BEFORE A HEARING PANEL: WHAKATĀNE DISTRICT COUNCIL AND BAY OF PLENTY REGIONAL COUNCIL

IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of submissions and further submissions on Plan Change 1 (Awatarariki Fanhead, Matatā) to the Operative Whakatāne District Plan and Plan Change 17 (Natural Hazards) to the Bay of Plenty Regional Natural Resources Plan

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STATEMENT OF EVIDENCE OF PETER BLACKWOOD ON BEHALF OF WHAKATĀNE DISTRICT COUNCIL

ENGINEERING – METEOROLOGY

15 January 2020

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1. Executive Summary

1.1. The 18 May 2005 event was an extreme case of severe convection. The cause seems to have been a combination of abnormally warm, moist air, very unstable conditions and, most importantly, a near stationary convergence line along the coastal fringe from Eastern Coromandel to Bay of Plenty.

1.2. My evidence presents peak rainfall intensities in appended tables. The significant rainfall had return periods between 200 and 500 years on known extreme value statistics but could be more frequent as they are perhaps part of a different distribution of storms that we know little about. In my professional opinion it is wisest to regard them as around 12 to 18 percent greater than the 1% AEP rainfall intensities.

1.3. The impact of global warming includes both increases in sea levels and rainfall intensities. The increase in rain intensities are forecast across four alternative futures in which scenarios of human activities result in different concentrations of greenhouse gases in the atmosphere, known as Representative Concentration Pathways (**RCPs**). It is clear ongoing climate change effects will increase the frequency of rainfall events such as that which occurred at Matatā on 18 May 2005. By the end of this century, under RCP 8.5 scenario these storms could be expected to occur on a 40 to 50 year return period, and under RCP 6.0, on a 60 to 80 year return period.

2. INTRODUCTION

2.1. My full name is Peter Lindsay Blackwood.

2.2. My evidence is given on behalf of the Whakatāne District Council (the **District Council**) in relation to:

(a) Proposed Plan Change 1 (Awatarariki Fanhead, Matatā) to the Operative Whakatāne District Plan; and

(b) Proposed Plan Change 17 (Natural Hazards) to the Bay of Plenty Regional Natural Resources Plan (a private plan change request from the District Council)

(together referred to as the **Proposed Plan Changes**).

2.3. My evidence relates to the meteorological effects aspects of the Proposed Plan Changes. My evidence will cover:

(a) The climatic conditions and associated rainfall that triggered the debris flows in the catchments behind the Matatā township in May 2005;

(b) The estimated rainfall recurrence interval for this event; and

(c) The increased likelihood of this occurring more frequently as a consequence of climate change factors.

2.4. This statement of evidence does not cover the estimate of the debris flows discharge. This is addressed in the evidence of Mr Tom Bassett and others.

3. QUALIFICATIONS AND EXPERIENCE

3.1. I hold the position of Principal Technical Engineer at Bay of Plenty Regional Council (**Regional Council**).

3.2. My qualifications include a Bachelor of Engineering (Civil) with Honours degree from Canterbury University.

3.3. I was awarded the IPENZ National Arch Campbell Award for river and catchment engineering in 2015.

3.4. I have 44 years' experience in central and regional government environmental and civil engineering. My areas of specialist advice include:

(a) Flood and rainfall frequency including detailed assessment of the extreme value frequency distributions and impacts of climatic trends such as the Interdecadal Pacific Oscillation (IPO). This includes research into and co-authoring of specialist computer programmes FRAN and FRANCES for the ex-Ministry of Works. These assessed up to seven different frequency distributions applied to continuous series and censored data.

(b) Climate change policy and design;

(c) River and stream hydraulics;

(d) Design of river protection works;

(e) River and catchment engineering; and

(f) Coastal engineering including impacts of storm surge on coastal inundation

3.5. Between 2006 and 2016 I was employed as Manager Design, Manawatu-Whanganui Regional Council, ostensibly to manage the design of a multimillion dollar flood protection works upgrade on the Manawatu, Oroua, Rangitikei and Pohangina Rivers and Mākino Stream and Floodway following the very large 2004 so-called "Manawatu Floods". I also designed the upgrade of stopbanks in Whanganui, including the major Balgownie Industrial Area stopbank

3.6. I was previously employed by the Regional Council (then known as Environment Bay of Plenty) as Technical Services Manager between 1996 and 2006.

4. MY ROLE

4.1. I was the Bay of Plenty Regional Council Duty Flood Manager on the day of the debris flow event, 18 May 2005. I inspected the Matatā devastation on the next day 19 May 2005 and was intimately involved in the design assessments for the rainfall event and debris flows. I revisited the site of the various debris flows several times in the ensuing months and in particular looked closely at the condition of Te Awatarariki Stream in the reach from approximately 400 m upstream of the railway bridge through to the Matatā lagoon.

