

# WATER & ATMOSPHERE

September 2013

## Extreme weather

How we cope with drought and storms

### **Cook Strait quake**

Tsunamis from seabed landslides

### **Terrible tornadoes**

The cycle of twisters

### **Chilled Calypso**

Why the coldest ocean is getting warmer



# WATER & ATMOSPHERE

September 2013

## Cover:

The 'wets' are getting wetter and the 'drys' are getting drier. Can New Zealanders cope? *(Dave Allen)*

*Water & Atmosphere* is published by the National Institute of Water & Atmospheric Research (NIWA). It is available online at [www.niwa.co.nz/pubs/wa](http://www.niwa.co.nz/pubs/wa)

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©National Institute of Water & Atmospheric Research Ltd 2013  
ISSN 1172-1014

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Production: NIWA Communications and Marketing Team

*Water & Atmosphere* is produced using vegetable-based inks on paper made from FSC certified mixed-source fibres under the ISO 14001 environmental management system.



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# Cook Strait quakes too small for landslide-tsunami

A seabed survey in Cook Strait by NIWA's flagship research vessel *Tangaroa* showed that the origin of the magnitude 6.5 July earthquake was a previously unknown 'blind' fault.

Within three days of the quake, the vessel headed to Cook Strait to survey the seabed using a multibeam echosounder. It surveyed an area crossing the epicentre to determine whether there were changes to the seafloor due to near-surface faulting.

The survey, which remapped the deep canyon system, supported research by NIWA Ocean Geologist Dr Joshu Mountjoy that showed the level of ground shaking generated by this earthquake was not sufficient to trigger submarine landslides – which pose a tsunami hazard in the area.

"This earthquake occurred near one of the least stable regions of Cook Strait Canyon," says Mountjoy. "Despite the significance of the event in Marlborough and Wellington, it was well below the level of ground shaking required to trigger sediment failure."

Mountjoy's research on submarine canyons, soon to be published in a special issue of the journal *Deep Sea Research Part II*, shows that about every 100 years a landslide in the region will displace 50 million cubic metres of seabed – more than four times the size of the landslide on Mt Cook in 1991.

"While the landslides focused on in this study were too small and far below the sea surface to cause tsunamis, they play an important role in the development of the canyon. There have been landslides ten times bigger within the canyon walls, and we are still working to determine the hazard risk related to them," he says.

The Cook Strait Canyon starts just 10 kilometres off Wellington's south coast and plunges from a depth of

150 metres to 2700 metres south of Cape Palliser. The canyon is the most prominent undersea feature of Cook Strait and is scarred by numerous large submarine landslides and active faults.

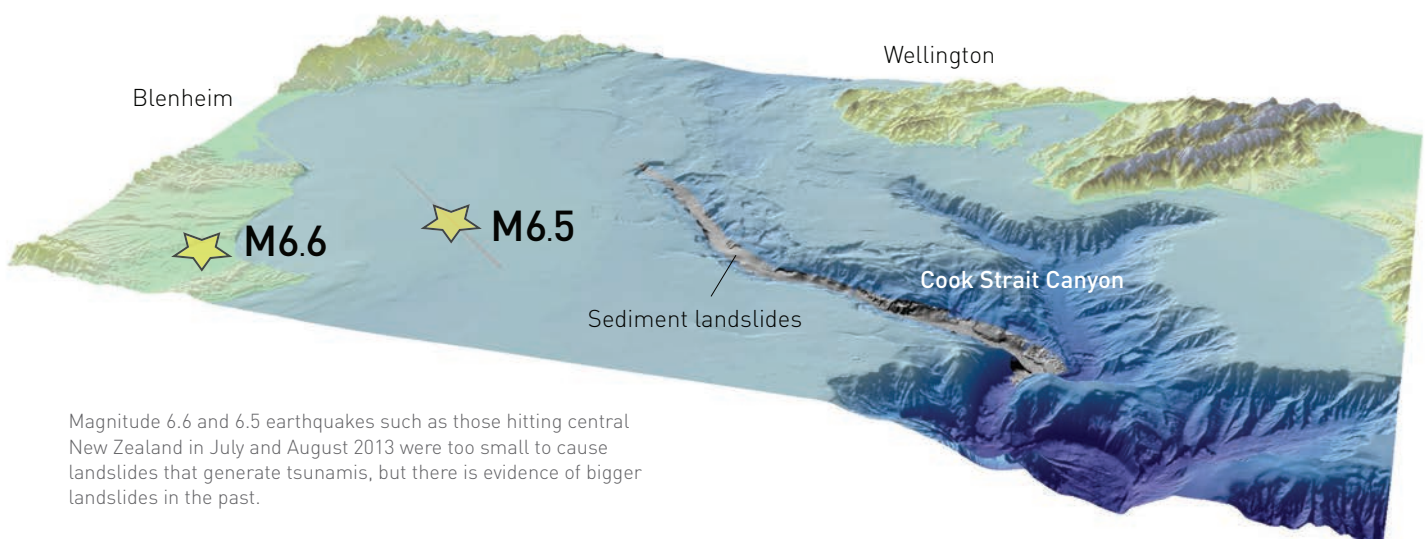
Mountjoy's research paper is based on data collected on board *Tangaroa* in February 2011, and measurements of ocean currents in 2006. He says early indications from the July 2013 survey back up the assessment of how sediment falls and moves within the Strait.

This work identifies that sediment is transported into the canyons by the strong tidal currents that scour the seafloor of Cook Strait. Sediment is accumulating in the central axis of Cook Strait Canyon at 400 metres water depth – the least stable region of the canyons. Landslide deposits in a sediment core sample taken further down the canyon support the modelling-based estimate of how often landslides occur.

"Soft sediment landslides flow down the canyon, eroding the canyon floor, much like a river in flood carrying sand and gravel," says Mountjoy. "This type of erosion is the main mechanism by which canyons form, and is also very important to biological communities," he says.


This work forms part of a larger, ongoing Natural Hazards Research Platform project by NIWA and GNS Science focused on determining the hazard posed by landslide tsunamis in Cook Strait.

*Tangaroa* had been stationed off the Marlborough coast mapping an area of Pegasus Basin as part of a Ministry of Business, Innovation and Employment-funded (MBIE) Ocean Survey 20/20 project. NIWA acknowledges the cooperation of MBIE in enabling this timely diversion.



Magnitude 6.6 and 6.5 earthquakes such as those hitting central New Zealand in July and August 2013 were too small to cause landslides that generate tsunamis, but there is evidence of bigger landslides in the past.





# New Zealand's tornado window

The tornado that damaged Hobsonville in 2012 occurred during a period of slightly elevated incidence of tornadoes in New Zealand.

New Zealand appears to be in a period of slightly elevated incidence of tornadoes, according to NIWA scientist Dr Richard Turner.

Dr Turner says that more tornadoes were reported over the past decade than during the 1980s and 1990s.

"We're seeing more than we've seen for 40 years," he said. "We're experiencing about the same frequency as occurred during the fifties and sixties."

On average, there are about seven to ten moderate to strong tornado events reported in New Zealand each year. In the past nine years, six people have been killed when tornadoes struck.

The Insurance Council estimated the cost of the fatal tornadoes that hit Auckland in December 2012 at \$8.7 million. The tornado hit Hobsonville and Whenuapai, killing three builders and damaging almost 400 homes. The Defence Force insurance bill for damaged property was \$1.4 million. It cost power companies about \$3.5 million to fix lines. The Auckland Council paid about \$1.5 million for staff to clean up the area.

Dr Turner says the history of tornadoes in New Zealand is not heavily studied and, because many go unobserved, it's hard to discern historical frequency trends and relate them to climate variations such as La Niña or the Pacific Decadal Oscillation.

"It's hard to ascertain, especially from old newspaper accounts, the actual wind phenomena that caused damage. For instance, damage caused by microburst winds is often wrongly attributed to a tornado.

"Taking this into account, there still does appear to be some trend on decadal timescales," he says.

One strand of research is developing the NIWA and GNS Science 'RiskScape' tool, which estimates asset impacts and losses for various natural hazards. RiskScape has damage models that relate building and human impacts and losses to wind hazard exposure.

Turner says that, until recently, damage estimates used international formulae. But New Zealand's housing stock has a prevalence of different construction materials and structural attributes, such as a timber frame with weatherboard cladding and sheet-metal roofs. Tornado damage here generally results from weaker events than overseas.

"So we've gone into the field to collect data about the sort of damage caused by tornadoes as well as different types of wind phenomena.

"We are collecting real New Zealand data for real New Zealand buildings, because relying on damage models developed overseas hasn't always given us realistic results.

"We can relate the actual damage and loss incurred to the likely range of wind speeds caused by a tornado (or microburst) like those in Hobsonville in December 2012, Albany in 2011 and Taranaki in 2007.

"This will improve the ability of RiskScape to accurately assess the impact of hazardous wind events such as tornadoes."

Dr Turner is optimistic about current research. "NIWA is designing very-high-resolution weather forecast models (which demand huge computational resources – NIWA's supercomputer) to predict the occurrence of mesocyclones (see sidebar: Tornado watch). If successful, this could potentially help forecasters identify mesocyclone formation between six and 12 hours in advance, increasing warning times."

## Tornado watch

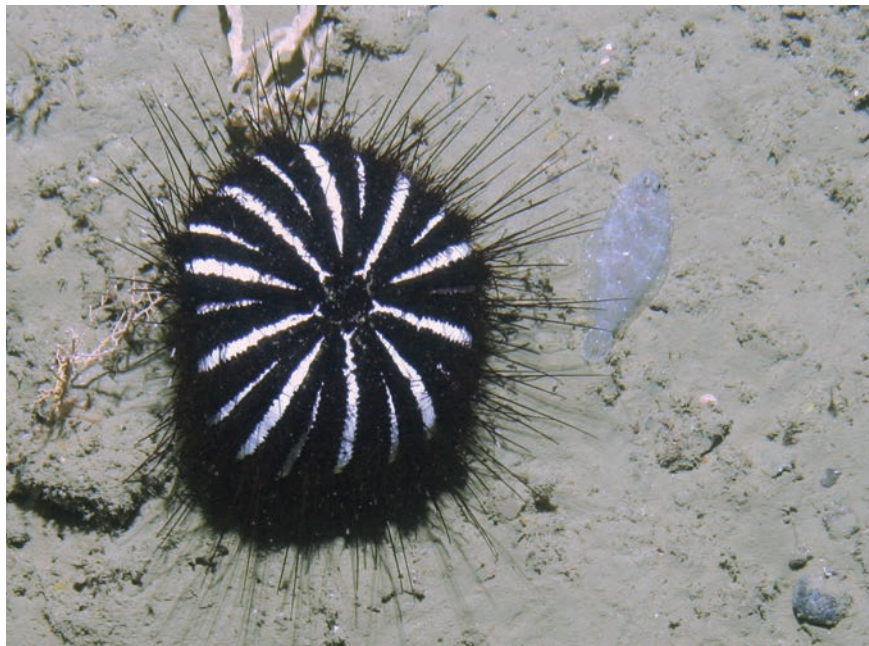
In New Zealand, tornadoes are usually around 20 to 100 metres in diameter, last for a couple of minutes, and travel two to five kilometres during that time. Wind speeds are typically between 115 and 180 kilometres per hour. Local tornadoes are usually spawned from mesocyclones – spinning updrafts of air in thunderstorms.

Warning signs of tornadoes can include hail or heavy rain followed by dead calm or a fast, intense wind shift; and large, dark, low-lying clouds.

# In brief



Large waves along the Esplanade, Owhiro Bay, Wellington. (Dave Allen)



Nearly one-third of the 50 known species of sea urchins, or tam o'shanter, can be seen in New Zealand waters. (NIWA)

## Storms not record breakers

Given the media coverage, you can be forgiven for thinking that the June storms were the worst ever to hit New Zealand.

One of the most discussed pieces of evidence was a NIWA wave buoy off Baring Head at Wellington Harbour. It measured waves there at 15 metres high from peak to trough – the largest on record. This surpassed the previous 'record' – anecdotal estimates that wave height during the 1968 'Wahine Storm' was 12 to 14 metres.

NIWA's analysis shows that, while the storms were extreme, they were not record-breaking.

For example, the maximum 10-minute average of sustained winds was 101 kilometres per hour at Wellington Airport. But sustained winds during the Wahine Storm reached 144 kilometres per hour – by far the strongest in the 50 years of records.

Snowfall in the central South Island was also less than the 1973 record. In Methven and Tekapo, snowfall from the June storms was 99mm and 600mm respectively, whereas the equivalent measures in 1973 was 610mm and 670mm respectively.

## The mystery of the tam o'shanter

The discovery of seven new species of sea urchins, known as tam o'shanter, has helped resolve more than a hundred years of confusion about their distribution in New Zealand waters. The discovery was found in a collection of preserved samples of urchins in NIWA's Invertebrate Collection.

*Araeosoma coriaceum* had previously been recorded off northern New Zealand by the Challenger Expedition in 1874 and again 100 years later by fishing trawlers in the Hauraki Gulf. But examination of old specimens, new material and original descriptions has led to the conclusion that the Challenger specimen had been mislabelled, with its true locality unknown.

The Hauraki Gulf specimen that followed had therefore been wrongly identified. It was not *A. coriaceum*, but a new species now known as *A. bakeri*.

Deepwater Fisheries Scientist Owen Anderson said research on where the species live revealed a particular

hotspot for tam o'shanter in the seamounts of the Bay of Plenty where nine separate species have been found.

"These urchins live in very deep water – up to 1200 metres – and don't have a hard shell like other more familiar species, such as their cousin kina, that live in shallower waters. Instead, they have a flexible leathery outer skeleton – well adapted for the deepsea environment in which they live."

New Zealand waters are rich with diversity when it comes to this urchin group. There are about 50 known species of tam o'shanter in the world, with nearly a third of these found in New Zealand waters. They are named tam o'shanter because of their resemblance to a 19th-century Scottish cap. Keen followers of poetry will know that the tam o'shanter cap was named after the eponymous hero of the poem by Robert Burns.



## In brief



NIWA Hydrologist Dr Christian Zammit measures snow depth on the roof of NIWA's Christchurch office. (Nelson Boustead)

### Kiwis become citizen scientists

Social media hasn't got the crowd-sourcing phenomenon all to itself. Science has long been a user of information gathered from a large number of widespread people. Even Darwin corresponded with amateur experts around the world, collecting evidence from their local fieldwork to support his theories.

The advantage is that amateur scientists can be in thousands of places at one time, collecting a much larger pool of data than the official scientists can collect by themselves.

