IN THE MATTER of the Resource Management Act 1991

AND

IN THE MATTER of an application by Meridian Energy Limited for resource consents for the Mokihinui Hydro Project

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STATEMENT OF EVIDENCE OF JAMES ARTHUR RENWICK ON BEHALF OF MERIDIAN ENERGY LIMITED

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1. QUALIFICATIONS AND EXPERIENCE

1.1 My full name is James Arthur Renwick.

1.2 I have the following qualifications: BSc (Hons) in mathematics from Canterbury University, MSc in statistics from Victoria University of Wellington, and PhD in Atmospheric Sciences from the University of Washington, Seattle, USA. I am a member of the committee of the Meteorological Society of New Zealand, vice-president of the New Zealand Association of Scientists, a member of the Royal Society of New Zealand and a member of its Climate Committee, a member of the American Meteorological Society (AMS), and a member of the American Geophysical Union. I am part of the World Meteorological Organisation (WMO) Commission for Climatology Expert Team on Seasonal Forecasting, and am the New Zealand contact for the WMO programme on Climate Information & Prediction Services.

1.3 I am employed as the Science Leader for Climate Variability and Change research at NIWA. I have around 30 years' experience in weather and climate research and prediction, with the last 15 years concentrating on climate variability and change research. I have 48 relevant publications in the refereed scientific literature, and written a similar number of related user-specific reports. My present role involves scientific research, advice to government agencies and industry groups on climate variability and change, liaison within national and international scientific communities, development and management of major research programmes, and development of science strategy within NIWA. I am an editor of the Journal of Climate (AMS) and on the editorial board of the International Journal of Climatology (Royal Meteorological Society). I was a lead author for Chapter 3 (*Observations: Surface and Atmospheric Climate Change*) of Working Group I (*Climate Change 2007: The Physical Science Basis*) of the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report, and the subsequent IPCC Technical Paper on Climate Change and Water. I was the 2005 Recipient of the

Edward Kidson Medal of the Meteorological Society of New Zealand, and was a co-recipient of the 2007 Nobel Peace Prize.

1.4 I have read the Code of Conduct for Expert Witnesses (Rule 330A, High Court Rules and Environment Court Practice Note) and I agree to comply with it. I have complied with it in the preparation of this statement of evidence.

1.5 I have reviewed the summary of the Mokihinui Hydro proposal ("MHP") given in Appendix 1 and the evidence of other experts giving evidence on behalf of Meridian Energy Limited ("Meridian") relevant to my area of expertise namely Timothy Fraser.

2. SCOPE OF EVIDENCE

2.1 I have been asked by Meridian to prepare evidence in relation to the science underlying climate change.

3. EXECUTIVE SUMMARY

3.1 Warming of the climate system is now unequivocal. Most of the observed increase in global average temperatures since the mid 20th century is very likely a result of the observed increase in anthropogenic greenhouse gas concentrations. Continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system.

3.2 Global action to reduce greenhouse gas emissions is required as a matter of urgency to prevent dangerous interference with the planet’s climate and ecosystems. In order to prevent serious impacts on natural and managed systems from climate change it will be necessary to substantially reduce global emissions of carbon dioxide and other greenhouse gases.

3.3 Renewable energy development is an important part of the climate change mitigation portfolio both globally and in New Zealand, since it reduces demand for energy generation by greenhouse gas–emitting thermal power plants.

3.4 Development of the MHP will contribute to this national climate change mitigation portfolio*.*

4. CLIMATE CHANGE

4.1 “Climate change” is defined in the Resource Management Act (RMA) as follows:

> *"a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods.”*

4.2 Naturally-occurring greenhouse gases (GHGs), including water vapour, carbon dioxide (CO_2), methane, nitrous oxide and ozone, trap heat within the lower atmosphere, leading to higher temperatures at the surface of the earth than would be the case if they were absent, the so-called “natural greenhouse effect”. The Earth’s natural greenhouse effect makes life as we know it possible[1]. An increase of greenhouse gas concentrations above natural levels (plus the emission into the atmosphere of some synthetic industrial greenhouse gases such as hydrofluorocarbons) enhances this effect, thereby changing the radiation balance of the Earth. Changes in the amount or distribution of incoming solar radiation reaching the earth, in the fraction of solar radiation that is reflected (e.g. by changes in cloud cover, atmospheric aerosol particles, or surface vegetation), or in the outgoing thermal radiation (e.g. through changing greenhouse gas concentrations) alters the Earth’s radiation balance. The climate system, in turn, responds directly to such changes,

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[1] *IPCC Fourth Assessment Report, Working Group I, Frequently Asked Question 1.3*

as well as indirectly through a variety of feedback mechanisms[2]. A sufficient increase in greenhouse gas concentrations in the atmosphere would lead to further warming (above the natural greenhouse warming) and would induce other changes in the global climate system.