4.2. In May 2005 I authored a report on the meteorology that triggered the multiple debris flows that impacted Matatā and environs in May 2005. In collaboration with Tom Bassett, I updated this report in 2019 to take into account the effects of global warming upon rainfall intensities and likelihood. These two reports are attached to this evidence as **Appendices 1** and **2**.

4.3. In preparing this evidence I have reviewed the following documents and reports:

(a) "High Intensity Rainfall Design System Version 4", Prepared for Envirolink, January 2018, Trevor Carey-Smith, Roddy

Henderson, Shailesh Singh, National Institute of Water & Atmospheric Research.

(b) "Climate Projections for New Zealand: Snapshot", June 2016, Ministry for the Environment (attached as Appendix 3 in 2019 document referenced preceding).

(c) "Matatā Hydrological Estimates 050624 – Folder Awatarariki", Excel spreadsheet produced by Mr P.M.West, Environmental Engineer, Bay of Plenty Regional Council, dated 7 June 2005.

5. CODE OF CONDUCT

5.1. Although this is a Council hearing I confirm that I have read the Code of Conduct for Expert Witnesses contained in the Environment Court Consolidated Practice Note 2014. I also agree to comply with the Code when presenting evidence to the Hearings Panel. I confirm that the issues addressed in this brief of evidence are within my area of expertise, except where I state that I rely upon the evidence of another expert witness. I also confirm that I have not omitted to consider material facts known to me that might alter or detract from the opinions.

6. 18 MAY 2005 SYNOPTIC SITUATION

6.1. This event was an extreme case of severe convection. The heavy rain was not driven by broadscale dynamic processes, and certainly no large scale orographically enhanced precipitation. The actual cause seems to have been a combination of abnormally warm, moist air, very unstable conditions and most importantly of all, a near stationary convergence line along the coastal fringe from Eastern Coromandel to Bay of Plenty (the trigger mechanism for the convection).

6.2. The convergence was between the weak northeast flow just offshore of the coastline and a weak southeast flow over the land. The convergence was considered weak, but remained slow-moving along the coastal fringe for much of 18 May 2005. It basically enabled the torrential downpours and thunderstorms to continue to re-form in the same area over many hours, rather than move away in half an hour or so, which is the usual case.

7. PEAK RECORDED RAINFALLS AND THEIR FREQUENCY

7.1. Peak rainfall intensities are presented in the appended tables. Unfortunately, there were no automatic or manual rain gauges in the storm centre. The closest automatic gauge is at Awakaponga some 5 km SSE of Matatā. This recorded:

(a) an event total from 17 to 19 May of 367.5 mm;

(b) peak 30 minute of 58 mm;

(c) peak one hour of 94.5 mm;

(d) peak two hour of 132.5 mm; and

(e) peak 24 hour of 307.5 mm.

7.2. Table One, below, presents depth-duration-frequency data for rainfall at Awakaponga based on the High Intensity Rainfall Design System (**HIRDS**) Version 4, together with the recorded rainfall depths on 18 May

Table One: Rainfall Depths in 18 May 2005 Storm and HIRDS V4 Design Rainfall Estimates (mm)

AEP (percent)	Return Period (years)	Rainfall Duration			
		30 minutes	1 hour	2 hours	24 hours
1	100	61.3	84.6	113	241
0.4	250	71.8	99	132	279
18 May 2005 depths		58	94.5	132.5	307.5

7.3. The HIRDS Version 4 software is documented in the publication "High Intensity Rainfall Design System Version 4", Prepared for Envirolink, January 2018, Trevor Carey-Smith, Roddy Henderson, Shailesh Singh, National Institute of Water & Atmospheric Research. The HIRDS software uses a regionalised index frequency method, and incorporates all available historical records and the available rainfall measurements to early 2017 gathered from multiple agencies. It produces estimates of high intensity rainfall at ungauged catchments for a range of return periods and event durations.

7.4. These rainfall figures show the one and two hour rainfalls are around 12 to 18% higher than the current 1% AEP (1 in 100 years) estimates and close to the 0.4% AEP (1 in 250 years) estimates. The 24 hours rainfall estimates are 28% higher than the 1% AEP estimates and 10% higher than the current 0.4% estimates. The rainfall return periods for this duration are higher than others because of an earlier 10 hour band of rain between 2200 hours on 17 May 2005 and 800 hours on 18 May 2005 – some 6 hours before the severe storm which commenced at 1600 hours.

