Court File Reference: ENV-2018-CHC-38

**BEFORE THE ENVIRONMENT COURT**

**I MUA I TE KOOTI TAIAO O AOTEAROA**

| | |
|---|---|
| **UNDER** | The Resource Management Act 1991 (RMA) |
| **IN THE MATTER** | Appeals under clause 14(1) of the First Schedule of the Act in relation to the Proposed Southland Water and Land Plan |
| **BETWEEN** | **MERIDIAN ENERGY LIMITED**<br>**Appellants** |
| **AND** | **SOUTHLAND REGIONAL COUNCIL**<br>**Respondent** |

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# STATEMENT OF EVIDENCE OF DR JENNIFER M PURDIE

**FOR**

**MERIDIAN ENERGY LIMITED**

**29 July 2022**

**Topic B6 – Infrastructure**

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**Judicial Officer:** Judge Borthwick


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**FONTERRA CO-OPERATIVE LTD**
(ENV-2018-CHC-27)

**HORTICULTURE NEW ZEALAND**
(ENV-2018-CHC-28)

**ARATIATIA LIVESTOCK LTD**
(ENV-2018-CHC-29)

**WILKINS FARMING CO**
(ENV-2018-CHC-30)

**GORE AND SOUTHLAND DISTRICT COUNCILS, INVERCARGILL CITY COUNCIL**
(ENV-2018-CHC-31)

**DAIRYNZ LTD**
(ENV-2018-CHC-32)

**H W RICHARDSON GROUP LTD**
(ENV-2018-CHC-33)

**BEEF + LAMB NEW ZEALAND**
(ENV-2018-CHC-34 AND 35)

**DIRECTOR-GENERAL OF CONSERVATION**
(ENV-2018-CHC-36)

**SOUTHLAND FISH & GAME COUNCIL**
(ENV-2018-CHC-37)

**MERIDIAN ENERGY LTD**
(ENV-2018-CHC-38)

**ALLIANCE GROUP LTD**
(ENV-2018-CHC-39)

**FEDERATED FARMERS OF NEW ZEALAND**
(ENV-2018-CHC-40)

**HERITAGE NEW ZEALAND POHERE TAONGA**
(ENV-2018-CHC-41)

**STONEY CREEK STATION LTD Appellants**
(ENV-2018-CHC-42)

**THE TERRACES LTD**
(ENV-2018-CHC-43)

**CAMPBELL'S BLOCK LTD**
(ENV-2018-CHC-44)

**ROBERT GRANT**
(ENV-2018-CHC-45)

**SOUTHWOOD EXPORT LTD, SOUTHLAND PLANTATION FOREST COMPANY OF NZ**
(ENV-2018-CHC-46)

**TE RUNANGA O NGAI TAHU, HOKONUI RUNAKA, WAIHOPAI RUNAKA, TE RUNANGA O AWARUA AND TE RUNANGA O ORAKA APARIMA**
(ENV-2018-CHC-47)

**PETER CHARTRES**
(ENV-2018-CHC-48)

**RAYONIER NEW ZEALAND LTD**
(ENV-2018-CHC-49)

**ROYAL FOREST AND BIRD PROTECTION SOCIETY OF NZ INC**
(ENV-2018-CHC-50)

**Appellants**

**AND** **SOUTHLAND REGIONAL COUNCIL**

**Respondent**

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## INTRODUCTION

1 My name is Jennifer Margaret Purdie. I hold a PhD in climate forecasting. I am a full member of the NZ Meteorological Society and the NZ Hydrological Society.

2 I am employed by the University of Otago as a Senior Research Fellow. At the University I work in the Centre for Sustainability. I am currently Principal Investigator on a 3 year research project funded by the Deep South National Science Challenge (MBIE contract number C01X19011). The title of the project is *Simulation of climate change impacts on the New Zealand energy system*. This project explores the projected impact of climate change on wind and water systems in New Zealand over the next three decades, and the effect of these changes on New Zealand's electricity system out to 2050. This is undertaken in collaboration with NIWA and University of Otago scientists, and uses a computer model which simulates the entire New Zealand electricity system, including generating plant, transmission, fuels, and electricity demand. This computer model is on licence to the University of Otago from its owner, Meridian Energy.

3 I am also sole director of a consulting company, ClimateWorks Ltd, which undertakes consulting work relating to climate and energy topics. In the past year I have undertaken consulting projects for Meridian Energy and MBIE.

4 Prior to this, I was employed by Meridian Energy from 2007 to 2020 as Energy and Fuels Advisor. It was during this period of employment that I provided evidence in relation to some climate change-related issues of relevance to appeals on the Proposed Southland Water and Land Plan. My earlier statement of evidence is dated 15 February 2019.

5 I have 30 years' experience in New Zealand climate science and its application to water resources. I have published 9 peer reviewed papers on hydro-climatological forecasting and the impacts of climate change on renewable energy in New Zealand, and dozens of technical reports. I have delivered about 20 papers on these subjects at national and international conferences.

6 Other previous relevant employment is as a climate scientist for Topoclimate South, a climate and soils research project in Southland, and as a contractor for Climate Management Ltd.

## BACKGROUND

7 I was actively involved in the operational management of Manapouri Power Scheme (MPS) from 2007 to 2020, in the role of planning water use over weekly to inter-annual time frames.

8 I am very familiar with the site having visited the MPS a number of times, as well as all control gates and climate monitoring stations. I have also tramped and climbed actively in the catchment and neighbouring catchments.

9 In forming my conclusions, I have considered the evidence of reports of the International Panel on Climate Change (IPCC), NIWA, the Ministry for the Environment (NZ), the NZ Climate Change Commission, Transpower, the Business Energy Council, and relevant scientific papers.

10 I have also read the evidence prepared by David Hunt, Dr Jack McConchie, Andrew Feierabend, Dr Kristy Hogsden and Jane Whyte in these proceedings.

## CODE OF CONDUCT

11 I confirm that I have read the code of conduct for expert witnesses as contained in the Environment Court's Practice Note 2014[1]. I have complied

[1] https://environmentcourt.govt.nz/assets/Documents/Publications/Practice-Note-2014.pdf

with the practice note when preparing my written statement of evidence and will do so when I give oral evidence before the Environment Court.

12 The data, information, facts and assumptions I have considered in forming my opinions are set out in my evidence to follow. The reasons for the opinions expressed are also set out in the evidence to follow.

13 Unless I state otherwise, this evidence is within my knowledge and sphere of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

## SCOPE OF EVIDENCE

14 This evidence repeats and updates my earlier evidence dated 15 February 2019. It considers current and projected future lake inflow variability over the next 30 years. It examines current variability of rainfall and inflows in the Waiau catchment, and climate cycles that impact this inflow variability. It then considers climate change projections of temperatures, rainfall, and lake inflows for New Zealand and the Waiau catchment. It also examines New Zealand's international emissions reductions commitments and New Zealand government legislation and targets.

15 I have structured my evidence as follows:

(a) Daily to monthly variability of Waiau catchment inflows

(b) Monthly to inter-decadal variability of Waiau catchment inflows

(c) Climate change projections for New Zealand and the Waiau catchment

(d) IPCC and Paris agreement

(e) New Zealand government climate change legislation and targets

(f) New Zealand emissions reduction commitments, and progress towards these

(g) Some observations based on my University of Otago research on the importance of hydro generation within the New Zealand electricity system as we tackle the challenges of climate change and the expected dramatic increase in demand for renewable electricity.

