and new development). Protection of infrastructural assets (i.e. stormwater and sewerage systems) should also be given high priority, especially in areas prone to erosion from high lake and/or river levels.

A regional flood hazard mapping project commenced in 1997, starting with the Waikato River and tributaries within the Waikato District. Work is currently focused on a quality check of the information. The final stage of the project will involve the information being loaded into Environment Waikato's Geographical Information System (GIS) and made available to District Councils and the public.

A new site has been added to Environment Waikato's website, http://www.ew.govt.nz to ensure everyone has the same information about their local rivers. Using http://www.ew.govt.nz/ourenvironment/riverlevelsandrainfall/index, landowners can find out what is happening to rivers and streams in their area as telemetry data is regularly updated into easily understood graphs and maps accessible to everyone with a computer. The Info phone lines are still in use, along with personal calls to farms and landowners in flood prone areas during an event.

The July flood in the Waikato Region was a very large event, but it wasn't the "biggest" that could be expected. The Really Big One may be just around the corner…

Alexandra:

A practical solution for managing flood risk

By Chris Kilby

Manager Policy, Ministry of Civil Defence and Emergency Management.

The Clutha catchment

BACKGROUND

In November 1999, the Southland and Otago regions experienced their worst floods in over 100 years. While not on the same scale as recent flooding in Europe, it was a time of intense emergency management activity as people and property were constantly monitored for their safety, river flows monitored and managed through hydro dam controls and stopbanks constantly monitored for their integrity. Civil Defence and emergency services quickly sprang into action. Through sound civil defence practice, no lives were lost, but there was extensive damage to property.

November 1999 was also just one month out from New Zealand general elections and the floods in Southland and Otago received a level of political interest.

THE PHYSICAL DIMENSIONS

During 15-18 November 1999, a record-breaking northwesterly storm hit the southwest of the South Island bringing torrential rain to Fiordland, south Westland, and the catchments of the Clutha River, resulting in flooding and disruption in Otago and parts of Southland. Businesses and homes were inundated in numerous towns, notably Queenstown, Wanaka, Alexandra, Balclutha, Kaitangata and Mataura. Power supplies were cut over much of Otago for a number of days and many roads were closed, including State highways.

Lake Wakatipu reached 312.7m above sea level on 18 November 1999, up half a metre on its 1878 record, and flooded about a third of downtown Queenstown. The lower business section of the town remained flooded by the Lake for about a week following this peak. Numerous people were evacuated, including those from 30 homes threatened by a potential landslide in Frankton.

At Alexandra, where a state of emergency was declared on the 17th, the Clutha River peaked at 142.5m early on the 18th, 7.5m above normal flow. About 200 businesses and homes were evacuated due to flooding, and water and sewerage systems were disabled. At the mouth of the Clutha River, in Kaitangata, 30 people were evacuated, and at Balclutha, where a state of emergency was declared, 100 people had to leave their homes, as a precautionary measure.

Also affected by the storm were 400 crew and cast filming the "Lord Of The Rings" trilogy - they lost a complete film set, washed away by flood waters. 'Middle Earth' had never been so destructive!

GOVERNMENT RESPONSE

The normal business of many government departments and agencies includes a role in emergency response and recovery. During and after the floods, Transit New Zealand worked 24 hours a day to reopen highways, deal with slips, and to replace the bridge over the Haast River. Other agencies with enhanced levels of activity throughout the response phase included Police, Fire Service, Department of Conservation, Search and Rescue, Health, and Work and Income. The Earthquake Commission was on location dealing with claims for slips, particularly in the Queenstown area. Ministry of Agriculture and Forestry specialists were deployed to the rural areas to monitor and provide advice to farmers and orchardists. Staff of the Ministry of Civil Defence and Emergency Management liaised with local civil defence personnel. The Department of Prime Minister and Cabinet and the Ministry of Civil Defence and Emergency Management were in close contact with the affected local authorities to ascertain their needs for government assistance.

In the midst of this activity, as affected communities began to focus on recovery from the effects of the floods, a Clutha Solutions Coordinator was appointed.

CLUTHA SOLUTIONS COORDINATOR

Following the flooding, the government was asked by affected local authorities (Queenstown Lakes District Council, Central Otago District Council, Clutha District Council and Otago Regional Council) to assist with finding long term solutions to the Clutha River flooding issues and the Ministry of Civil Defence and Emergency Management was tasked with coordinating this activity. Following discussions with the local authorities concerned, the then Prime Minister, Rt. Hon. Jenny Shipley, appointed Alex Adams as the Clutha Solutions Coordinator. Mr Adams would work with stakeholders to find ways to reduce the likelihood of future flooding along the river. While the primary focus of the Clutha Solutions Coordinator's work was to be on urban areas, he would take into account issues along the length of the Clutha catchment.

The Clutha Solutions Coordinator's Terms of Reference set out his key tasks:

- Identifying the issues relating to flood management of the Kawarau and Clutha Rivers;
- Helping the communities affected to pull together the necessary information so that the principal causes of flooding can be understood and analysed;
- Being a single point of contact and liaison between the communities, the district councils, the Otago Regional Council and Contact Energy Limited;
- Facilitating processes to identify practicable options for mitigating the risks;
- Examining the specific issues of siltation of the hydro lakes and the repeating flooding at Alexandra;
- Providing informed context to allow communities to debate long term solutions to reduce social and economic disruption from flooding of these rivers.

The appointment of the Clutha Solutions Coordinator was supported by the affected local authorities. During the ensuing months, Mr Adams regularly met with the local authorities and reported to John Norton, Director of the Ministry of Civil Defence and Emergency Management.

The Clutha Solutions Coordinator produced an interim report on the Clutha flooding issues in February 2000. This report was publicly circulated and created substantial discussion among the Otago communities. While Mr Adams was researching and talking with the communities, the Alexandra Community Board commissioned Optimx Consultants to examine flood protection options specifically for Alexandra township.

Optimx produced a discussion document for the Alexandra Community Board. Following a period of community consultation, a strategy was proposed and endorsed by the Central Otago District Council (*Future Directions for Alexandra Strategy Study - Strategy Proposal*, June 2000). The strategy contained a number of recommendations for flood protection options for Alexandra and further investigations into flood-related issues.

THE RECOVERY PLAN

Government policy on providing assistance for recovery of areas affected by emergency events is set out in the Recovery Plan (*Recovery Plan: Natural Disasters*

CLYDE DAM SPILLING
Note the four spillway gates well open and high water levels on the administration building island. (Photo: ODT)

and Emergencies within New Zealand). Previously administered by the Department of Prime Minister and Cabinet, the Plan is now administered by the Ministry of Civil Defence and Emergency Management.

The Recovery Plan takes the approach that local risks and emergency events can generally be managed locally. However, where a community is overwhelmed by an emergency event, the government may share the implementation of recovery outcomes. If the effects of an emergency are of such substantial effect and existing policies are insufficient to assist with recovery the government considers to what degree it might further assist the local community to recover, having regard for factors such as:

- continued risk to life
- magnitude of impact on the community
- sustainable, long-term solutions to reduce risks
- community ownership of the recovery solutions proposed.

ALEXANDRA: A UNIQUE CASE

The Clutha Solutions Coordinator delved into the causes of flooding along the Clutha River and options for reducing the flood risk. He found that flooding in the Queenstown Lakes and Clutha Districts was caused by natural processes and any measures to reduce the flood risk were the responsibility of the local authorities concerned. In these areas, community discussion was generated around a number of options. For example, a flood bank to protect Queenstown Bay, minor landscape works for Wanaka, and reviewing land uses in the Barnego area, Clutha District. In these areas it was however determined that it was the responsibility of the respective local authorities in consultation with their communities to develop and implement the most appropriate solution.

The situation in Alexandra was however found to be entirely different. The Clutha Solutions Coordinator found that Alexandra had suffered substantial problems as a result of a series of floods in 1994, 1995 and 1999. The 1999 flood resulted in the second highest flow on record with a considerably higher water level than the historical 1878 flood.

The increased flood level at Alexandra was found to be the result of sediment settling in Lake Roxburgh, raising the bed of the Clutha River. This process had been ongoing following construction of the Roxburgh hydroelectric dam in 1956 by the New Zealand Electricity Department. The rate of river bed elevation had however decreased since construction of the Clyde Dam upstream of Alexandra.

The issue of the impact of sedimentation build-up caused by hydro dam construction on flooding in the area had been recognised in the past. However with the transformation of the New Zealand Electricity Department into the State Owned Enterprise, Electricity Corporation of New Zealand and the subsequent selling of the Roxburgh and Clutha dams to Contact Energy Limited, confusion surrounded who should pay for the management of the flood risks which Alexandra now faced. Recognising Alexandra's unique circumstances, extensive discussions took place between officials from the Ministry of Civil Defence and Emergency Management, The Treasury, Department of Prime Minister and Cabinet, Ministry of Agriculture and Forestry, Ministry for the

Roxburgh Dam spilling with a massive flow in the Clutha River. (Photo: ODT)

Environment, Ministry of Economic Development, Land Information New Zealand, Central Otago District Council and Otago Regional Council representatives, technical specialists and Contact Energy. Comprehensive consultation was facilitated by Clutha Solutions Coordinator and Optimx investigations throughout the Alexandra community.

