

## FLOODS

A flood occurs when the amount of water in a river exceeds the capacity of the river channel and inundates adjacent land. Floods are an integral part of a river's natural cycle – they transfer sediment through the river system to floodplains and offshore.

New Zealand's early settlers lived close to rivers to take advantage of fertile soils, fresh water, and the transport links that rivers provided. The settlers, with limited knowledge of New Zealand's landscape and climate, didn't realise the high flood hazard.

Floods continue to be New Zealand's most frequent and costly natural hazard. Today, with structural protection works and monitoring and warning systems, floods claim few lives, but they still regularly cause millions of dollars' worth of damage to structures, infrastructure, and agriculture.

### Factors that control flooding

The size of a flood in a river depends on the intensity, duration and total amount of rainfall, and the characteristics of the catchment and floodplain.

#### Widespread heavy rain

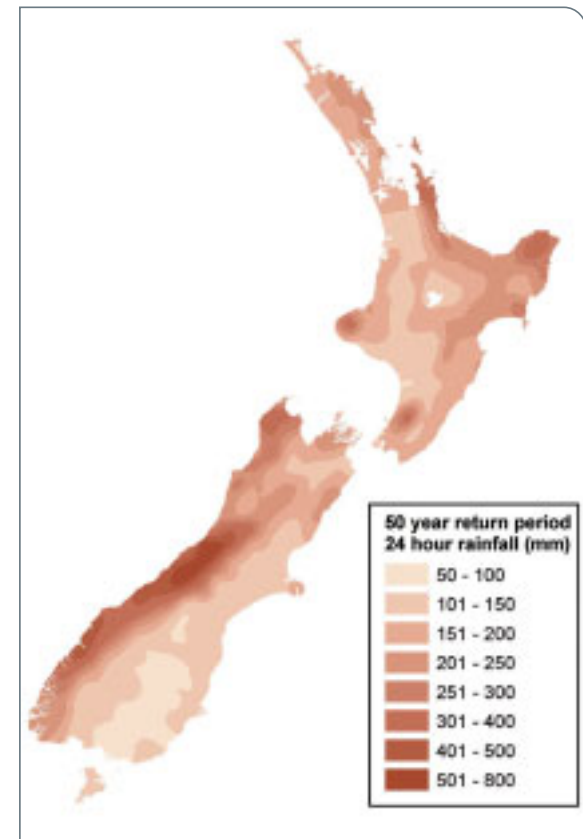
New Zealand is surrounded by ocean and lies in the zone of strong westerly winds which flow around the southern hemisphere where warm, moist air of tropical or subtropical origin meets cold, dry air from high latitudes. Topography and the angle at which the airstream hits New Zealand's ranges, along with the temperature and humidity of the air, dictate the distribution of rainfall over the country. Consequently, heavy rainfall can occur at any time of the year in any part of the country.

Widespread heavy rain occurs when air is forced upwards either within a frontal system, as moist warm air is driven up over a mass of colder air (frontal rain), or within moist air that is forced to rise over mountains (orographic rain), or as a combination of the two processes.

Heavy rainfall in the west and south of the South Island is common and is produced by a combination of fronts within west or northwest airflows and one of the highest rates of orographic uplift of air in the world. Moisture-laden air arriving from the west is forced up over the Southern Alps, rising 2500 to 3500m within 10–20km of the coast. Annual precipitation (both rain and snow) is up to 15m in the Southern Alps and rainfall of more than 600mm in one day has been recorded on the West Coast.

Heavy rainfall in the North Island and the northeast of the South Island is often associated with mid-latitude cyclones or ex-tropical cyclones that move over or past New Zealand from the north. Very strong winds often accompany ex-tropical cyclones.

Heavy rain in the southeast of the South Island may be produced by slow moving mid-latitude cyclones to the east of the island or north-south oriented fronts between a mid-latitude cyclone in the Tasman Sea and a high pressure system in the Pacific Ocean.



The 50-year return period rainfall for a 24-hour period. The west coast of the South Island, Mt Taranaki, the Tararua Range and the northeastern North Island have the highest 24-hour rainfalls. *National Institute of Water and Atmospheric Research.*

## FEBRUARY 2004 STORM

The February 2004 storm was New Zealand's most widespread and damaging flood since Cyclone Bola in 1988.

Unusually wet conditions were created during late January and early February by a series of westerly airflows across central New Zealand. On 11 and 12 February a front brought northwesterly rain and winds to the lower North Island, with almost 400mm of rain recorded over 24 hours in the Tararua Range, bringing the Otaki, Hutt, and Wairarapa rivers into flood.

