Summary

This document is a summary of the NIWA Report titled: 'A methodology to assess the impacts of climate change on flood risk in New Zealand'. The document outlines how councils can take steps to prepare for climate change by assessing their own flood risk.

Climate change is happening.

Our climate is already changing.

Since 1900, global temperatures have increased by about 0.6° C. There is broad scientific support for the assessment of the United Nations' Intergovernmental Panel on Climate Change that most of the increase in the world's average temperature over the past 50 years is due to human activity (such as burning fossil fuels) pumping more greenhouse gas into the atmosphere, which traps more of the sun's heat and so warms the planet.

Average global temperatures are projected to increase between 1.4° C and 5.8° C by the end of the century if no efforts are made to reduce greenhouse gas emissions, while the global mean sea level could rise by about 30–50 cm. And it won't stop there – changes are expected to continue long into the next century.

How will it affect flooding?

Dramatic, concentrated downpours, such as the 2002 Coromandel 'weather bomb', or the extremely heavy rain which caused the October 2003 Paekakariki floods, are likely to become more common. Widespread rain, such as the February 2004 storms that affected much of the lower North Island, will also become heavier.

At the root of this is the expected temperature rise across the whole country. Average temperatures are projected to increase about 1°C by the 2030s and about 2–3°C by the 2080s. The warmer the air, the more moisture it holds: about 8% more moisture for every 1° C temperature rise. This means the risk of heavy rainfall increases – and so does the risk of flooding.

In addition, the heat that comes from the condensation of this extra moisture will make storms more intense.

Westerly winds are likely to become more prevalent, so more rain is likely to fall in the west of the country and less in the east, but all regions will be more vulnerable than at present to intense storms.

All this adds up to heavier rainfall and consequently more frequent and intense flooding.

To compound the risk for coastal regions, sea levels are most likely to rise 30–50 cm by 2100. This will increase the risk of flooding from high tides.

The time to act is now

Since March 2004, the Resource Management Act has required councils to consider the effects of climate change in their planning and decision making.

Being proactive about climate change can save your community money in the long run. The cost of damage from the February 2004 floods in the lower North Island has been estimated at approximately $355 million. By considering the impact of climate change when you make investment and planning decisions, you're boosting the community's resilience to present-day flooding, and you can avoid locking your council into land-use decisions that put major infrastructure or housing developments at risk in future.

For councils, that means taking into account the likely effect of climate change on flood risk on issues such as:

- Long-term emergency management planning
- Long-term flood management, such as design and construction of stop banks
- Decisions about stormwater capacity and design
- Development decisions for areas prone to river and sea flooding
- Land-use decisions which may affect the vulnerability of a catchment to flooding

What should you do?

The New Zealand Climate Change Office of the Ministry for the Environment has produced a series of guidance notes to assess the impacts of climate change on flooding. The first step is to use a simple screening test to assess whether climate change is likely to significantly affect flooding in your region. If so, a further, more detailed analysis should be carried out for each catchment and area of your region.

This process has six steps:

1. Select climate change scenarios, e.g., temperature rise

2. Select a representative sample of past storms/rainfall events

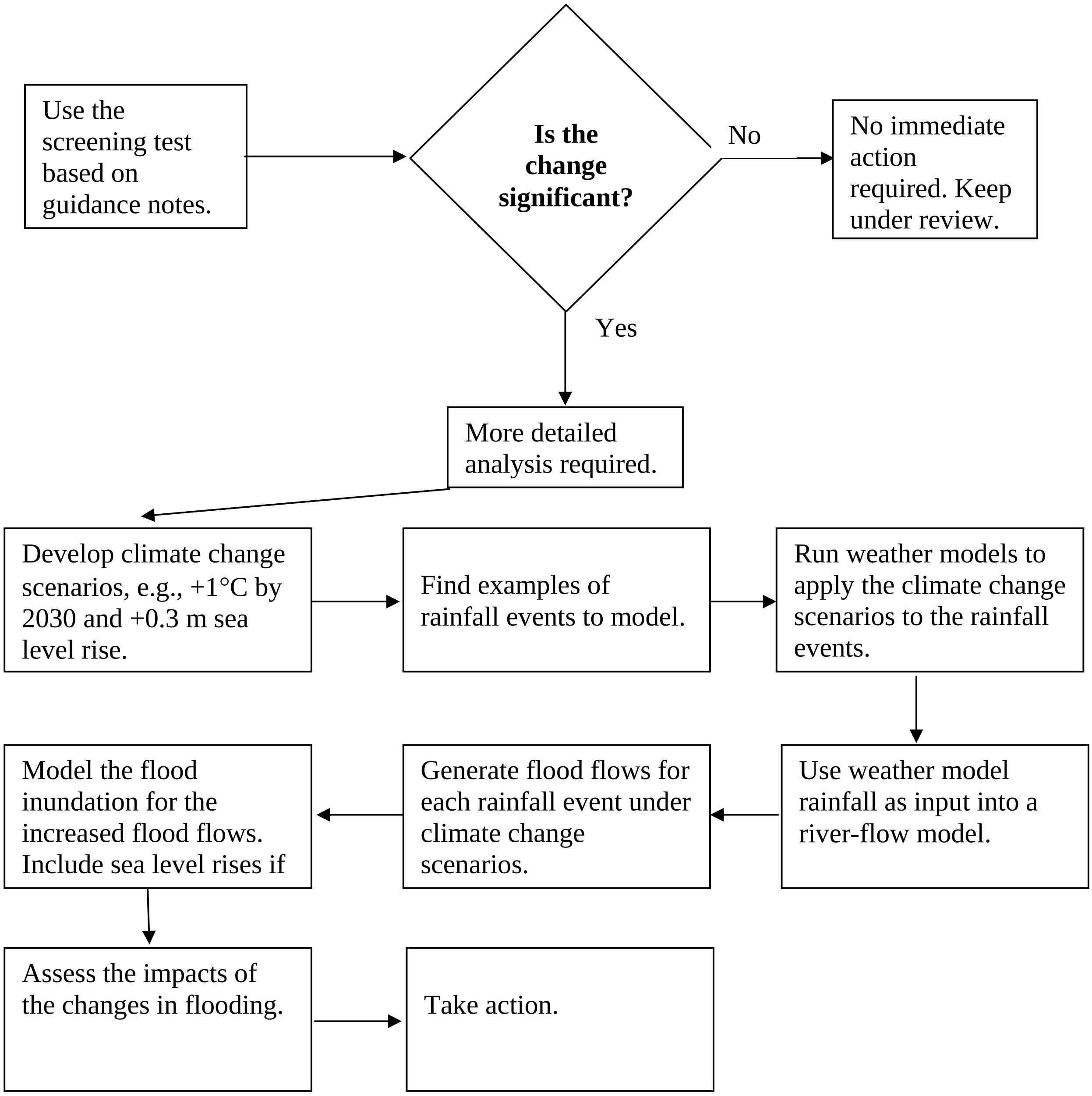
3. Determine the impact of projected temperature rise (step 1) on the rainfall of the these storms (step 2)

4. Translate projected rainfall into river flow

5. Assess any other relevant changes, e.g., tide, storm surge

6. Translate projected river flow (step 4) & any other factors (step 5) into projected flooding

Step by step


Use the screening test based on guidance notes.
Is the change significant?
No
No immediate action required. Keep under review.
Yes
More detailed analysis required.
Develop climate change scenarios, e.g., +1°C by 2030 and +0.3 m sea level rise.
Find examples of rainfall events to model.
Run weather models to apply the climate change scenarios to the rainfall events.
Use weather model rainfall as input into a river-flow model.
Generate flood flows for each rainfall event under climate change scenarios.
Model the flood inundation for the increased flood flows. Include sea level rises if
Assess the impacts of the changes in flooding.
Take action.