FLOOD PROTECTION PACKAGE

Following consideration of the Clutha Solutions Coordinator's recommendations, as well as those in the Optimx report, on 7 September 2000 the government and Contact Energy announced the signing of a Deed to formalise joint contributions to address flood problems in Alexandra.

The Minister of Civil Defence, George Hawkins, the Deputy Prime Minister, Jim Anderton and Paul Anthony, chief executive of Contact Energy, said of the Deed:

"We are pleased to be able to provide this assistance to the people of Alexandra. The package is designed to provide Alexandra with a high standard of flood protection for the future, and will also offer help to those who were most seriously affected by past flooding."

On 12 September 2000, the government announced a package totalling $21.58 million (including GST) to protect the town of Alexandra from future flooding by the Clutha River. The package, intended to provide 100–150 year flood protection, has two principal components; physical works and property purchase, and amenity enhancement.

PHYSICAL WORKS AND PROPERTY

Physical flood protection works to protect against future risks of flooding, including:

- building new stopbanks that will be one metre higher (143.3 metres above sea level) than flood levels from November 1999;
- infrastructural alterations to water, waste and storm water, roading, telecommunications and power systems arising from the stopbank's construction;
- property issues including the purchase of property that will be needed for constructing the new stopbank.

The location and design of the flood protection works would be based on recommendations by the Otago Regional Council's independent engineers, set out in the Alexandra Flood Protection report released in August by the Otago Regional Council.

AMENITY ENHANCEMENT

Townscape and facility enhancement, which includes landscaping, roading, and restoration of facilities such as the swimming pool owned by the Central Otago District Council.

A spectacular view of the Clyde Dam looking towards the Clyde township. (Photo: ODT)

IMPLEMENTATION

The Ministry for the Environment and Land Information New Zealand have been tasked with administering the government's flood protection package for Alexandra, with financial oversight by the Treasury. The affected local authorities, Central Otago District Council and Otago Regional Council, will implement the flood protection and amenity measures through normal resource management processes.

In addition, all the local authorities affected by the November 1999 flooding are encouraged by the Ministry of Civil Defence and Emergency Management to continue testing and improving their civil defence emergency management systems.

CONCLUSION

Although 'Middle Earth' had demonstrated her powers, the waters subsided, the sun came up, the community gathered together and their focus turned to what they could do, rather than what they could not. Although government played a more prominent role than usual in this particular event because of the hydro dam issues, the process by which Alexandra came together to address its flood risk and determine appropriate long term solutions for ensuring their townships viability, is one which should be encouraged as a sound approach to identifying and implementing long term sustainable recovery solutions.

REFERENCES

The Project Seeking Practicable Solutions for Clutha River System Flooding (Alex Adams, Clutha Solutions Coordinator, June 2000).

Final Report to the Ministry of Civil Defence and Emergency Management. The report can be viewed on the Ministry's website at www.mcdem.govt.nz/publications.

Future Directions for Alexandra Strategy Study Strategy Proposal (Alexandra Community Board, June 2000)

The Impact of Sedimentation in Lake Roxburgh on Flood Levels at Alexandra. A Review following the November 1999 Flood. February 2000. Otago Regional Council.

Clutha River Catchment Updated Flood Frequency Analyses Following the November 1999 Flood Event. March 2000 Otago Regional Council.

Alexandra Flood Protection Feasibility Assessment. May 2000. Otago Regional Council.

Managing THE FLOOD HAZARD

Volunteers shovel a mountain of sand into waiting sandbags in Helwick Street, Wanaka, as the rising Lake Wanaka floods into the central business area in November 1999. (Photo ODT)

by Janine Kerr

Policy Analyst, Ministry of Civil Defence and Emergency Management

Flooding is the number one cause of declared civil defence emergencies in New Zealand. It can cause substantial community trauma and disruption, damage to property and infrastructure, business losses and economic hardship.

Of all emergency declarations since 1963, over 70% have been flood-related.[1] Flooding costs New Zealand more than $125 million each year – these costs are in addition to the estimated $30 million spent annually on flood protection, and the millions more spent on insurance. Flood risk and flood losses are continuing to rise, largely through the continued intensive use of floodplains, and increasing urbanisation.[2] Successfully managing flood hazards by managing river systems is crucial to the many New Zealand communities living on floodplains.

Primary responsibility for managing rivers and reducing risks of the flood hazard to communities falls with local government. It is an interest shared by the Ministry of Civil Defence and Emergency Management. Reducing risks and disruptions to communities is central to the Ministry's roles and responsibilities in carrying out the Government's overall responsibility in protecting the security, safety and welfare of its citizens and communities.

As such, the Ministry has acknowledged a need to outline its role, interest in, and understanding of, responsibilities for management of the flood hazard throughout New Zealand. To begin this process, the Ministry has developed an information paper, *Managing the Flood Hazard*, for local government staff including chief executive officers and managers, planners, engineers, hazard analysts and technical advisers, and civil defence emergency management officers. The following is an excerpt from this paper which aims to:

- outline the role of civil defence emergency management agencies in managing the flood hazard;
- look at local authority legislative responsibilities for river management and flood control as they relate to the respective roles of regional and territorial local authorities; and
- discuss ways river management regimes and mitigation measures can reduce the impacts of the flood hazard.

ACHIEVING EFFECTIVE FLOOD RISK MANAGEMENT

Legislative requirements for river management are complex and varied. Careful interpretation and co-ordination is needed to ensure thorough and effective implementation. The combination of legislation requires that local authorities address issues well beyond just actual physical mitigation works to include a range of practices such as river catchment management, channel maintenance, flood and erosion control, hazard management, and land use management.

The existing legislation regarding river management and flood control provides for:

- regional councils to be responsible for minimising and preventing damage by floods and erosion. This can be achieved through a combination of mechanisms including catchment management, river channel maintenance and flood and erosion control;
- the delegation of these responsibilities with legal responsibility for compliance still resting with the regional council;
- both regional councils and territorial authorities to have responsibilities under the Resource Management Act 1991 (RMA) for natural hazard management (including flooding) and recognise the need to coordinate management of these functions; and
- territorial authorities to have a role in achieving effective flood management through land use controls and practices which recognise the impacts of land use in all areas of the district, particularly in both the upper river catchments and floodplain areas.

THE MINISTRY'S RESPONSIBILITIES

The Ministry of Civil Defence and Emergency Management has a role in advising and supporting local government around managing the flood hazard, particularly where it:

- may be required to assist with response to a large scale flood event;
- is required to advise the Government on recovery from events; or
- is required to promote the reduction of future risk to ensure the security, safety and welfare of New Zealand citizens and communities.

LOCAL GOVERNMENT RESPONSIBILITIES

At local government level, councils are required through various statutes to carry out a vast range of duties and functions around managing the flood hazard. If these were fulfilled in a coordinated and integrated manner, there could be a more effective flood hazard management regime across New Zealand. Key areas among those duties and functions are those relating to:

- river catchment management, channel maintenance, flood and erosion control;
- hazard management;
- land use management.

STATUTES AND TOOLS FOR UNDERTAKING RIVER MANAGEMENT

Statutes setting out responsibilities for river management, and tools to assist with managing the flood hazard, include:

- Soil Conservation and Rivers Control Act 1941
- Local Government Reorganisation Order 1989
- Resource Management Act 1991
- Building Act 1991
- Local Government Act 1974
- Local Government Act Amendment (No.3) 1996
- Rating Powers Act 1988
- Land Drainage Act 1908

LAND USE MANAGEMENT

Land use controls and practices play a significant role in effective flood management. Although regional councils do have a role in land use management, territorial authorities have the primary role as required under the RMA and the Building Act.

The Building Act (s.36) allows territorial authorities to require an entry on the certificate of title to land where a building consent has been issued for a building on flood-prone land, thus relieving the territorial authority of any civil liability should the building flood. Section 36 notices, combined with other mechanisms, make a stronger case for territorial authorities when imposing restrictions on flood-prone land.

In order to achieve a sustainable land use pattern that will minimise flood impact in flood-prone areas, it is important that territorial authorities take a coordinated approach with regional councils to identify the most suitable and effective management tools for these areas.

ANTICIPATED BENEFITS

Through improved management of the flood hazard, the Government hopes to have:

- safer, better informed communities with a raised awareness of the flood risk;
- community ownership of the flood risk;
- partnerships developed between regional councils, territorial authorities and the Government;
- decreased demand for community; and government assistance as a result of damage from flood events.

The Ministry is undertaking the development of a range of policies and programmes to assist the civil defence emergency management sector, and particularly, local authorities to do their job. Of particular relevance are:

CIVIL DEFENCE EMERGENCY MANAGEMENT BILL

The Government has approved the development of new Civil Defence Emergency Management legislation to repeal and replace the Civil Defence Act 1983. The purpose of this Bill is to give legislative effect to the principles underlying civil defence emergency management. The Bill was introduced in Parliament at the end of 2000 and is expected to be enacted in mid 2001.