7.5. Conversely, the 30 minutes rainfalls are just below the 1% AEP estimates.

7.6. The Awakaponga hyetograph is appended in the attached reports. It is clearly evident that at this site rainfalls were extreme for a period of 1.5 hours. The conclusions from the above data are that the significant rainfall had return periods between 200 and 500 years on known extreme value statistics, but could be more frequent as they are perhaps part of a different distribution of storms that we know little about. In my professional opinion it is wisest to regard them as around 12 to 18 percent greater than the 1% AEP rainfall intensities.

7.7. The one hour figure plots just below an envelope curve of New Zealand Record Rainfalls (NZ Meteorological Service Provisional List, October 1972). Whilst this curve would require some updating (the one hour record value has only increased to 107 mm, cf. Leigh, 30 May 2001), clearly this Matatā event is extremely rare in New Zealand’s experience.

7.8. Morphological evidence (of extreme flows based on scour that occurred) at both Matatā and the lower Manawahe area strongly indicates that rainfall intensities in the storm centre were somewhat higher again.

7.9. Other points evident from the rainfall records (refer to **Appendix 2**, 2019 report) are:

(a) The line of high intensity rainfall peaked just inside the coastline and travelled to at least Tumurau Lagoon (71 mm in one hour). The high intensity rainfall is evident from Tauranga Airport (58 mm in one hour) and Te Matai (57.7 mm in one hour). The Tauranga at Airport one hour rainfall is around 4% AEP and Te Matai figure is around 5% AEP (HIRDS V4);

(b) The band of very intense rain was narrow at Matatā. It was described by Mr R. Williamson whose residence in Herepuru

Road is 5.1 km from the coast, as heavy, but not unusual. Mr C. Mountfort, at 583 Herepuru Road (almost directly across the road from the Williamson house and 4.8 km from the coast), recorded 225 mm for 18 May 2005. Mr J. Ouwerhand, further up the road at number 808 (5.5 km from the coast), recorded 170 mm that day and 130 mm the next day. The Ohinekoao automatic rain gauge (4.1 km from the coast) recorded a peak one hour fall of 44.5 mm and 24 hour fall of 250 mm. These indicate decreasing 24 hour/daily rainfalls with distance from the coast;

(c) A curious fact is that, neglecting the one hour peak, the rainfall for 18 May 2005 at the Awakaponga, Tumurau and Ohinekoao gauges is very similar, at around 210 mm. Whilst the rainfall outside the peak period was similar, during the peak intensities the particularly extreme rainfall was confined to a relatively small area along and to the south of the Matatā escarpment. The high intensities were clearly not observed at the Ohinekoao gauge, nor those in Herepuru Road. However, in the Pikowai and Manawahe catchments the width of the band of rain reaches the divide, several kilometres inland. Maybe the steep increase in terrain at the Matatā catchments focussed the rain – particularly during the 1.5 hours at the peak of the storm; and

(d) Similarly, behind Te Puke, there was a significant one hour fall of 74 mm at Mangorewa. Whilst HIRDS V4 attributes this to be a 2% AEP event, it was the second such rainfall in six years. A rainfall frequency assessment of the 24 years of annual maxima data recorded by Regional Council concludes a frequency midway between 5% AEP and 2% AEP.

8. DESIGN RAINFALLS

8.1. Design rainfalls should be based on HIRDS Version 4, modified by orographic enhancement factors not included in the HIRDS database. These factors have proven necessary in past designs, after inspection of generated peak flows. They have been implemented after discussion with Dr C.Thompson, NIWA, who was a principal developer of the original HIRDS database.

8.2. Dr Thompson advised that HIRDS produces site data through a Gaussian interpolation between relevant rain gauges. This interpolation process takes no account of the significant orographic uplift at the high cliffs in the vicinity of Matatā. Whilst orographic enhancement is a very small component in convective (thunderstorm) rainfalls, it is clear that there is a very steep rainfall gradient immediately inland from the coast that is not represented in the HIRDS dataset. Thus, based on catchment location, it is considered that the HIRDS rainfalls should be increased by the following factors:

(a) Catchments immediately inland of the Matatā Coast by 1.30; and

(b) Awakaponga Stream catchment by 1.15.

9. GLOBAL WARMING

9.1. The impact of global warming includes both increases in sea levels and rainfall intensities. Whilst the increase in sea levels has been measurable for several decades and is forecast to accelerate, the increase in rainfall intensities had up until comparatively recently been less accurately forecast. Environment Bay of Plenty included a factor of 10 percent in the design of the Lake Rotorua outlet control structure, during its design in 1989. However, now much more detailed information is available and is presented in the HIRDS V4 database.

9.2. This information is presented for four scenarios for New Zealand, which align with those in the IPCC Fifth Assessment Report. Information on these scenarios is presented in several publications including those produced by the Ministry for the Environment, and specifically including the summary document "Climate Projections for New Zealand: Snapshot", June 2016, Ministry for the Environment (attached as **Appendix 3**).