In the digital and social media age, the means for asking for, coordinating and collecting information has never been easier.

Throughout the June storms, NIWA mobilised its own teams in the South and North islands over a period of three days to gather much-needed information about snowfall at low and mid-range elevations. This generally covers anything below 200 metres above sea level to under 900 metres (sub alpine).

Immediately before the June storms, NIWA went out to the public to increase the scope of measurements. The public were invited to measure backyard snowfall via the website and Facebook page.

Hydrologist Dr Christian Zammit calls it snow mobilisation. He's using it to collect snow information at the same location over a long period of time.

"We have very little New Zealand-specific information about snowfall at repeated locations, so gathering information from this storm is important. In the future, this information could help prevent building collapses and stock loss, and indicate areas where power lines are vulnerable to ice, snow and wind."

Dr Zammit says the information is important for the Building and Housing Group at the Ministry of Business, Innovation and Employment to inform building standards and codes. The Group needs accurate information about how ground snow is translated into load on the roof. Electricity providers, like national grid owner

and operator Transpower, use the information to inform the design of the lines providing electricity to consumers and to study the combined effect of snow, ice and wind on overhead conductors under New Zealand conditions.

"Citizen-collected information is helping adapt our snowfall prediction model."

Clearly, citizen scientists will continue to play an important part in helping science. The potential benefit goes even further than collecting vast amounts of data quickly. Citizen science can help develop a more scientifically literate society. It can build the capacity for people to see their lives in terms of science, to collect and assess information they receive in their everyday lives and make choices based on what they learn.

## In brief



Dr Joshu Mountjoy preparing the applied acoustics boomer and hydrophone for operation off Kaikoura. (Dave Allen)

### Kaikoura tsunami hazard

NIWA Ocean Geologist Dr Joshu Mountjoy is checking the validity of a theory that a massive undersea landslide could hit Kaikoura with a 13-metre-high tsunami.

The effect of submarine landslides is very real. Devastating tsunamis generated by submarine landslides occurred on the Grand Banks off Newfoundland in 1929 and Papua New Guinea in 1998, killing 28 and 2200 people respectively.

A 1999 scientific paper (Lewis and Barnes) posed that a large amount of sediment had recently accumulated in the head of Kaikoura Canyon. Work published by Walters et al. (2006) showed that collapse of this sediment would cause a large tsunami.

The canyon feeds sediment directly into the 1500-kilometre-long Hikurangi Channel, which sweeps along the east coast of New Zealand 400 kilometres east of East Cape. The canyon is up to 4000 metres deep and comes to within 500 metres of the coast south of Kaikoura, closer than any other New Zealand submarine canyon.

So Environment Canterbury (ECan) asked NIWA to resurvey the area in March this year, using state-of-the-art techniques to determine if the submarine landslide scenario is realistic.

"We spent three days surveying the head of the Kaikoura Canyon, mapping the seabed, imaging the sediment and rock beneath the seabed and sampling the sediment," Dr Mountjoy said.

The survey used three different techniques.

A hull-mounted echosounder imaged approximately eight square kilometres of the seabed.

"The bathymetry and backscatter data enable us to assess previous landslide history and to map the distribution of surface sediments."

A multichannel boomer seismic refraction system was used to 'see' 50 metres into the sediment and rock below the seafloor.

"We are able to unravel the history of sediment deposition and erosion in the area during the last 20,000 years."

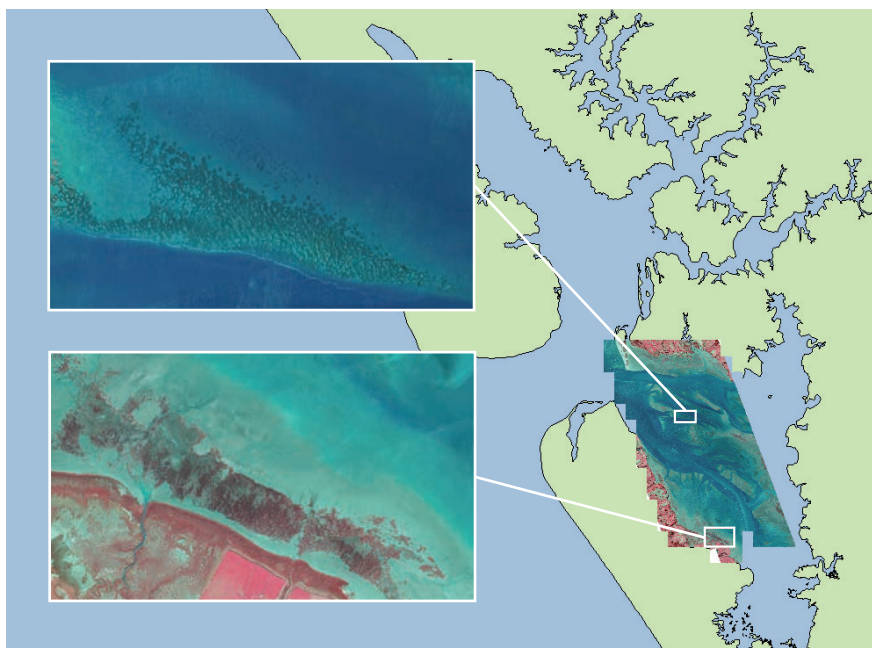
The survey also used two coring techniques to collect seven seafloor sediment cores up to one metre long.

"We are analysing these to determine the rate at which sediment is accumulating on the seafloor on modern (last 100 year) timeframes."

The project team is now assessing the data collected over the three days to learn more about the way the sediment moves and accumulates in the canyon, and whether a landslide is realistic. It will report to ECan later this year.



## In brief



Eye from the sky: Aerial photography is being used to map the shallow-water habitats of the southern Kaipara Harbour.



Signs of recovery: Eels are returning to Lake Ōmāpere following efforts to improve the lake's health. (Rohan Wells)

### NIWA takes to the skies to map seabed

Aerial photography is being used to map the shallow-water habitats of the southern Kaipara Harbour. The technique allows NIWA scientists to identify seagrass meadows – important for sustaining coastal fisheries such as snapper – down to their maximum growing depth of 3 to 4 metres below the low tide mark.

By combining aerial photography with fish sampling, NIWA can map the location of critical fish nurseries, and monitor their health over time through remote sensing.

Fish were collected using small, hand-hauled, fine-mesh beach seines, pulled up onto a specially designed ramp deployed from an oyster barge. About 100 sites were sampled, spread across 150 square kilometres in the southern Kaipara.

The habitats provide a range of important ecological 'goods and services', such as seagrass material which finds its way into food webs and small invertebrates associated with seagrass meadows.

Dr Mark Morrison, Marine Ecologist, said that underwater seagrass meadows were critical to supporting high numbers of juvenile snapper, trevally, parore, spotties, piper, pipefish and other species, particularly in northern New Zealand.

"This study examines what components of these habitats are most important to small fish. It samples across seagrass habitat landscapes and quantifies where fish densities and numbers of species are highest.

"Sampling quantifies what fish species are associated with each habitat type and associated environmental conditions. That means we can identify which factors are most critical for supporting particular types of fish species, so that the most important habitats can be identified, mapped and protected."

The aerial photography was funded by the Ministry for Primary Industries (MPI), while the fish-sampling research is being funded by the Ministry of Business, Innovation and Employment (MBIE).

### Eels return to lake

Eels are returning to Lake Ōmāpere in Northland, thanks to efforts to prevent over-nutrication.

The *Northern Advocate* reports that the 1200-hectare lake about five kilometres north of Kaikohe fell to an average depth of 2 metres after drainage that paved the way for nearby farming a century ago.

Fertiliser runoff then fuelled the growth of algae, which restricted fish life. Carp were introduced to eat the algae, and the lake – unique because it is owned by Māori – is recovering.

NIWA researchers helped the local community environmental group, Te Roopū Taiao o Utakura, gather data about fish stocks in Lake Ōmāpere and its outlet to the Hokianga Harbour, the Utakura River.

The group was also helped by NIWA Freshwater Fishery Ecologists Dr Erica Williams and Dr Jacques Boubee. NIWA has produced two reports for the project team: one on metal levels in tuna from the Lake Ōmāpere catchment and the other analysing the lake's nutrient levels.

# In brief



National interest: Marine Ecologist Dr Leigh Torres shares with media her findings on blue whale foraging habits. (Dave Allen)



RV *Tangaroa* is equipped to scan the seafloor and the sediment and rock beneath.

## Looking for the blue whales

It's long been thought that blue whales only transit through New Zealand waters when migrating between the Antarctic and equatorial waters. But a ground-breaking NIWA study into their distribution patterns off the south Taranaki coast confounds this hypothesis.

NIWA's study of historical whaling data, opportunistic sightings of blue whales and seismic survey data since 1979 show that blue whales, occur more regularly and with greater densities in the South Taranaki Bight than expected.

NIWA Marine Ecologist Dr Leigh Torres linked the observed sighting patterns of blue whales with a prominent upwelling near the South Island's Farewell Spit to set out the hypothesis that blue whales are using the area as a foraging ground. The area is well known for high zooplankton biomass, including a known prey item of blue whales, as a function of the upwelling plumes that generate huge clouds of plankton that are transported into the South Taranaki Bight.

"We know they need to eat vast amounts of food to support their energy demands. So the south Taranaki coast could be a perfect place for them to feed.

"With just four confirmed blue whale foraging grounds in the Southern Hemisphere, these findings add considerably to human understanding of one of the world's most elusive creatures."

The new information may also prompt a rethink on how blue whales are classified in New Zealand. Currently, they're classified as a migrant under the New Zealand Threat Classification System. This means they are not given the same level of conservation protections as other whales that regularly use New Zealand coastal waters.

## Sweeping the floor

When *Tangaroa* was called to survey the site of the undersea earthquake that rocked Marlborough and Wellington, it was busy fulfilling the Government's Ocean Survey 20/20 initiative.

The cross-agency initiative, coordinated by Land Information New Zealand (LINZ) promotes research in the New Zealand marine environment.

Land Information Minister Maurice Williamson had announced a few weeks earlier that LINZ would contribute \$2.1 million this year to the Ocean Survey 20/20 initiative. That will pay for 40 sailing days of *Tangaroa*.

"Two voyages will undertake seafloor mapping of the southern Colville Ridge off the coast of Auckland, geological and biological sampling, and mapping the seafloor in the Aotea and Reinga basins off the North Island's west coast," the Minister said.

Another voyage will deploy ocean bottom seismometers and pressure recorders offshore from Gisborne to monitor earthquake tremor activity over a two-year period.

The data being collected by NIWA is available at a dedicated website: [www.os2020.org.nz/](http://www.os2020.org.nz/).



# In brief



Suburban spawners: Ten years of NIWA research culminated in the discovery of a giant kokopu whitebait breeding area in a Hamilton stream. (Bob McDowall)

## Whitebait breeding sites found

A suburban Hamilton stream has turned out to be the first spawning ground ever found of the giant kokopu whitebait.

NIWA's 10-year research into the species was rewarded with the discovery of the breeding area earlier this year by NIWA Fisheries Technician Josh Smith and Fisheries Scientist Dr Paul Franklin.

The elusive fish were found in Bankwood Stream in Donny Park, near the suburb of Chartwell, a few kilometres from the Waikato River.

The team fitted electronic tags to 43 adult giant kokopu and placed antennae at the lower end of the stream to detect any fish leaving.

"When only one left, it gave us a good idea that they were spawning in the stream," Dr Franklin said.

A hand-held electronic tag reader was used to track the movement of fish in the stream during the day. At night, the scientists used spotlighting with a torch to find and then catch fish in a net so they could identify them and check their condition.

Last year, they found several ripe (ready to breed) males, which made them "reasonably confident" they were spawning in the stream. Then it became a matter of narrowing down where and when the fish were actually spawning.

"In the first week of June this year, we finally found a couple of ripe females in the stream for the first time. We expected them to spawn on a bank when the water level was higher after rain."

A few days later, their endeavours paid off when Smith discovered several nests of eggs on the banks of the Bankwood Stream.

When the giant kokopu spawn, they lay their eggs in the grasses and vegetation on the bank where there is shade and high moisture content to provide the optimum conditions for hatching. But hatching will only take place when the stream rises again.

"This finally fills in the gap for all whitebait species. We know that spawning is a critical and susceptible part of the life cycle. They require a specific vegetation and water flow to lay and hatch eggs, which is a risky strategy. But the more the environment is modified by humans, the more risky that strategy becomes," Dr Franklin said.

"There is a good chance they are spawning in other streams around Hamilton and if we can provide and protect the right kinds of habitat, others may stay.

"If one of these habitats is not available, the species will ultimately die out."



Angela Hunt crossing a dry dam which is normally used to supply stock with drinking water on Peter Gaskin's Wairarapa farm. (Dave Allen)

# Dust bowled

The sun scorched New Zealand's rural hinterland over the summer of 2013. The drought reached across more of the country than any other in the past 40 years. The heat burnt through \$2 billion dollars the country desperately needed in the middle of an economic downturn. **Mark Blackham** examines how the nation coped.



## Dust bowled

The *New Zealand Herald* photograph was designed to shock. A farm contractor held a gun to the head of a cow. The headline proclaimed 'Drought takes deadly toll'.

That same night, television news led with a story that the Wellington region had only 20 days' water left.

It was 13 March 2013; the day New Zealanders turned from loving the exceptional summer, to fearing it.

A few days later the summer reached its driest point, according to NIWA's calculations. The whole of the North Island was officially declared to be in drought on 15 March.

The first signs had been spotted by NIWA five months earlier, when rainfall fell sharply below its average. By mid-November, a full month earlier than usual, the ground in some areas of the North Island's east coast had lost 75 millimetres more water than it had received. Spurred by the data, Primary Industries Minister Nathan Guy called the situation a "'green drought', where the land looks green, but still isn't growing fast enough".

Lower soil moisture levels mean less water for grass and other plants, so growth is retarded. Lack of grass means less for stock to eat.

So by the time townies stopped sunbathing and heard Campbell Live say the drought was "becoming the worst in living memory", farmers were already under great stress.

It was the widespread nature of the drought that hurt the worst. With everywhere suffering, there was nowhere to move stock, and nowhere nearby to source stock feed.

Some farmers were spending upwards of \$2000 a day to buy stock feed. Many calculated that it was cheaper to send stock to slaughter earlier, and in greater numbers, than usual. Forty per cent more cattle were killed than usual during the period, and 23 per cent more sheep.

Lame cows that couldn't walk to find grass were killed rather than be left to starve. Hence, a busy time for the slaughterman pictured by the *New Zealand Herald*.