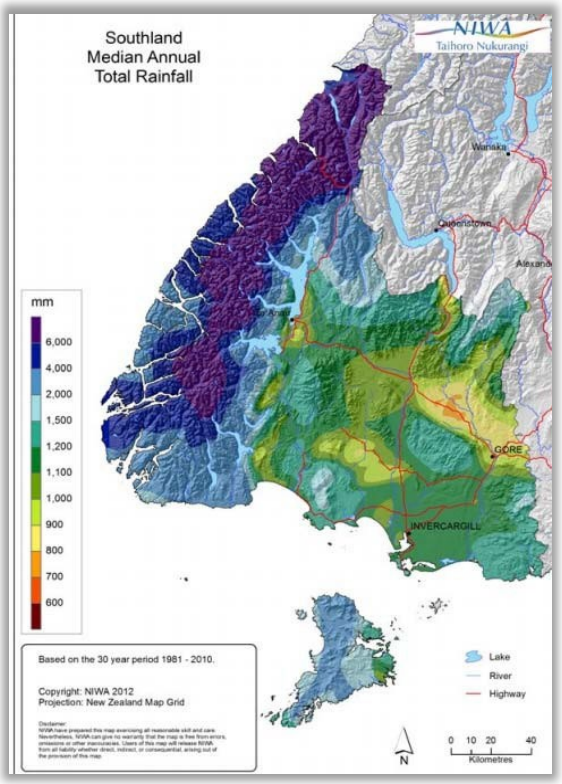
(h) Summary.

## DAILY TO MONTHLY VARIABILITY OF WAIAU CATCHMENT INFLOWS

16 New Zealand is situated in the middle of a zone of mid-latitude westerly winds, and in the path of the sub-tropical high-pressure belt. Anticyclones tend to cross New Zealand every six to seven days, interspersed by troughs of low pressure and associated frontal bands. The presence of the Southern Alps extending the length of the South Island, and significant mountain ranges in the North Island has a major effect on the climate of the various regions, by causing significant orographic uplift as the westerlies hit this barrier. This produces sharp climatic contrasts from the west to the east of both main islands, but especially the South Island, where the mountains provide a long high barrier to the westerlies.

17 The Waiau catchment is impacted by this strong rainfall gradient, with annual rainfalls ranging from six metres in the west of the catchment to less than one metre in the east of the catchment (see Figure 1).

*Figure 1 – Southland and Fiordland median annual total rainfall 1981– 2010*[2]

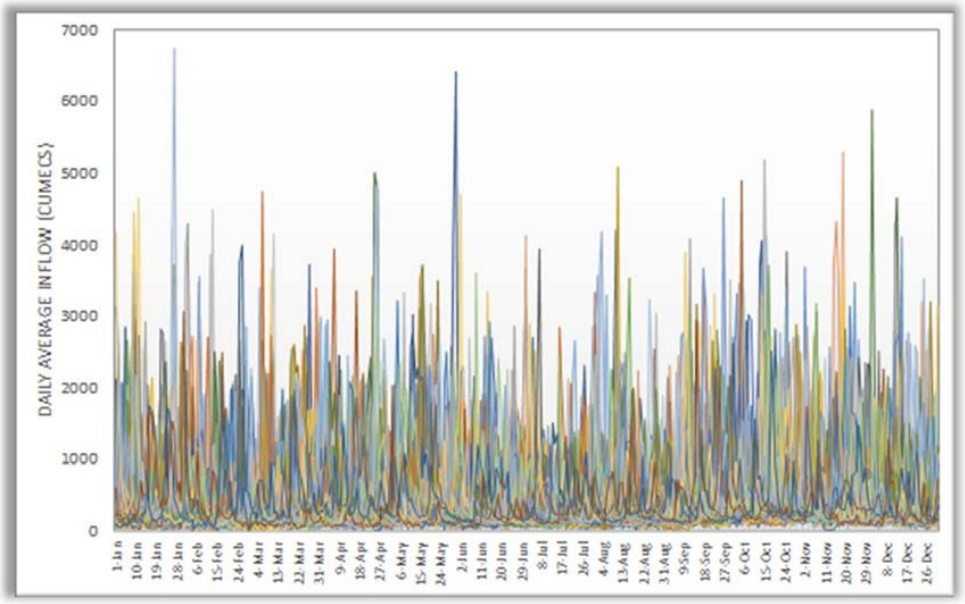



18 In addition to this dramatic rainfall gradient, day to day rainfall variability is high in the Waiau catchment. For example, the lowest rainfall recorded over the past 20 years, at the head of the middle arm of Lake Te Anau, on a single day, was 0mm, and the highest was 450mm – more rain than is

[2] Niwa 2013: The Climate and Weather of Southland, Niwa Science and Technology series #63

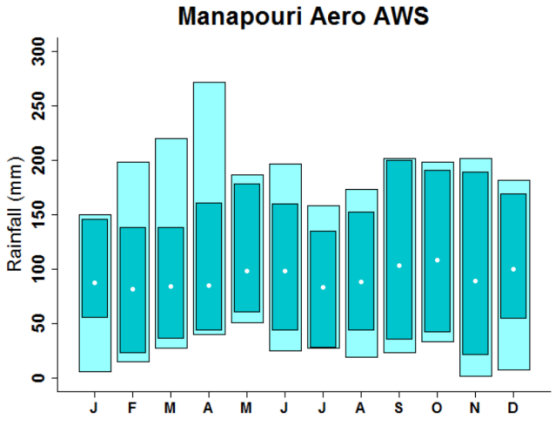
normally received in a year in Central Otago. This day to day variability can be seen in Figure 2.

*Figure 2 – Daily average inflows into the combined Te Anau and Manapouri catchments, 1932-2018. Each coloured line is a year of daily inflows (Source: Meridian Energy)*




19 There is some seasonal pattern in rainfall in the Waiau catchment, with a lower rainfall received in late summer, and higher rainfalls through spring (see Figure 3). However, there is significant variability in monthly rainfall totals, with April total monthly rainfall over the past 20 years ranging from 0 to 270mm.

*Figure 3 – Monthly variability of rainfall at Manapouri aero weather station*[2]