9.3. These pathways are known as Representative Concentration Pathways (**RCPs**). They describe four alternative futures, in which scenarios of human activities result in different concentrations of greenhouse gases in the atmosphere. The four pathways are abbreviated as RCP2.6, RCP4.5, RCP6.0 and RCP8.5 and are:

(a) A low emissions, mitigation scenario (RCP2.6) in which global carbon dioxide emissions stop after 2080, after which some is actually removed from the atmosphere;

(b) A high emissions, business as usual scenario (RCP8.5); and

(c) Two middle scenarios (RCP4.5 and RCP6.0) which represent futures where global emissions stabilise at different levels.

10. GLOBAL WARMING IMPACTS ON STORM RAINFALLS

10.1. The impacts on storm rainfalls are presented in Table 5 of the HIRDS V4 publication. This is presented in Table Two.

Table Two: Percentage change factors per degree Celsius to project rainfall depths derived from the current climate to a future climate[1]

DURATION/ARI	2 YR	5 YR	10 YR	20 YR	30 YR	40 YR	50 YR	60 YR	80 YR	100 YR
1 HOUR	12.2	12.8	13.1	13.3	13.4	13.4	13.5	13.5	13.6	13.6
2 HOURS	11.7	12.3	12.6	12.8	12.9	12.9	13.0	13.0	13.1	13.1
6 HOURS	9.8	10.5	10.8	11.1	11.2	11.3	11.3	11.4	11.4	11.5
12 HOURS	8.5	9.2	9.5	9.7	9.8	9.9	9.9	10.0	10.0	10.1
24 HOURS	7.2	7.8	8.1	8.2	8.3	8.4	8.4	8.5	8.5	8.6
48 HOURS	6.1	6.7	7.0	7.2	7.3	7.3	7.4	7.4	7.5	7.5
72 HOURS	5.5	6.2	6.5	6.6	6.7	6.8	6.8	6.9	6.9	6.9
96 HOURS	5.1	5.7	6.0	6.2	6.3	6.3	6.4	6.4	6.4	6.5
120 HOURS	4.8	5.4	5.7	5.8	5.9	6.0	6.0	6.0	6.1	6.1

10.2. Based on the catchment times of concentration for Te Awatarariki catchment of 35 minutes (as per Mr PM West's detailed design flow estimates assessed in 2005) the increases will be around 13.6 percent per degree of climate change. Thus, design rainfalls and flows will markedly increase in the future, and storms of the nature of 18 May 2005 will occur more frequently.

10.3. Table Three presents details of the changes in the 1% AEP rainfalls to the period 2081-2100 for the one hour and two hour durations for the various future concentration pathways.

Table Three: Forecast changes in the 1% AEP design rainfalls (mm) to the period 2081-2100

1 This table is extracted from Table 5 of the report "High Intensity Rainfall Design System Version 4 – Prepared for Envirolink", NIWA, April 2018.

Climate Change Scenario	Rainfall Duration	
	1 hour	2 hours
18 May 2005 Depths	94.5	132.5
Current Climate	84.6	113
RCP2.6	91.4	122
RCP4.5	98.6	131
RCP6.0	103	137
RCP8.5	114	151

10.4. Table Four presents details of the changes in frequency of the 18 May 2005 rainfalls to the period 2081-2100 for the one hour and two hour durations.

Table Four: Forecast changes in frequency (years) of the 18 May 2005 rainfalls to the period 2081-2100

Climate Change Scenario	Rainfall Duration	
	1 hour	2 hours
Current Climate	200-500	200-500
RCP2.6	100-150	150-250
RCP4.5	80	100
RCP6.0	60	80
RCP8.5	40	50

10.5. The information in Table 4 indicates that the risk of these events increases by 1.3 to 12 times under the various scenarios.

10.6. Thus, it is plain that rainfall events of the nature that occurred at Matatā on 18 May 2005 will occur much more frequently. By the end of this century, under RCP 8.5 scenario these storms could be expected to occur on a 40 to 50 year return period, under RCP 6.0 on a 60 to 80 year return period.