On 14 February a depression deepened rapidly east of the North Island, bringing further falls of heavy rain to the already saturated lower North Island and upper South Island during 15 and 16 February. Many districts in the southern half of the North Island received more than 100mm of rain, and up to 250mm fell in the Tararua and Ruahine ranges.

Rivers and streams in the Hutt Valley, Kapiti, Wairarapa, Manawatu, and southern Taranaki all flooded. The Oroua, Whangaehu and Turakina rivers in the Manawatu experienced at least 100-year return period flows. Four stopbanks burst in the Manawatu, inundating farmland, settlements, and roads. Many bridges were damaged, and water and gas lines across them cut. The Manawatu Gorge was closed for almost 3 months. No lives were lost but more than 1800 people were evacuated from their homes in the Manawatu.

The storm was the largest rainfall event in the lower North Island since major vegetation clearances of the early 1900s. Shallow landslides affected more than 16 000km<sup>2</sup> of hill country and more than 200 million tonnes of soil is estimated to have been lost from the Manawatu-Wanganui region. The soil was deposited over farmland downstream, and significantly raised riverbeds reducing flood carrying capacity.

The storm caused losses estimated at \$380 million (2006 value). This included \$195 million in agricultural losses from stock, crop, and pasture loss; milking interruption; and fence and farm building damage. Roads suffered more than \$75 million worth of damage, and flood protection schemes and rivers more than \$25 million. Insured losses totalled \$121 million.



Ngaputahi Station in the Manawatu after the February 2004 storm. Millions of tonnes of soil was washed into flooded rivers and deposited on farm land downstream. Westmount School.

## Localised rain

Localised intense rain is generally associated with thunderstorms – unstable air masses formed by convective conditions as air rises and cools rapidly through solar heating, or frontal or orographic uplift. Thunderstorms can generate very intense rain, damaging winds, hail and lightning. They often develop rapidly, making them difficult to forecast accurately, but they are generally short-lived and often only affect a small area, usually less than 100km<sup>2</sup>.

Thunderstorms most commonly occur in New Zealand as small, brief storms lasting for less than half an hour. Larger and longer-lived thunderstorms known as multicell line storms may last for several hours but are generally mobile and only affect individual areas for a short time. Multicell line storms, also known as squall lines, can produce intense rain, hail, strong wind gusts, and occasionally small tornadoes. Supercell thunderstorms, which bring intense rain, severe wind gusts including damaging tornadoes, and large hail (golfball-sized or larger), are also occasionally observed in New Zealand but are uncommon.

The intense rain produced in thunderstorms is the main cause of flash flooding in New Zealand. Twenty-one people were killed in 1938 at Kopuawhara Stream near Wairoa when around 130mm of rain fell in one hour, creating a flash flood that washed away 47 workers' huts. The May 2005 Matata flash flood and resulting debris flow was the result of a thunderstorm that delivered 95mm of rain in one hour in the catchments behind the village. Intense rain can produce shallow landslides, soil erosion, and debris flows, particularly in rural catchments, and surface flooding is common in urban catchments where stormwater systems may not cope.

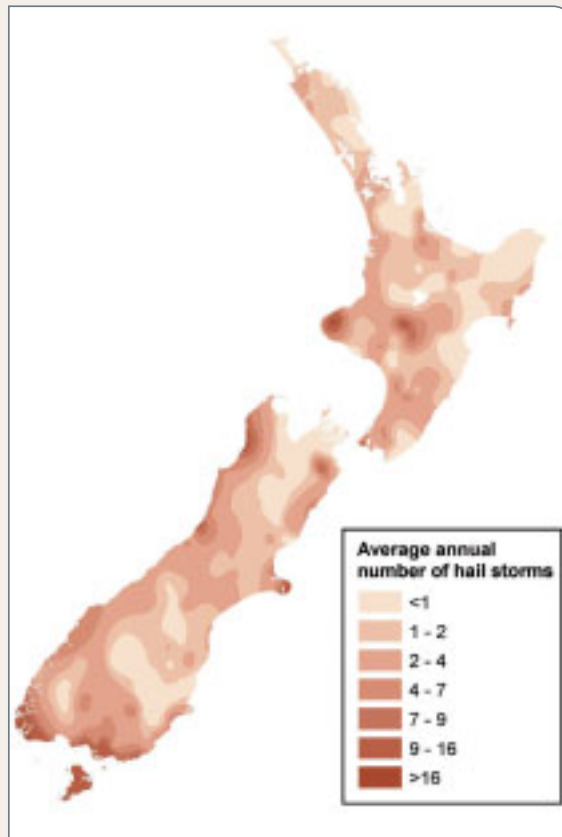
## HAIL AND LIGHTNING

Along with flooding, the hail and lightning produced by thunderstorms can affect property, infrastructure and crops.