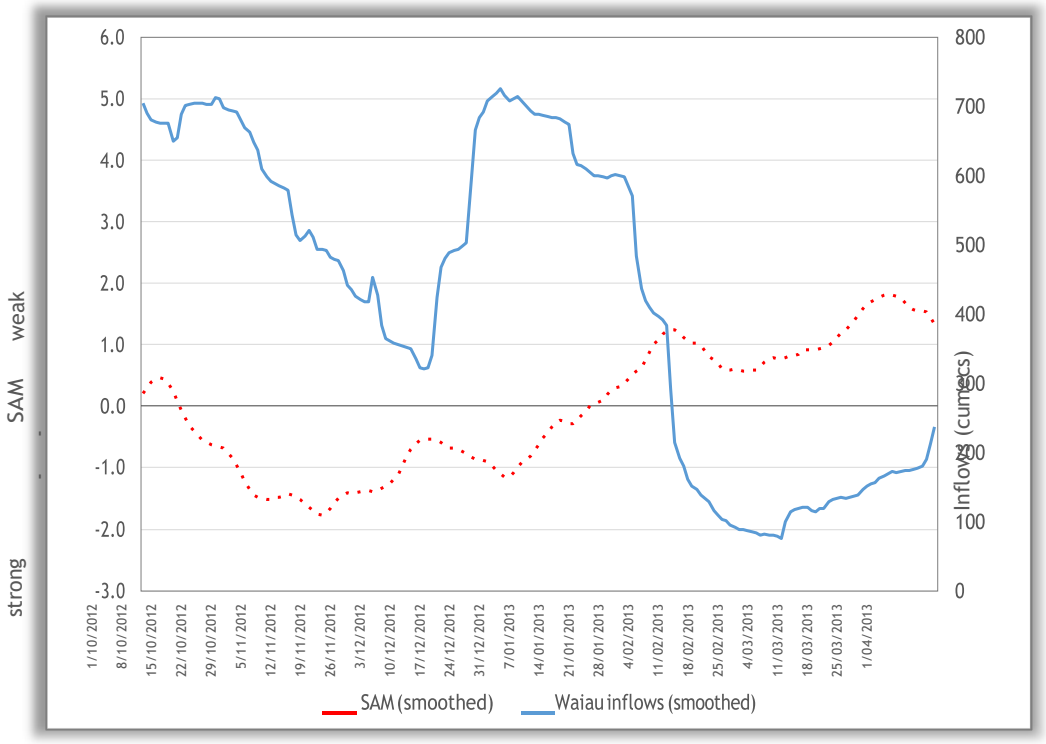


## MONTHLY TO INTER-DECADAL VARIABILITY OF WAIAU CATCHMENT INFLOWS

20 In addition to the progression of fronts and highs over the catchment, Waiau catchment inflows are also affected by monthly to interannual and decadal climate cycles.

21 The Southern Annular Mode (SAM) is a ring of climate variability that encircles the South Pole and extends out to the latitudes of New Zealand[3]. The SAM involves alternating changes in windiness and storm activity between the middle latitudes, (where New Zealand lies) and higher latitudes (over the southern oceans and the Antarctic sea ice zone). In its positive phase, the SAM is associated with relatively light winds and more settled weather over New Zealand. In its negative phase, the westerlies increase over New Zealand, with more unsettled weather[2]. Although the relationship between SAM and Waiau inflows is not strong, at times its impact can clearly be observed (Figure 4).

*Figure 4 – Example of Southern Annular Mode[4] (SAM) (red) and Waiau catchment inflows (blue) (Source: Meridian Energy) summer 2012-2013, showing their inverse relationship*



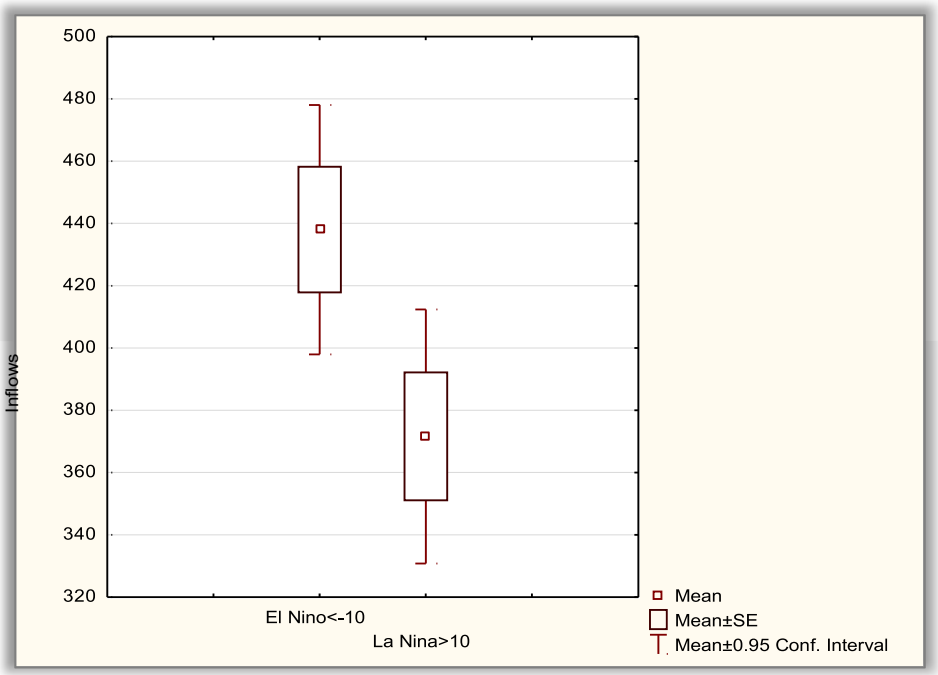

22 The El Nino-Southern Oscillation (ENSO) is another climate cycle which impacts Waiau catchment inflows. ENSO is an irregularly periodic variation

[3] Renwick and Thompson 2006: The Southern Annular Mode and New Zealand Climate, Water & Atmosphere 14(2)

[4] http://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/aao/aao.shtml

in winds and sea surface temperatures over the tropical Pacific Ocean which affects the climate of the Pacific, and also New Zealand. It swings from an El Nino to a La Nina phase every 2-5 years. In the El Nino phase, New Zealand experiences stronger or more frequent winds from the south-west, leading to generally wetter conditions on the west coast and drier in the east. In La Nina conditions the country experiences more winds from the north-east, leading to drier conditions in the west. There is a statistically significant difference (~15%) between mean Waiau catchment inflows during an El Nino compared to a La Nina (see Figure 5).

*Figure 5 – Box and Whisper plot of Waiau catchment daily inflows (source Meridian Energy) for all days 1932-2021 under strong El Nino[5] conditions, compared with all days under strong La Nina conditions (strong = ENSO>10 or <-10)*

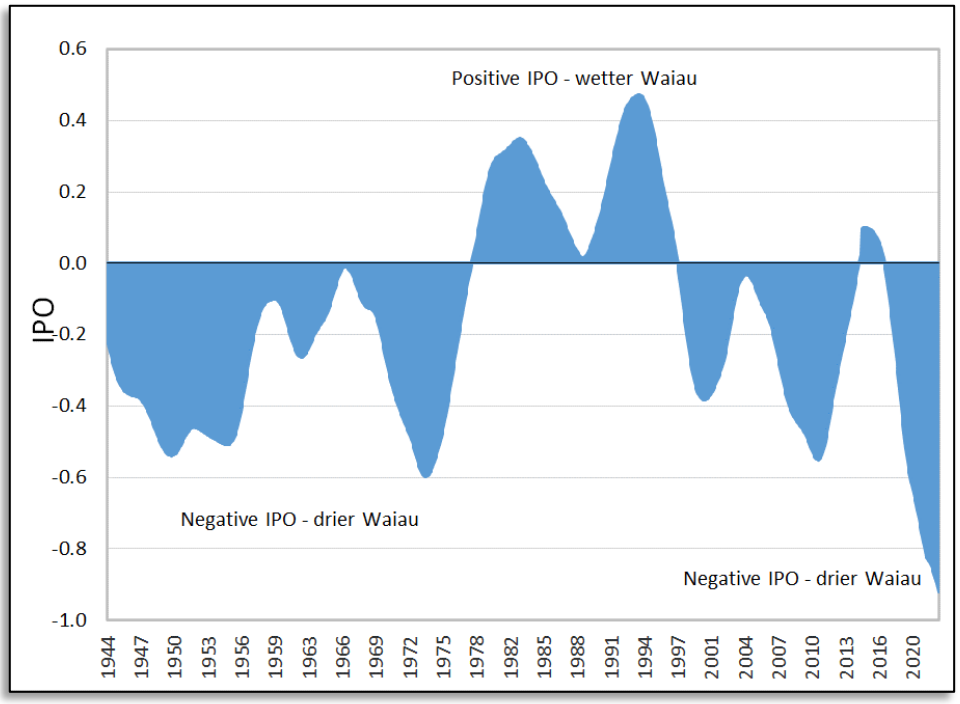



23 The Interdecadal Pacific Oscillation (IPO) is an oscillation in sea surface temperatures across the Pacific Basin, that influences climate variability all around the Pacific. The IPO phases last around 20 to 30 years (see Figure 6). Positive values indicate periods when stronger westerlies occur over New Zealand, and more anticyclones over northern New Zealand. During the positive phase of the IPO, the intensity and frequency of El Ninos increases[5]. Negative values of the IPO indicate periods with more north-easterlies in northern regions, and generally drier conditions in the south and west of the country.