The Bill contains a requirement for the Government to develop a National Civil Defence Emergency Management (CDEM) Strategy, and for all local authorities to form CDEM Groups and develop CDEM Group Plans.

NATIONAL CDEM STRATEGY

The National CDEM Strategy is to provide overarching strategic direction for civil defence emergency management in New Zealand by setting out the Government's broad policy framework and expectations for the civil defence emergency management sector. The National CDEM Strategy will guide and inform relevant policies and programmes of central Government, and CDEM Group Plans of local government.

The proposed CDEM legislation and the National CDEM Strategy will assist in clarifying Government's expectations of local authorities. The strategy is to be released within one year of the proposed CDEM Bill being enacted.

FURTHER INFORMATION

In 2000, the Ministry distributed the guidelines:

- *Preparing response funding assistance claims*: *guidelines for local government.*

These guidelines are to assist local authorities following an emergency event. The Ministry is currently preparing similar guidelines for recovery funding assistance claims.

Two more recent publications from the Ministry are:

- *The Formation of Civil Defence Emergency Management Groups: Information for Local Government*; and
- *Civil Defence Emergency Management Planning: Information for Local Government.*

These documents are intended to inform and support local authorities wishing to move towards the new civil defence emergency management arrangements prior to enactment of the proposed CDEM legislation.

The guideline documents, as well as the full paper *Managing the Flood Hazard* are available on the Ministry's website at: www.mcdem.govt.nz.

[1] Ministry for Emergency Management *Civil Defence Declarations since 1 January 1963*. Internal document. Ministry for Emergency Management, Wellington (2000)
[2] Ministry for the Environment *The State of New Zealand's Environment* Government Press, Wellington (1997)

On the Web

Some interesting sites on the Internet that provide flood-related information

Regional and District Councils

http://www.govt.nz/localgov/councils.php3

Gives addresses for Regional and District Councils that have responsibilities for flood protection and flood warning in New Zealand. Some examples are:

ENVIRONMENT CANTERBURY

http://www.ecan.govt.nz/echome/gis&database/telemetry/telemetry.htm

Gives details of current flows and rainfalls at a selection of stations in Canterbury.

HORIZONS MANAWATU

http://www.horizons.govt.nz/river-levels.asp

Gives details of current flows, water levels and rainfalls at a selection of stations in the Whanganui-Manawatu region.

WELLINGTON REGIONAL COUNCIL

http://www.wrc.govt.nz/fp/index.htm

Outlines the council's flood protection strategy.

National Institute of Water & Atmospheric Research (NIWA)

http://www.niwa.cri.nz/pgsf/waterfluxes/

Outlines current research efforts on determining the pathways that precipitation takes moving through catchments in streams and rivers, including during storm events leading to floods.

http://www.niwa.cri.nz/pgsf/freshwater/

Describes the collection of water quantity and quality data for the National Water Resource Archive, for a multitude of uses including estimating the frequency of past floods and for warning of impending floods.

http://katipo.niwa.cri.nz/salpex/

Gives details of the Southern Alps Experiment (SALPEX) on extreme storm rainfall across the Southern Alps.

United States Geological Survey

http://water.usgs.gov/dwc/

Provides a map of current daily streamflows across the United States.

National Weather Services of the United States

http://www.nws.noaa.gov/oh/hic/flood_stats/index.html

Estimates of flood damage in the USA.

North Dakota State University

http://www.ndsu.nodak.edu/fargoflood/

Detail about floods in the Red River of the north, North America.

British Hydrology Society

http://www.dundee.ac.uk/geography/cbhe/

Provides a chronology of hydrological events, including floods, in the United Kingdom.

You can link to the above sites by visiting the Ministry's website at http://www.mcdem.govt.nz

Research for Resilience!

A flooded Lake Wakatipu laps some of the properties most at risk from the landslip on Frankton Road in November 1999. (Photo: ODT)

Dr Warren Gray
National Institute of Water & Atmospheric Research (NIWA)

Each year floods remind us of the hazard that rainfall can be. The Clutha River flood in November 1999 led to losses which have been estimated to be as high as $50m[1]. As significant as the monetary losses was the disruption to people's lives. Fifty businesses in Queenstown were inundated, and the jobs of over 300 people were affected. A major landslide at Frankton led to evacuations of over 24 households. Fifty properties were flooded in Kingston and 55 in Glenorchy. Warnings to boil water lasted for two weeks in many areas and over 2 months for some Queenstown residents.[2]

In this area lake levels have only been as high in one other event in the 122 years of records, but significant floods occur somewhere in New Zealand in most years. For example, in 1998, the rainfall during October 18-21 led to flooding near Waikanae as the river burst its bank at Otaihanga; one man was drowned after being swept away. In 1997, rainfall on 3 June over Northland caused schools to close, power to be cut, and road closures due to slips. After such events, communities are motivated to take precautions against future floods. But memories tend to be shorter than the "average recurrence interval" and preparedness drops off. To make us more resilient to events like this we will need not only high-quality quantitative forecasts of rainfall and river/lake levels leading up, during and after the event, but also to have been prepared for it well beforehand.

NIWA has developed a new programme designed to improve predictions of floods and droughts and to improve our knowledge of the risk of flooding.

If we are to improve our resilience to floods then we need better forecasts, a better understanding of the risks, and knowledge of how people respond to the flood hazard. The first of these can be achieved through an advance in our understanding of the processes involved in flooding. From this basis we will develop tools that will improve our ability to forecast floods better. These tools will take advantage of the new data and technology that is now available to us. Important also is the assessment of the risk that floods present. Understanding the way people view risks and respond to hazards is a significant new part to this programme. Knowledge of the way people behave will help us prepare and warn them of a hazard. As importantly, we must connect with the organisations charged with hazard mitigation and response if our work is to be geared best to help them and if they are to take best advantage of our latest ideas.

We look below first at the tools we use to generate forecasts and the improvements to them, which lie at the heart of our programme, then at the process studies and the impact studies that are being undertaken to support this work.

FORECASTING TOOLS

RIVER FLOW FORECASTS FROM RAIN GAUGE DATA.

Flooding depends on river flow and this depends in turn on rainfall and runoff. Relating riverflow accurately to measured rainfall is the first task. Hydrologists at NIWA have developed the TOPNET model to estimate the riverflow from catchment rainfall. Each catchment is divided up into smaller sub-catchments, which are connected by a river network. Modelled river flow is generated by rain that falls in the sub-catchments, and then flows through the river network towards the mouth of the river, moving like a wave. The model is spatially distributed, so that each sub-catchment can have different rainfall, radiation, soils and vegetation from other sub-catchments. Within each sub-catchment, only the effects of varying topography on subsurface flow processes are modelled. For each sub-catchment we model processes such as interception and transpiration by plants, infiltration and surface runoff, soil water storage and shallow subsurface flow. The number of sub-catchments to use for a catchment can be controlled by the modeller, and is chosen to suit the problem. The typical inputs to such models are rain gauge and air temperature time series, and digital maps

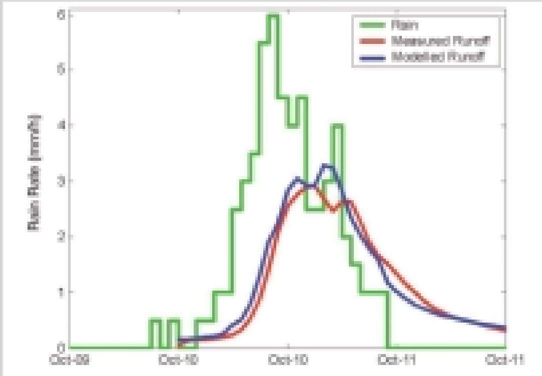


FIGURE 1: Prediction for the Leith Stream in Dunedin, New Zealand, in October 1984. (For convenience, the river flows have been plotted in the same units as the rainfall, i.e., cumecs/ catchment area)

of soil type, vegetation type, the pattern of annual rainfall and terrain height. The main outputs from the model are the time series of water flow at selected points on the river network. Many other hydrological aspects of the catchment (e.g. sub-surface saturation) can be displayed and animated.

Despite the variability of New Zealand topography and land types, the skill of the hydrological model using rain gauge information as input has been impressive.

Figure 1 shows an example for the Leith Stream, which drains a catchment of about 50 square kilometres to the north of Dunedin, New Zealand. The model for this catchment can provide us river flow forecasts with a lead time of around 2 hours, but it can be larger for bigger catchments. However, the amount of lead time we get for our river flow forecasts is limited as gauges only measure the rainfall as it falls. An additional difficulty is that there are often only a few gauges in any catchment, and so their data may well be unrepresentative of the rainfall that has fallen.

QUANTITATIVE RAINFALL FORECASTS

One of the key ideas in this programme is to use new technology to provide forecasts of rainfall for input into the hydrological model rather than gauge measurements or empirical guesses. The first of these uses the output of computer model forecasts of precipitation. NIWA runs such a computer model to forecast the weather up to 48 hours ahead at a resolution of 20 km. When this mesoscale[3] model is used as input into the hydrological model, the output will give us an estimate of the river flows and lake level for the next 48 hours.