4.3 The greenhouse effect and the effects of increasing greenhouse gas levels have been understood for over a century. Some of the key scientific papers on the natural greenhouse effect are listed below, in chronological order:

a. Tyndall, J, 1863: On radiation through the Earth's atmosphere. *Philosophical Magazine*, **ser. 4, 25**, 200-206.

b. Tyndall, J., 1863: On the relation of radiant heat to aqueous vapor. *Philosophical Magazine*, **ser. 4, 26**, 30-54.

c. Arrhenius, S., 1896: On the influence of carbonic acid in the air upon the temperature of the ground. *Philosophical Magazine*, **41**, 237-276

d. Callendar, G.S., 1938: The artificial production of carbon dioxide and its influence on climate. *Quarterly Journal of the Royal Meteorological Society*, **64**, 223-40.

e. Kaplan, Lewis D., 1952: On the pressure dependence of radiative heat transfer in the atmosphere. *Journal of Meteorology*, **9**, 1-12.

f. Revelle, R., and H.E. Suess, 1957: Carbon dioxide exchange between atmosphere and ocean and the question of an increase of atmospheric CO2 during the past decades. *Tellus*, **9**, 18-27.

g. Bolin, B., and E. Eriksson, 1959: Changes in the carbon dioxide content of the atmosphere and sea due to fossil fuel combustion. In *The Atmosphere and the Sea in Motion*, edited by Bert Bolin, pp. 130-42. New York: Rockefeller Institute Press.

h. Manabe, S., and R.T. Wetherald, 1967: Thermal equilibrium of the atmosphere with a given distribution of relative humidity. *Journal of the Atmospheric Sciences*, **24**, 241-59.

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[2] *IPCC Fourth Assessment Report, Working Group I, Frequently Asked Question 1.1*

i. Sundquist, E.T., 1987: Ice core links CO_2 to climate. *Nature*, **329**, 389-90.

4.4 An excellent summary of the history and the physics of human-induced climate change is given in:

a. Weart, S. R., 2003: *The discovery of global warming*. Harvard University Press, 228 pp.

4.5 In 1988 the Intergovernmental Panel on Climate Change (IPCC) was established by the United Nations Environment Programme and the World Meteorological Organization. Its role is to assess, on a comprehensive, objective, open and transparent basis, the latest scientific, technical and socio-economic literature produced worldwide relevant to the understanding of the risk of human-induced climate change, its observed and projected impacts and options for adaptation and mitigation[3]. IPCC assessment reports have provided key inputs to the development of the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol.

4.6 The IPCC provides comprehensive Assessment Reports once every 5 to 7 years, and also Special Reports and Technical papers. The comprehensiveness of the scientific content is achieved through contributions from experts in all regions of the world and all relevant disciplines, and through a two-stage review process by experts and governments. This wide authorship and extensive and careful review process means the IPCC provides the most complete and authoritative assessments of climate change that are available.

4.7 The most recent IPCC assessment, *Climate Change 2007: The Fourth Assessment Report*, draws on the expertise of more than 450 lead authors, 800 contributing authors and 2,500 scientific expert reviewers, from over 130 countries.

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3 *http://www.ipcc.ch/about/index.htm*

4.8 Some key findings of the Fourth Assessment Report are set out below.

Atmospheric Concentrations of Greenhouse Gases:

4.9 Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750, and now far exceed pre-industrial values. These values have been determined from ice cores spanning many thousands of years. The global increases in carbon dioxide concentration are mainly a result of fossil fuel use and land-use change. Increases in methane are very likely to be predominantly a result of agriculture and fossil fuel use, and nitrous oxide increases are primarily a result of agricultural practice.