[5] http://www.bom.gov.au/climate/current/soihtm1.shtml

24 The IPO has been in a negative phase since about 1999, bringing anomalously dry conditions to the West Coast of New Zealand. There is a likelihood it will change to a wet phase some time in the next few years.

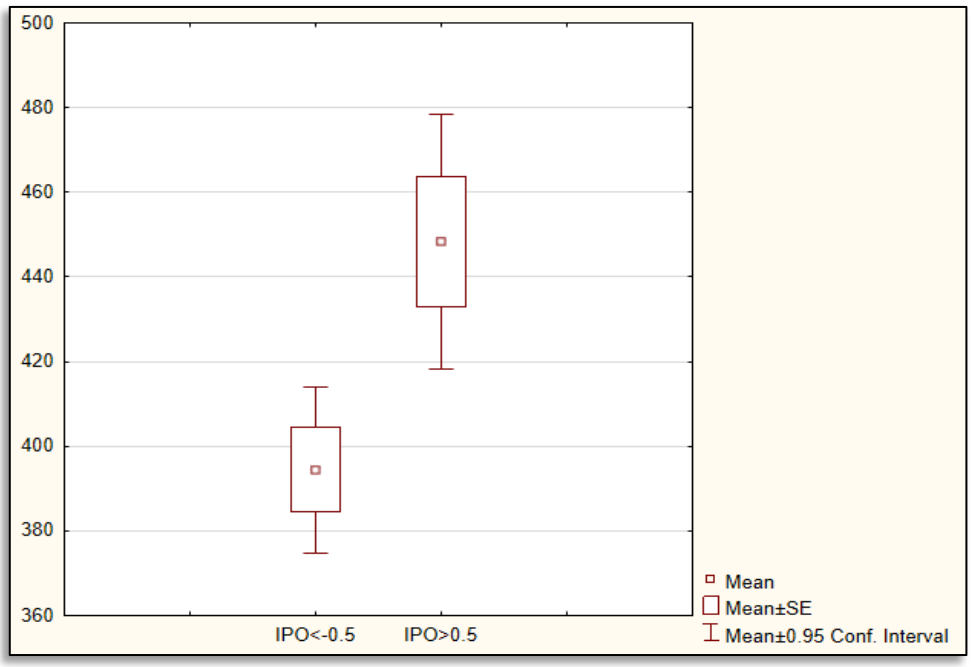
*Figure 6 – The Interdecadal Pacific Oscillation[6], smoothed, 1944-2022*




25 The impact of this cycle on Waiau catchment lake inflows during strong IPO phases can be seen in Figure 7. There is a statistically significant positive relationship between IPO and Waiau inflows, so that during a negative phase of the IPO Waiau catchment inflows are generally drier, and during a positive phase they are generally wetter.

[6] https://www.esrl.noaa.gov/psd/data/timeseries/IPOTPI/tpi.timeseries.ersstv5.data

*Figure 7 – Lake Manapouri and Lake Te Anau catchments daily inflows (cumecs), under strong positive and negative phases of the IPO for the period 1932-2022 (source Meridian Energy)*




26 In summary, the variability of inflows in the Waiau catchment is influenced by both the passage of synoptic weather systems and the impact of longer-term climate cycles with different frequencies.

27 Overlaying the impact of the observed climate cycles on Waiau inflows is the long-term trend associated with climate change. This is also impacting the timing and magnitude of Waiau catchment lake and river flows. It is thought that climate change will affect the timing and magnitude of future ENSO events and other climate cycles[7], although the impact of this is uncertain. This is examined in more depth below.

## CLIMATE CHANGE PROJECTIONS FOR NEW ZEALAND

28 All governments in the world (apart from the Holy See) are currently signed up to the Paris Agreement[8], which states that climate change is caused by humans through greenhouse gas emissions, and pledges to reduce these emissions by self-defined amounts. This is explained further in below sections.

[7] Yeh and Kirtman 2007: ENSO Amplitude Changes due to Climate Change Projections in Different Coupled Models, Journal of Climate vol 20, pp 203-217. https://doi.org/10.1175/JCLI4001.1

[8] https://www.un.org/en/climatechange/paris-agreement

29 193 parties have ratified the agreement (which makes them legally bound to comply with the agreement), and therefore agreed to cut greenhouse gas emissions to prevent catastrophic climate change.

30 Climate change projections around the world are derived from Global Circulation Models (GCMs), which use different scenarios of the amounts of greenhouse gas emissions to project different impacts on the atmosphere. To ease understanding of projections, they are generally discussed as "low emissions", "mid-range emissions", and "high emissions" scenarios. High emissions scenario model projections of climate will show stronger impacts on the climate than low emissions scenarios.

31 Despite the signatories to the Paris Agreement pledging to keep global warming below 2 degrees (by adhering to a low-mid range emissions scenario), current government policies will likely result in a global, warming of approximately 2.7°C (above pre-industrial levels) by 2100[9], because the planet currently appears to be heading down a mid-range emissions scenario pathway.

32 New Zealand is projected to see:

(a) warmer temperatures everywhere (see Figure 8)

(b) wetter conditions in the west and south of NZ (see Figure 9)

(c) drier conditions in the east and north (see Figure 9)