Farming support networks were putting most of their time into dealing with the emotional stress on farmers. The *Waikato Times* published a story about an accountant who talked down the gun a share milker had to his head.

The economic cost was high. Treasury has estimated the cost to be up to \$2 billion over the entire period – knocking 0.7 percentage points off the annual GDP.

It was variously described as the worst drought in 30 years, the worst in 70 years and the worst in history. NIWA has since calculated that no other drought in the past 40 years has been so intense over such a wide area of New Zealand.

The emotional response to the drought confirmed our nation's sensitivity to weather and water, and particularly to its effect on our rural economy.

Federated Farmers President Bruce Wills summed up the reason for the acute reaction: "We are a grass-fed economy. If the grass does not grow, the entire economy feels it."

**"We are a grass-fed economy. If the grass does not grow, the entire economy feels it."**

Bruce Wills, President, Federated Farmers

### Speed reading the drought

NIWA is a permanent member of Ministry for Primary Industries' (MPI) National Adverse Events Committee – a group of experts and representatives from primary industry, rural support groups and government agencies. The Committee discusses and shares information on the scale and nature of adverse events affecting the primary sector – such as drought, floods and snow – to coordinate recovery activities and help the primary sector to get back on its feet quickly.

MPI's Resource Policy Manager, North Island Regions, Stuart Anderson says NIWA kicked off each of the regular meetings during the drought with a run-down on the climatic conditions and outlook.

"The national and local picture of climatic conditions, soil dryness and the long-range seasonal outlook gave us the big picture. Then each industry described how they were being impacted, and how they were coping."

"That understanding of the size and magnitude of the drought, and how it was directly affecting people, meant we

could discuss ways of helping."

Trish Burborough, MPI Policy Manager for the South Island, sat on the Adverse Events Committee along with NIWA's representative, Dr Andrew Tait.

"NIWA helped us understand the size and severity of drought – to put it in historic context and establish that we were indeed facing a significant adverse event."

Burborough says there was a particular focus on helping farmers. "Farmers needed NIWA's information for their decisions on how to adapt."

As the drought began to end, and particularly following NIWA's analysis of the 2013 drought, Anderson says Committee discussion also focused on long-term adaptation.

"There's a lot of interest in the causes of this particular drought. It was a different pattern to what we are used to. People are worried about the prospect of more in the future and asking, 'What do we do?' That's why MPI continues to invest in research on adaptations and resilience."

## Dust bowled



Havelock North sheep farmer Bruno Chambers was forced to feed out silage, his winter feed, due to the exceptionally dry summer weather. (APN)

### How hot was it?

It was hot during the summer. The highest temperature reached was 35.1 degrees in Clyde and Gisborne in January.

NIWA's records show that mean temperatures in February were above average, but not exceptionally so – the light winds and clear skies meant the afternoon maximum temperatures were well above average, but the overnight minimum temperatures were below average.

It was the sunniest February on record for numerous locations across both islands. Wellington and Hamilton recorded their sunniest February on record, Tauranga experienced its second sunniest February, and Christchurch observed its third sunniest February.

The real protagonist – the killer of grass and plants – was not heat, but lack of water.

February rainfall totalled less than 15 millimetres (a mere 15 per cent of normal) in parts of Northland, Auckland and the Bay of Plenty.

It was the driest February on record for Leigh (north Auckland) and Milford Sound. In the case of Leigh, it was also the driest month (of any month) since records began in 1966.

The dryness was widespread. Rainfall was less than 25 per cent of February's norm around Taupō, parts of Gisborne and Hawke's Bay, and along the West Coast of the South Island.

Which is why, when NIWA was asked by the Ministry for Primary Industries (MPI) to review the drought, it concentrated on calculating levels of soil moisture.

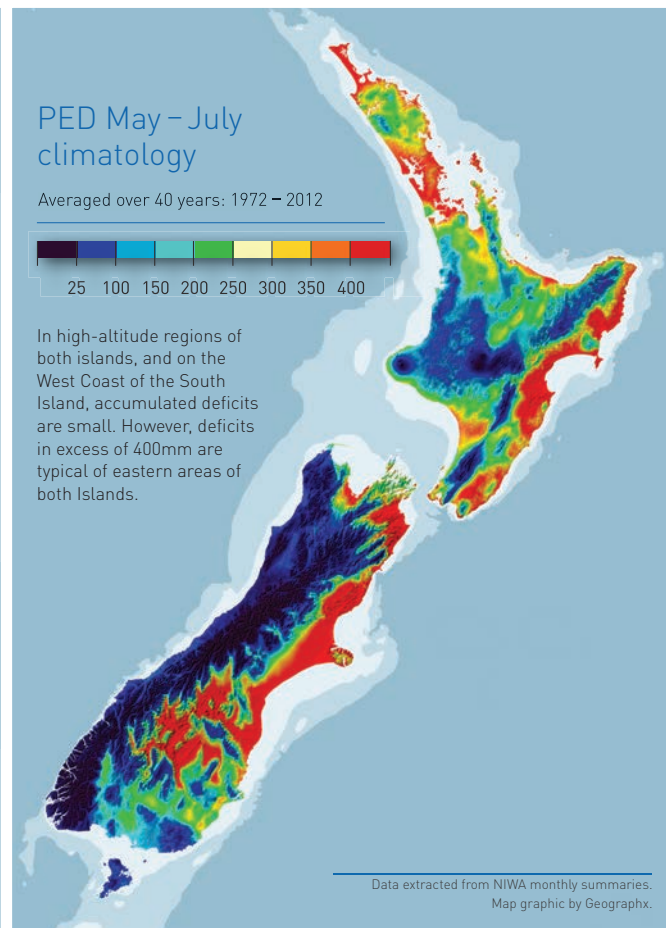
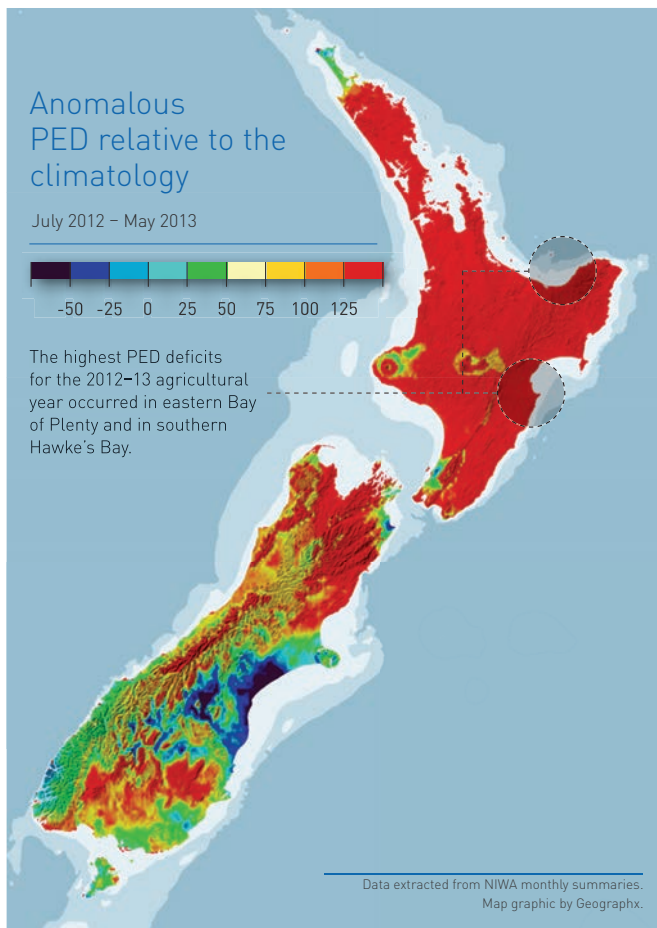
A useful method to estimate dryness is a soil moisture model that calculates potential evapotranspiration deficit (PED). PED is the amount of plant-available soil water needed to be added as irrigation, or replenished by rainfall, to keep pastures growing. The model estimates the moisture deficit balance between the net loss of soil moisture by evaporation and transpiration (evapotranspiration) and the gain by rainfall.

PED was calculated on a daily basis at rainfall-measuring locations in NIWA's climate station network, and at grid points on the Virtual Climate Station Network (VCSN), which are spaced about five kilometres apart over the country.

As the growing season advances, evapotranspiration typically exceeds rainfall, and the moisture deficit increases. The higher the PED rating, the higher the water deficit, and the soil becomes drier. The typical threshold for moisture-constrained plant growth is about 75 millimetres of water deficit – reached by many North Island farms a month or more earlier than usual during the 2012–13 growing season.

NIWA Principal Scientist, Climate Variability, Dr Brett Mullan says the PED over the growing season from July 2012 to May 2013 was "one of the most extreme on record".





The maps above compare the scale of the 2013 drought (left) to the average conditions between 1972 and 2012 (right). They show moisture-level deficit as predicted by the potential evapotranspiration deficit (PED) model. In practice, PED shows the amount of water which would be needed to keep pastures growing as if they were not constrained by a shortage of water. Virtually the entire North Island had a water deficit at least 125mm greater than normal, and most of the north and west of the South Island had a deficit more than 75mm above normal.

“The PED was the most severe and widespread since at least 1972, with one-third of the North Island having the highest deficit in the VCSN data period.”

NIWA's VCSN system goes back to 1972, but longer-term station records go back to the early 1940s. So NIWA was able to calculate that in some regions it was the most severe drought since 1945–46.

In total, the areas most affected were southern Northland, Auckland, Waikato, Bay of Plenty, the central North Island, Gisborne, Hawke's Bay, Wairarapa, and parts of the north and west of the South Island.

## Sunburnt

According to the MPI's Pastoral Farm Monitoring Report, farmers racked up \$2.5 billion of debt with banks between January and April.

They needed loans to cover drops in production, lower value of products sold when supply was high and increased costs of feed.

Tauranga Chamber of Commerce Chief Executive Max Mason estimates that dairy farmers in the Bay of Plenty lost about \$74 million from the drought.

DairyNZ recorded an 11 per cent drop in that region's milk production compared with the previous season, an average

loss of \$95,000 to \$135,000 per farm. Meanwhile, costs went up. Bay of Plenty Federated Farmers Provincial President Rick Powdrell says feed prices increased by 20 per cent, raising the feed bill per farm to at least \$25,000.

Derek Spratt, Chairman of New Zealand's Rural Support Trust, was telling farmers to “forget about this season; start concentrating on next season”.

Financially squeezed and budget-conscious farmers had a flow-on effect throughout their communities.

Max Mason says dairy farmers had stopped spending.

“The firms who supply the industry are often forgotten and the drought will have impacted on their livelihoods and survival.”

Around 22,000 people are employed in the \$2 billion rural contracting industry. Rural Contractors New Zealand Chief Executive Roger Parton says many of their 450 members have suffered flow-on effects from the drought. Farming contractors in the Bay of Plenty claim to have lost up to 50 per cent of their work over the period.

It wasn't just the agricultural sector with dust between its toes. Low lake levels due to drought lifted wholesale power prices. The average wholesale price for power jumped to about \$250 per megawatt hour in Wellington and \$400 per megawatt hour in the upper North Island – about four or five times normal levels.

## Dust bowled

Meridian Energy reported that the February rainfall into Lake Te Anau was the lowest since records began 80 years ago. Other hydro power stations on low lakes were at Manapouri, Lake Taupō and Lake Tekapo.

April was Mighty River Power's lowest month ever for hydro production, contributing to a 16 per cent fall in electricity generation in the last quarter of its financial year.

And it wasn't only sheep and cattle starving over summer. The drought is thought to have made it tough for many native species.

Anecdotal reports from the far north said thirst and dry soil were pushing the brown kiwi into residential areas.

A University of Canterbury study revealed that about a quarter of the hardy but endangered native brown mudfish died over the drought period. This effect on a fish known to handle long periods without water has worried scientists that the drought will have harmed less-resilient species.

According to Pete McIntosh, Hawke's Bay Fish & Game New Zealand Regional Manager, reduced river flow during the period changed the ecology of rivers, reducing the size and numbers of fish.

**“Drought is a protracted period of deficient precipitation resulting in extensive damage to crops, resulting in loss of yield.”**

National Drought Mitigation Center – USA

## Still burning

In early April, three long dry weeks after that controversial cow photo crystallised public concern, NIWA Principal Scientist, Climate Variability, Dr Andrew Tait appeared on TV3's Firstline programme to declare that “the most likely outcome [for Autumn] is to get about normal rainfall for the three month period”.

Within two weeks rain began falling. In many places it began falling hard. At Tauranga, the first three months of the year were exceptionally dry – at 4mm (Jan), 31mm (Feb) and 20mm (Mar). Yet this was followed in April by a total of 284mm (236 per cent of normal).

The coming of the rain was not the end of the drought. The poor growing season, slow recovery of bores and weakened financial state of agricultural communities meant New Zealand was ill-prepared for the heavy rains and snow of winter.

Katie Milne, Adverse Events Spokesperson for Federated Farmers, tells W&A that there will be a long-term “carry-over” effect of the drought.

“There is no doubt this year has been challenging to say the least.

“The adverse winter comes on the back of people having to offload stock where appropriate and buying in extra feed at a high cost.

“This has led to a lower number of milkers in some cases, and lower lambing rates are still in the making. Beef + Lamb New Zealand estimates a drop of three million lambs in the coming spring.”

MPI's Resource Policy Manager, North Island Regions, Stuart Anderson says that although the rain returned and farms started to recover over the good autumn conditions, the economic and social impact of the drought continued.

“The [July] snow makes it harder for farmers to see themselves through the winter and manage feed supply and pastures.”

He says the adverse event declaration of the drought will remain in place until 30 September to “allow rural communities to get through winter and into early spring”.

Federated Farmers' Katie Milne says the full effect on farmers is yet to become clear.

“The drought has truly sunk its teeth into farmers. The average sheep and beef production is down 10 to 20 per cent in live weights, and dairy 8 to 10 per cent for milk production. There are still a few issues yet to raise their heads.”

Although the picture for the rural sector is mixed, New Zealand's economy scraped through the drought with only a little pain.

Before the drought hit, the New Zealand economy was thought to be in relatively good shape. Although the high

## What caused the drought?

New Zealanders have begun to understand the fluctuations and impact of the El Niño and La Niña systems. Severe droughts in 1972–73 and 1997–98 were both El Niño years. But this drought was caused by neither.

NIWA found that the dryness was due to slow-moving high pressure systems over the Tasman Sea and New Zealand during summer. These effectively blocked any other sorts of weather systems approaching the country.