4.10 The Fourth Assessment Report finds that the global atmospheric concentration of carbon dioxide has increased from a pre-industrial value of about 280 ppm (parts per million) to 379 ppm in 2005[4]. The atmospheric concentration of carbon dioxide in 2005 exceeds by far the natural range over the last 650,000 years (180 to 300 ppm) as determined from ice cores[5]. The annual carbon dioxide concentration growth-rate was larger during the last 10 years (1995 – 2005 average: 1.9 ppm per year) than it has been since the beginning of continuous direct atmospheric measurements (1960–2005 average: 1.4 ppm per year), although there is year-to-year variability in growth rates[6].

Observed Climate Changes

4.11 The IPCC Fourth Assessment Report states that *“warming of the climate system is unequivocal, as is now evident from observations of increases*

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[4] *Climate Change 2007: The Physical Science Basis, Summary for Policymakers. Page 2*

[5] *Climate Change 2007: The Physical Science Basis, Summary for Policymakers, Page 2*

[6] *Climate Change 2007: The Physical Science, Summary for Policymakers pg 2*

in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea level[7]*"*.

4.12 Eleven of the twelve years before the IPCC report was published (1995-2006) ranked among the 12 warmest years in instrumental records. The total temperature increase from 1850-1899 to 2001-2005 is 0.76°C[8].

4.13 The Assessment concludes with very high confidence[9] that the globally averaged net effect of human activities since 1750 has been one of warming[10]. Most of the observed increase in global average temperatures since the mid-20th century is very likely[11] a result of the observed increase in anthropogenic greenhouse gas concentrations. Discernible human influences now extend to other aspects of climate, including ocean warming, continental-average temperatures, temperature extremes and wind patterns[12].

4.14 Global average sea level rose at an average rate of 1.8 mm per year [uncertainty range 1.3 to 2.3[13] mm per year] over 1961 to 2003. The rate was faster over 1992 to 2003: about 3.1 [2.4 to 3.8][14] mm per year. Whether the faster rate for 1993 to 2003 reflects decadal variability or an

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7 Climate Change 2007: The Physical Science Basis Summary for Policy Makers page 4.

8 Climate Change 2007: The Physical Science Basis 3.2 (Summary for Policymakers pg 5 para 4)

9 Very high confidence represents at least a 9 out of 10 chance.

10 Climate Change 2007: The Physical Science Basis Summary for Policy Makers page 3.

11 Very likely indicates a likelihood of more than 90%

12 Climate Change 2007: The Physical Science Basis Summary for Policy Makers page 10.

13 These uncertainty ranges represent 90% uncertainty levels, that is, there is an estimated 5% likelihood that the value could be below 1.3 mm / year, and a 5% likelihood it could be above 2.4 mm/yr. The best estimate is 1.8 mm/year.

14 As before, the numbers in square brackets represent the 90% uncertainty range.

increase in the longer term trend is unclear[15]. The total 20th century sea level rise is estimated to be 0.17 [0.12 to 0.22] m[16].

Projected Future Changes

4.15 Advances in climate change modelling now enable best estimates and likely assessed uncertainty ranges to be given for projected warming for different emission scenarios. Continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century[17]. For the next two decades a warming of about 0.2°C per decade is projected for a range of emission scenarios. Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected[18]. The best estimate for global average surface warming at the end of this century for the lowest of the six SRES emissions marker scenarios[19] is 1.8°C. This was considered in the IPCC's Fourth Assessment Report. The best estimate for the highest of these marker scenarios is 4.0°C[20].

4.16 Other projected changes over the 21st Century include: contracting of snow cover, shrinking of sea-ice in both the Arctic and Antarctic, and (very likely) an increased frequency of extreme hot days, heat waves and heavy precipitation events. Changes in precipitation patterns are

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15 *Climate Change 2007: The Physical Science Summary for Policymakers page 5*

16 *Climate Change 2007: The Physical Science. Summary for Policymakers page 7.*

17 *Climate Change 2007: The Physical Science Basis Summary for Policy Makers page 13*

18 *Climate Change 2007: The Physical Science Basis 10.3, 10.7 (Summary for Policymakers pg 12 para 5)*

19 SRES refers to the IPCC Special Report on Emission Scenarios (2000). The SRES scenarios do not include additional climate initiatives. Marker scenarios represent a given SRES scenario family. Approximate carbon dioxide-equivalent concentrations in 2100 for the lowest (B1) and highest (A1F1) marker scenarios are about 600 and 1,550 parts per million respectively. (Footnote on Page 12 of Climate Change 2007: The Physical Science Basis. Summary for Policymakers).