(d) heavier rain, when it does rain

(e) bigger floods

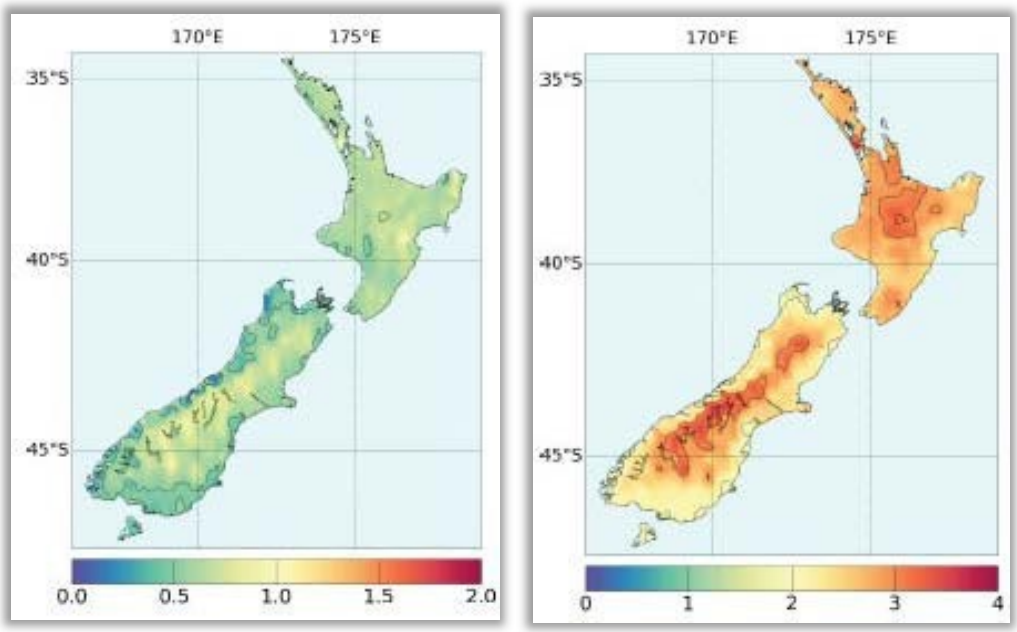
(f) stronger and more frequent westerly winds

(g) higher snowlines

(h) much reduced glacier volumes.

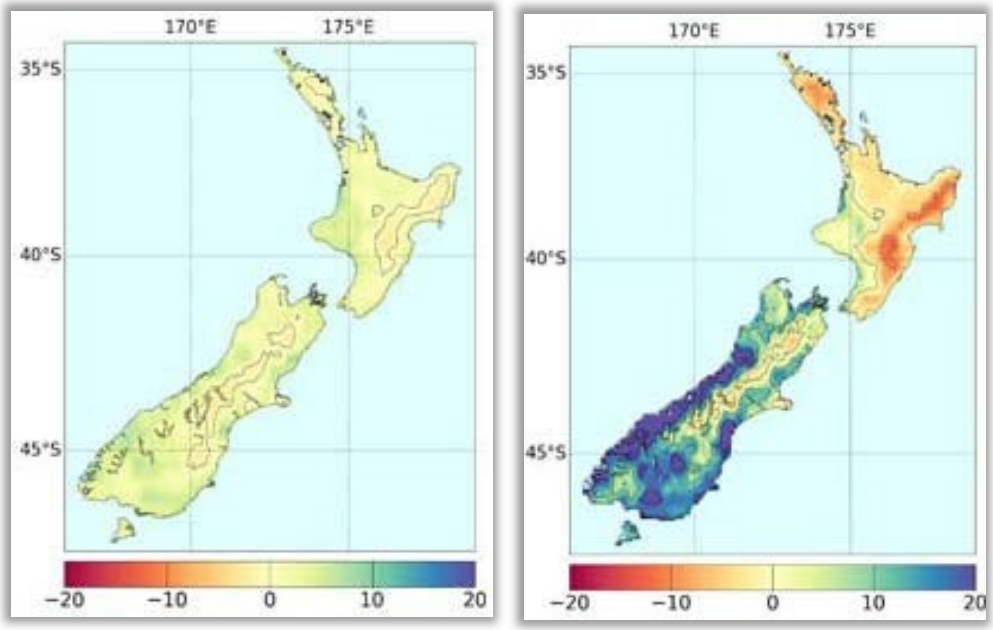
[9] *https://climateactiontracker.org*

*Figure 8 – Projections of annual temperature changes from 1995–2090 (°C), from average of 6 global circulation models, for a low-mid range emissions scenario (left) and high emissions scenario (right)*[10]




33 NZ temperature increases relative to present are projected to be between 0.5 and 3 degrees warmer than 1990 levels[11].

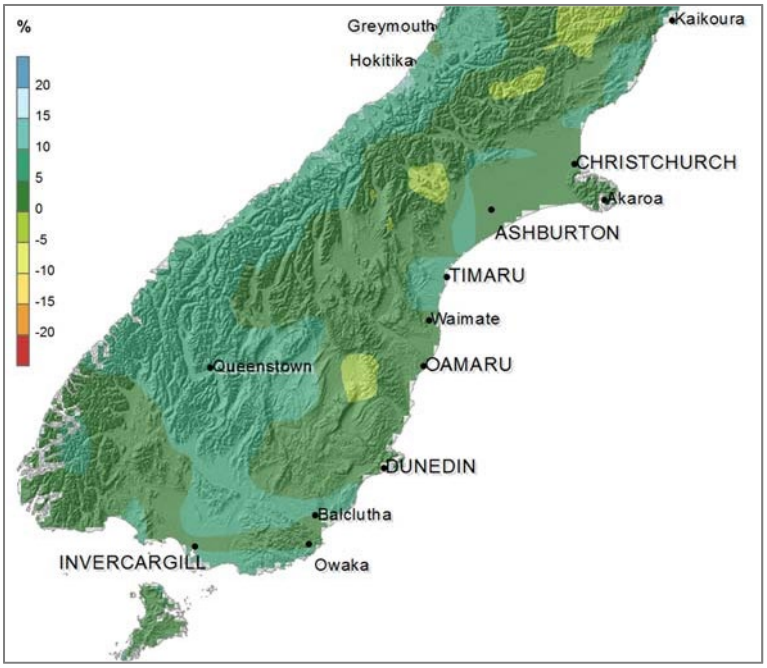
*Figure 9 – Projections of annual rainfall changes from 1995–2090 (%), from average of 6 global circulation models, for a low-mid range emissions scenario (left) and high emissions scenario (right)*[10]




[10] Ministry for the Environment 2016: Climate Change Projections for New Zealand: Atmosphere Projections Based on Simulations from the IPCC Fifth Assessment, Wellington, 127 pp.
[11] https://www.niwa.co.nz/our-science/climate/information-and-resources/clivar/scenarios

34 Annually, Waiau catchment rainfall is forecast to increase by 0 to 10% (range of rainfall change resulting from a range of emissions scenarios) by mid-century, compared to 1995 levels (see Figure 10).

*Figure 10 – NIWA 50-year projections of annual rainfall changes from 1995–2055 (% change), from average of 6 global circulation models, for a low-mid range emissions scenario[12].*




35 In addition to annual changes, rainfall is projected to be subject to seasonal changes as well. Waiau rainfall is expected to get wetter in all seasons, but particularly in winter (see Figure 11), where it is expected to be about 10–15% wetter by mid-century, and about 0–10% wetter in summer (under a low-mid range emissions scenario)[12] (see Figure 12).