Dr Andrew Tait famously told TV3's Firstline show: “The climate got stuck.”

The unusual weather created a special challenge for forecasters. “We had a lot of anticyclones sitting over the country. There were fewer patterns, so we were relying on less useful information.”

Dr Brett Mullan agrees that the latest drought was very different from others, but believes we'll see more of these sorts of droughts.

“High-pressure anticyclones during summer is a trend that is increasing, according to century-long pressure records.”



## Dust bowled



Stock struggling in hot, dry weather – Te Ore Ore Bideford Road, Wairarapa. (Dave Allen)

New Zealand dollar, at US86 cents, was capping the excitement of very high international milk prices, interest rates were low, GDP was growing and imports were cheap.

The New Zealand Treasury's Monthly Economic Indicators Report in June said reduced agricultural production would cut growth by about 0.7 percentage points over 2013. It says the impact will be relatively short-lived, because the nation's growth will accelerate again "as the drought impacts fade over the second half of the year".

But the experience of the 1997 and 2007 droughts is that it takes about two years to get production back to normal levels after such droughts. Those droughts put 2013 into perspective. The 2007–08 drought cost \$2.8 billion. It is credited with combining with the global financial crisis to tip New Zealand into recession.

That is why NZIER Principal Economist Shamubeel Eaqub was able to tell W&A that the drought will knock between 0.5 per cent and 1 per cent off GDP over two years. But he says that is relatively low by previous standards, and was only made possible because New Zealand was in a reasonable condition to face the drought.

"Going into the drought, the economy was forecast to grow by 2.5 to 3 per cent. Mortgage rates were low, businesses optimistic, the Canterbury rebuild was under way and surveys were showing strong hiring and investment intentions."

The optimism was confirmed when, in August, commentators said it would end up being a bumper season for the dairy industry. Fonterra announced that its 2013–14 season payout would be \$7.50 per kilogram of milk solids.

### Horticulture smiles

Some primary industries did very well basking under the intense sun. The wine industry was cock-a-hoop over the season.

Larry Morgan, Viticulturist at Te Mata Estate winery in Hawke's Bay, tells W&A that the taste and quantity of the 2013 grape harvest will make it an "exceptional" year for wine.

"2013's drought conditions concentrated both sugar and acid in the grapes, giving remarkable quality. From fresh, early-release whites, through to Hawke's Bay's greatest full-bodied reds, these wines will raise the bar for New Zealand wine."

Morgan says cool clear nights generally result in higher acid levels in New Zealand grapes than achieved in other countries. The acids in grapes are critical to the flavour and aroma of the wine.

"The favourable balance of sugar and acid gives New Zealand wines their unique taste. Daytime heat during the drought allowed sugar to rise to about 22 per cent of the grape content, but cool clear nights prevented the grapes from respiring their acid."

## Dust bowled

Morgan says even some of the 2013 harvest wines already coming onto the market are noticeable for the quality of their taste and aroma.

"Some of the finer wines won't be available until 2015, but they will be absolute stunners."

Even grapes need water, though. Throughout the four months of the drought, New Zealand's vineyards applied about four litres of water per vine per day. Virtually all of it was sourced from on-site bores drawing from the water table.

"We could see the bore level falling over the period, but it never looked like running out," Morgan said.

## Learning to cope

Bores into underground aquifers kept agriculture watered during the drought when low river flows triggered restrictions on water-take.

Dougall Gordon, Groundwater Scientist at Hawke's Bay Regional Council, was watching closely as the water in those bores emptied. He told W&A that his region's bores were working overtime during the drought.

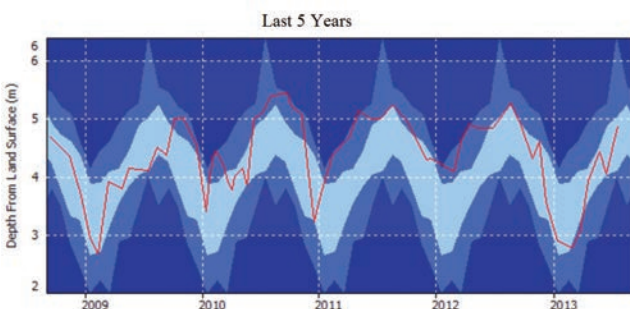
"We know the aquifer was stressed, because some of the groundwater monitoring bores hit their lowest recorded levels."

Despite the public alarm over lack of rain, the water supply was strained but not critical. In fact, it appears that the bores quickly recovered once the drought broke.

"Monitoring data have shown that water levels in the aquifers recovered once the drought broke. The 'normal' predicted winter rain restored groundwater levels to its normal long-term range."

Gordon says the drought alerted people to the importance of security of supply of water.

"Groundwater can provide a more secure supply at times of drought, but taking too much groundwater has a cumulative effect on river flows when more water is abstracted from the system than is recharged.



Groundwater levels measured over the past five years in a well at Hawea, Hawke's Bay. Although low by recent experience, the water level was still higher than at least seven other summers over the previous 20 years.

## Declaring a drought

The National Drought Mitigation Center in the United States says a drought occurs when there is not enough rain for an activity or environmental sector for at least a complete season, or more.

A drought is not just a physical phenomenon, measured by environmental factors. The Center says the stress of a drought results from "the interplay between the natural event (less precipitation than expected) and the demand people place on water supply".

NIWA's drought analysis was essential to New Zealand's understanding of the big picture, according to MPI Resource Policy Manager, North Island Regions, Stuart Anderson.

"Anecdotally we were told the drought was the worst some farmers had experienced, but it is important to have this analysis to understand how dry the regions were compared with previous droughts."

Declaring a drought matters administratively, because it is the threshold at which the Government provides extra funding through rural support trusts to support rural communities, and some people experiencing hardship may also be eligible for income support through Rural Assistance Payments. Some tax measures can also be accessed through Inland Revenue.

The New Zealand Government needs to be requested by local authorities to declare a drought. MPI collects information to help the Minister make the official decision. It considers the environmental factors using data supplied nationally by NIWA and locally by local authorities. It then considers the operational effects – how people, stock and commerce are faring.

"This is why science to help underpin allocation decision-making is so important, and over the long term the challenge is to consider options for storing enough water for the times it is needed."

While bores fed plants, animals needed more than just water. A crucial decision for farmers was whether to sell stock for slaughter or buy feed to keep them going.

Dairy farmer Kevin White, who manages a 350-cow herd in Te Aroha, told Fairfax that he kept adjusting his plan every 10 days through the drought. His aim was to do what he could afford to "keep a core group of cows milking and at a healthy weight to set them up for winter". In mid-March he reduced the herd by about 70 cows so he could afford to feed the rest.

Crucial to those sorts of decisions during the drought were weather predictions and updated climate outlooks for the next few months. Farmers needed to know if and when rain would arrive. The longer it took, the tighter their budgets would need to be.



## Dust bowled

NIWA's analysis of the current climate, using observations from both NIWA and MetService climate networks, and its outlook for the next 15 days to 3 months were regularly presented during the drought to the National Adverse Events Committee (NAEC) run by MPI. This Committee has met regularly over the past few years to maintain an ongoing assessment of the impacts of New Zealand's variable climate on primary production. NIWA weather and climate updates are typically one of the first items on the NAEC agenda. The updates are an important part of the mix of information that is used by MPI and other agencies for regional planning of rural support during adverse-weather events.

NIWA has also been supplying data to the Climate-Smart Farmers website (<http://climate-smartfarmers.wikispaces.com/>). This project, in collaboration with PGG Wrightson and funded by MPI under the Sustainable Farming Fund, maintains the site as a 'wiki' where farmers can get their hands on weather data and tools, and discuss management options with other farmers.

"We're working with specific farmers over a period of at least two years to determine what information is most useful for farmers to use in their decision making," says Alan Porteous, Group Manager, Climate Data and Applications, at NIWA.

PGG Wrightson and NIWA have held workshops with farmers to develop or adapt a range of climate products, including data sets, maps and derived information, specifically focused to assist farmer decision making on a day-to-day basis.

Porteous says it's not just about forecasting future weather. Being able to compare current weather conditions with past conditions helps farmers use their own records to judge what to do this time around.

Another NIWA tool helping the rural sector is the new NIWA forecast subscription-based service (see Q&A, page 42). The online tool creates a range of forecasts for properties as little as 12 kilometres apart. Information and forecasts calculated on NIWA's supercomputer incorporate data from the NIWA weather station that best represents climatic conditions on each property.

Not surprisingly, the drought caused consternation about the long-term challenges of regular droughts as the climate changes.

Finance Minister Bill English warned that farmers could not expect government support over continuous droughts.

Whether it's daily decision making or long-term planning, some adaptations appear necessary to get through future droughts.

"We have to adapt – there is no doubt about it," Federated Farmers President Bruce Wills says.

The New Zealand economy may have been lucky this time around, but the rural sector was undoubtedly hard hit. With many parts of the country expected to spend more time in drought as the century progresses, New Zealand appears determined to adapt.

Nathan Guy says water storage is a crucial answer to current and future droughts. "We don't have a shortage of water in this country – we don't have an ability to store that water."

That work is well under way in one of the regions hardest and most regularly hit by drought – Hawke's Bay. The region is considering a proposal for a new dam (Tukituki Catchment) and a water-storage scheme (Ruatanuiwha), which includes a dam and reservoir on the Makaroro River and irrigation canals on the Ruatanuiwha Plains.

NIWA is also part of a project in Canterbury aimed at vastly improving the efficient management of irrigation by using evapotranspiration measurements to judge the timing and amount of irrigation.

NIWA Water Resources Scientist Maurice Duncan says the Environment Canterbury-sponsored project is producing data essential to establishing the economic justification for irrigation and storage projects.

The project is showing that close monitoring of soil can enable many types of farming across many types of soil.

"It's a matter of understanding the flow of water through soils to keep moisture within a sweet spot for plant growth.

"We can accurately measure the water flows of different soils – and assess how much additional water is required to recharge soils.

"We're learning how farmers can fine-tune their use of water – to keep plants growing with the minimum amount of irrigated water."

NIWA's Canterbury irrigation project is a perfect example of the value of connecting weather science with farming techniques.

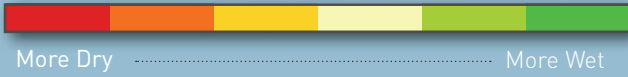
Brett Mullan says on-farm water storage, irrigation and drought-resistant grasses hold some of the keys to getting through future dry periods in more comfort.

Applying science to farming adaptation is not only possible, it is essential, says Alan Porteous. "New Zealand experiences a dry period in some region of the country almost every year. It's a fact of life here that we must plan for."

# Drought in New Zealand

Soil moisture deficit as of 17 March 2013 and regional conditions

Soil moisture deficit



## Hot

The highest summer (December 2012–February 2013) temperature was 35.1°C, recorded three times during summer: at Clyde on 5 January, and at Gisborne on both 9 and 10 January.

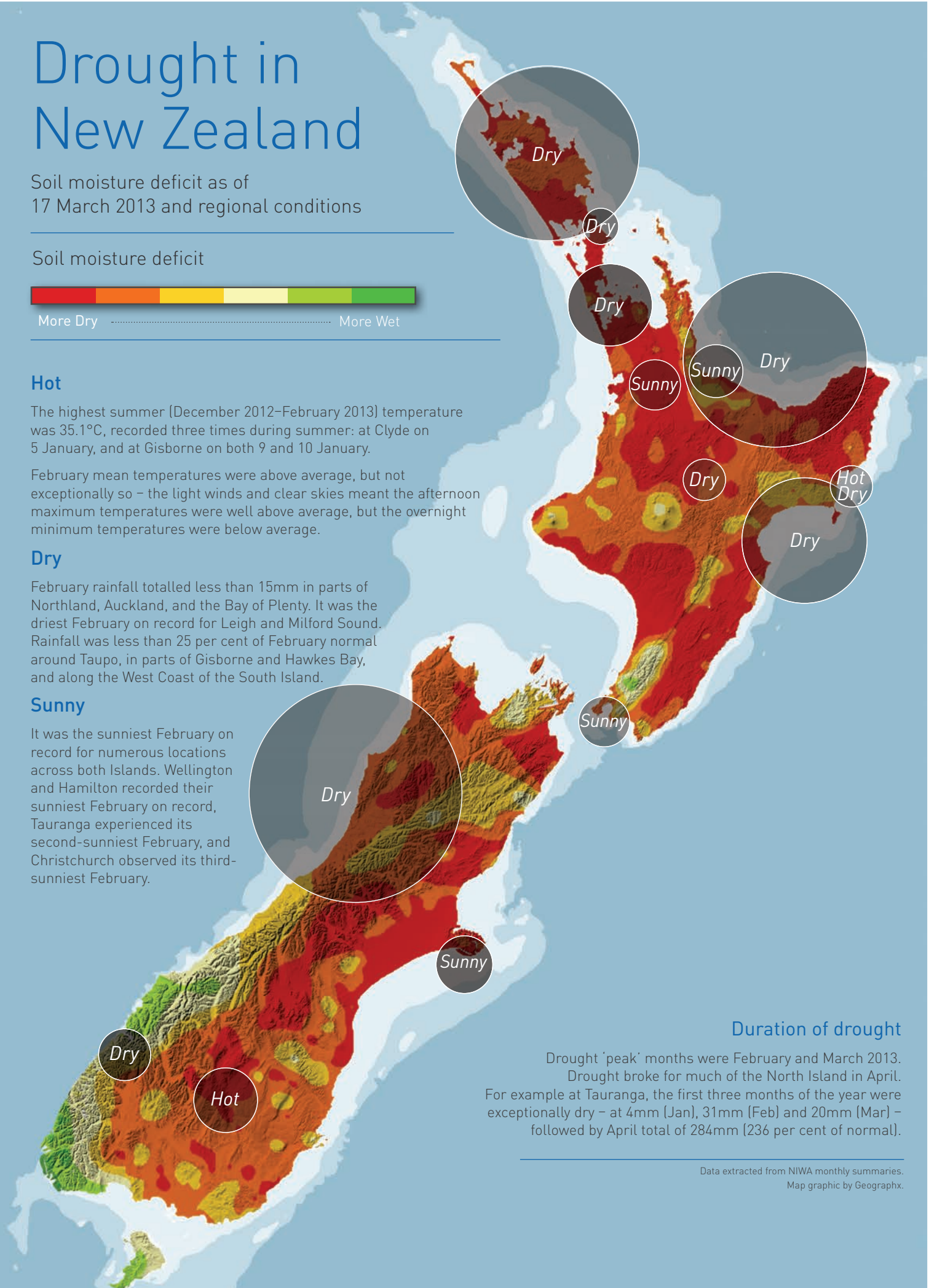
February mean temperatures were above average, but not exceptionally so – the light winds and clear skies meant the afternoon maximum temperatures were well above average, but the overnight minimum temperatures were below average.