The difficulty in the past has been that the weather forecasts, although increasingly accurate at estimating weather patterns, have not been able to provide quantitative precipitation forecasts. An

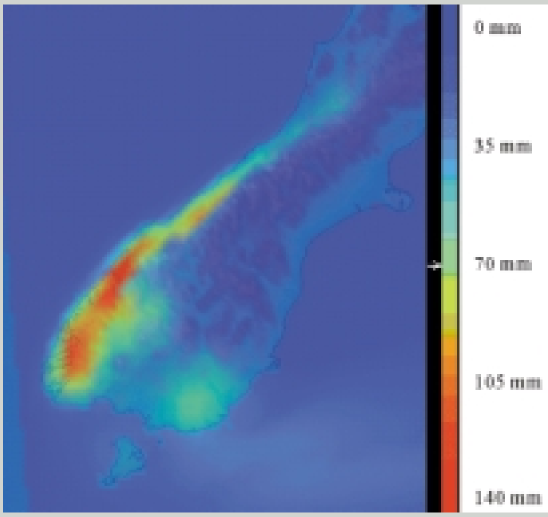


FIGURE 2: Modelled rainfall totals (mm) for the storm event of 4 Oct. 2000.

example of a forecast from a current model is given in Figure 2 and Figure 3. Here the mesoscale model has forecast up to 130 mm in the mountains in the period. Comparisons of the rainfall and river flow records show that the mesoscale model has underestimated the amount of rainfall over the mountains. Research into the processes modelled suggests that the parameters describing the properties of the clouds may not be suited to our New Zealand environment. Research into improving the model and increasing its resolution will help to improve these rainfall estimates. Once the mesoscale model has been improved useful forecasts with lead times of up to 60 hours may be feasible.

RAINFALL NOWCASTING

The second source of quantitative forecasts of rainfall comes from the extrapolation of radar echoes. Radar can be used to forecast rainfall for the immediate future, from 15 minutes ahead out to perhaps the next 3-6 hours. Such short-term forecasts have come to be called "Nowcasts". Metservice operates 3 rain radars, sited near Leigh (north of Auckland), Wellington and Rakaia (south of Christchurch). Radars transmit a pulse of radio waves. Planes, hills or cars can reflect this pulse, but in this case we are measuring the power reflected by rain. By tracking the motion of the rainfall seen in successive images (15 minutes apart), it is possible to forecast where the rain will be falling for the next few hours.

A difficulty in the past has been that small-scale rainfall features such as small showers last only a short time. It is not then possible to forecast the whereabouts of such showers at times longer than their lifetime.

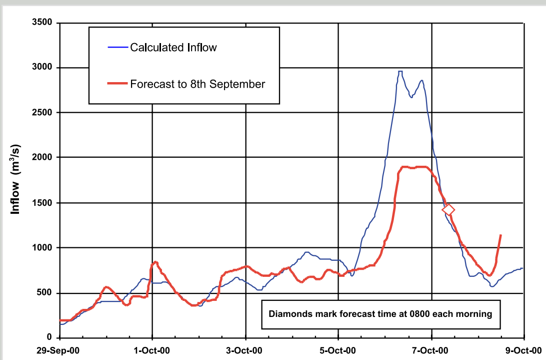


FIGURE 3: River flow as diagnosed until 0800 8 Oct, and forecast for the next 12 hours.

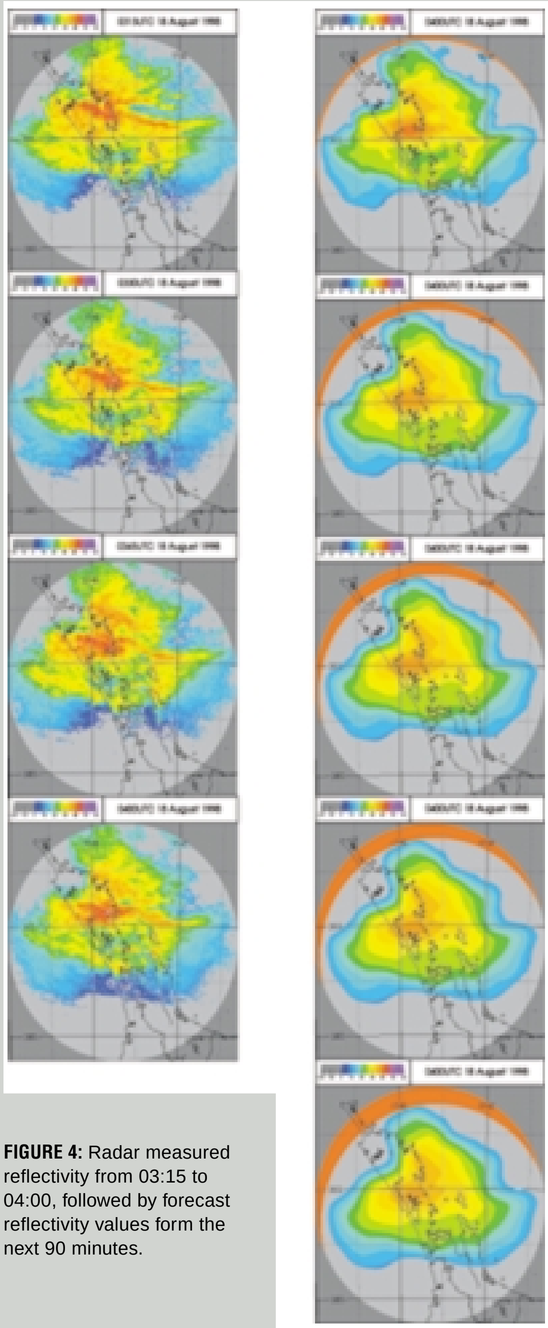


FIGURE 4: Radar measured reflectivity from 03:15 to 04:00, followed by forecast reflectivity values form the next 90 minutes.

Including these small showers in the forecast degrades its quality. By removing the smaller scales by smoothing, forecasts contain only the rainfall whose scale is large enough (and hence life is long enough) to survive till the end of the forecast period. This can lead to a significant improvement in forecast quality, particularly when averaged over larger catchment areas. The component of rainfall at these scales is therefore missing in the forecast. Simulations can be made to reintroduce those missing scales. Thus multiple forecasts for the same time can be made. The differences between these realisations can be used to show the uncertainty in the forecast that results from the removal of these small scales. This work is being done in collaboration with the Australian Bureau of Meteorology. Figure 4 shows the forecast of the rainfall for the passage of a frontal system observed during the Marvex[4] campaign. It shows that, as the forecast period increases, so the forecast rainfall field becomes smoother.

Output from the new NIWA Nowcasting scheme is being used as input for the Topnet hydrological model and trial short-term forecasts are being made of river flow. Combining the hydrological model and Nowcasting is particularly appropriate for the fast-response rivers such as the Otaki and Hutt rivers. For rivers such as these, and for areas where gauge data upstream of the catchment cannot be obtained (e.g., over the sea) Nowcasting can usefully extend the lead time of the forecasting of river flow from a few hours up to around 6 hours. For catchments such as the Otaki River, where the response of the river to rainfall is around 2 hours, Nowcasting can double lead-times. This can mean that authorities can respond to emergencies with enough time to be effective.

LONG-TERM FORECASTS

Another new component of work in this programme is the contribution made by our hydrologists to the "climate update" information disseminated by NIWA. This publication contains a summary of the last month's weather, soil and river flow conditions, and makes a forecast of the conditions expected for the next three months (see http://www.niwa.cri.nz/NCC/current.html.) The hydrologists in our team map the soil moisture and river levels for the last month and, along with NIWA's climate scientists, make a forecast of the climate expected for the next 3 months.

HAZARDSCAPE

The word hazardscape has been coined to collectively describe the extent of the risk associated with a hazard. In our case, hazardscape describes the collective areas of risk circumscribed by heavy rainfall and flooding. Understanding the hazardscape can enable us to be better prepared for the extreme event.

AVERAGE RECURRENCE INTERVAL

Part of being prepared for flooding events means understanding the extent of the flooding likely in any particular area. For many situations, this can be expressed in terms of the depth of rainfall likely to fall over a certain time frame, with a certain average recurrence interval (ARI) [5]. NIWA has developed a computer system to estimate the return period of rainfall for areas throughout New Zealand. The High Intensity Rainfall Design System (HIRDS) takes into account terrain height and nearby raingauge data and can provide estimates of the size of event for a particular ARI. Table 1 lists an example for Tauranga, and shows that, for example, the 173 mm received at Tauranga airport on 9 April 2000, would have an ARI of between 2 and 5 years (Figure 5). A detailed analysis of this rainfall event is being undertaken by Environment BOP. Analysis of the 28 years of Tauranga Airport gauge data would suggest that the ARI was indeed much longer than HIRDS suggests. In view of such discrepancies, NIWA is revisiting the software, updating the data within, and moving it to a "web-style" interface. This updating will not only improve the estimates produced by the software, but should provide a user-friendlier environment from which to interface with it!