20 *Climate Change 2007: The Physical Science Basis 10.5 (Summary for Policymakers pg 13 para 2&3)*

also projected, and based on a range of models it is likely that in future tropical cyclones will become more intense[21].

4.17 Model-based projections of global average sea level rise at the end of the 21st century (2090-2099) for six SRES emissions marker scenarios are shown in Table SPM.3 (reproduced below). The projections range from 0.18m to 0.59m relative to 1980 to 1999. The projections do not include uncertainties in climate-carbon cycle feedbacks or the full effects of changes in ice sheet flow, therefore the upper values of the ranges are not to be considered upper bounds for sea level rise[22]. In the longer term, the eventual contributions to sea level rise from Greenland ice sheet loss could be several metres, and larger than from thermal expansion, should warming in excess of 1.9 to 4.6 °C above pre-industrial levels be sustained over many centuries[23].

4.18 Increasing atmospheric carbon dioxide concentrations are projected to lead to increasing acidification of the ocean over the 21st century, adding to the change that has already occurred since pre-industrial times[24].

[21] *Climate Change 2007: The Physical Science Basis Summary for Policy Makers pages 15-16*

[22] *Climate Change 2007: Synthesis Report. Summary for Policymakers page 8.*

[23] *Climate Change 2007: Synthesis Report. Summary for Policymakers page 20*

[24] *Climate Change 2007: The Physical Science Basis Summary for Policy Makers page 14*

Table SPM.3. *Projected global average surface warming and sea level rise at the end of the 21st century. {10.5, 10.6, Table 10.7}*

Case	Temperature Change (°C at 2090-2099 relative to 1980-1999)[a] Best estimate	*Likely* range	Sea Level Rise (m at 2090-2099 relative to 1980-1999) Model-based range excluding future rapid dynamical changes in ice flow
Constant Year 2000 concentrations[b]	0.6	0.3 – 0.9	NA
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

Table notes:
[a] These estimates are assessed from a hierarchy of models that encompass a simple climate model, several Earth System Models of Intermediate Complexity and a large number of Atmosphere-Ocean General Circulation Models (AOGCMs).
[b] Year 2000 constant composition is derived from AOGCMs only.

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Observed Effects of climate change

4.19 Observational evidence from all continents and most oceans shows that natural systems are being affected by regional climate changes, particularly temperature increases. For example there is high confidence that increased runoff and earlier spring peak discharge is occurring in many glacier- and snow-fed rivers, and that lakes and rivers are warming in many regions with effects on thermal structure and water quality.

4.20 There is very high confidence that recent warming is strongly affecting terrestrial biological systems, including such changes as earlier timing of spring events such as leaf-unfolding, bird migration and egg laying, and that poleward and upward shifts in ranges are occurring for plant and animal species[26]. A global assessment of data since 1970 has shown it is likely[27] that anthropogenic warming has had an impact on many biological and physical systems[28].

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25 Climate Change 2007: The Physical Science Basis 10.5, 10.6 Table 10.7 (Summary for Policymakers page 13)

26 Climate Change 2007: Impacts, Adaptation and Vulnerability. Summary for Policymakers. Page 8.

27 "Likely" means more than 66% chance of a stated outcome

28 Climate Change 2007: Impacts, Adaptation and Vulnerability Summary for Policy Makers pages 8, 9

Projected Future Effects of Climate Change

4.21 Figure SPM.7 which is reproduced from the IPCC Fourth Assessment Synthesis Report[29] provides examples of impacts expected to be associated with various amounts of further global average temperature increase (compared to 1980-1999 temperatures). The temperature rises projected by the end of the 21st Century for the six SRES emissions marker scenarios are shown at the base of the diagram. Approximately 20-30% of plant and animal species assessed so far are likely to be at increased risk of extinction if increases in global average temperature exceed 1.5-2.5°C[30].