Hailstones larger than 5mm in diameter can damage fruit and vegetable crops; for example, hailstorms in 1997 caused more than \$50 million worth of damage to apple crops in Hawke's Bay. Hail can block stormwater drains and increase surface flooding in urban areas.

More than 100 000 lightning strikes hit New Zealand each year. Lightning strikes are most frequent in or to the west of the main mountain ranges, particularly in spring and summer, as air is pushed up over the mountains. The less frequent lightning strikes in eastern areas occur mostly during summer afternoons and evenings when surface temperatures are high. Lightning kills someone every 5–10 years in New Zealand, regularly disrupts electricity and telecommunications, and can also start fires.

Susceptibility to hail and lightning can be mapped at a regional scale, based on historical data. This helps with making decisions about locating crops and infrastructure. Because hail and lightning are localised events, they are unlikely to be of national significance unless they affect important infrastructure or a densely populated urban area.



Average annual number of hailstorms in New Zealand. Hailstorms most frequently occur in western areas in winter and spring, but the most damaging hailstorms occur in eastern areas during spring and summer. *National Institute of Water and Atmospheric Research.*

## Catchment conditions

The size and effects of a flood are influenced by conditions within the river catchment that control the relationship of rainfall to runoff. The more permeable the ground surface, the more rainfall it can absorb before it becomes saturated and the water runs off into streams and rivers. Previous weather conditions have a large influence on the severity of a flood caused by a particular rainfall event. For example, rainfall on an already saturated catchment will lead to a more extreme flood than in a dry catchment where there is capacity for rain to infiltrate the soil.

The type of bedrock, soil, and vegetation in a catchment also influence runoff rates during rainfall. Vegetation clearance in a river catchment increases the rate of runoff causing rapid and high flood peaks. Shallow landslides and soil erosion are also much more likely on cleared hill country, causing more sediment to be fed into flooded rivers. The sediment is deposited on floodplains and raises river bed levels, reducing the flood-carrying capacity of the river.

Wetlands act as storage areas and slow the flow of water into waterways. In contrast, impermeable surfaces in urban areas increase runoff rates because rainfall is unable to infiltrate the soil.

## Flooding in New Zealand

New Zealand's river catchments are relatively short and steep, compared to other countries. This makes for a short interval (from hours to a few days) between when the rain falls and when the flood peaks. Warning times are therefore short and water speeds can be high, but the flood itself is over relatively quickly.

There is no standard measure of flood hazard or risk across New Zealand. Flood-hazard maps are developed by individual regional

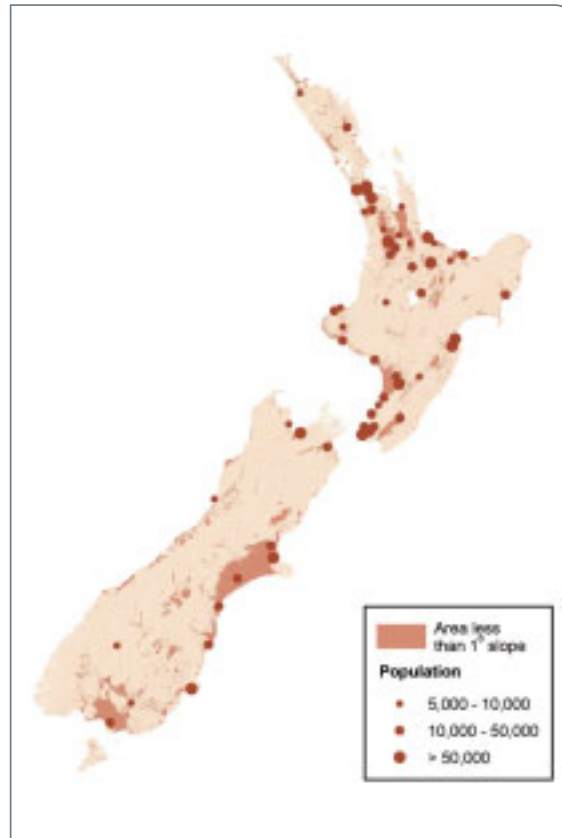
councils and do not necessarily depict the hazard from floods of the same frequency. Flood-hazard assessments are often only carried out for major rivers and in areas where significant flooding has occurred in the past. Flood hazards also depend on the existence or otherwise of protection works, which vary in design and standard across New Zealand.