[12] Niwa 2019: Our Future Climate NZ (*https://ofcnz.niwa.co.nz/#/home*)

*Figure 11 – Projected winter mean rainfall change (%) between 1995 and 2055, six model average, low-mid emissions scenario*[12]

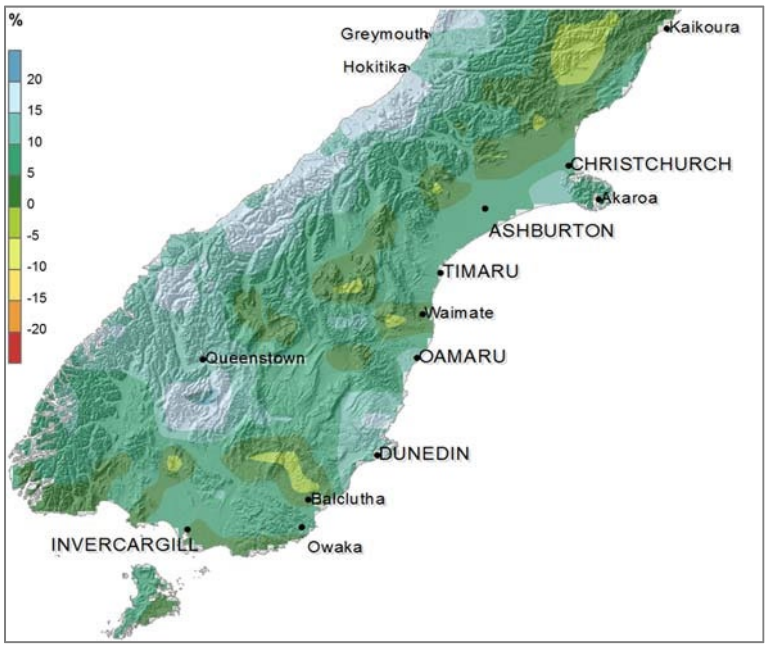
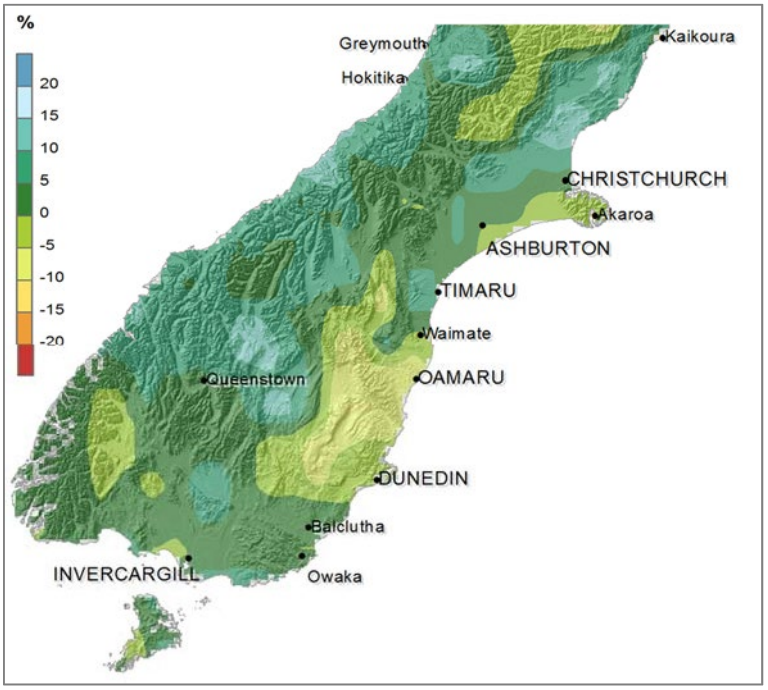



*Figure 12 – Projected summer mean rainfall change between 1995 and 2055, six model average, low-mid emissions scenario*[12]




36 Waiau catchment inflows are expected to see a significant change in seasonality over coming decades.

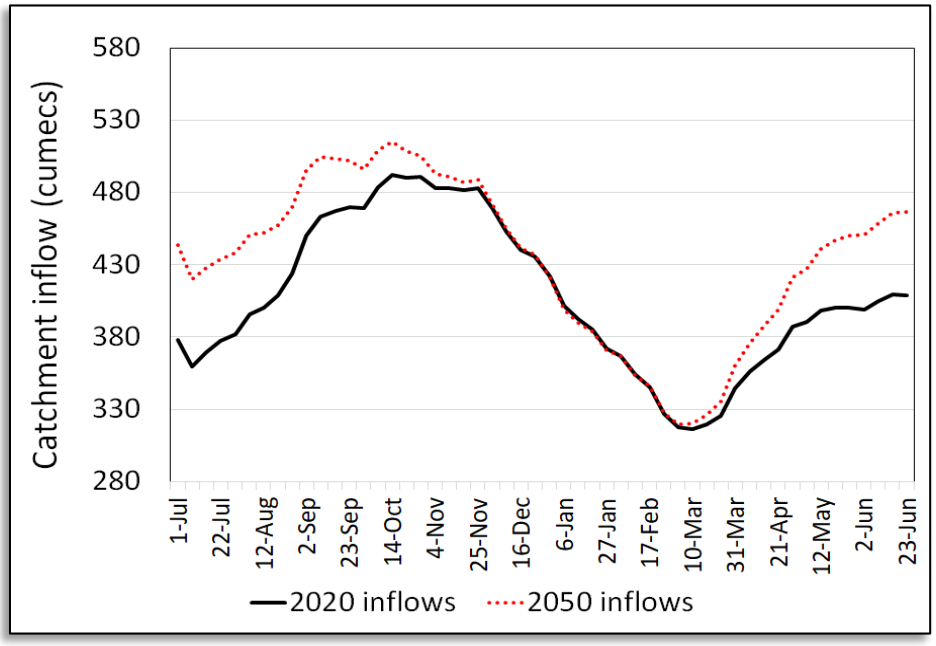
37 Approximately 8% of Waiau catchment summer inflows currently derive from snow melt[13]. Projected increases in temperatures will result in a rise

[13] McKerchar et al 1998: Dependency of summer lake inflows and precipitation on spring SOI, J. of Hydrology 205 66–80.

in snowlines, and a corresponding reduction in the volume of water stored as snow in the catchment[14]. Consequently, river flows into the lakes will be higher in winter. Conversely, smaller snow packs will likely result in less snowmelt in summer and therefore potentially lower river flows than in the past. This is complicated by likely higher summer rainfall, and higher winter rainfall resulting in more snow stored at higher elevations during winter. Modelled lake inflows from all these changes are shown below.

38 Modelling has been undertaken based on the above NIWA regional rainfall projections, combined with projected snow melt changes[15]. This modelling shows that changes in inflows on average throughout the year vary significantly by season, with autumn to spring inflows all being higher than in the past, and summer inflows remaining the same or being lower than in the past (see Figure 13).

*Figure 13 – Modelled changes to average seasonal inflows into the Manapouri catchment between historical inflows (last 90 years) and 2050 inflows (projected) from a mid-range emissions scenario[15].*




39 Annual inflows are expected to increase by about 4% by 2050[15] but this is an average projected change, and uncertainty around this change is large, with scenarios ranging from no increase to larger increases than this. For example, the range of forecast seasonal rainfall increases on the West

[14] Hendrikx et al 2010: The Potential Impact of Climate Change on Seasonal Snow Conditions in New Zealand, NIWA Cient Report: CHC2010-153 Nov 2010 48pp

[15] Purdie 2022: Modelling climate change impacts on inflows, lake storage and spill in snow-fed hydroelectric power catchments, Southern Alps, NZ. J. of Hydrology (NZ) 61(2) 151-178.