4.22 Confidence has increased that a 1 to 2°C increase in global mean temperature above 1990 levels (about 1.5°C to 2.5°C above pre-industrial levels) poses significant risks to many unique and threatened systems including many biodiversity hotspots[31].

4.23 Human beings are also likely to face mounting difficulties in some regions. For example Figure SPM.7 suggests a rise in Global mean annual temperature relative to 1980-1999 of just 1°C would lead to hundreds of millions of people becoming exposed to increased water stress, a tendency for cereal productivity to decrease in low latitudes, increased damage from floods and storms, an increasing burden from malnutrition, diarrhoeal, cardio-respiratory and infectious diseases, and increased morbidity and mortality from heat waves, floods and droughts.

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[29] *Climate Change 2007: Synthesis Report. Figure SPM.7, page 10.*

[30] *Climate Change 2007: Impacts, Adaptation and Vulnerability 4.4, Table 4.1 (Summary for Policymakers pg 11 para 9)*

[31] *Climate Change 2007: Synthesis Report. Page 19*

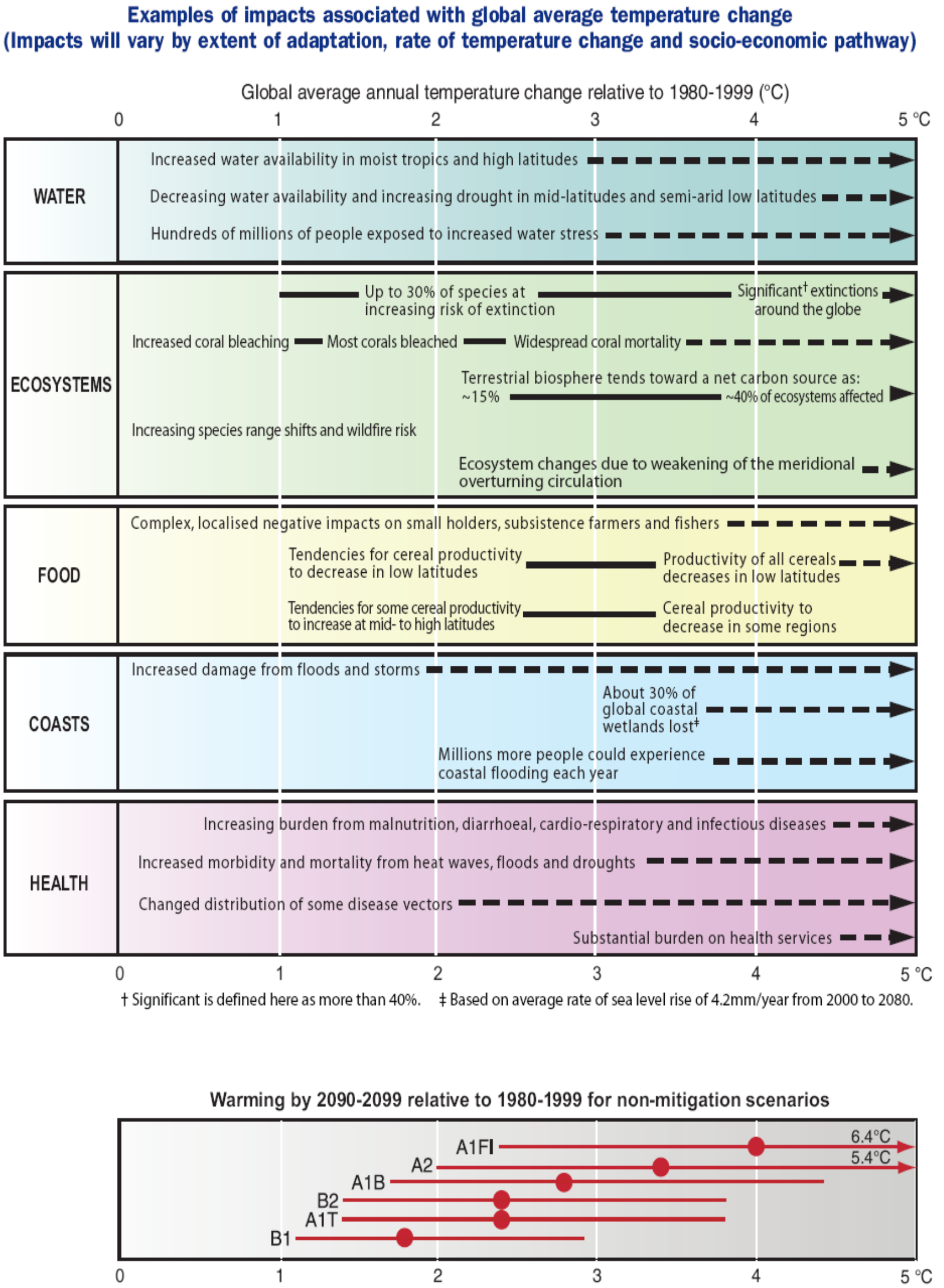

Figure SPM.7. *Examples of impacts associated with projected global average surface warming.* ***Upper panel:*** *Illustrative examples of global impacts projected for climate changes (and sea level and atmospheric CO_2 where relevant) associated with different amounts of increase in global average surface temperature in the 21st century. The black lines link impacts; broken-line arrows indicate impacts continuing with increasing temperature. Entries are placed so that the left-hand side of text indicates the approximate level of warming that is associated with the onset of a given impact. Quantitative entries for water scarcity and flooding represent the additional impacts of climate change relative to the conditions projected across the range of SRES scenarios A1FI, A2, B1 and B2. Adaptation to climate change is not included in these estimations. Confidence levels for all statements are* high. ***Lower panel:*** *Dots and bars indicate the best estimate and likely ranges of warming assessed for the six SRES marker scenarios for 2090-2099 relative to 1980-1999. {Figure 3.6}*

Climate Change in New Zealand

4.24 In New Zealand, mean air temperatures have increased by 1.0°C over the period 1855 to 2004, and by 0.4°C since 1950. Local sea surface temperatures have risen by 0.7°C since 1871. From 1951 to 1996, the number of cold nights and frosts declined by 10-20 days per year[32].