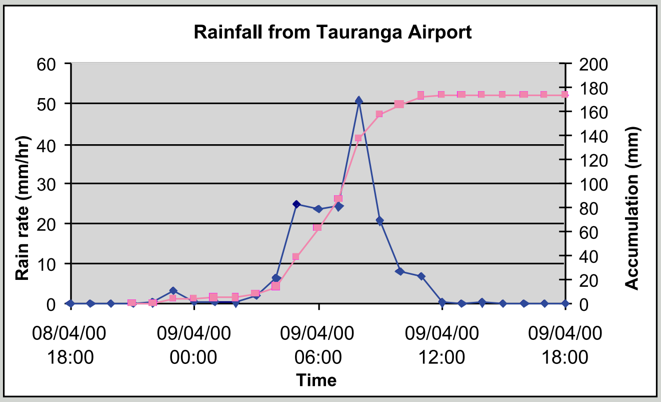


FIGURE 5: Rainfall measured at Tauranga Airport.

PROBABLE MAXIMUM PRECIPITATION

One of the concepts that has been found useful in design work is that of the largest rainfall event that can reasonably be conceived. This is termed the probable maximum precipitation (PMP). Concepts like this are used to assess the worst case scenario for dam design. PMP and the resultant probable maximum flood (PMF) are only estimates, with most of the uncertainty associated with the PMP estimate.

The PMF can be set as a mandatory requirement when building dams and stop banks. The reason for compelling owners of a structure to provide for a PMF is so that there is no doubt about survival of the structure. It is common for structures to be built for the worst possible loading plus a safety margin for uncertainty. In the case of dams and stopbanks, however, it has been customary to build for less than the worst possible flood and accept a small probability of failure during every year in the life of the structure.

However, consider the particular case where urban stopbanks were built with a flood passing capacity less than the PMF.[6] It was recognized that in urban settings this requirement could actually "create disasters"! This would happen where urban development after the banks were built leads to more structures being at risk. When the small amount of risk from overtopping is compared to the amount of money at risk, it would often have been better not to have built the stopbanks and not build so close to the river! That is, it is less costly in the long run if such stopbanks are not built.

There is more than one way to compute the PMP and PMF values. When a government makes PMF design criteria mandatory, guidance about the computation is needed. The currently used prescription for estimating PMP in New Zealand includes a map of "24-hour PMP" rainfall contours for a catchment area of 25 km^2. This PMP was determined as 3.05 times the 24-hour rain depths observed at gauges with 0.01 AEP[7]. To estimate the PMP on a catchment area >25 km^2 and where the duration from onset of rain to flood peak is > 24 hours, the procedure is to take the average from this map and reduce it by a prescribed area reduction factor and a prescribed duration reduction factor. This prescription is based on practice in the USA and was developed for application to large dams in New Zealand, and has since been applied at all those dams. However, we need to consider further the effects of the large enhancement of precipitation caused by windflow over our mountains.

In the current practice this is estimated by comparing the 24-hr 0.01 AEP precipitation depth in the mountains (e.g. 900mm at Ivory Glacier) and on flat land near sea level (e.g. 130 mm at Christchurch). However where it is as large as this, applying a 3.05 factor is believed to overestimate the PMP. The remedy adopted is to apply an "m factor" developed in USA and used there to reduce the estimate during short period very intense precipitation. Whether this is a reasonable practice needs closer scrutiny, as there appears to be no explanation in terms of atmospheric physics for this reduction for orographically enhanced precipitation. Summarising, the current practice uses a flat land PMP, and in the mountains increases it by an orographic enhancement factor which can be as large as 6.

An alternative will be to maximise the various factors that contribute to precipitation in mountains and to estimate the probable maximum combination of these. We can take advantage of the new knowledge gained during NIWA's SALPEX and TARPEX research. The factors will be: incoming flux of atmospheric vapour, orographic uplift, additional frontal uplift, the

Rainfall depths (mm) at Tauranga

ARI						**Duration**					
(y)	**10**	**20m**	**30m**	**1h**	**2h**	**3h**	**6h**	**12h**	**24h**	**48h**	**72h**
2	15	22	28	41	57	69	94	121	156	193	214
5	21	31	38	56	76	92	125	161	207	257	285
10	25	36	45	66	89	107	146	187	241	299	332
20	28	41	52	76	101	121	165	213	274	340	377
30	30	44	56	82	108	130	177	227	293	363	403
50	33	48	61	89	117	140	191	246	317	393	435
60	34	50	62	91	120	144	196	252	325	403	447
70	35	51	64	93	122	147	200	258	332	412	456
80	35	52	65	95	125	150	204	263	338	419	465
90	36	53	66	97	127	152	207	267	344	426	472
100	36	53	67	98	129	154	210	270	348	432	479

TABLE 1: HIRDS estimated ARI figures for Tauranga Airport.

duration of the additional frontal uplift, embedded convection and seeding of precipitation by falling ice particles. Durations much longer than the maximum of 96 hours contemplated in the prescription of the current practice seem to be necessary for estimating PMPs into some of the southern lakes. Therefore the proposed method will be extended to longer durations. The role of snow melt increases as the duration of the PMP increases. NIWA's recent research has provided new knowledge for a fresh approach to this aspect of the PMF.

CLIMATE CHANGE

Changes in climate, both natural and man made, have the potential to alter the number and severity of floods and their impacts. Current modelling suggests that we can expect to see more extreme weather in our region. This is in part due to the greater water holding capacity of the atmosphere at warmer temperatures, and in part due to the increase in temperature gradient between the tropics and the pole.

To understand our future hazardscape, we are looking back over past records to identify past changes in flood risk with climate and use current climate forecasts to project these flood risks into the future. At the same time, using our understanding of the processes involved in flooding, we will model how we expect climate change to change the flood hazardscape. As well as being a check on using the past records, it will enable us to forecast the hazard should the future climate lie outside previously observed states.

PROCESS STUDIES

RAINFALL DISTRIBUTION IN TIME AND SPACE

Fundamental to the rainfall forecasting research is an understanding of the way the lifetime of bands of rain are dependent on the space and time scale. To bolster our understanding in this area, we are going to analyse radar data, using techniques such as 2-D multifractals, to identify any preferred scales or processes that can improve the skill of our forecasting. This is particularly aimed at the Nowcasting and Mesoscale model forecasting techniques. In both cases there are assumptions made about the variability at small scales. This work will test whether these assumptions are valid, and quantify their significance. For example, the Nowcasting technique assumes that the smaller scales have shorter lifetimes. This work on the time and space dependency of rain will help provide the Nowcasting research with the optimum approach to quantifying this dependence. Similarly, the mesoscale model assumes that variability at scales below the grid-scale do not significantly affect rainfall totals. The space/time research will identify the sub-grid scale contribution, and may even be able to provide a statistical technique for simulating the missing scales. Multiple simulations could then be made, and the resulting variability in the rainfall and hence river flow forecasts would show the "unpredictable" component of the rain.

OROGRAPHIC ENHANCEMENT

One of the most important rainfall processes for New Zealand catchments is that induced by windflow over hills and mountains. It is this process that causes the impressive rainfall on the West Coast of South Island. While annual totals of rainfall upwind are around 1200mm, totals in the Southern Alps can exceed 10,000 mm! In the lee of the mountains, places like Christchurch experience annual totals of around 800 mm. Field campaigns like SALPEX and TARPEX have been carried out to identify the mechanisms by which the uplift over the hills turns the resulting cloud into rain. TARPEX results have shown that there are two primary mechanisms for enhancing rainfall over the Tararua ranges. The first enhances the rainfall by triggering more showers over the hill. The second uses pre-existing rain to wash out the moisture in clouds formed by the uplift over the hill. It is the later process that is suspected to produce the greatest increase in rainfall over the hills. For the Southern Alps, the SALPEX research has targeted the processes that lead to the greatest "spillover" of the rain into the catchments to the east (downwind) of the Alps. This is important, as it is in this area that our large hydro dams collect their water. For each of these programmes, the aim is now to find approaches that can lead to forecasting which of the enhancement processes will operate, and to quantify its influence.

RIVERBED PROCESSES

Knowledge of the potential size of a flood flow is not sufficient to evaluate risk to life and property because it is information on the floodwater depth that is essential for predicting potential damages. Thus the processes that influence the relation between flood flow and flood depth are of fundamental importance to flood prediction. These processes include:

- the geometrical layout of a river channel;
- the physical roughness of the bed of the river and its floodplains; and
- bed scouring and deposition that can occur during a flood.

Research into these processes is currently being carried out by NIWA to:

- determine optimum stopbank spacing to minimise the siltation which reduces channel capacity;
- improve measures for quantifying channel and floodplain roughness; and

• improve methods for quantifying morphological changes caused by floods.

Where stopbanks are widely spaced, floodwater velocities fall and the ability of the flow to transport sediment is reduced. This results in deposition of sediment on the channel bed which, in turn, results in increased flood levels. On the other hand, channels which are too narrow have insufficient bed surface to transport high volumes of bedload (the sand and gravel which rolls and bounces along the bed in a flood). The optimum width for a flood channel to maximise sediment transport is presently being sought.