The effects of a flood depend on the depth and speed of water in the flooded area. These in turn depend on the 'size' of the flood, which is measured by the amount of water involved or, more commonly, by its estimated return period.

New Zealand has a low population density and many of the country's fertile floodplains are intensely farmed. A large proportion of flood losses in New Zealand are therefore related to damage to farm infrastructure, livestock and pasture loss, and indirect economic impacts.

Floods are one of the more significant hazards for agriculture. The on-farm effects from flood events are often long-lasting with economic and social impacts continuing for several years after the event. Floods often result in livestock welfare issues.

Roading and rail infrastructure is also often damaged, particularly by rainfall-induced landslides that often accompany flooding. Scour of bridge piers is a major contributor to flood damage, and lives have been lost as a direct consequence. Flooding in urban areas leads to evacuations, damage to houses, and environmental and public health issues as water and sewerage systems are overcome and hazardous substances released. Risk to life from flooding in New Zealand is relatively low compared to other countries, but social disruption can be considerable when people are evacuated for long periods of time.



Areas of New Zealand with gentle slopes of less than 1°, giving a general indication of flood-prone land. The actual flood hazard in these areas depends on regional catchment and floodplain management, including physical flood-protection measures. These areas contain some of the country's richest agricultural land, and several towns and cities have a high flood risk, either because of the high flood hazard or the number of people and amount of assets that are exposed. *National Institute of Water and Atmospheric Research.*

## Managing floods

Where and when rain falls cannot be controlled but what happens to the water once it reaches the ground can be influenced to reduce the flood hazard. Decreasing the rate of runoff into streams and containing the flood within the river channel are two measures that can be taken. However, these measures cannot eliminate flooding, and land will still occasionally be inundated. The consequences depend on how communities choose to use flood-prone land.

### Risk reduction

Reducing flood risk involves managing entire river systems from the catchment to the sea.

Traditionally, flood risk reduction in New Zealand has focused on

building structures to keep water away from people. Less regard was given to non-structural measures such as land-use planning to keep people and property away from flood-prone areas, and adopting building standards to keep people and property above flood levels. Effective flood-risk reduction involves a combination of structural and non-structural measures on floodplains and managing land use in river catchments.

Regional councils and territorial authorities are both involved in managing flood risk using a variety of approaches and design standards. There is a growing interest in a more consistent approach to flood-risk reduction across New Zealand, which has generated three recent projects. The Ministry for the Environment funded the Floodplain Management Planning Guidelines, released in 2001, to guide regional councils on floodplain-management planning practice and methodology.

The 2004 lower North Island and Bay of Plenty floods prompted two further flood-risk management initiatives – the Flood Risk Management Review led by central government, and the Flood Risk Management Protocol sponsored by local government. In March 2007, the government decided that a national policy statement on flood risk management was desirable. The formal process under the Resource Management Act 1991 to develop a national policy statement is currently underway.

### STRUCTURAL MEASURES

Flood protection structures – most commonly stopbanks but also including groynes and floodgates – modify river behaviour and protect people and property from floods up to a specified standard.

Design standards for stopbanks vary greatly throughout New Zealand, from protection from a flood with a 5-year return period for some rural stopbanks, to floods with 400–500-year return periods for major rivers like the Hutt and Waimakariri rivers.

Early flood protection structures were piecemeal, often deflecting flood water onto neighbouring properties. Catchment boards, established in 1941, adopted an integrated catchment and river management approach including soil conservation, with a focus on engineering works. About 3000km of central government-subsidised stopbank were built in the 1950s and 1960s to protect agricultural land and some urban areas.

Stopbanks offered a sense of security, and high-density development has occurred behind them, in areas such as in Christchurch, the Hutt Valley and the Heretaunga Plains in Hawke's Bay. Stopbanks have failed in the past in New Zealand, through poor construction, a lack of maintenance, or through floods exceeding the design capacity of the protection work. A significant residual flood risk still exists despite many flood protection schemes.