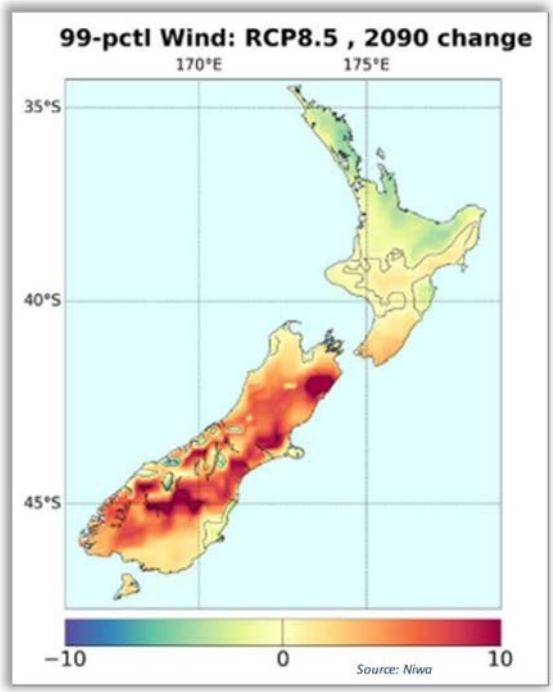
Coast of the South Island over the next hundred years is between 2% to 29%, and in Southland increases in seasonal rainfall projections range from no change to 22%.

40 Volatility of lake inflows in the Waiau catchment is forecast to increase.

41 Individual storm events are projected to become larger under climate change in coming decades. A warmer atmosphere can hold more moisture (about 7% more for every 1°C increase in temperature)[16], so that individual storm events will tend to be wetter in the future, and floods are likely to be larger[17].

42 In addition to this, regional atmospheric circulation changes are likely to further increase rainfall extremes, as they result in projected increases in extreme wind speeds in the south-west of New Zealand (see Figure 14). These are likely to result in greater orographic rainfall in the Waiau catchment.

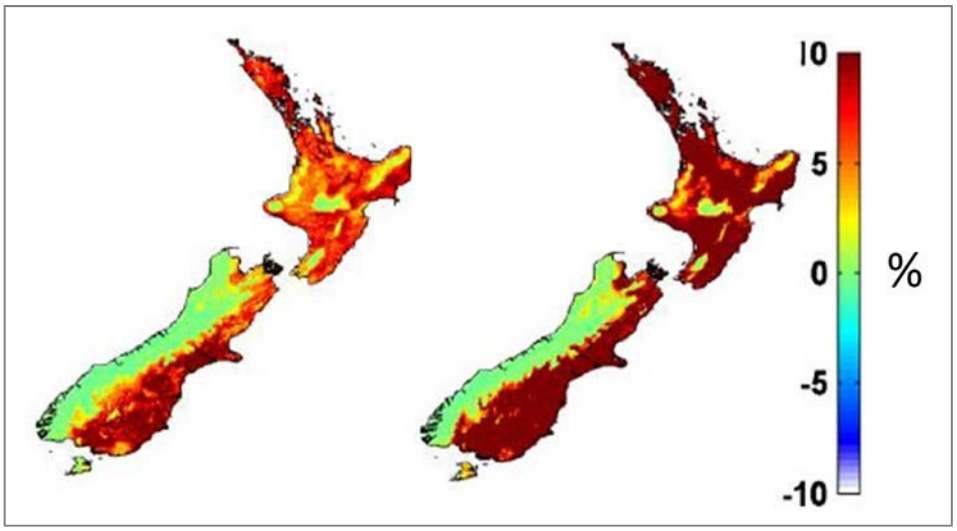
*Figure 14 – Projected changes in extreme daily wind speed (%) by 2090, for the mean of 6 climate models under the highest $CO_2$ concentration scenario RCP8.5 from the IPCC 5th Assessment*[18]




[16] https://www.niwa.co.nz/natural-hazards/hazards/climate-change
[17] *Collins, D.B.G. 2020: New Zealand River Hydrology under late 21st Century climate change. Water 12(8): 2175. https://doi. org/10.3390/w12082175*
[18] https://www.niwa.co.nz/our-science/climate/information-and-resources/clivar/scenarios

43 Although no change in drought length or severity is forecast for the headwaters of the Waiau catchment (see Figure 15), some increase in the time in drought is expected in eastern parts of the catchment. This, combined with the above-mentioned volatility of inflows, and bigger flood peaks, may make operational management of the catchment and planning of generation more challenging in the future than in the past.

*Figure 15 – Projected increase in percentage of time spent in drought by 2040 (on the left) and 2080 (on the right), relative to 1990 levels. Results summarise 19 global climate models*[19]




44 Projections of changes to rainfall and river flows over the next 50–100 years[20] are sourced from global climate models around the world, and regional downscaling models within New Zealand, all of which are acknowledged to have significant uncertainty[21]. However, the general trend is towards a slightly wetter, but more volatile, rainfall regime in the Waiau catchment.

## INTERNATIONAL PANEL ON CLIMATE CHANGE AND THE PARIS AGREEMENT

45 The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body which assesses existing published science on climate change and is the internationally accepted authority on climate change.

46 The most significant climate agreement ever signed is the Paris agreement[8], signed at the "Conference of the Parties" to the United Nations Framework

[19] Clark et al 2011: Scenarios of Regional Drought under Climate Change. Niwa Client Report WLG2010-32, 135pp

[20] *Collins, D.B.G. 2020: New Zealand River Hydrology under late 21st Century climate change. Water 12(8): 2175. https://doi. org/10.3390/w12082175*

[21] *https://www.niwa.co.nz/our-science/climate/information-and-resources/clivar/models*

Convention on Climate Change, in 2015. 193 parties have signed the agreement, including almost every country in the world. Of these, all have now ratified it, including New Zealand. The Paris Agreement's goal is to keep the increase in global average temperature to "well below 2°C" above pre-industrial levels, and preferably below 1.5°C". It requires all parties to define their own "nationally determined contributions" (NDCs) to greenhouse gas emissions, to report on these efforts, and to continue to increase their contributions in the years ahead.

## NEW ZEALAND CLIMATE CHANGE LEGISLATION AND TARGETS

47 NZ has signed and ratified the Paris Agreement[8], and is therefore committed to reducing our greenhouse gas emissions to 30% below 2005 levels by 2030.

48 The Zero Carbon Act came into force July 2019 and commits NZ to achieving net zero greenhouse gas emissions by 2050.

49 The Interim Climate Change Committee was set up in 2018 to advise the NZ government on how to deal with climate change. It was replaced by the independent Climate Change Commission under the Zero Carbon Act. The Climate Change Commission's purpose is to provide independent, evidence-based advice to government on climate issues. The Climate Change Commission's first advice to government was in May 2021 and was a report[22] advising on their first three emissions budgets.

50 The NZ government then produced its Emissions Reduction Plan[23] in June 2022, which lays out emissions reductions targets, and plans to meet those targets. Targets include that long-lived greenhouse gases will be net zero by 2050, and that biogenic methane emissions will be 24-47% below 2017 levels by 2050.

51 Plans to meet those targets include a target to generate 100% renewable electricity by 2030 (in an "average hydrological year"), phasing out coal boilers, banning offshore fossil fuel exploration, and supporting electric

[22] *https://www.climatecommission.govt.nz/our-work/advice-to-government-topic/inaia-tonu-nei-a-low-emissions-future-for-aotearoa/*
[23] *https://environment.govt.nz/what-government-is-doing/areas-of-work/climate-change/emissions-reduction-plan/*

vehicle uptake. The government has also committed to planting 1 billion trees by 2028, as a carbon sink (carbon storage)[24].

52 New Zealand has signed up to the Powering Past Coal Alliance, which commits the country to phasing out coal in electricity generation by 2030.