Many flood hazard maps and building line restrictions rely on numerical models that calculate flood depths. The numerical models require a channel roughness coefficient. Present techniques for estimating channel roughness include comparing the roughness of similar known rivers or by taking samples of bed material for grain-size analysis. None of these techniques are particularly accurate and improved measures involving non-disruptive sensing of surface roughness are being evaluated by NIWA.

The larger gravel bed rivers of New Zealand may have beds that are several kilometers wide. Surveying bed levels of these braided channels is no small undertaking and conventional survey results do not indicate the position of the bed during floods. State of the art remote sensing techniques using airborne laser scanning systems, digital photogrammetry and *in-situ* video monitoring are under development as part of the NIWA Floods and Droughts programme.

HUMAN DIMENSION

In developing this programme we put effort into making sure the “people” part of the equation was dealt with. This was divided into two categories. The first category is the assessment of the impact that flooding has on people. This includes the effectiveness of the warning message, the communication chain, and the response of people. The aim is to improve our knowledge of how human behaviours, beliefs and actions influence their response to floods. This fits our priority of clearly relating extreme weather-related hazards to community vulnerability and mitigation and response measures. One aspect of this work will be to identify the public expectation of forecasts of natural physical hazards and their likely response to warnings of imminent risk. The results we gather will be fed back into the systems we generate as part of our work on forecasting floods.

The second category is the need to make sure the ideas, tools, and information we gather get passed on to the organisations that might benefit from them. This needs to be a two-way process, making sure they are consulted in the planning of our work so that the work undertaken is geared best to their needs. We are dedicated to improving the links with these organisations.

SUMMARY

Communities that are resilient to the effects of floods is a laudable aspiration. If our research is to help improve resilience then we need to do several things. We need to improve our knowledge of the processes that are important in understanding floods. From this basis we will develop tools that will improve our ability to forecast floods better. These tools will take advantage of the new data and technology that is now available to us. Important also is the assessment of the risk that floods present. This understanding of the hazardscape represents an encapsulation of our knowledge honed to present the most pertinent information. Understanding the way people view risks and respond to hazards is a significant new part to this programme. Knowledge of the way people behave will help us prepare and warn them of a hazard. Finally, we must connect with the organisations charged with hazard mitigation and response if our work is to be geared best to help them, and if they are to take best advantage of our latest ideas.

1. The November 1999 Queenstown floods and Frankton landslide, New Zealand. IGNS Science Report 2000/12

2. However, cellphone coverage continued with only some intermittent reception caused by overloading.

3. Mesoscale means “middle” scale. This means the model will resolve features on scales smaller than that of Highs and Lows as seen on weather maps, but not as small as individual cloud systems

4. See the Marvex references at http://www.niwa.cri.nz/pgsf/waterfluxes/marvex.html

5. Average recurrence interval represents how frequently an event of a particular size and duration could occur. For example, we should expect to see 10 events of a 1-year ARI size over a 10 year period.

6. Design of stopbanks so they were just sufficient for a “100 year flood” was mandatory for entitlement to Government subsidies until subsidies ended in 1989. This was to ensure that the available subsidy was widely distributed and not focused on unnecessarily expensive structures.

7. AEP = annual exceedance probability; an event with 0.01 AEP is also called a 100 year event.

Wairoa

A town living with the risk of flooding

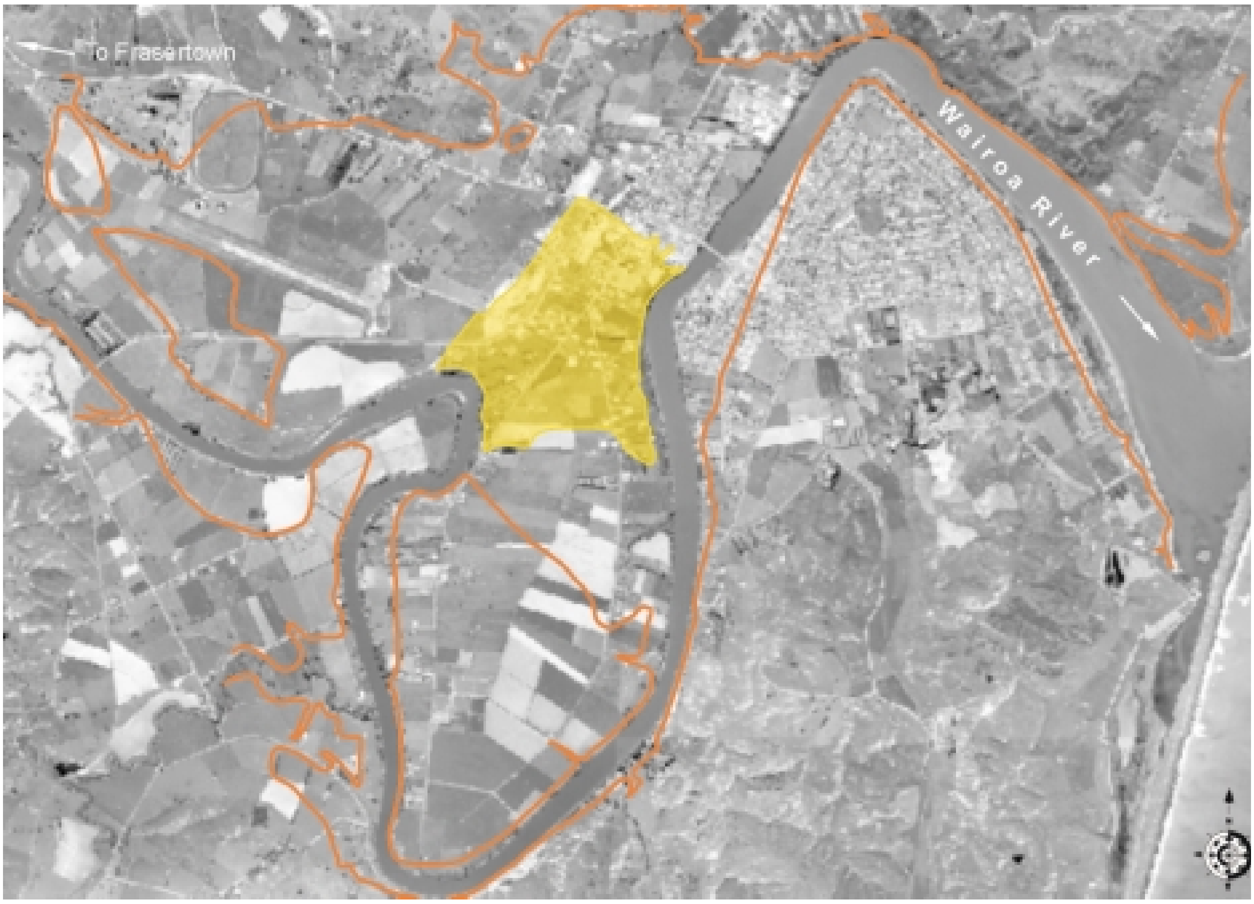
The missing Wairoa bridge, destroyed during the 1988 floods that accompanied Cyclone Bola (Photo – Daily Telegraph)

Mike Adye

Group Manager Asset Management, Hawke's Bay Regional Council

Wairoa is a town with a population of approximately 5,000 situated in northern Hawke's Bay. Like many other New Zealand towns it was built adjacent to the local river as early Wairoa relied entirely on the sea for access to the outside world and markets. The town subsequently grew with much of the development being on the flat land adjacent to the original town. That flat land was formed from deposits from successive river floods and remains at risk from flooding. The infrequent flooding of that developed flat land and the lack of significant development in recent years in the area meant that even in the days of significant government subsidy for the construction of flood control schemes, Wairoa was overlooked as justifying flood mitigation works.

Wairoa therefore remains at risk from flooding with no mitigation works ever being built. To compound Wairoa's risk, water levels in the lower reaches of the river, can be artificially heightened when the river mouth bar has a reduced flood capacity. The



The above plan shows the flood extent in Wairoa (shaded yellow) which resulted from Cyclone Bola in March 1988, during which the town bridge collapsed. This event had a return period of about 30 years. The outer line (orange) indicates the flood extent for a flood with a return period exceeding 100 years. The condition of the Wairoa River mouth has a big influence on the flood levels in the Wairoa township.

river mouth drifts up or down the coast over a distance of approximately 2km depending on sea and river conditions. Under certain sea conditions, or when the river mouth is in certain locations the mouth can become blocked. Lower areas of Wairoa town can be flooded unless the river mouth is mechanically opened.

Two notable events this century resulted in floodwaters escaping from the river channel and discharging overland through the town. These were:

1. May 1948. A quote from the publication "Floods in New Zealand 1920-53" (with metric conversions included) aptly describes this flood:

"The Wairoa River rose to a record height to submerge the decking of the town's traffic bridge and enter buildings to a depth of 0.9m. The bridge itself took a battering from the large amount of debris and timber which came down in the flood waters. The peak discharge was 11,440 cumecs, this being one of the highest recorded discharges of any river in New Zealand."