Stopbanks are costly to build and maintain. Central government subsidies for stopbank construction and maintenance ended in the

## THE FLOOD RISK MANAGEMENT REVIEW AND THE FLOOD RISK MANAGEMENT PROTOCOL

The Ministry for the Environment began the *Flood Risk Management Review* in July 2005 in response to the large floods of 2004. The review, expected to be completed in 2007, focuses on three key areas:

- current flood-risk management practices and whether they are appropriate
- central and local government's role in ensuring good flood-risk management practices are adopted
- who benefits, who pays, and who can afford flood-risk mitigation.

The draft *Flood Risk Management Protocol*, an initiative sponsored by regional councils and supported by central government, gives councils a set of principles for managing flood risk. The protocol was also developed after the 2004 floods to help address increasing development pressures in flood-prone areas, the increasing cost of flood mitigation measures, increasing public expectation for protection and the limitations of some present mitigation measures.

The protocol outlines key elements and implementation principles for sustainable, integrated and holistic flood-risk management, promoting engineering, building design, land-use planning, and emergency management. The draft protocol is currently being developed into a New Zealand standard.



The Fitzherbert stopbank at Palmerston North during the February 2004 storm. The stopbank had recently been upgraded and held the Manawatu River during the flood. Had the stopbank been breached or overtopped, however, the city would have suffered major flood damage. *Horizons Regional Council.*

late 1980s. Since then local government has been solely responsible for their funding. In some areas, this cost is becoming increasingly difficult for some ratepayers to bear.

Structural measures also include maintaining the capacity of river channels through realignment or gravel extraction, and using flood detention dams, although detention dams are not often used for flood reduction alone for a variety of reasons, including costs.

All structural measures have effects on the environment. They affect sediment transport and deposition, and ecological habitats. Poorly designed structures can also increase the downstream flood hazard. Structural measures are an important component of floodplain management but the costs and benefits must be appropriately managed across social, economic, and environmental values.

### NON-STRUCTURAL MEASURES

Floodplain management aims to reduce vulnerability to floods through a variety of measures, rather than by attempting to control flooding through structural measures alone.

The simplest way to reduce flooding exposure is to not develop in flood hazard areas. This is relatively easy to do at undeveloped sites where flood-prone land can be used for parks, sports fields, or car parks, rather than housing and infrastructure. However, as floodplains are often intensively farmed due to the productive soils, their potential for damage is often significant within the agricultural community. Awareness in these communities is likely the best option for risk reduction.

Discouraging further development in existing flood-prone communities is more difficult. It involves complex political, social, and economic issues. Relocation may be an option in some situations.

Flood-hazard zones are often incorporated into district plans, where rules may apply to building construction or alteration and earthworks. Accurate information on flood inundation levels and their frequency is important in mapping hazard zones. Some of this information is available, to different degrees of accuracy, for some parts of New Zealand. NIWA is currently revising flood frequency estimates for New Zealand rivers, building on work completed in 1989, to determine both river flow and floodplain inundation levels using hydraulic modelling.

Building standards, including minimum floor levels, are often used to reduce the effects of flooding. The Building Code specifies that floor levels must be above the 50-year return period flood level. Some district plans, however, set out provisions that require floor levels in flood-hazard zones to be above that specified in the Building Code.

## CATCHMENT MANAGEMENT

Catchment management involves managing land use in upper river catchments to reduce the amount of sediment that goes into rivers, and therefore reduce the flood hazard. Catchment management requires long-term, multi-pronged approaches including education, advice, farm planning, possible land purchase by local and central government, regulations, monitoring, and financial assistance to help farmers with the capital cost of changing land use.

Risk-reduction initiatives by farmers and others include planting forest and other vegetation to help stabilise ground and absorb water.

Restoring wetlands in river catchments can also help reduce the flood hazard. Wetlands store water and reduce the rate at which it enters rivers.

### Readiness

The MetService issues a severe-weather warning when more than 50mm of rain is expected in a widespread area within the following 6 hours, or when more than 100mm is expected in a widespread area within the following 24 hours. A severe-weather watch is generated if more than 50mm of rain in 6 hours or more than 100mm of rain in 24 hours is expected 24 to 72 hours ahead. Severe weather outlooks are issued for severe weather which could occur 3–6 days ahead. These messages are sent to local authorities and CDEM Groups.

The MetService is currently developing a warning service for small-scale intense thunderstorms and is proposing to install additional weather radars to support this.