4.25 New Zealand's climate is virtually certain (at least 99% probability) to become warmer through the 21st century, with changes in extreme events. Floods, landslides, droughts and storm surges are very likely (at least 90% probability) to become more frequent and intense, and snow and frost are very likely to become less frequent. Large areas of eastern New Zealand are likely to have less soil moisture, although western New Zealand is likely to receive more rain[33]. A warming in average temperatures of 0.1 to 1.4°C is likely by the 2030s and 0.2 to 4.0°C by the 2080s[34].

4.26 As a result of reduced precipitation and increased evaporation, water security problems are projected to intensify by 2030 in Northland and some eastern regions. Rain events are likely to become more intense, leading to greater storm runoff. This is likely to cause greater erosion of land surfaces, more landslides, redistribution of river sediments, and a decrease in the protection afforded by levees[35]. New Zealand is already vulnerable to weather extremes: of the total NZ$1.5billion (adjusted to 2004 dollars), New Zealand insurance payouts for natural hazards

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[32] *Climate Change 2007: Impacts, Adaptation and Vulnerability 11.2.1*

[33] *Climate Change 2007: Impacts, Adaptation and Vulnerability. Chapter 11 (Australia and New Zealand), Section 11.3.1*

[34] *Climate Change 2007: Impacts, Adaptation and Vulnerability. Chapter 11 (Australia and New Zealand), Section 11.3.1*

[35] *Climate Change 2007: Impacts, Adaptation and Vulnerability. Chapter 11 (Australia and New Zealand), Section 11.4.1.2*

between 1968 and 2004 of approximately 75% was for weather–related losses[36].

4.27 Ongoing coastal development and population growth in areas such as Northland to Bay of Plenty are projected to exacerbate risks from sea-level rise and increase in the severity and frequency of storms and coastal flooding by 2050[37].

4.28 Production from agriculture and forestry is projected to decline by 2030 over parts of eastern New Zealand, due to increased drought and fire risk. However, initial benefits to agriculture and forestry are projected in western and southern areas, and close to major rivers, due to a longer growing season, less frost and increased rainfall[38].

Emission changes to stabilise greenhouse gas concentrations in the atmosphere.

4.29 The IPCC concludes there is high confidence[39] that neither adaptation nor mitigation alone can avoid all climate change impacts; however, they can complement each other and together can significantly reduce the risks of climate change[40].