Telephone lines 4.3m above road level were carrying grass and twigs, showing the phenomenal rise of the floodwaters. Several bridges were swept away and others severely damaged."

2. March 1988. (Cyclone Bola). Floodwaters left the channel and crossed overland through part of the town to rejoin the river further downstream. Considerable damage resulted including loss of the State Highway 2 bridge in the centre of Wairoa.

It is not simply a remote (or low probability) storm event which can cause serious flooding of the Wairoa township and river flats. The May 1948 event was a 100 year flood in the river, yet it was in response to a 10 to 15 year rainfall event. Likewise, the August 1980 event arose from only moderate rainfall yet produced a flood of average magnitude. The event would not have been significant if it had not been for the combination of the flood peak arriving with a high spring tide and poor mouth conditions which resulted in lower areas of the Wairoa urban area being flooded.

These two flood events act as reminders that flooding can happen and it will happen again in the future. So how do we prepare for that eventuality?

In order to reduce flood losses or avoid the flood hazard there are two broad approaches that could be taken:

MODIFY THE FLOOD.

This method attempts to control the flood path and reduce the rapid runoff from the catchment.

It takes the form of physical works including stopbanks, channel improvements, and catchment planting.

MODIFY THE FLOOD LOSS POTENTIAL.

This method alters the human use and occupation of the floodplain so that the flood risk is minimised.

It takes the form of land use control, building code and sub-division regulations, zoning, flood proofing and possibly relocation of buildings.

Flood forecasting, civil defence and emergency preparedness are important aspects of modifying the flood loss potential.

In addition there is the option of saving life only and accepting that property will be damaged during any flood. If this option is taken then personal property loss can be mitigated through ensuring that individuals have the ability to restore their property and businesses without undue hardship. This may be done through adequate insurance cover, but this may not be available if the risk is believed by the insurance industry to be too great.

The above options have all been considered with some aspects being actioned. Some aspects of these options are however highly unlikely to proceed because of an inability to afford them, or they would be too complex to administer.

Hawke's Bay Regional Council and Wairoa District Council recognise that they have obligations under the Soil Conservation and Rivers Control Act 1941 and the Resource Management Act 1991 to mitigate the effects of flooding. However, both Councils are grappling with just what is required to fulfill their obligations as set out in that legislation.

A number of options have been developed with some already implemented.

1. RAINFALL INDEX.

According to Wairoa District Council civil defence staff the results of a survey of Wairoa urban area residents indicated that approximately 90% of householders recognise that their properties are at risk of flooding. Given this knowledge, civil defence staff were keen to ensure that they had as much time as possible to warn residents of an impending major flood.

To meet this requirement Regional Council staff developed the Rainfall Index. This is an early warning system for Wairoa that models the antecedent and forecast rainfall in the entire catchment. On receipt of a heavy rain warning a computer model is used to predict the likely flood discharges. This discharge information can then be converted to flood levels and inundation maps used to determine flooding extents. The model has been developed and used a number of times to assist Wairoa civil defence staff to determine possible river levels during rainfall events. However, although results to date have provided reasonably accurate predictions, more events will need to be monitored and predicted before staff have confidence in the model for very large events. Accurate predictions are important if Wairoa or parts of the floodplain need to be evacuated before the flooding actually occurs.

2. CATCHMENT WORKS AND STOPBANKING

A report outlining stopbank requirements as a mitigation option was prepared in 1994. Channel improvements and catchment planting for interception of some flood water, are not considered to be practical options as, due to the size of the catchment, they will have little overall affect on the runoff from the catchment. Stopbanking of the entire floodplain is not feasible because of the cost and the difficulty of controlling silt-banked rivers, and inundation of the floodplain in larger events will remain a relatively high risk. Stopbanking of some areas to isolate them from direct effects of a flood is feasible and a staged construction sequence was outlined in the report.

Indicative estimates for the cost of the work necessary for stopbank construction are given below.

	Indicative estimate of cost
Stopbank construction stage 1	$1,450,000
Stopbank construction stage 2	$2,000,000
Stopbank construction stage 3	$1,750,000
TOTAL	$5,200,000

This total equates to approximately $2,600 per rateable property. The potential loss of an attractive view of the river that would result from constructing a stopbank is one reason why stopbanking is not an option favoured by parts of the Wairoa community.

3. RIVER MOUTH CONTROL

The Wairoa River mouth migrates over approximately 2km of coastline depending on river levels and sea conditions. The state of the Wairoa River mouth affects the level of flood water in the lower section of the river in small to medium events. If the Wairoa River mouth could be trained or encouraged to stay open and remain in a location such that flood waters are efficiently discharged, the risk of flooding the low lying areas would be reduced. A major flood is expected to force its own mouth, although the location and timing of a forced opening are unknown, and increased flooding levels may result before an efficient opening is achieved.

There are several options available for

maintaining an opening through the barrier beach, including groynes. If the construction of groynes is the favoured option then a number of alternative groyne designs and layouts are possible. A pre-feasibility design study has been carried out by a coastal engineering consultant to determine the most cost effective option including the use of new technology to keep the mouth open and efficient.

The study examined a short groyne field (low cost, high risk) and a duel groyne system (high cost, low risk) as part of the conventional methods of maintaining an opening through the barrier beach.

Two innovative solutions using largely unproven technology were also examined. These were

- fluidisation of the beach barrier, and
- constructing an impermeable barrier within the beach crest.

Both have the potential to achieve the desired objective with less risk from marine forces and less environmental disruption. However, as the technology is unproven, the risk of either option not operating as designed is high.

It is estimated that ensuring an efficient river mouth would reduce the risk of flooding to 152 urban properties in Wairoa.

Although these options appear to have some promise, the cost and the risk of them failing to function as designed, mean that it would be difficult to obtain political or community agreement to them.

4. NON PHYSICAL OPTIONS

Options such as insurance and the establishment of a flood relief fund have also been considered but ruled out. To be equitable, property owners who had insured their properties should be treated equally to those who had inadequate or no insurance cover. The administration of such a scheme would be a major undertaking and it was decided on this basis that these options were impractical.

CONCLUSION

Hawke's Bay Regional Council is well aware of its responsibilities under the Soil Conservation and Rivers Control Act 1941, to mitigate the effects of flooding. It has taken what it believes to be a practical and realistic approach to establishing the risk and assessing options for the mitigation of that risk. It has also implemented an early warning system which will minimise the risk of loss of life or personal injury in a major flood event.

The information has been presented to the community, and although Council intends to seek further community comment on the options, initial feedback is that the physical mitigation options such as stopbanks and river mouth training groynes are unlikely to receive the support of the community on the grounds of both cost and visual impact. Once the community has been fully consulted and assuming that the initial feedback is correct, Council believes it will have fully met its statutory obligations.

Council is however aware that when properties suffer damage from a flood event in the future they will receive criticism from parts of the community and possibly central government for failing to adequately fulfill their statutory obligations. Present legislation does not however provide Council with sufficient powers to impose mitigation options on the community, and it is debatable whether this power should be given to Councils.

I therefore believe that there would be benefit from the establishment of clear national guidelines with regard to what will constitute the fulfillment of statutory obligations for the mitigation of the effects of flooding on communities.

Floodplain
management planning

Failure of a section of Anzac Parade, SH 4 near Shakespeare's Bluff, Wanganui. This section dropped into the Whanganui River following the flood event in early October 2000. (photo – Opus International Consultants Ltd)

By Tracy Berghan and Sharyn Westlake

OPUS International Consultants

Exposure to flood hazard and the effects of flooding are very costly for New Zealand. Flooding is estimated to have cost about $90 million per year since 1968. As one hundred New Zealand communities are flood prone and over two thirds of the population live within these communities, the high risk will remain, even with improved flood protection works.

PLANNING

A project to develop guidelines for Floodplain Management Planning in New Zealand is presently underway. This is being carried out in partnership with the Ministry for the Environment, Opus International Consultants and practitioners in floodplain management practice in New Zealand[1], and with assistance from the Ministry of Civil Defence and

Surface flooding at the intersection of Manukau Road and Subway, Pukekohe following high rainfall in January 1999. (photo – Opus International Consultants Ltd)

Emergency Management.

In the project to date, approaches currently being used by practitioners have been reviewed, best practice discussed, and common issues and problems addressed. Guidelines and relevant case studies are being developed from a series of workshops held with the practitioners participating in the project. The development of the guidelines, in association with case studies, will provide a decision support system to provide guidance for site-specific floodplain management problems. Once draft guidelines have been reviewed, these will be disseminated for wider comment and review.

The outcomes of this project are to:

- Promote the sustainable use of flood prone land.
- Provide practical guidance and methodologies to maximise the effectiveness of floodplain management activities.
- Promote greater awareness of environmental issues and public consultation associated with floodplain management activities.
- Provide useful and relevant information of value for communities.