Regional councils have primary responsibility for flood forecasting and public warnings, using MetService information and data from NIWA's and their own rainfall and river level recorders. Warning times

are relatively short because New Zealand's catchments are short and steep. NIWA is increasing its flood-forecasting capacity to complement regional council functions, using rainfall-runoff models incorporating rainfall data and river catchment conditions. It is also developing routine rainfall forecasts up to 48 hours ahead and integrating these into a rainfall-runoff model to give a longer warning time for impending floods.

### Response and recovery

The Earthquake Commission (EQC) insures residential land (but not houses or contents) against storm or flood damage for those home owners who hold fire insurance. EQC will contribute to the cost of removing flood debris from under and around homes, and will cover damage to retaining walls, bridges, or culverts within 60m of a house.

Like earthquakes, more consideration could be given to pre-event recovery planning for floods – identifying in advance the land-use planning decisions that will need to be made during the recovery phase. Unlike damaging earthquakes, damaging floods often occur at the same location on a frequent basis. Recovery from recent floods, such as the February 2004 storm, has concentrated on communities regaining daily functioning rather than taking the opportunity to improve long-term resilience.

Floods are New Zealand's most common and costly natural hazard, but generally they do not affect more than one region at the same time. Particularly large floods, such as those of central New Zealand in February 2004 and those in the South Island of the mid-1980s, are of national interest and have required central government support with response and recovery.

Any coordinated local or national CDEM response to floods follows generic response and recovery procedures set out in CDEM Group

plans, the National CDEM Plan and the Guide to the National CDEM Plan.

MAF's On-Farm Readiness and Recovery Plan for Adverse Climatic Events and Natural Disasters sets out individual and community responsibility to adverse events that affect farm businesses and outlines available recovery measures for different scale events.

## FURTHER INFORMATION

### GENERAL FLOOD AND WEATHER INFORMATION

TE ARA ENCYCLOPAEDIA OF NEW ZEALAND

[www.teara.govt.nz/EarthSeaAndSky/NaturalHazardsAndDisasters/Floods/en](http://www.teara.govt.nz/EarthSeaAndSky/NaturalHazardsAndDisasters/Floods/en)

[www.teara.govt.nz/EarthSeaAndSky/ClimateAndAtmosphere/Weather/en](http://www.teara.govt.nz/EarthSeaAndSky/ClimateAndAtmosphere/Weather/en)

MINISTRY OF CIVIL DEFENCE & EMERGENCY MANAGEMENT

[www.civildefence.govt.nz/MEMWebsite.nsf/Files/tephra97/\\$file/tephra97.pdf](http://www.civildefence.govt.nz/MEMWebsite.nsf/Files/tephra97/$file/tephra97.pdf)

[www.civildefence.govt.nz/memwebsite.nsf/wpg\\_URL/For-the-CDEM-Sector-Publications-Tephra-2001-Index?OpenDocument](http://www.civildefence.govt.nz/memwebsite.nsf/wpg_URL/For-the-CDEM-Sector-Publications-Tephra-2001-Index?OpenDocument)

[www.civildefence.govt.nz/memwebsite.nsf/wpg\\_URL/For-the-CDEM-Sector-Publications-Tephra-2003-Index?OpenDocument](http://www.civildefence.govt.nz/memwebsite.nsf/wpg_URL/For-the-CDEM-Sector-Publications-Tephra-2003-Index?OpenDocument)

MOSLEY, M P AND PEARSON, C P (EDS), 1997, FLOODS AND DROUGHTS. New Zealand Hydrological Society, Christchurch.

### FLOODPLAIN MANAGEMENT PLANNING GUIDELINES

MINISTRY FOR THE ENVIRONMENT

[www.mfe.govt.nz/withyou/funding/smf/results/9035\\_floodplain](http://www.mfe.govt.nz/withyou/funding/smf/results/9035_floodplain)

[\\_management\\_planning\\_guidelines.pdf](#)

### FLOOD RISK MANAGEMENT REVIEW

MINISTRY FOR THE ENVIRONMENT

[www.mfe.govt.nz/issues/land/natural-hazard-mgmt/flood-risk-review.html](http://www.mfe.govt.nz/issues/land/natural-hazard-mgmt/flood-risk-review.html)

### FLOOD RISK MANAGEMENT PROTOCOL

CENTRE FOR ADVANCED ENGINEERING

[www.caenz.com/info/MFR/MFR.html](http://www.caenz.com/info/MFR/MFR.html)

### METSERVICE WARNINGS

METSERVICE

[www.metservice.co.nz/default/index.php?alias=weatherwarningcriteria](http://www.metservice.co.nz/default/index.php?alias=weatherwarningcriteria)