11. CONCLUSION

11.1. The following are my key conclusions:

(a) This 18 May 2005 rainfall event was an extreme case of severe convection. The heavy rain was not driven by broadscale dynamic processes, and certainly no large scale orographically enhanced precipitation. The actual cause seems to have been a combination of abnormally warm, moist air, very unstable conditions and most importantly of all, a near stationary convergence line along the coastal fringe from Eastern Coromandel to Bay of Plenty (the trigger mechanism for the convection);

(b) The convergence basically enabled the torrential downpours and thunderstorms to continue to re-form in the same area over many hours, rather than move away in half an hour or so which is the usual case;

(c) Unfortunately, there were no automatic or manual rain gauges in the storm centre. The closest automatic gauge is at Awakaponga some 5 km SSE of Matatā. This recorded peak rainfall intensities at this gauge were:

 (i) An event total from 17 to 19 May of 367.5 mm;

 (ii) A peak 30 minute of 58 mm;

 (iii) A peak one hour of 94.5 mm;

 (iv) A peak two hour of 132.5 mm; and

 (v) A peak 24 hour of 307.5 mm.

(d) It is clearly evident that at this site rainfalls were extreme for a period of 1.5 hours. The severe storm rainfalls commenced at 1600 hours.

(e) The conclusions are that the significant rainfall had return periods between 200 and 500 years on known extreme value statistics but could be more frequent as they are perhaps part of a different distribution of storms that we know little about. In my professional opinion it is wisest to regard them as around 12 to 18 percent greater than the 1% AEP rainfall intensities.

(f) The impact of global warming includes both increases in sea levels and rainfall intensities. Whilst the increase in sea levels has been measurable for several decades and is forecast to accelerate, the increase in rainfall intensities had up until comparatively recently been less accurately forecast. However, now much more detailed information is available and is presented in the HIRDS V4 database.

(g) This information is presented for four scenarios for New Zealand, which align with those in the IPCC Fifth Assessment Report. Information on these scenarios is presented in several publications including those produced by the Ministry for the Environment, and specifically including the summary document "Climate Projections for New Zealand: Snapshot", June 2016, Ministry for the Environment (attached as **Appendix 3**).

(h) These pathways are known as RCPs. They describe four alternative futures, in which scenarios of human activities result in different concentrations of greenhouse gases in the atmosphere. The four pathways are abbreviated as RCP2.6, RCP4.5, RCP6.0 and RCP8.5 and are:

(i) A low emissions, mitigation scenario (RCP2.6) in which global carbon dioxide emissions stop after 2080, after which some is actually removed from the atmosphere;

(ii) A high emissions, business as usual scenario (RCP8.5); and

(iii) Two middle scenarios (RCP4.5 and RCP6.0) which represent futures where global emissions stabilise at different levels.

(i) It is plain that ongoing climate change effects will increase the frequency of rainfall events such as that which occurred at Matatā on 18 May 2005. By the end of this century, under RCP 8.5 scenario these storms could be expected to occur on a 40 to 50 year return period, and under RCP 6.0, on a 60 to 80 year return period.

Peter Lindsay Blackwood

15 January 2020

APPENDIX 1 – MATATA FLOODING 18 MAY 2005: METEOROLOGY

Matata Flooding 18 May 2005: Meteorology

Peter Blackwood
28 June 2005
File 5810 03 2005-06-28

Synoptic Situation

This event was an extreme case of severe convection. The heavy rain was not driven by broadscale dynamic processes, and certainly no large scale orographically enhanced precipitation. The actual cause seems to have been a combination of abnormally warm, moist air, very unstable conditions and most importantly of all, a near stationary convergence line along the coastal fringe from Eastern Coromandel to Bay of Plenty (the trigger mechanism for the convection). The convergence was between the weak northeast flow just offshore the coast and a weak southeast flow over the land. The convergence was considered weak, but remained slow moving along the coastal fringe for much of the 18th May. It basically allowed the torrential downpours and thunderstorms to continue to reform in the same area over many hours, rather than move away in half an hour or so which is the usual case. The significantly lower rainfall amounts about the main ranges of Bay of Plenty (and other inland areas) can be accounted for, by the fact that this convergence did not spread that far inland. (Andrew Downs, New Zealand MetService forecaster).

Peak Rainfalls

Peak rainfall intensities are presented in the appended tables. Unfortunately there were no automatic or manual rain gauges in the storm centre. The closest automatic gauge is at Awakaponga some 5km SSE of Matata. This had an event total over 17-19 May of 367.5mm, peak one hour 94.5mm and peak 24 hour 307.5mm. These latter two figures are both around 20% higher than the HIRDS 1% AEP estimates at Awakaponga and are between 2-500 years on known extreme value statistics – but are likely more frequent as they are perhaps part of a different distribution of storms that we know little about. It is best to regard them as being around 20 Percent greater than the 1% AEP estimated rainfall intensities. The one hour figure plots just below an envelope curve of New Zealand Record Rainfalls (NZ Meteorological Service Provisional List, October 1972). Whilst this curve would require some updating now, the one hour record value has only increased to 107mm (Leigh, 30 May 2001) and clearly this is an extremely rare event. The Awakaponga hyetograph is appended. It is clearly evident that at this site rainfalls were extreme for a period of 1.5 hours.