## Dry

February rainfall totalled less than 15mm in parts of Northland, Auckland, and the Bay of Plenty. It was the driest February on record for Leigh and Milford Sound. Rainfall was less than 25 per cent of February normal around Taupo, in parts of Gisborne and Hawkes Bay, and along the West Coast of the South Island.

## Sunny

It was the sunniest February on record for numerous locations across both Islands. Wellington and Hamilton recorded their sunniest February on record, Tauranga experienced its second-sunniest February, and Christchurch observed its third-sunniest February.



## Duration of drought

Drought 'peak' months were February and March 2013. Drought broke for much of the North Island in April. For example at Tauranga, the first three months of the year were exceptionally dry – at 4mm (Jan), 31mm (Feb) and 20mm (Mar) – followed by April total of 284mm (236 per cent of normal).

Data extracted from NIWA monthly summaries. Map graphic by Geographx.



Climate change is making its presence felt in the Southern Ocean with warmer water, acidification and a decline in the salinity and density of the deep bottom water which drives the planet's crucial carbon cycle. *(Adrian Bass)*

# Chilled Calypso

Humanity wants to discover the reasons behind thinning ice, acidic water and rising temperatures in the Southern Ocean.

**Susan Pepperell** finds that NIWA scientists are racing against time in taking on this challenge.



## Chilled Calypso

In late summer, the sea ice near the Mertz region of Antarctica should mostly be gone. Or at least it should have broken into small enough pieces to allow a ship to pass through into open water without too much cause for concern.

But last summer the sea ice didn't break up and disperse as usual. Instead, it refroze, thickened and stayed put.

From his Wellington base, Dr Mike Williams had been closely monitoring satellite images showing what was happening to the sea ice some 3500 kilometres south. The NIWA Marine Physicist was about to lead a 42-day voyage to the eastern coast of Antarctica aboard NIWA's deepwater research vessel *Tangaroa*, and part of the plan was to pass through the sea-ice zone to retrieve crucial data recorded by instruments moored to the seafloor.

If the sea ice didn't budge, *Tangaroa* – ice-strengthened, but not an icebreaker – wouldn't make it, and Williams and his team would need to change focus.

*Tangaroa* slipped out to sea on a sunny Wellington day in early February. Onboard were 16 crew and 22 scientists – oceanographers, geologists, biologists and technicians – from three research institutes: NIWA, the Australian Antarctic Climate and Ecosystem Cooperative Research Centre, and the French equivalent, L'ocean (Laboratoire d'Océanographie et du Climat).

The team was well prepared. Survival training had taught them how to get into a cumbersome immersion suit, the

signs of exposure they might observe in their colleagues and what frostbite looked like and how to avoid it.

They were also given survival bags and a box of equipment and food in case they had to abandon ship on to the ice and wait to be rescued.

Each scientist worked in 12-hour shifts, battling seasickness, fatigue and an environment that became increasingly unfriendly the further south they went.

Also onboard was a range of complex scientific equipment for measuring water, atmosphere, ice and sediment and taking samples that, in the coming months and years, will help scientists understand what is causing the Southern Ocean to change, and what those changes might mean to sea levels, rainfall, wind patterns and temperatures around the world.

The information gathered on this voyage contributes to the pool of information gathered by other scientists from previous voyages, with the aim of enhancing the sum of knowledge of the role the Southern Ocean plays in global climate change.

"In some ways the true value of this trip was in how it fitted together with the larger question of what's going on in the Southern Ocean," says Williams.

"There is a bigger, better story to tell from multiple voyages and the information they all provide."

*Tangaroa's* destination was the Mertz Polynya, an open area of water surrounded by ice off the eastern coast of Antarctica.

### Continuous Plankton Recorder

Metal boxes shaped like fish are playing a key role in monitoring changes in the Southern Ocean.

Officially called Continuous Plankton Recorders (CPR), these instruments were invented in 1926 and are towed by ships all over the Southern Ocean as part of an international programme to keep an eye on plankton levels and quality.

In February, NIWA Biologist Mark Fenwick was on *Tangaroa* for this 42-day journey to the east coast of Antarctica.

He was part of the team deploying the CPR behind the vessel as it headed south. "We ran it from just south of Stewart Island to about 60 degrees south at about a depth of 10 metres, collecting plankton samples and preserving them for analysis."

Water is fed through an aperture of about one square centimetre and filters the plankton between two moving bands of silk.

With the aid of an ingenious water-powered propeller, the silk spools into a storage tank of formaldehyde where the plankton are preserved until they can be analysed. The silk from this journey will be analysed in Hobart by the Australian Antarctic Division. While the technology is old, the CPR

nevertheless provides vital consistency over time.

Fenwick's work is part of the Southern Ocean Continuous Plankton Recorder Survey, an international programme which has been running for more than 20 years.

Data from previous surveys have revealed significant changes to the number and distribution of plankton in the Southern Ocean. Given that they are a crucial source of concentrated food for krill, the staple diet of fish and whales, any changes act as an early warning sign that all is not well in the ocean food chain.

This programme has covered more than half the ocean, taken tens of thousands of samples, with a CPR being towed for more than 300,000 kilometres.

Fenwick says the February CPR sampling would add vital information as scientists sought to discover what is driving changes in the Southern Ocean.

Meanwhile, NIWA scientists are also near the end of a five-year study funded by the Ministry for Primary Industries to map changes in the distribution of plankton species in surface waters between New Zealand and the Ross Sea. It is due to be completed in October.



## Chilled Calypso



Icebergs like this in the Southern Ocean are being studied by NIWA scientists for the information they can reveal on climate change. (Adrian Bass)

Polynyas are typically small, but common around Antarctica, and are exceptionally efficient at making sea ice – the water on the surface freezes and forms sea ice, then strong winds come across from the coast blowing the ice away, allowing the surface water to refreeze and start the whole process again.

The Mertz Polynya is of special interest to scientists because it is one of the few places in the Southern Ocean where 'Antarctic bottom water' is formed. This oxygen-rich water is exceptionally dense because it contains the salt crystals left behind to sink when sea ice forms. Because of its density, this bottom water is one of the main drivers of ocean currents.

Polynyas are also delicate and easily disturbed. Three and a half years ago, in February 2010, a large iceberg – a remnant of one that had broken free from the Ross Ice Shelf in the late 1980s – collided with the tongue of the Mertz Glacier, causing a huge piece of roughly 25,000 square kilometres to break off.

Ice conditions in the region then changed. The glacier tongue had been helping to hold back the sea ice, and its calving resulted in the polynya being less effective at forming Antarctic bottom waters. Less bottom water affects deep water circulation, the crucial carbon cycle and, ultimately, the Earth's climate.

But this environmental 'accident' is far from being the only culprit to cause changes in the Southern Ocean.

## Due south

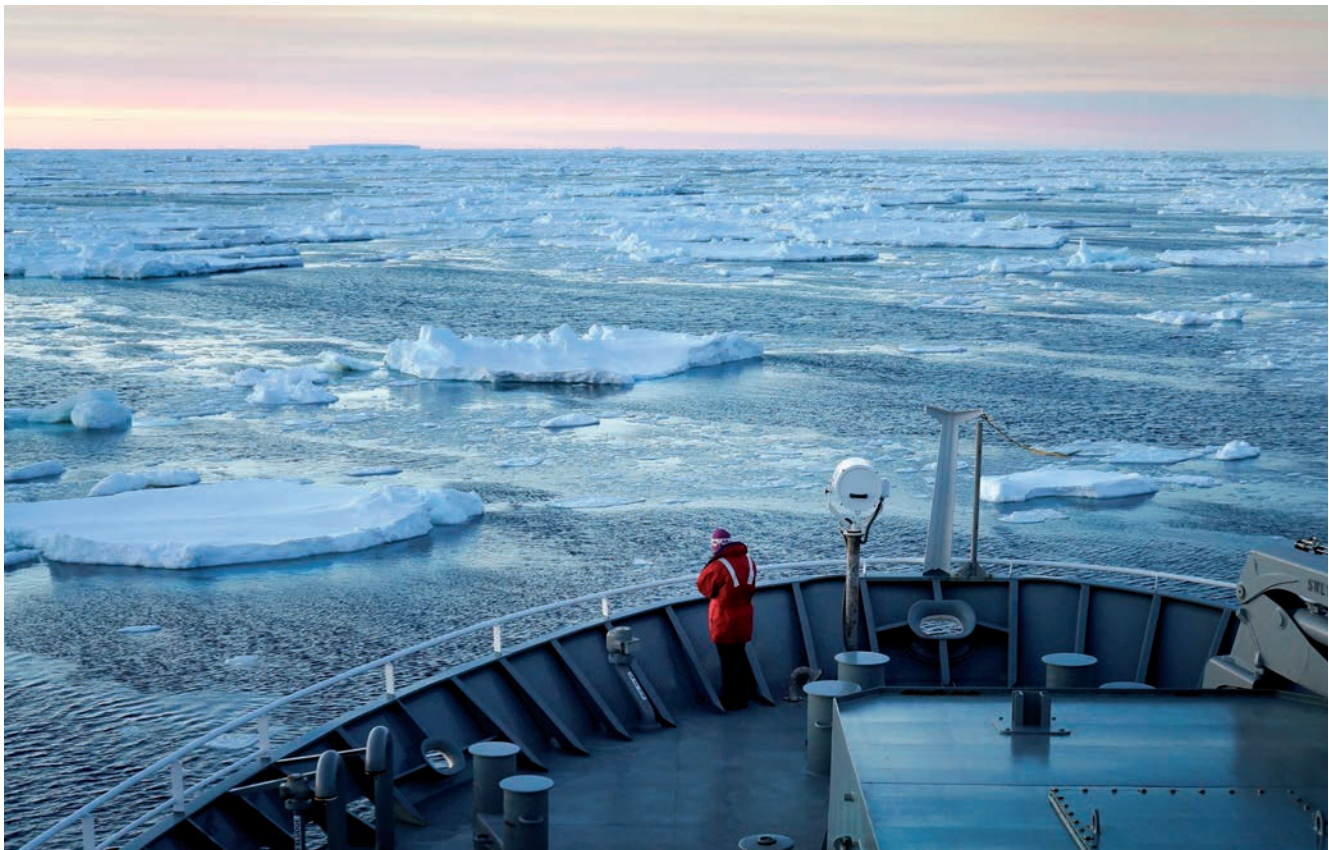
Head south from New Zealand for 700 kilometres and you will come across Campbell Island, a nature reserve known for its albatross population and rugged terrain. South from there, the vast Southern Ocean encircles Antarctica.

Officially named in just 2000 by the International Hydrographic Organization, the Southern Ocean comprises the southern parts of the Atlantic, Indian and Pacific oceans, and includes the Amundsen Sea, Drake Passage, Ross Sea, Bellingshausen Sea, Weddell Sea and part of the Scotia Sea.

The Southern Ocean is home to the world's strongest ocean current, the Antarctic Circumpolar Current. Driven by strong westerly winds, this exceptionally powerful current flows clockwise around Antarctica and makes the Southern Ocean one of the most turbulent, vigorous areas on the planet.

But probably the best known feature of the Southern Ocean is its rich and abundant wildlife. More than 10,000 species, including penguins, whales, fish and seabirds, thrive here in mostly sub-zero temperatures. A close watch is kept on these species to ensure any changes to their populations are quickly identified.

## Chilled Calypso



Courtney Derriman, of Sydney's Macquarie University, on the bow of *Tangaroa* as it headed south in February. (Helen Bostock)

### “How much can the ocean take?”

NIWA Physical Oceanographer, Dr Mike Williams

Governance of the waters of the Southern Ocean is complex and managed via a number of international protocols, conventions and organisations. The Antarctic Treaty, of which 50 countries are members, is the principal governing document and reserves the continent as a place of scientific endeavour. It also bans all military activity, prevents development and includes protocols on environmental protection.

In 1982, the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) was set up with the objective of conserving Antarctic marine life and ensuring unique ecosystems in the region were not adversely affected by activities such as fishing.

It has 25 member countries and was established mainly because of concern that increasing krill catches could seriously affect the Antarctic food chain. Similar concern has been expressed about the Patagonian toothfish, also known as Chilean sea bass.

Membership of CCAMLR is voluntary and decisions are reached by consensus. The organisation came to international attention in July when a New Zealand-led plan to create a 2.27 million square kilometre marine reserve in the Ross Sea was blocked by Russia.

### Deep trouble

Scientific research in the Southern Ocean has become more critical in recent decades in determining the impacts of climate change, both in New Zealand and globally. However, understanding the consequences and the extent of that change remains a significant challenge.

What is known is that the Southern Ocean is getting warmer and more acidic, despite having an incredible capacity to absorb heat and carbon dioxide. Wind patterns have also changed, which is linked to the ozone hole and increased greenhouse gases.

Climate modelling suggests more change, including higher sea levels, less sea ice and different rainfall patterns – all of which will influence climates in New Zealand and around the globe. Given this level of significance, it was perhaps not surprising that in May this year the Deep South (the Southern Ocean and Antarctica) was named as one of 10 National Science Challenges identified by the New Zealand Government.

The challenges, according to Science and Innovation Minister Steven Joyce, were designed to take a more strategic approach to science investment and tackle “some of the biggest science-based issues and opportunities facing New Zealand”.



## Campbell Island rockhopper penguins

Right now the rockhopper penguins of Campbell Island should be happily splashing about somewhere in the Southern Ocean feeding.

Exactly where they spend the winter is not known, but NIWA scientists hope to be closer to finding out by the end of the year.

In April, Marine Ecologist David Thompson and his team placed electronic tags that record light levels on about 50 rockhoppers as part of ongoing research to find out what these birds can tell us about changes in the Southern Ocean.

The tags will be retrieved after the penguins return to the island to breed in October and the data are analysed to determine their movements.

There are so many unknowns about the rockhopper that Thompson calls it "a bit of a black box".

What is known is that the species on Campbell Island declined from about 800,000 breeding pairs to just 152,000 pairs between 1942 and 1985.

"We know that there are far fewer than there were in the 1940s, and that the population is a bit lower than it was in the 1980s.

"However, we don't know if the 1940s population was the largest it had ever been or whether the decline between the 1940s and '80s was something that happened naturally over time. And we don't know if the population has bottomed out and will recover, or whether there are other things at play."