FLOODPLAIN MANAGEMENT PLANNING

Floodplain management planning is carried out to keep people away from floodwater and better prepare them for coping when a flood occurs. The floodplain management planning process aims to ensure that any future development of the floodplain takes flood risk into account. It also attempts to match in a cost effective way the public acceptance of flood risk against the investment they wish to make to

Opotiki flooding, 1964 (photo – Environment Bay of Plenty)

SH1, Hurunui River during the August 2000 flood event. The bridge survived! (photo – Opus International Consultants Ltd)

alleviate that risk.

Approaches to floodplain management planning vary, from addressing one issue to a stand-alone plan or a wider programme encompassing erosion control, improved water quality, flood management and environmental enhancement. Development may be controlled in floodplain areas through a variety of methods including district and regional plan rules, provision of hazard information and maps, and community education.

WHY "FLOOD MANAGEMENT PLANNING GUIDELINES"?

The project has arisen from a need identified by the project team and the project partners for guidelines on floodplain management planning. Floodplain management planning has been undertaken in various guises for many years in New Zealand. However, some Councils have radically changed their approach to floodplain management planning while others are having difficulty in maintaining expensive flood protection schemes which were previously subsidised by central government. Balancing the costs to the community versus the level of flood protection provided is now a major issue for all Councils.

The work of the Water and Soil Directorate of the Ministry of Works and Development in floodplain management ceased in the mid 1980's. Regional councils have carried out subsequent work often on an individual basis. From our joint experience and understanding of floodplain management planning, this has resulted in limited information sharing and co-ordination between regional councils nationally. The quality of plans is varied and there is some "reinvention of the wheel". We also recognise that floodplain management planning can be time consuming and costly, particularly when floodplain management plans are developed individually and may not be easily reproducible. The guidelines are being developed to address these issues.

DEVELOPMENT OF THE GUIDELINES

WHAT HAS BEEN ACHIEVED ?

The project started in October 1999 and is due for completion in early 2001. In carrying out the project, three workshops have been held with the project partners, to discuss strategies, best practice and areas requiring emphasis in the guidelines. The workshops were also aimed at drawing out points of

Flooding over SH43 on the Tatu Flats, between Taumarunui and Ohura, during the October 1998 floods (photo – Opus International Consultants Ltd)

commonality, differences and gaps and issues that need to be highlighted, and that are suitable for use in case studies for practical discussion of the guidelines application. The draft guidelines are currently being developed and will be circulated for review, initially by the project partners and then to a wider audience.

GUIDELINE OBJECTIVES

The aim is to provide a set of guidelines and best practice examples for floodplain management planning in New Zealand.

The guidelines define the context of floodplain management planning and identify key issues. The best practice case studies will provide practical examples and aid in understanding the applicability of the guidelines.

These guidelines have been developed to assist all levels of government and the community to understand the floodplain management planning process and to aid the sustainable management of floodplains for present and future generations.

TARGET AUDIENCE

The guidelines will be of interest to practitioners from local, regional and national government, who are involved in floodplain management planning. We also envisage that the guidelines will have a wider audience including those people who are directly and indirectly affected by flooding.

The aim of the guidelines is to bring together the principles and best practice associated with floodplain management planning in New Zealand. The guidelines and best practice put forward ways in which issues can and are being addressed using best practice examples to illustrate different approaches.

WHAT WILL BE INCLUDED IN THE GUIDELINES ?

The main areas that the guidelines are covering are summarised below:

- Introduction about floodplain management planning and definitions.
- Economic and social factors, mitigation options, environmental considerations, management options and assessment criteria.
- Planning for over design events, flood standards including floor levels/freeboard/design standards.
- Risk analysis/impediments residual risk, including a case study.
- Plan integration with other plans, the Resource Management Act and regional policy statements.
- Relationships with asset management plans/ long term financial strategy funding – potential case study.
- Flood hazard –data collection/flood characteristics and flood scenarios.
- Flood management plans, including a case study; implementation/obstacles to implementation; effective relationships with territorial local authorities.
- Legal liability and insurance.
- Consultation, information dissemination and community education.

The guidelines have the underlying focus of "sustainable development" and a discussion on this is central to the guidelines. To achieve sustainability, the consequences of events out to the Probable Maximum Flood need to be investigated. This will result in the application of measures to avoid flood damages, not just mitigate their effects.

EXISTING DIVERSITY

In carrying out a project of this nature, the project team was very aware that different approaches were being used in floodplain management planning. The diversity of current approaches would need to be reflected in the guidelines, in that the guidelines should be able to be adapted and accommodate varying approaches. To aid in identifying approaches and concerns, questionnaires were sent to all the project partners prior to the workshops. Examples of information returned in the questionnaires, and discussed in the workshops are as follows:

- It was found that considerable variability exists between partners in different areas and even within areas, regarding the extent and complexity of issues addressed in floodplain management planning. Responses received varied across the spectrum from the formal to informal. In some cases full flood hazard management strategies and risk assessments have been carried out for flood plain areas, with flood hazards mapped and included as hazard zones in district and regional plans. Modelling and reporting of historical events has been carried out in some instances, and strategies prepared. In other cases, the work carried out to date may not yet be complete or particularly comprehensive.

- Management options presently used for floodplain management include structural measures such as stopbanks and dams; and non-structural measures, such as zoning, building and development control, community awareness, community preparedness, emergency management and flood prediction and warning. The actual adoption and implementation of each of these varies from case to case, location to location and over time. The "willingness" to adopt the range of measures varies considerably.
- Economic and social factors are studied to various degrees in most cases and the resulting information incorporated into the planning process. This may not be done specifically, but could be carried

The Tinwald Burn outlet under SH6, north of Cromwell after the November 1999 flood event showing scour after overtopping of the road. (photo – Opus International Consultants Ltd)

The swollen Countess Stream, SH7 (north of Culverden) during the August 2000 flood event (photo – Opus International Consultants Ltd) out to some degree implicitly. Social factors and costs are often incorporated but the extent of these (in terms of cost) may be guessed at in economic assessments. The assessment is used to help to prioritise certain areas in terms of vulnerability and the ability to cope and recover following a flood event.

- The environmental characteristics of the river and floodplain are taken into account only in some areas. This is stated to depend on the local environment to some extent, as for example, silt phase rivers have little fish life. Liaison with the Department of Conservation and Fish & Game is carried out for some projects, and regularly for river works. The environmental characteristics may also be taken into account through the resource consent process (for stopbank construction, gravel extraction etc) in carrying out an assessment of environmental effects.
- Some Councils presently prepare floodplain management plans, which are incorporated directly into district/regional plans. Some do not have specific floodplain management plans, and some are in the process of having plans prepared, which are almost universally non-statutory. For the non-statutory plans, implementation may be achieved in part via district plan rules. These are therefore a "Strategy" rather than a "Plan". Non-statutory floodplain management plans may stipulate statutory processes, such as plan changes, as a suggested method for achieving the plans policy outcomes. In a number of cases the mandate for floodplain management plans comes from the Regional Policy Statement.

These issues are discussed in the guidelines. Other issues that have been raised, and are also discussed in the guidelines include:

- Buildings permitted under S36(2) of the Building Act are not necessarily covered for damages occurring associated with the risk identified at the time. This has ramifications with respect to flood management planning.
- Government policy toward funding rehabilitation of areas affected by a flood event.
- Legal liability – when should information be provided? At the point of knowing or some other point? How is this identified?
- Community understanding and acceptance of information changes and how Councils ensure appropriate and ongoing communication of issues.

WHERE WE ARE AT AND HOW TO GET INVOLVED

The draft guidelines were circulated to project partners for review in September 2000. Once comments have been considered and the draft revised, the guidelines will be circulated to other regional and local authorities for wider review. If you would like to be involved in this process please contact the authors for further information. tracy.berghan@opus.co.nz/ sharyn.westlake@opus.co.nz.

[1] Environment Waikato
Hawkes Bay Regional Council
Environment Bay of Plenty
Environment Canterbury
Wellington Regional Council
Marlborough District Council
Gisborne District Council

FLOODS

Disastrous floods have struck most parts of New Zealand at some time or other. Floods are the most common cause of a civil defence emergency.

Before a Flood Strikes

DO Assume that you will have to cope with a flood. Several so-called '100-year' floods can happen in quick succession.

DO Find out about the worst flood in your locality and how high it rose. Calculate where such a flood would reach in your home.

DO Find out about present and future plans for building flood protection schemes in your locality.

DO Know how to reach the nearest high ground.

DO Keep your valuables and some food and clothing above what you judge to be the high-water mark.

DO Store weedkillers, insecticides and other chemicals above your estimated high-water mark.

DO Consider building some form of storage above your ceiling.

DO Keep your insurance cover up-to-date.

DO Read the emergency advice section at the back of your Yellow Pages.

When a Flood Threatens

DO Listen to your radio for information. Follow Civil Defence advice and instructions.

DO Disconnect electrical appliances and move valuables, clothing, food, medicines and chemicals above the likely reach of floodwater.

DO Take your Getaway Kit with you if you have to leave your home. Turn electricity and gas off at the mains.

DO Take your pets with you.

DON'T Go into floodwaters alone.

DON'T Go sightseeing through flooded areas.

DON'T Drink floodwater. It could be contaminated.