Morphological evidence at both Matata and the lower Manawahe area strongly indicates that rainfall intensities in the storm centre were somewhat higher again.

Other points evident from the rainfall records are:

1. The line of high intensity rainfall peaked just inside the coastline and travelled to at least Tumurau Lagoon (71mm in one hour). The high intensity rainfall is evident from Tauranga Airport (58mm in one hour) and Te Matai (57.7mm in one hour). The Te Matai figure is around 5% AEP (HIRDS).

2. The band of very intense rain was narrow at Matata. It was described by Mr R. Williamson whose residence in Herepuru Road is 5.1km from the coast, as heavy, but not unusual. Mr C.Mountfort, at 583 Herepuru Road (almost directly across the road from the Williamson house and 4.8 km from the coast) recorded 225mm for the 18th of May. My J. Ouwerhand further up the road at number 808 (5.5 km from the coast) recorded 170mm that day and 130mm the next day. The Ohinekoao automatic rain gauge (4.1 km from the coast) recorded a peak one hour fall of 44.5mm and 24 hour fall of 250mm. Therefore, there is a consistent decrease in 24 hour/daily rainfalls (the event was largely contained during the daily records of 18 May 2005) with distance from the coast.

3. A curious fact is that the rainfall for the 18th May outside the one hour peak at the Awakaponga and Ohinekoao gauges is very similar at around 210mm. Thus it appears that it was mainly during the peak intensities that the extreme rainfall was confined to a relatively small area.

4. However, in the Pikowai and Manawahe catchments the width of the band of rain reaches the divide, several km inland. Maybe the steep increase in terrain at the Matata catchments focussed the rain – particularly during the peak 1.5 hours.

5. Similarly, behind Te Puke, there was a significant one hour fall of 73mm at Mangorewa. Whilst, HIRDS, attributes this to be a 2% AEP event, it is the second such rainfall in six years (although there was a long period with these intensities absent prior to these events) and maybe around 5% AEP.

Design Rainfalls

Design rainfalls are based on HIRDS Version 1.50b, modified by orographic enhancement factors not included in the HIRDS database. These factors have proven necessary in past designs, after inspection of generated peak flows. They have been implemented after discussion with Dr C.Thompson, NIWA, who has carried out the principal production of HIRDS. Dr Thompson advises that HIRDS produces site data through a Gaussian interpolation between relevant rain gauges. In the case of the Matata catchments the relevant gauges are located at Thornton (10 km east on the coast), Mahoetahi (20 km inland in the Rotoeuhu forest) and Pongakawa (20 km west). This interpolation process takes no account of the significant orographic uplift at the high cliffs in the vicinity of Matata. Whilst orographic enhancement is a very small component in convective (thunderstorm) rainfalls, it is clear that there is a very steep rainfall gradient immediately inland from the coast, that is not represented in the HIRDS dataset. Thus, based on catchment location, the HIRDS rainfalls should be increased by the following factors:

Catchments immediately inland of the Matata Coast:	1.3
Awakaponga Stream:	1.15

Global Warming

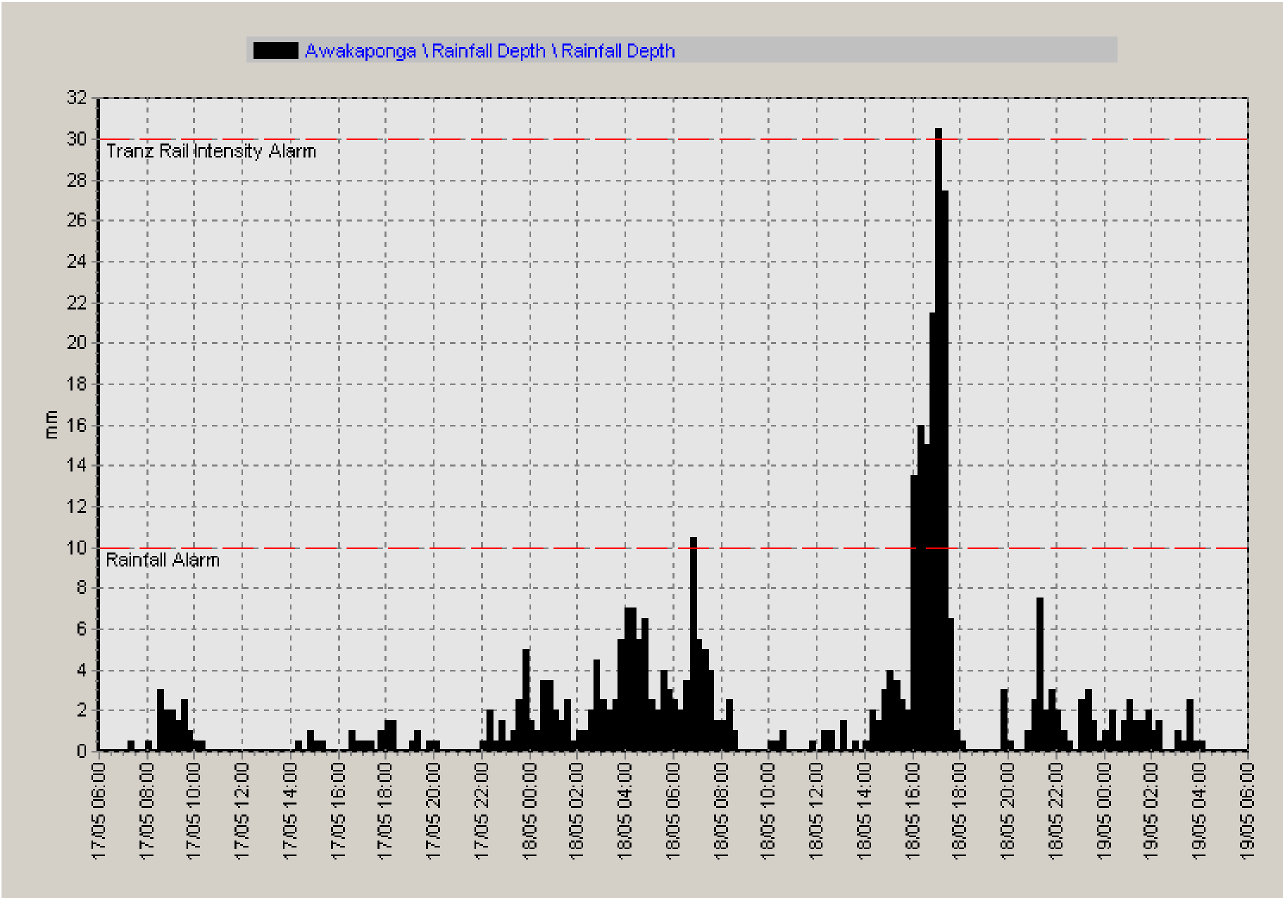
The impact of global warming includes both increases in sea levels and rainfall intensities. Whilst the increase in sea levels has been measurable for several decades and forecast to accelerate, the increase in rainfall intensities has been less accurately forecast. Environment Bay of Plenty included a factor of 10 percent in the design of the Lake Rotorua outlet control structure, during its design in 1989. Much more detailed information is produced in Table 5.2 (below) from the recently produced document "Overview of Climate Change Effects and Impact Assessment, A Guidance Note for Local Government in New Zealand", April 2003, New Zealand Climate Change Office, Ministry for the Environment. Based on the catchment times of concentration (varying 11 to 105 minutes) and the estimated mid range increase in temperature in the Bay of Plenty of 2.0 degrees Celsius by the year 2080, the estimated increase in rainfall intensity is assessed as 15 percent for storms of 2% AEP or larger.

Table 5.2: Factors for use in deriving extreme rainfall information for preliminary scenario studies (screening assessments)

ARI (years) → Duration ↓	2	5	10	20	30	50	60	70	80	90	100
< 10 minutes	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
10 minutes	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
30 minutes	7.4	7.5	7.6	7.6	7.7	7.7	7.7	7.7	7.7	7.7	7.7
1 hour	7.1	7.2	7.4	7.4	7.5	7.5	7.5	7.5	7.5	7.5	7.5
2 hours	6.7	7.0	7.1	7.2	7.3	7.3	7.3	7.3	7.4	7.4	7.4
3 hours	6.5	6.8	7.0	7.1	7.1	7.2	7.2	7.2	7.2	7.2	7.2
6 hours	6.3	6.6	6.8	7.0	7.0	7.1	7.1	7.1	7.1	7.1	7.1
12 hours	5.8	6.2	6.5	6.6	6.7	6.8	6.8	6.8	6.9	6.9	6.9
24 hours	5.4	5.9	6.2	6.4	6.5	6.6	6.6	6.6	6.7	6.7	6.7
48 hours	4.6	4.9	5.1	5.2	5.3	5.4	5.4	5.4	5.4	5.5	5.5
72 hours	4.3	4.6	4.8	5.0	5.1	5.2	5.2	5.2	5.3	5.3	5.3

Note: This table recommends *percentage* adjustments to apply to extreme rainfall *per degree Celsius of warming*, for a range of average recurrence intervals (ARIs.). The percentage changes are mid-range estimates per degree Celsius and should only be used in a preliminary scenario study. The entries in this table for durations of 24, 48 and 72 hours are based on results from a regional climate model driven by an equilibrium climate model, and will be updated once regional model runs driven by transient climate models are available for New Zealand. The entries for 10-minute duration are based on the theoretical increase in the amount of water held in the atmosphere for a 1°C increase in temperature (8%). Entries for durations between 10 minutes and 24 hours are based on logarithmic (in time) interpolation between the 10-minute and 24 hour rates.