Adding to the sum of unknowns is that the birds don't breed in one place on the island, but in many sub-colonies, some of which have disappeared in recent years and some of which have increased in size.

For the past three summers, doctorate student

Kyle Morrison has spent several months counting the rockhoppers on Campbell Island.

He is currently writing up his research and says it appears the rockhopper penguin population has stabilised in recent years, possibly due to greater availability of food.

Campbell Island is rugged, inhospitable and a long way south of New Zealand. It's costly to get there, and rockhoppers don't make it easy for scientists to get to know them.

"They are bold and aggressive birds for their size," Morrison says, "but also extremely charismatic."

The best way to find out about how the population is faring is to count them.

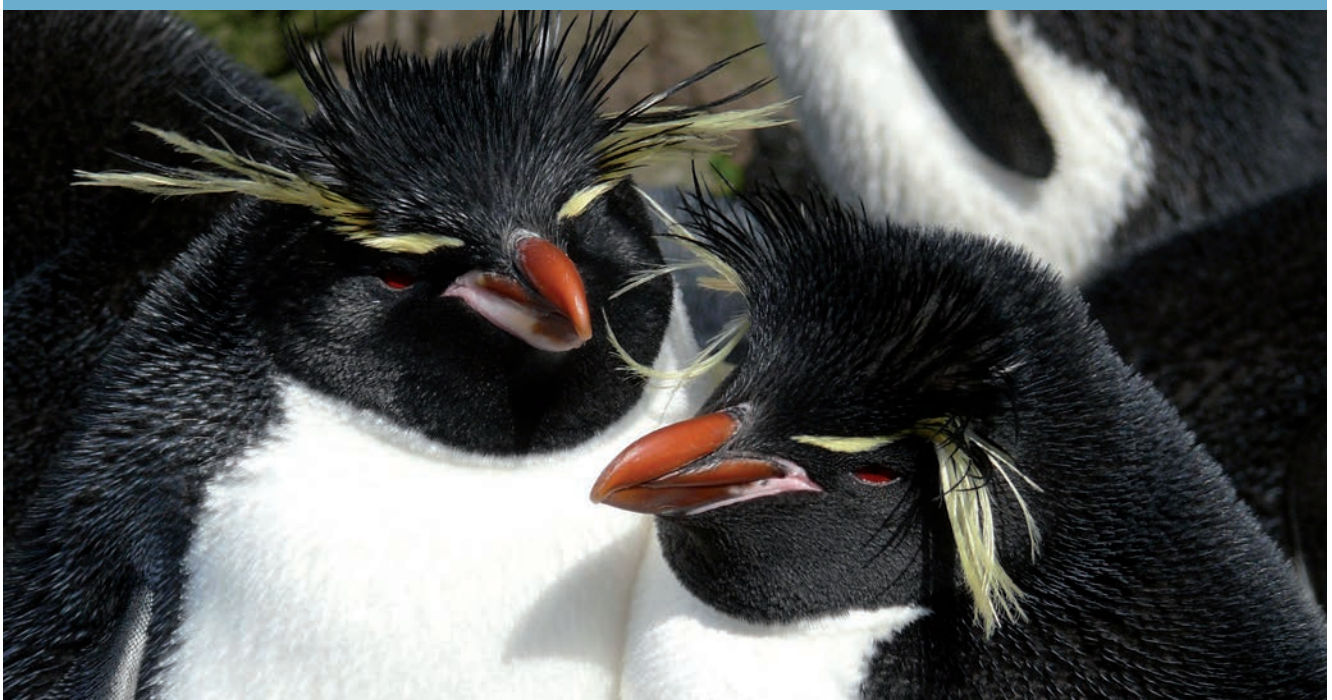
"It sounds easy, but it's actually very difficult," says Thompson. You need to do it over several years – they live for about 20 to 30 years, so they tend to survive quite well. Tracking changes in size, therefore, involves a lot of work over many years."

Also complicating matters is that the birds tend to live at the bottom of cliffs or on very steep slopes, where they are often obscured.

"Counting birds on the island is fraught with problems, and the resources required to do it properly over a number of years are quite mind-boggling."

However, the threatened rockhoppers are not the only species breeding on Campbell Island whose population has declined. They keep ever-diminishing company with the southern elephant seal and the grey-headed albatross.

"There is no convincing explanation of why all three are declining, but it's certainly telling us something about the Southern Ocean."



Rockhopper penguins on Campbell Island have an intriguing story to tell about changes to the Southern Ocean. (Paul Sagar)



NIWA's Ian Smith guides the CTD (Conductivity, Temperature, Depth) profiler back on board *Tangaroa* after it has been sampling salinity, pressure, oxygen and temperature to and from the seafloor. The CTD is deployed from the side of the vessel as seen at the right. (Helen Bostock, Eva Cougnon)

More government funding has been allocated and Joyce is calling for greater collaboration across institutions and disciplines.

Specific details about the challenge – understanding the role of the Antarctic and the Southern Ocean in determining our climate and future environment – should be known in the next few months, but NIWA is expected to take a lead role.

If there is something for the Minister to be heartened by, it is the high level of collaboration that already exists in the

science community when it comes to Antarctica and the Southern Ocean.

As Mike Williams says: "There's nothing like six weeks on a boat to get to know someone and forge relationships."

Gathering more information to help understand some of the "biggest science-based issues facing New Zealand" was precisely what the scientists on *Tangaroa* were doing in February.

## Core sampling

At the bottom of the sea, a scientist can go back in time. That's where there is layer upon layer of sand, mud and microfossils that have built up over tens of thousands of years.

Each layer has a story to tell of environmental change, each skeletal remain can be identified and its chemical composition revealed, and each core compared with the next to build up a more complete history of the ocean.

For NIWA Marine Geologist Dr Helen Bostock, the sediment at the bottom of the sea will tell her something about what has happened to the water masses in the Southern Ocean over the last 30,000 years or more.

She was on *Tangaroa* for its February journey to the Mertz region of Antarctica. Her interest lies in learning what happens to the sea over long periods of time, and to do that she and her team took core samples – some up to six metres long – from the ocean floor.

The corers were driven into the sediment by a two tonne weight.

Once back onboard, the cores were cut into 1 metre sections and split lengthwise, and the team set to work recording what they could see before the whole lot was wrapped up and stored for further analysis back on land.

"We look for distinct colour or composition changes in the sediment, we analyse the chemistry of organisms and changes in the microfossils, which provide clues about changes in temperature and nutrients. And from all that, we piece together all the different data to come up with a theory to explain what might have happened over time."

The ages of the core layers won't be known until the sediment has been dated, which will be done by identifying when particular fossils became extinct or by radiocarbon dating.

"The Southern Ocean is thought to have played an important role in causing large natural climate transitions, but we still know very little about this region," says Bostock.

"We hope this will provide a small piece of information to the giant puzzle of understanding Earth's changing oceans and climate."



## Chilled Calypso

As they headed south, the team collected samples from the surface waters and the atmosphere. They towed a CPR to collect and preserve plankton, and deployed a CTD (Conductivity, Temperature and Depth profiler) that measures salinity, temperature, pressure and oxygen on its way to the seafloor. Water samples were collected at different depths on the way back for analysis onboard or back on shore, and other instruments measured the speed of currents.

Once they came close to the Antarctic coast, and with the Mertz Polynya cut off, the team's focus went onto the Antarctic Continental Slope and the heavy, dense water that flows over it to the bottom of the ocean.

Scientists know this mass of bottom water is changing. It is not as dense or as salty as it was 10 years ago, and it is much fresher and warmer than it was 40 years ago, due to increasing levels of carbon dioxide in the atmosphere – a key part of global warming.

Increased carbon dioxide in the atmosphere in turn leads to warmer oceans that are increasingly acidic. Increased acidification affects marine life, in particular animals whose shells and skeletons are made from calcium carbonate.

Warmer sea temperatures also affect the growth of phytoplankton that are not only vital to the ocean food chain, but are also an important link in moderating climate change.

As Williams says: "How much can the ocean take? When we look at climate variability over the last decade, the atmosphere has not changed as much as in previous decades. But for carbon, the story is not as clear."

The Southern Ocean is changing, but the full impact of the changes is not yet fully understood. However, scientists know that further research and analysis is needed now for a better understanding of how these processes are linked to climate change.

Technological advances are helping fill in the gaps, and scenario modelling is becoming increasingly important in forecasting future changes. However, there is a collective sense of urgency expressed by the science community that the changes need to be understood at least at the pace with which they are occurring.

Six months after *Tangaroa* returned to Wellington, work is progressing on analysing the huge amount of information collected on the six-week voyage.

NIWA is taking a leadership role in ensuring this takes place as soon as possible and the wealth of data will be available for scientists around the world to examine and work on. Decisions are still being made on just who is looking at what, but Williams says it will be nothing if not collaborative.

"Now, six months later, I'm starting to look at the data and the papers we might write, the stories we might tell. The hard, demanding part is over and I'm now doing what I most enjoy – trying to unlock the mystery."

### Sea ice

Dr Craig Stevens calls his work the "easiest oceanography there is – you don't get seasick".

But 'easy' is a relative term when the alternative to being on a ship is spending several weeks at a time living and working in insulated containers in Antarctica where it is minus 30 degrees outside.

The NIWA scientist's interest is in how sea ice grows. He is part of a collaborative project working with other scientists from NIWA, Callaghan Innovation, and Otago and Victoria universities examining changes to the Antarctic sea ice.

"Sea ice is the biggest annual geophysical change on earth; the bottom of the planet effectively turns white, and the coverage controls the way the ocean works."

It also provides the perfect environment for algae that are eaten by krill, and so forms a home for the bottom of the food chain.

While the Southern Ocean from which this sea ice is formed is getting fresher and warmer, and sea levels are rising, unlike in the Arctic region, the area of sea ice around Antarctica on the whole doesn't seem to be changing much. Certainly, there are regions where it is changing, but large regions stubbornly maintain the same coverage – or are even expanding. A theory being explored is that the giant ice shelves, features not found in the Arctic, play a controlling role in the growth of sea ice, and so a warming world might see more Antarctic sea ice up to a point.

"Understanding the role of sea ice in the Earth's system has never been more important. But understanding how this role will change over the next century is vital for our society as a whole."

A large part of Stevens' work involves connecting sea ice and ice shelf processes through their interactions with the ocean beneath.

About half of the Antarctic coastline is surrounded by enormous ice shelves, huge frozen expanses up to more than a kilometre thick, which are responsible for maintaining sea levels by holding back giant polar ice sheets.

Stevens and his colleagues are studying how water mixing at the face of the ice shelves is affecting their resilience and stability. Stability, they believe, plays a huge role in rising sea levels.

"A warmer ocean will melt the underside of an ice shelf more quickly, a thinner shelf is more prone to collapse and this in turn unlocks the Antarctic ice sheet, enabling the ice to flow more rapidly into the ocean – thus increasing sea levels dramatically.

"We are trying to understand the building blocks of how this rapidly changing climate system works. We can't assume it is operating in the way it has in the past."

# Urban thirst

When Nature turns the tap off, urban water managers have their work cut out keeping ours turned on. In early 2013 they passed a stern test, but climate change and sustained urban growth are demanding new thinking, finds **Colin Barkus**.

On 13 March this year – yet another breathless scorcher across most of the country – news headlines trumpeted that Wellington would run out of water in 20 days' time. Media devoured the story, relishing the irony of looming supply failure in a region renowned – often maligned – for its soggy climate.

"Actually," says Chris Laidlow, "it was serious, but we weren't close to running out. The '20 days' comment made by one of our councillors was reported a little out of context. If there'd been no other sources of water available, and given the demand at the time, our Te Marua storage lake would've lasted for about 20 days. It's Murphy's Law that, during one of the driest summers on record, the other storage lake was out of commission for a planned upgrade.

"But although river levels were dropping steadily, there was still water available, and we had the aquifer source. We could've sustained a limited supply indefinitely."

Nevertheless, Laidlow admits, the media frenzy did the region a big favour. "It galvanised public action and led to a big drop-off in demand – staving off more serious conservation measures until decent rain finally arrived."

Laidlow is General Manager, Water Supply, at the Greater Wellington Regional Council. He oversees the infrastructure that captures, stores and treats bulk water for the region and delivers it to city councils, who reticulate it to homes and businesses. It's Laidlow's job to balance inputs and outputs, and when inputs are meagre – as they were during the first 12 weeks of 2013 – reducing demand is paramount.

The Regional Council draws water from rivers fed by three surface catchments: the Tararua Range to the northeast of the city, and the Wainuiomata and Orongorongo hills to the east – and from an aquifer running under the Hutt Valley and into Wellington Harbour.

All up, the Wellington region actually received near average rainfall over summer (see graphic: How dry was it?). But it fell in just a few, isolated events. In mid-February, water shortage warning 'trigger' levels hadn't been reached, but with river flows declining, no rain in the 14-day forecast and only half the region's usual storage capacity available, Laidlow and his team knew they had to act. "We upped our media activity, raising the possibility of a water shortage and sprinkler ban."

During a normal summer, says Laidlow, the region receives rain at least every seven to ten days, "but this year the dry spells between rain events went on and on. River flow was declining, so we increased abstraction from the aquifer. But by the end of February it was also dropping away.

"We started thinking about what we'd need to do if the unusual weather continued for another three or four weeks. With two lakes available, there wouldn't have been a problem, but with reduced storage capacity we raised the possibility of rationing with our customers as a worst-case scenario. It's a serious step ... [and] very difficult to implement in local reticulation systems, so we agreed that additional demand controls were needed to preserve storage."



Analysis by NIWA suggests that urban water managers may need to prepare for more – and more challenging – dry spells as our climate changes. (Dave Allen)



## Urban thirst



"It was Murphy's Law," says Chris Laidlow, "that one of our Te Marua storage lakes was out of commission for a planned upgrade during one of the driest summers on record." (Dave Allen)

On 12 March, the Regional Council agreed with the city councils to ban all outdoor water use – the highest restriction ever imposed on the region's residents. The media and public sat up and took note.

### Beyond reasonable drought

It was a similar story elsewhere across the parched North and upper-South islands.

Even before Wellingtonians were coming to grips with their extraordinary ban, residents in the far-north towns of Opononi, Omapere, Kaitaia, Rawene and Dargaville faced exceptional restrictions of their own. In Dargaville, the Kaipara District Council had drawn up the paperwork to extract water from the Kaihu River.

The Manawatu District Council trucked water from Feilding to supplement a struggling supply in Sanson.