4.30 In order to stabilise the concentration of greenhouse gases in the atmosphere, emissions would need to peak and decline thereafter. The

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[36] *Wratt et al, 2006: New Zealand climate change – water and adaptation. In R. Chapman et al (Editors), Confronting Climate Change – Critical Issues for New Zealand. Victoria University Press, Wellington, pp149 – 162.*

[37] *Climate Change 2007: Impacts, Adaptation and Vulnerability. Chapter 11 (Australia and New Zealand), Section 11.4.5, 11.4.7.*

[38] *Climate Change 2007: Impacts, Adaptation and Vulnerability. Chapter 11 (Australia and New Zealand), Sections 11.4.3, 11.4.4.*

[39] In the Summary for Policymakers the following levels of confidence are used to express expert judgments on the correctness of the underlying science: high confidence represents at about an 8 out of 10 chance of being correct

[40] *Climate Change 2007: Synthesis Report 5.3 (Summary for Policymakers pg 19)*

lower the stabilisation level, the earlier the peak needs to occur and the more quickly the decline needs to follow the peak.[41]

4.31 Table SPM.6 (reproduced from the Synthesis Report)[42] summarises the emission levels associated with various stabilisation concentrations and the resulting equilibrium global warming and long-term sea level rise due to thermal expansion only.

Table SPM.6. Characteristics of post-TAR stabilisation scenarios and resulting long-term equilibrium global average temperature and the sea level rise component from thermal expansion only.[a] {Table 5.1}

Category	CO_2 concentration at stabilisation (2005 = 379 ppm)[b]	CO_2-equivalent concentration at stabilisation including GHGs and aerosols (2005 = 375 ppm)[b]	Peaking year for CO_2 emissions[a,c]	Change in global CO_2 emissions in 2050 (percent of 2000 emissions)[a,c]	Global average temperature increase above pre-industrial at equilibrium, using 'best estimate' climate sensitivity[d,e]	Global average sea level rise above pre-industrial at equilibrium from thermal expansion only[f]	Number of assessed scenarios
	ppm	ppm	year	percent	°C	metres	
I	350 – 400	445 – 490	2000 – 2015	-85 to -50	2.0 – 2.4	0.4 – 1.4	6
II	400 – 440	490 – 535	2000 – 2020	-60 to -30	2.4 – 2.8	0.5 – 1.7	18
III	440 – 485	535 – 590	2010 – 2030	-30 to +5	2.8 – 3.2	0.6 – 1.9	21
IV	485 – 570	590 – 710	2020 – 2060	+10 to +60	3.2 – 4.0	0.6 – 2.4	118
V	570 – 660	710 – 855	2050 – 2080	+25 to +85	4.0 – 4.9	0.8 – 2.9	9
VI	660 – 790	855 – 1130	2060 – 2090	+90 to +140	4.9 – 6.1	1.0 – 3.7	5

Notes:
a) The emission reductions to meet a particular stabilisation level reported in the mitigation studies assessed here might be underestimated due to missing carbon cycle feedbacks (see also Topic 2.3).
b) Atmospheric CO_2 concentrations were 379ppm in 2005. The best estimate of total CO_2-eq concentration in 2005 for all long-lived GHGs is about 455ppm, while the corresponding value including the net effect of all anthropogenic forcing agents is 375ppm CO_2-eq.
c) Ranges correspond to the 15th to 85th percentile of the post-TAR scenario distribution. CO_2 emissions are shown so multi-gas scenarios can be compared with CO_2-only scenarios (see Figure SPM.3).
d) The best estimate of climate sensitivity is 3°C.
e) Note that global average temperature at equilibrium is different from expected global average temperature at the time of stabilisation of GHG concentrations due to the inertia of the climate system. For the majority of scenarios assessed, stabilisation of GHG concentrations occurs between 2100 and 2150 (see also Footnote 21).
f) Equilibrium sea level rise is for the contribution from ocean thermal expansion only and does not reach equilibrium for at least many centuries. These values have been estimated using relatively simple climate models (one low-resolution AOGCM and several EMICs based on the best estimate of 3°C climate sensitivity) and do not include contributions from melting ice sheets, glaciers and ice caps. Long-term thermal expansion is projected to result in 0.2 to 0.6m per degree Celsius of global average warming above pre-industrial. (AOGCM refers to Atmosphere-Ocean General Circulation Model and EMICs to Earth System Models of Intermediate Complexity.)