The simple screening test

One approach to determining how climate change will affect extreme rainfall in your community is to use a standard multiplication factor. This provides a simple screening test, to tell you whether or not you need to conduct a full risk assessment using more complex scenarios.

These multiplication factors are set out in Table 7 of *Preparing for climate change* (see Further Reading, below). The table recommends percentage adjustments to apply to extreme rainfall for a range of average recurrence intervals. The multiplication factors are per degree Celsius of warming. Take, for example, a 1-in-50-year event lasting 3 hours. The amount of rain expected to fall under today's climate should be multiplied by 7.2% for every degree Celsius of projected increase in the annual mean temperature.

The multiplication factors are mid-range estimates. They take into account the extra rainfall likely as a result of the extra moisture holding capacity of the air. They do not take account of local catchment characteristics, nor do they reflect the fact that storms are likely to be more intense due to the heat released by this moisture nor the increase in contrast between the temperatures at the south pole and equator.

If the simple screening test indicates that climate change could significantly affect an important or large-scale council function or service, we recommend a more complex approach using weather and flooding models. This will provide a truer and more detailed picture of the increased intensity of rainfall. For instance, the models may show that extremely heavy rain is concentrated more in particular locations, while nearby areas get lighter rain than would be expected under the current climate.

Designing the base flooding event

In order to assess the changes, the council will need to choose a storm or storms that can be used as a basis for comparison. It is often best to choose real examples of past storms, where their impact on flooding is known. These storms do not need to be the biggest storms experienced, but they should be broadly representative of the weather situations your region is likely to experience at present.

Choosing real examples means you can check how accurately weather and rainfall-to-river flow models are replicating current conditions.

Current extreme rainfall rates for particular locations, durations and average recurrence intervals can be obtained from historical rainfall data sets from monitored sites, or from the High Intensity Rainfall Design System (HIRDS) CD-Rom, available from NIWA.

For coastal settlements, councils may wish to consider the flooding risk posed by a combination of heavy rain with high tides and storm surges

Which climate change scenarios?

It is impossible to predict the precise amount by which the Earth will warm over the next century. We recommend councils consider at least two temperature change scenarios covering the expected lifetime of infrastructure and other major developments, for example, mid-low and mid-high scenarios for the 2030s and 2080s.

There are a number of factors to consider when deciding which climate change scenarios are most appropriate, including:

- The permanence of decisions to be made
- The nature and value of the assets which may be at risk
- The extent of the assets which may be at risk

The projected changes in average temperature for each region of New Zealand are summarised in Table 2 of *Preparing for climate change* (see Further Reading, below). More details can be found on pages 11 and 12 of *Climate Change Effects and Impacts Assessment* (see Further Reading, below).

Rainfall: take a detailed look

The next step is to model each rainfall event with weather models taking into account the climate change scenarios. This shows how much, where and when the rain falls during the storm under current climate conditions, and under each climate change scenario.

These weather models compute, using physical principles, the movement of air, heat and moisture, and thereby can be used to either replicate past storms or forecast the weather. They form the basis of all modern weather forecasting.

The weather model needs to be sophisticated enough to reproduce the weather on a scale relevant to the catchment. For example, for the Southern Alps, the model would need a resolution of around 5 km to accurately represent the uplift of the air over the steep hills. The Regional Atmospheric Modelling system (RAMS) has been used by NIWA to replicate the rainfall over New Zealand including the Southern Alps and Bay of Plenty. Such models can produce estimates of hourly rainfall that can be used as input into rainfall-to-river flow models. The weather model's starting conditions can be changed to reflect future environments of the storms. For example, the temperature of the air and sea can be raised to reflect the projected environment expected in say 2050.

What else could change?

Factors such as a rise in mean sea level, change in risk of storm surge, or change in river run-off caused by possible future change in land use, may heighten the risks of flooding even more.

For coastal regions, an inundation model should include storm surge and projected sea level rises. The guidance manual, *Coastal Hazards and Climate Change* (see Further

Reading, below), recommends that in developing scenarios, councils use at least the most likely mid-range scenario for sea-level rise. It recommends staff use a figure of 0.2 m by 2050 and 0.5 m by 2100 when considering sea-level rise in projects or plans.