Hamilton reached level three on a four-level restriction scale – putting garden hoses out of action for several weeks. Hamilton City Council ran a comprehensive public awareness campaign, including a 'dob in your neighbour' hotline during the hosing ban, but the situation worsened – prompting extraordinary measures. The city draws its water from the Waikato River and as the drought took hold, the river threatened to drop below the level of the intake pipe. The Council positioned a barge on the river, equipped with pumps ready to transfer water into the intake if necessary.

Mercifully, significant rain arrived in late March and continued throughout April, averting the need for costly contingencies like this in Hamilton, Wellington, the far north and across other affected areas.

### Demanding future

All in all, Chris Laidlow is pleased with the way the Regional Council's management strategies stood the test and the public responded to restrictions. But, he concedes, "we were fortunate. Our awareness campaigns were helped by some keen interest from the media, and then Nature intervened just at the right time."

Analysis by NIWA suggests urban water managers may need to prepare for more – and more challenging – dry spells as our climate changes. Computer models indicate droughts are likely to become more frequent and more severe in eastern and northern parts of New Zealand. A drought in those regions with a one-in-20-year return period now, for example, may occur twice – even four times – as often by the end of this century.

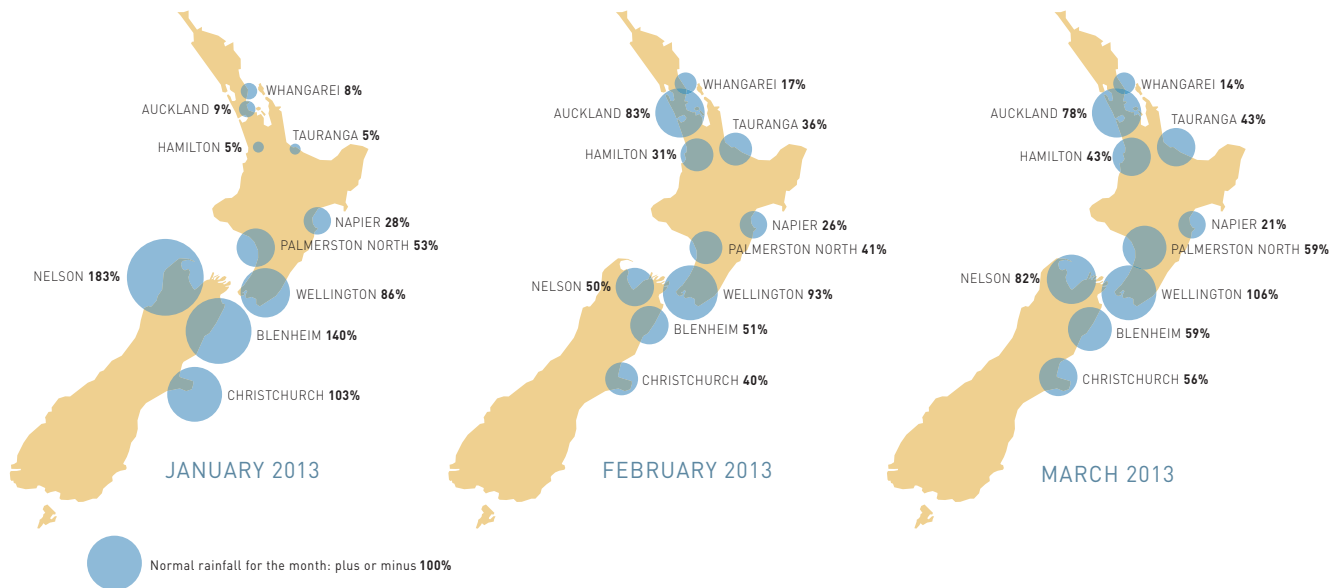
In 2011, NIWA used its Urban Impacts Toolbox (a resource to help urban planners assess potential impacts of climate change – see [www.niwa.co.nz/climate/urban-impacts-toolbox](http://www.niwa.co.nz/climate/urban-impacts-toolbox)) and the Regional Council's hydrological computer model (the Sustainable Yield Model, or SYM) to estimate how the Wellington region's water supply would cope with the combined effects of climate change and population growth. The study found that, by 2040, climate change could decrease available water by as much as five per cent, or 12 million litres per day, while population growth could inflate average demand by over two million litres per day during January and February – in a 'normal' year. Existing supply infrastructure would not cope.

Chris Laidlow took action. "Building new infrastructure seems an obvious answer," he says, "but it's costly and time-consuming, so we're looking for other ways to extend supply."

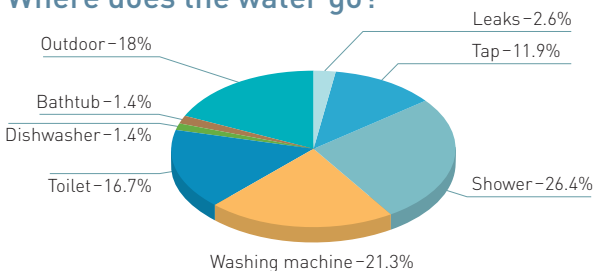
# Urban thirst

## How dry was it?

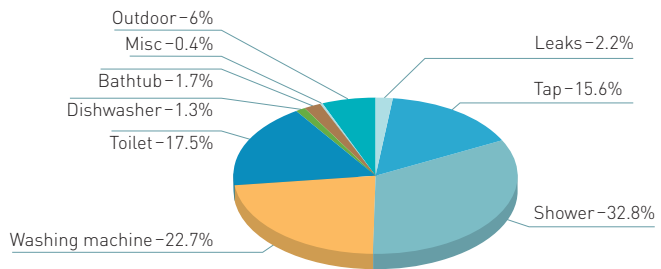
Monthly rainfall below normal affected many parts of New Zealand between January and March 2013.



## Where does the water go?



Summer average end-use distribution per household



Winter average end-use distribution per household

© Auckland Water End Use Study, Matthias Heinrich and Hans Roberti, BRANZ, 2008

His team is investigating the impacts of drawing more water from the Hutt aquifer. "If we can get a small increase without damaging the health of the aquifer or river, it could defer capital spend on new surface water sources," he says. "We're spending upfront to investigate, model, and put test bores down. It's indicating that our current operating levels are quite conservative."

But Laidlow acknowledges that augmenting supply is only part of the equation. And he's not alone.

In 2010, the Ministry for the Environment and the then Ministry of Consumer Affairs introduced the New Zealand Water Efficiency Labelling Scheme (WELS), which applies an efficiency rating label to new household products that use water. Consumers can compare, at point of sale, the water efficiency of different brands and models of washing machines, dishwashers, toilets, showers and taps – and choose accordingly.

Many local authorities offer a range of policies and guidelines for reducing water use in homes and businesses. They advocate a combination of good habits – turning off

taps when brushing teeth, taking shorter showers, using dishwashers and washing machines only when full and establishing drought-tolerant gardens, for example – and one-off actions, like fitting low-flow shower heads and fixing leaks.

Leak-fixing campaigns by each of the Wellington region's city councils are partly responsible for a drop in demand experienced recently. Other factors, like more water-efficient household appliances and changes in consumer behaviour, have also had an impact.

## Efficiency by design

Meanwhile, recent innovations in the design of urban water management systems have given authorities fundamentally new ways of thinking about meeting the supply challenge.

The idea of incorporating surface drainage infrastructure into urban design, variously known as Water-sensitive Urban Design (WSUD), Low-impact Urban Design and Development (LIUDD) and Low-impact Design (LID), has



## Urban thirst

slowly gained ground over the last couple of decades. WSUD, the Australian term adopted in some New Zealand centres, emerged during the supply-crippling drought that gripped Melbourne for 10 years around the turn of the century.

"Historically, authorities sought to pipe untreated stormwater, along with wastewater, out of the city as quickly as possible to reduce flooding and to prevent outbreaks of disease," explains NIWA Urban Aquatic Scientist Dr Annette Semadeni-Davies. "WSUD is about managing and treating stormwater in situ, by diverting it into inner-city 'blue-green corridors' – park-like spaces in which carefully selected vegetation, detention systems and engineered soils are used to slow down and filter the stormwater.

"To all intents and purposes it looks like landscaping, but WSUD plays a vital flood management and water treatment role."

Rainwater harvesting and 'grey water' recycling are other key WSUD principles that, says Semadeni-Davies, "will become increasingly important as things get drier".

Rain butts and tanks to collect roof runoff are already widely used in rural New Zealand and are gaining popularity in urban areas. Rainwater, explains Semadeni-Davies, is "perfectly suitable for a range of non-potable purposes, including watering your garden, washing your car and even flushing your toilet. Recent studies in Australia suggest rainwater harvesting may save as much as 50 per cent of household water use."

Landcare Research can add weight to that claim. Landcare captures rainwater from the main roof of its new building in Auckland and uses it in flushing toilets and glasshouse irrigation systems. City water is used in laboratories, the kitchen, washbasins and showers, which feature low-flow fittings. The harvesting system meets about half the water needs of Landcare and other tenants in the building.

A new greenfields suburban development just north of Melbourne takes the idea several steps further. The Kalkallo Stormwater Harvesting and Reuse Project will collect stormwater from a 160-hectare area and treat it, on site, to a potable standard. Initially the water will feed into a recycled water network, but the goal is to purify it sufficiently to supplement domestic supply.

'Grey water' is what drains from your shower, washbasin, dishwasher and washing machine ('black water' is the nasty, unsanitary stuff). "Grey water is also suitable for many non-potable purposes," says Semadeni-Davies. "Alongside low-water-use appliances and toilets, water reuse is gaining popularity as a way of reducing demand on domestic supply and lessening the burden on sewer networks."

In Australia and Japan, some new residential developments are plumbed so that toilet cisterns receive only grey water. Grey water in-ground irrigation systems are also common overseas.

"Part of the challenge in New Zealand is to make the public and developers aware of options," adds Semadeni-Davies, "but that's slowly happening. Architects and urban engineers are now more commonly incorporating rainwater harvesting and grey water recycling considerations into their design guidelines for residential and commercial property.

"There are also important regulatory and cost issues for urban authorities to consider. Auckland Council recently undertook a study looking at impacts and implications if residents were required to install rain harvesting systems. The Kapiti Coast District Council is among others that have recently published rainwater and grey water codes of practice."

In the meantime, Chris Laidlow and his team at Greater Wellington Regional Council hope that Nature is a lot more cooperative next summer. He's in no doubt, however, about the salutary lesson delivered in 2013: "We have to extend our contingency planning out into the unknown."

### Quenching the desert city

Phoenix, Arizona, receives 207 millimetres of rain annually, on average. That's about 60 per cent of the rain normally received by New Zealand's driest town, Alexandra, and less than one-fifth of the yearly watering received by Auckland, Hamilton or Wellington.

Greater Phoenix's 3.8 million residents receive water via the Central Arizona and Salt River projects – networks of canals hundreds of kilometres long that draw from the Salt, Verde and Colorado rivers. Supply is supplemented by groundwater and reclaimed water.

But as the city's population burgeons, the decades-old projects are struggling to meet demand.

The Arizona Department of Water Resources has a 100-year plan, updated every five years, to manage agricultural, residential and commercial needs. Public education is a significant component. Initiatives range from teaching homeowners how to capture and store rainwater and determine when gardens need irrigating, to fitting restaurant kitchens with high-pressure, low-flow hoses. Phoenix led a nationwide 'fix a leak' campaign, which saw specialists helping homeowners curb the estimated 3.7 trillion litres of water wasted in the US each year.

The stakes, however, are high, and Phoenix needs a back-up plan. It comes in the form of a gift from Nature. Aquifers beneath the city hold immense reserves of water – largely untouched – that authorities are 'banking' for future emergency use.

In the meantime, conservation and prudent management are the pillars of a plan that aims to keep Arizona's desert city quenched for generations to come.

## Solutions

# Putting the sting into climate change preparation at the coast

Almost seven in ten Kiwis live along New Zealand's coastline. And that's where the impacts of climate variability and change are likely to be hardest felt.

It's the job of local authorities to prepare coastal communities for more frequent and extreme incursions from the sea, in the form of damaging waves and storm surges. That task relies on good data about local risk.

The coastal sting of climate change is being evaluated using NIWA's web-based Waves And Storm-surge Prediction (WASP) tool.

It uses a sophisticated model, validated by historical data, to hindcast the scale and frequency of waves and storm surges off the New Zealand coast over a 40-year period (1960–2000), and then to predict them for two climate change scenarios. It's proving to be a hit with regional councils using its outputs to guide resource management and infrastructure planning.

"WASP quantifies the offshore drivers of coastal inundation, which, when modelled locally, allow regional councils to set robust planning guidelines for coastal development," says Dr Rob Bell, Project Manager and NIWA Hazards Programme Leader.

"The ability to extract regional information from nationally consistent data helps standardise the approach taken by local government, infrastructure operators and coastal communities in their efforts to adapt to climate change impacts."

Users log on to the WASP website (<http://wrenz.niwa.co.nz/webmodel/coastal>) and then zoom in on a map of the New Zealand coastline to locate their area of interest. Data are available at a mouse click for the 50-metre depth contour at regular intervals around the coast, providing offshore conditions that are used to drive more detailed coastal models.

Dr Bell says the WASP data were the starting point for a review NIWA has just completed of coastal inundation levels in Bay of Plenty.

Mark James, Principal Engineering Hydrologist at Bay of Plenty Regional Council, says that several coastal inundation studies recently completed by NIWA gave him confidence to

invite NIWA to review and calculate the potential reach of high tides and storm surges along the coast and rivers of his region.

"WASP was a component of the review. It provides the offshore sea state information which was then translated to the shore and along the coastline. The analysis has given us reliable tidal, wave and storm-surge data to guide building of flood control schemes and help with real-time flood management of our large rivers. It is also crucial for accurate setting of things like minimum levels for coastal structures."

He says that Stage 2 of the Council's process will be to extend the open coast analysis results into Tauranga Harbour using information generated from NIWA's review of tidal expectations for Tauranga Harbour.

A feature of the WASP tool is that it can show present day likelihood of wave and storm-surge events, and indicate how that likelihood changes under two of the standard global climate change scenarios used in the Intergovernmental Panel on Climate Change assessment reports.

Under each output option, users are provided with:

- hourly time-series data of tide, storm-surge, significant wave height, wave period and wave direction
- summary statistics for these variables, including distribution plots such as histograms, and probability and cumulative distribution functions
- maps of the spatial distribution of these variables around New Zealand.

WASP builds on guidance previously published by the Ministry for the Environment.