53 The New Zealand Emissions Trading Scheme (NZ ETS) is the key tool for reducing emissions and meeting New Zealand's emission reduction targets[25]. The NZ ETS requires all sectors of New Zealand's economy to report on their emissions and (apart from the current exception for biological emissions from agriculture) to purchase and surrender emissions units to the Government for those emissions. Just over half of New Zealand's greenhouse gas emissions are covered by NZ ETS surrender obligations.

54 The current NZ price of carbon[26] has risen from NZ$17 per tonne CO2 in early 2017 to $85 per tonne in February 2022.

55 An amendment to the Resource Management Act in 2004 now requires persons exercising functions and powers under that Act to have particular regard to the effects of climate change and the benefits to be derived from the use and development of renewable energy in achieving the purpose of the RMA[27]. Sections of the RMA that prevent decision-makers having regard to the effects that activities have on climate change cease to have effect from the end of this year.

## NEW ZEALAND EMISSIONS REDUCTION COMMITMENTS AND PROGRESS TOWARDS THESE

56 New Zealand's first Nationally Determined Contribution (NDC1) to the Paris Agreement was updated on 31 October 2021. The new NDC sets a headline target of a 50 per cent reduction of net emissions below our gross 2005 level by 2030[28].

[24] *https://www.mpi.govt.nz/funding-and-programmes/forestry/planting-one-billion-trees/*
[25] *http://www.mfe.govt.nz/ets*
[26] *https://www.commtrade.co.nz/*
[27] *https://www.legislation.govt.nz/act/public/2004/0002/latest/DLM237590.html*
[28] *https://environment.govt.nz/what-government-is-doing/areas-of-work/climate-change/nationally-determined-contribution/#new-zealands-nationally-determined-contribution*

57 NZ's projected emissions are acknowledged to be likely to fail to meet our Paris commitments (NDCs) and are projected to stay in the "highly insufficient" bracket when related to our "fair share" of global emissions[29].

58 Projected global temperature increases by 2100 if all Paris pledges are honoured is expected to reach 2.1°C, and the estimate based on current international government policies is 2.7°C[27].

59 As a result of international moves to reduce greenhouse gas emissions, more pressure is almost certain to come to bear on New Zealand to reduce emissions further.

## THE IMPORTANCE OF NEW ZEALAND'S HYDRO GENERATION

60 I have read and agree with the evidence of David Hunt.

61 An aspect of my research at the University of Otago involves modelling likely future electricity supply and demand scenarios in the context of climate change. This involves understanding how the changing climate will impact on electricity generation (i.e., how will rainfall, snow melt, and wind, change in the future) and how New Zealand's electricity needs will change as the country responds to its climate change commitments.

62 I agree with Mr Hunt's comments about the prospect that New Zealand's demand for electricity is going to grow substantially, and at a much faster rate than we have seen before. While the exact rate of growth depends on many assumptions, the reality of a need for a great deal of new renewable generation to be constructed over the next 20-30 years is common to all scenarios, and in my view is inevitable.

63 As Mr Hunt explains, one of the features of most new renewable electricity generation is its intermittent nature. That is, wind and solar generation are only as reliable as the wind and sunshine that provide their 'fuel', and these cannot be stored. By contrast, hydro schemes that have operational flexibility and the ability to store water for later use are especially valuable now and will become increasingly so as the proportion of renewable electricity generation that is intermittent increases.

[29] *https://climateactiontracker.org*

64 In addition to this, it is discussed earlier in this document that inflows in the large Southern hydro lakes (which includes the Manapouri catchment) will become more volatile as flood peaks increase under climate change.

65 Mr Hunt references the high capital cost of constructing new hydro generation infrastructure as a future barrier. In addition to that there are major policy and legislative barriers to the construction of new hydro, particularly large-scale hydro.

66 The research my group undertakes includes projecting what new generation infrastructure is likely to be built to meet future demand growth. To do this we gather information from generators, industry groups and government agencies.

67 While there are different scenarios about what new renewable generation projects will be built and when, a common theme is that there is an expectation that no new major hydro generation will be constructed in New Zealand in the foreseeable future because no planned major hydro schemes in the past 25 years in New Zealand have succeeded getting through the resource consent and public opinion process (the only potential exception to this is the Lake Onslow *seasonal* pumped storage project[30], which is part of a wider exploration of electricity storage solutions currently being undertaken by the NZ government.

68 The implication of this is that the contributions of the existing large hydro schemes, including the Manapouri Scheme, are especially important to New Zealand security of energy supply and decarbonisation.

69 Achieving sufficient new renewable generation build to keep pace with growing demand as the economy decarbonises will be very challenging, and relies on significant growth in wind, solar and geothermal generation. Importantly, as Mr Hunt's Figure 8 shows, projected future electricity supply scenarios assume that hydro generation will not decrease. If for any reason the contributions of the major hydro schemes were to significantly decrease in the future this could have major implications for New Zealand's ability to deliver its decarbonisation strategy as a means to meet its climate change commitments.

[30] *https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/low-emissions-economy/nz-battery/*

**SUMMARY**

70 In summary, my principal conclusions are:

(a) The scientific community and the governments of the world are overwhelmingly in agreement about the need to cut greenhouse gas emissions to prevent catastrophic climate change. New Zealand scientists and the New Zealand government agree.

(b) New Zealand is expected to get between 0.5 and 3 degrees warmer than 1990 levels by the end of the century. It is expected to get wetter in the west and south of the country, and drier in the north and east. Heavy rain, when it occurs is expected to get heavier, and floods bigger. Wind speeds are expected to increase.

(c) Waiau catchment inflows are expected to have a significant change in seasonality in coming decades, with winter inflows increasing and summer inflows staying the same or decreasing. Annual inflows are expected to stay the same or increase slightly, and there is significant uncertainty around the magnitude of change. Individual rain events are expected to be about 7% wetter for every degree of temperature increase, which would lead to more volatility of inflows on a daily or weekly basis. Other catchments will also experience significant changes to the seasonality and volatility of their inflow regimes.

(d) This increased inflow volatility in the Waiau catchment is likely to make operational management and planning of generation more challenging in future.

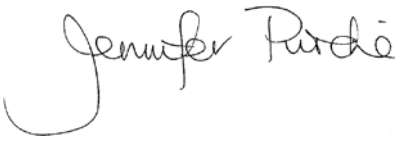
(e) 193 parties globally have signed the Paris Agreement to limit global greenhouse gas emissions, including almost every country in the world. NZ has both signed and ratified this agreement and promised to reduce our greenhouse gases significantly.

(f) In alignment with this goal, significant government legislation and targets have been instituted in recent years. These include targets for the country to reach zero carbon by 2050, 100% renewable electricity by 2030, phase out coal in electricity generation by 2030, and plant a billion trees by 2028.

(g) NZ greenhouse gas emissions are not projected to meet our Paris commitments, and are projected to stay in the “highly insufficient”

bracket when related to our “fair share” of global emissions. More international pressure to comply is likely in the future.

(h) The commitment to decarbonise New Zealand is expected to result in greatly increased electricity demand from the electrification of both the transport and industrial sectors. In addition to this, intermittency of both electricity demand and supply are expected to increase in coming decades. Without the backup of thermal (coal, gas) generation, the ability to store electricity is vital, and with no new large hydro schemes in current planning, the only currently viable solution to this storage problem is our current hydro storage. This makes the retention of the size and flexibility of operation of our current large hydro schemes incredibly valuable.



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25th July 2022