From rainfall to river flow

Having chosen suitable weather events, and modelled the likely effect of climate change on the rainfall, this information should be run through a suitable rainfall-to-river flow model.

Rainfall-to-river flow models need to be able to reproduce the movement of rainfall across the ground to the river channel and into the soil. The models then need to be able to reproduce the flow of water down the channel

Flood peaks are caused by the rainfall that does not seep into the ground and that moves quickly across the land to the river channels. The rate at which the water runs off the land depends on:

- The steepness of the land;
- The type of land surface present in the catchment
- How wet the ground surface is when the rainfall occurs; and
- The ability of the land to store water on vegetation, in the soil and in depressions in the ground.

The water that seeps into the ground does not usually reach the river in time for it to add to a flood peak.

Once the amount of water running off the ground into the river channels has been calculated, the model needs to work out how long it will take the water to find its way down the channel network. The time it takes for the water to reach a given location downstream, such as a place where a river might breach its banks (a “breakout point”), depends on:

- The steepness of the various parts of the river channel network;
- The roughness of the channel bed;
- The density of the channel network;
- The shape of the catchment;
- The direction in which a storm moves relative to the catchment;
- “Catchment resonance” or the way several upstream tributaries may all deliver their peak runoff to a main channel at about the same time and so compound the flood flow arriving at a downstream breakout point.

To cope with all the above sources of variation, a rainfall-to-river flow model must be “spatially distributed”. What this means is that the model must be able to:

- Accept rainfall that varies in both space and time;

- Calculate the surface runoff from areas that separately contribute runoff to a river channel; and
- Combine the flows from these sub-areas.

Ideally, the rainfall-to-river flow model should also take account of the potential effects of climate change on conditions in the catchment, such as land use changes. In some cases, however, the effects will be small compared to the overall uncertainities involved in such a complex prediction exercise.

From river flow to flooding

Once the rainfall-to-river flow model has produced peak river flows, an inundation model takes this information combined with other aspects such as tide and storm surge, to show not only where flooding would occur, but how deep and fast floodwaters could flow through the community.

To do this, inundation models need to make calculations on a very fine scale and use detailed information on the ground surface including its height and roughness.

Such models calculate the movement of the water by examining each cell in a computational grid and finding which of the adjacent cells are “upstream”, i.e., the water level is higher than in the cell being considered, and which are downstream. The rate at which the water moves is determined by the relative height of the water surface in adjacent cells. The model uses the ground elevation and the height of the water surface to calculate both the water depth and the speed of flow for all the points in the grid. From this analysis comes a picture of the areas that will be inundated for each scenario, and the depths of inundation.

What to do with the results?

Producing detailed projections of likely flooding with as much accuracy as is possible will provide your council with a basis for community consultation and informed decision-making. The Climate Change Office is available to assist.

Computer models and techniques are being refined all the time, as are climate change predictions, so you may wish to review the findings from time to time.

Further reading

Preparing for climate change. A guide for local government in New Zealand (2004), New Zealand Climate Change Office, Ministry for the Environment

Climate Change Effects and Impacts Assessment (2004), report prepared for the Climate Change Office of the Ministry for the Environment by David Wratt, Brett Mullan and Jim Salinger (National Institute of Water & Atmospheric Research Ltd), Sylvia Allan and

Tania Morgan (MWH New Zealand Ltd), and Gavin Kenny (Earthwise Consulting Ltd), in consultation with a range of people from local government organisations.

Coastal Hazards and Climate Change: A guidance manual for local government in New Zealand (2004), report prepared for the Climate Change Office of the Ministry for the Environment by scientists, planners and engineers from NIWA, Beca Consultants Ltd, DTec Consultants Ltd, and Tonkin and Taylor Ltd, in consultation with a range of people from local government organisations.

All documents are available at
www.climatechange.govt.nz/resources/local-govt/guidance.html