Its development was funded by the Foundation for Research, Science and Technology (now the Ministry for Business, Innovation and Employment).

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(Dave Allen)



Portfolio

# Stormy times

Ahead of the storm: A Cook Strait ferry sails placid waters ahead of a dramatic southerly front that, shortly afterwards, whipped the Strait into a seething frenzy. *(Dave Allen)*





## Stormy times



Imminent landfall: Wellington's south coast braces for the passage of the front. *(Katja Riedel)*



Downtown dash: The storm pelts Wellington with torrential rain and destructive winds. *(Dave Allen)*



Stormy times

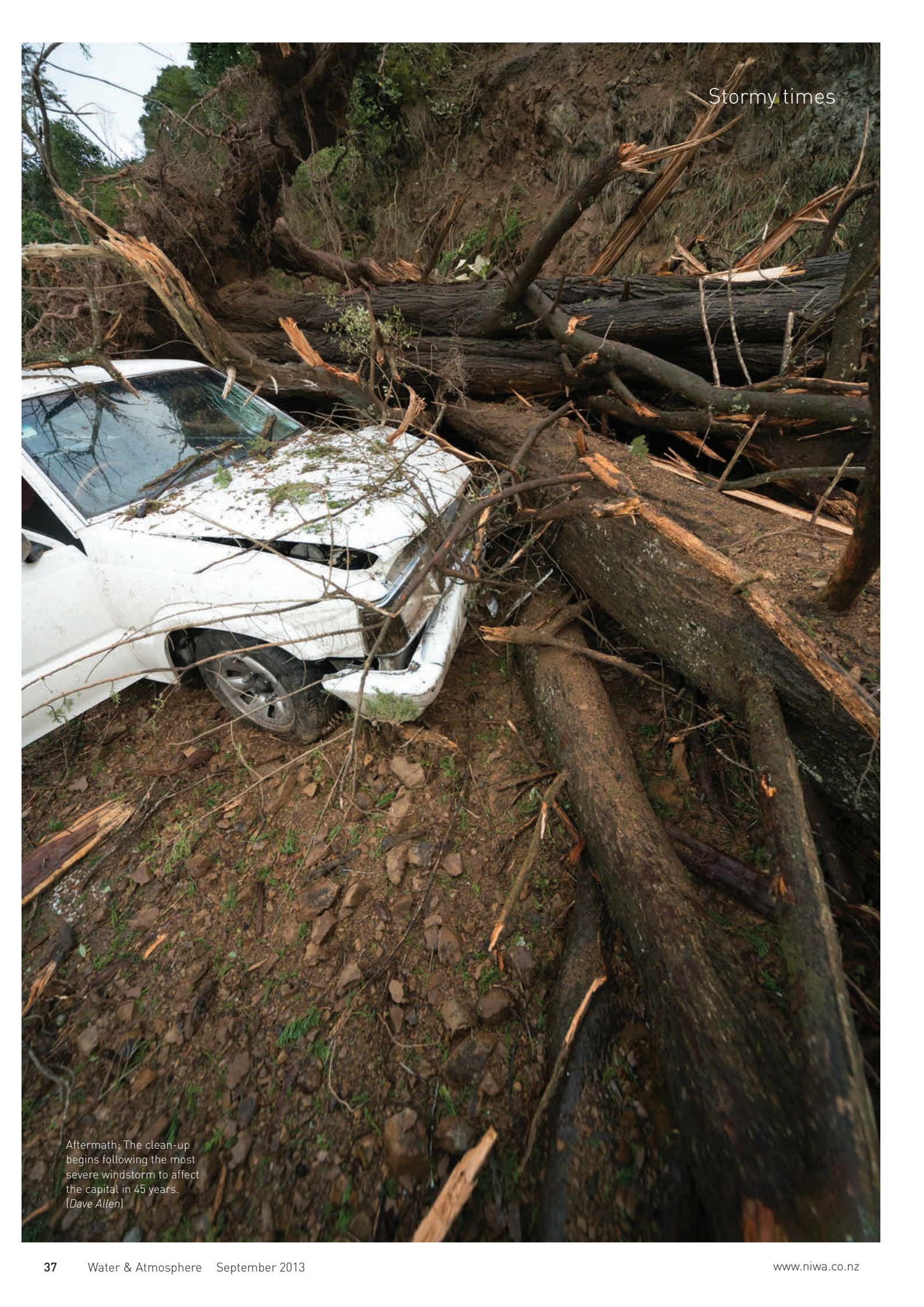


(Dave Allen)



(Dave Allen)



A photograph showing the aftermath of a severe windstorm. A white car is partially buried under a large, dark, charred tree trunk that has fallen across it. The car's front end is crushed, and its roof is covered in debris and branches. The surrounding area is a dense forest with many trees that have been stripped of leaves or broken. The ground is covered in dirt, rocks, and fallen branches.

Stormy times

Aftermath: The clean-up begins following the most severe windstorm to affect the capital in 45 years.  
*(Dave Allen)*



# The fun of fieldwork

Petra Chappell's first job for NIWA was sifting through stormwater sediment – mud. Petra picked up the part-time job while studying science at university. "I learned first-hand the hard graft that goes into the glossy results and reports," she says, "and I loved it".

That willingness to get her hands dirty at fieldwork led her into a slew of part-time jobs at NIWA, such as market sampling at Whitianga with the fisheries team, and sanding kauri slabs for dendrochronology (tree-ring reading).

"Many of my university friends were envious – the NIWA job was ideal for a science student.

"University is all about theory and book learning, whereas the NIWA work was in the lab and in the field. It was hands-on science collecting specimens and data. It wasn't complicated, but I was seeing what went on behind the high level material I was learning at university," she says.

The NIWA work also taught Petra that applied natural science was what she wanted to pursue. "Many women from my high school were specialising in medical sciences at university, but the NIWA work proved my passion for environmental science. I love being outdoors, interacting with the natural world."

Petra's love of the outdoors started early in life. Growing up in Parnell, she recalls that summers were spent at the family bach near Russell, in the Bay of Islands. "My parents were outdoor types. We tramped throughout Northland and were often at the beach and fishing."

She always knew that her future career would be connected with the environment. "At my high school, young women were being encouraged to be lawyers, but I knew that life wasn't for me."

Robert Frost, the great poet of Nature, said, "I am not a teacher, but an awakener". The teacher that awakened Petra to environmental science was her high school geography teacher. "Many students took geography at high school because they thought it was easy – they had no real interest. But our teacher was incredibly enthused by the subject, and we were all caught up in her passion for it. She took us on many fascinating field trips, which made the subject fun and interesting."

At university Petra was again encouraged by a "really inspirational" Honours supervisor, who was impressed with her work on the influence of vegetation and wood on the

shape of rivers in different climatic regions. He suggested she do a Master's degree, in which she looked at controls on river channel shape at different spatial and temporal scales across different landscapes – native forest, pine forest and pasture.

"My Honours was effectively a literature review. But the Master's was heavy on novel fieldwork. I had to traipse up and down cold Waikato waterways in July."

Nowadays, Petra lives with her partner Shaun, a builder, in Howick, East Auckland. They regularly tour New Zealand in their small campervan. "We considered renting a campervan to trip around the South Island. But we figured, why not buy an old one and fix it up how we wanted it."

Her favourite camping experience was a three-week summer tour of the South Island in the van, staying at isolated Department of Conservation campsites along the West Coast.

"My favourite was in Kahurangi National Park. We walked through the Oparara Basin. The area has incredible huge limestone caves with rivers running through them that are coloured like tea, from the tannins in the soil. The road there was hellish: a one-lane gravel road, steep and washed-out. We thought the van's brakes were going to bust – but it was definitely worth it!"

Petra is now part of NIWA's National Climate Centre, which comprises about 30 staff throughout NIWA.

One of her main tasks is pulling together data and assessments for monthly, seasonal and annual assessments of New Zealand's climate. She also handles enquiries from the public and media on climate data.

With core funding, as well as with the help of clients like the Hawke's Bay Regional Council, the Centre is in the process of updating regional climatology reports last published by the Meteorological Service of New Zealand in the 1980s. "I'm working my way through a publication for each region. We've updated the format for six regions so far – new data, new maps."



## The fun of fieldwork



NIWA Climate Scientist Petra Chappell: "I wouldn't change my job for all the world." (Geoff Osborne)

Petra's favourite project to date has been work at Lake Tennyson looking at glacial deposits on moraines. "We're dating greywacke boulders using cosmogenic nuclide tests (measuring decay of quartz exposed to sunlight) to see how long ago the glacier retreated, which will give us a sense of climate changes over the time."

"I wouldn't change my job for all the world. I'm spending a couple of weeks a year out in the field, and I'm collaborating daily with smart and fun people on practical science challenges."

She's hoping to someday work on a part of the environment that has featured so strongly in her life and study: waterways. "There are connections between rivers and climate, but not much has been researched in that space in New Zealand so far."

So when you hear about the unfolding of connections between waterways and climate, remember that it started with a focused young woman wading through Waikato creeks in winter. And she was there because of an enthusiastic geography teacher.

## Q&A

# Weather or not

NIWA has launched two new online weather forecasting services designed to help Kiwis from different walks of life decide when to carry out weather-dependent activities.

### What are the new NIWA forecasting services?

**NIWA forecast** is a subscription service that helps farmers and growers make important operational decisions like when to fertilise, spray or move stock, and when to protect against adverse weather such as frosts or high winds. Subscribers receive a continuous online feed of current weather conditions from the NIWA weather station that best represents conditions on their farm or orchard. They also receive a suite of forecasts tailored to that weather station (rather than an entire region), as well as valuable climate information and analyses (see below for details).

**NIWA Weather** is a free web-based service ([www.niwaweather.co.nz](http://www.niwaweather.co.nz)) that provides urban New Zealanders with an instant visual snapshot of the temperature, rainfall, wind speed and direction, and general weather conditions expected in their town or city over the next six days. Forecasts are hourly for the first 24 hours and three-hourly thereafter.

### What's special about them?

**NIWA forecast** is capable of generating separate forecasts for locations as little as 12km apart, using the computational power of NIWA's IBM p575 POWER 6 supercomputer (known as 'FitzRoy'). The service uses data from a 300-strong weather station network, giving farmers and growers access to information and predictions tailored as closely as possible to their own property.

Data and forecasts are updated regularly and automatically, so subscribers always have access to the very latest information.

The NIWA forecast user interface is customisable, so subscribers can ensure all of the information most important to them is front and centre whenever they log on.

Subscribers can also set automated alerts, which trigger an email or SMS to be sent whenever conditions pass (or are forecast to pass) pre-set thresholds. This facility is particularly helpful to farmers and growers whose operations are susceptible to specific weather conditions, such as frost.

**NIWA Weather** – like NIWA forecast – is backed by FitzRoy's state-of-the-art high-resolution forecasting capability. The site's striking contemporary design features location-specific animated illustrations, colour spectrums to depict the time of day and cloud cover, and mouse-over data reveals.



NIWA staff explain the intricacies of NIWA forecast to interested farmers at this year's National Fielddays at Mystery Creek. (Dave Allen)

NIWA Weather is designed to help urban New Zealanders find their window of opportunity to get things done outside – like drying the washing or exercising. Its forecasts are presented graphically and are supplemented by simple data, meaning little interpretation is required to understand how the days ahead are shaping up.

NIWA Weather is also designed to work on smartphones and tablets.

### As a NIWA forecast subscriber, what do I get?

For your chosen weather station, you receive:

#### A continuous feed of current weather conditions

Air temperature, relative humidity, precipitation amount, wind speed and direction, soil moisture and temperature (if available from chosen station).

#### Automatically updated weather forecasts

*High-resolution forecasts out to two days (updated four times daily, hourly forecast intervals)*

Air temperature, relative humidity, precipitation amount, wind speed and direction, cloud cover, and animated maps showing hourly precipitation, pressure and wind.

*Medium-resolution forecasts out to six days (updated once daily, three-hourly forecast intervals)*

Air temperature, relative humidity, precipitation amount, wind speed and direction, and animated maps showing three-hourly precipitation and wind.



## Q&A: Weather or not

*Probabilistic forecasts out to 15 days (updated once daily, daily forecast intervals)*

Maximum and minimum air temperature, precipitation amount, average wind speed, soil temperature (if available from chosen station) and probability of air temperature falling below 0°C.

*Seasonal climate outlook*

A three-month look ahead at expected rainfall, temperature, soil moisture and river flows in your region (relative to long-term averages).

### Up-to-date summaries

*National summary maps*

Last 15 days' precipitation, month-to-date precipitation, soil moisture deficit, soil moisture anomaly, last 15 days' sun, month-to-date sun, last 15 days' temperature and month-to-date temperature.

*Summaries for your chosen station*

Accumulated precipitation, mean soil temperature, soil water balance, mean temperature, mean wind speed and frost occurrence.

### How are the services accessed?

For more information on, or to subscribe to, NIWA forecast, contact us at [forecast@niwa.co.nz](mailto:forecast@niwa.co.nz) or visit [www.niwa.co.nz/online-services/niwa-forecast](http://www.niwa.co.nz/online-services/niwa-forecast).

You can visit NIWA Weather any time and find the latest forecasts for your town or city, at [www.niwaweather.co.nz](http://www.niwaweather.co.nz).

### Are more forecasting services planned?

Yes. NIWA is continuously evolving and adding new products and features to its online services based on weather, river and ocean forecasting. Our aim is to provide New Zealanders with tailored information and forecasts to help them make an increasingly wide range of commercial and recreational decisions.

At the same time, our work to improve the accuracy and resolution of our weather forecasts is ongoing.

## NIWA

enhancing the value of New Zealand's natural resources

NIWA (the National Institute of Water & Atmospheric Research) was established as a Crown Research Institute in 1992. It operates as a stand-alone company with its own Board of Directors, and is wholly owned by the New Zealand Government.

NIWA's expertise is in:

- Aquaculture
- Atmosphere
- Biodiversity and biosecurity
- Climate
- Coasts
- Renewable energy
- Fisheries
- Freshwater
- Māori development
- Natural hazards
- Environmental information
- Oceans
- Pacific rim

NIWA employs approximately 600 scientists, technicians and support staff. Our people are our greatest asset.

NIWA also owns and operates nationally significant scientific infrastructure, including a fleet of research vessels, a high-performance computing facility and unique environmental monitoring networks, databases and collections.

*Back cover:*

A Sandy Bay sea elephant is a reluctant host to rare human visitors to its sub-Antarctic home – photographed during Gareth Morgan's 'Our Far South' expedition last year. (Rob Murdoch)