4.32 The discussion earlier in this evidence about Figure SPM.7 indicates that various serious impacts are expected if global temperatures rise by 1-2°C above 1990 levels (about 1.5 to 2.5°C above pre-industrial levels). Table SPM.6 suggests that by 2050 a reduction of 50 to 85% of global carbon dioxide emissions (compared to the year 2000) would be

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[41] *Climate Change 2007: Synthesis Report 5.4 (Summary for Policymakers pg 19)*

[42] *Climate Change 2007: Synthesis Report. Summary for Policymakers. Page 20.*

required in order to hold eventual long-term global equilibrium temperature change to this level[43].

Role of renewable energy as a climate change mitigation tool

4.33 This evidence has explained that reductions in global carbon dioxide emissions of between 50 and 85% may be required by 2050 to prevent the occurrence of some serious climate change impacts. The IPCC Fourth Assessment Report states that many impacts can be reduced, delayed or avoided by mitigation[44], and identifies renewable power generation as one of the key mitigation technologies and practices currently commercially available[45] for the energy sector.

4.34 New Zealand has substantial renewable energy resources that have not yet been developed, including expanded hydro generation, extensive wind energy, geothermal and wave energy resources, potential for woody biomass production, and a good solar resource.

4.35 Increasing New Zealand's supply of renewable energy will assist with mitigating the problem of increasing emissions in the electricity sector. New renewable power stations such as the MHP will reduce dry year demand for generation by existing thermal plant. Conversely, if the two percent annual growth in demand is not met by an increase in supply of renewable energy then that demand will cause growth in emissions from thermal plant. This is why new renewable energy power stations are an essential part of New Zealand's emission management response.

4.36 In his evidence Mr Watts has calculated that the MHP electricity generated will avoid approximately 225,000 to 256,000 tonnes of CO_2 emissions per annum, if the equivalent amount of energy was generated by thermal means, and that after approximately 1.2 years of operation

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43 Climate Change 2007: Synthesis Report Table 5.1 (Summary for Policymakers pg 20)

44 Climate Change 2007: Mitigation of Climate Change. Summary for Policymakers, Page 19

45 Climate Change 2007: Mitigation of Climate Change. Summary for Policymakers, Page 10.

will be equivalent to offset all the CO_2 emissions produced during construction. After 10 years of operation of the MHP, the net amount of CO_2 emissions saved equates to removing over 50,000 cars from the roads. In my opinion the CO_2 emissions reductions afforded by the MHP will have significant benefits in helping New Zealand reduce its overall greenhouse gas emissions profile.

5. SUBMISSIONS

5.1 The submission by the Royal Forest and Bird Protection Society (Inc) refers to the loss of forest capacity as a carbon sink, and the emissions resulting from decomposition of submerged vegetation. I understand from the evidence of Dr Spigel, and that of Mr Watts, that the emissions from decomposing vegetation would amount to only 5-6% of total avoided emissions, and would last for only the first decade of operation of the MHP. I further understand from the terrestrial ecology evidence of Dr Bartlett that the MHP would require the inundation or clearance of approximately 368 ha of forest. In my opinion, whilst there is a loss of forest capacity, and a temporary source of greenhouse gas emissions (as discussed above), the benefits of the MHP in avoiding the need to emit CO_2 as part of thermal electricity generation far outweigh these effects.

6. CONCLUSION

6.1 Global action to reduce greenhouse gas emissions is required as a matter of urgency to prevent dangerous interference in the planet’s climate and ecosystems.

6.2 Warming of the climate system is now unequivocal, and most of the observed increase in global average temperatures since the mid 20th century is very likely a result of the observed increase in anthropogenic greenhouse gas concentrations.

6.3 Continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system.

6.4 In order to prevent serious impacts on natural and managed systems from climate change it will be necessary to substantially reduce global emissions of carbon dioxide and other greenhouse gases.

6.5 Renewable energy development is an important part of the climate change mitigation portfolio both globally and in New Zealand, since it reduces demand for energy generation by greenhouse gas–emitting thermal power plants.

6.6 Development of the MHP will contribute to this national climate change mitigation portfolio.