APPENDICES



Awakaponga \ Rainfall Depth \ Rainfall Depth
mm
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Tranz Rail Intensity Alarm
Raintall Alarm
17/05 06:00
17/05 08:00
17/05 10:00
17/05 12:00
17/05 14:00
17/05 16:00
17/05 18:00
17/05 20:00
17/05 22:00
18/05 00:00
18/05 02:00
18/05 04:00
18/05 06:00
18/05 08:00
18/05 10:00
18/05 12:00
18/05 14:00
18/05 16:00
18/05 18:00
18/05 20:00
18/05 22:00
19/05 00:00
19/05 02:00
19/05 04:00
19/05 06:00

	Rainfall (mm) Recorded at Automatic Gauges								
	17-May-05				18-May-05				19-May-05
Site	**15 min max.**	**30 min max.**	**1 hour max.**	**24 hour total**	**15 min max.**	**30 min max.**	**1 hour max.**	**24 hour total**	**24 hour total**
Western Bay Catchments									
Tuapiro	6.5	10.0	13.0	70.5	3.0	4.5	7.0	25.0	11.0
Waipapa	2.5	4.0	7.5	42.5	3.5	3.5	5.0	31.0	10.5
Tauranga Airport	-	-	3.0	14.0	-	-	58.0	346.2	5.4
Kaituna Catchment									
Whakarewarewa	1.5	2.0	2.5	8.0	2.0	3.5	6.0	33.0	4.0
Rotorua Airport	-	-	3.6	12.8	-	-	8.4	62.2	3.2
Kaharoa	3.0	4.5	7.5	37.5	4.0	5.5	9.0	65.5	12.5
Mangorewa	3.0	5.0	8.5	32.5	22.0	41.0	73.0	220.0	12.5
Te Matai	4.0	7.0	9.5	36.0	4.0	34.5	57.5	216.0	9.5
Te Puke AWS	-	-	5.0	25.2	-	-	24.4	158.0	4.8
Central Catchments									
Pongakawa	4.5	7.0	12.5	31.5	11.5	12.5	16.5	126.5	15.5
Ohinekoao	6.0	9.5	12.5	39.5	13.0	23.5	44.5	250.0	44.0
Plains									
Tumurau Lagoon	4.0	7.0	9.5	37.5	21.0	39.0	71.0	274.5	33.0
Awakaponga	5.0	7.5	9.0	39.0	30.5	58.0	94.5	307.5	20.5
Thornton	2.5	4.5	8.0	28.5	17.5	32.5	44.0	109.5	22.5
Whakatane Airport	-	-	6.8	22.6	-	-	28.2	80.4	10.8
Rangitaiki Catchment									
Kokomoka	1.0	1.5	1.5	8.0	1.5	2.0	3.0	17.5	2.0
Whirinaki	2.0	3.5	4.5	13.5	12.0	16.5	20.5	76.5	8.5
Aniwhenua	3.0	4.0	6.0	19.5	7.0	11.0	15.5	109.5	12.0
Waimana Catchment									
Huiarau	2.0	3.5	6.5	21.5	7.5	11.0	14.0	47.5	8.5

Ranger Stn	1.5	3.0	5.5	13.0	4.0	5.0	6.5	37.5	6.0
Waioeka Catchment									
Koranga	1.0	2.0	3.5	14.5	1.0	2.0	3.0	12.0	2.0
Cableway	1.5	2.0	3.0	9.0	3.0	4.0	5.5	20.0	4.5
Mouth of Gorge	1.0	2.0	3.0	6.0	7.0	10.5	13.5	22.5	8.0
Otara Catchment									
Pakihi	1.0	2.0	3.0	4.5	2.0	3.0	4.0	9.0	4.5
Tutaetoko	1.0	2.0	3.5	9.0	6.5	8.5	12.0	21.5	3.5
Browns Bridge	1.0	1.5	2.5	5.0	4.5	5.5	7.5	15.0	6.0
Opotiki Wharf	1.0	1.0	1.5	4.0	4.0	7.0	7.5	19.0	9.0

2005 FLOOD EVENT

Name	Address	NZMS260 Map Ref	Time	15-May	16-May	17-May	18-May	19-May	20-May	21-May
Public Raingauges										
D Beattie	16 Kauri St	V15: 4618 5117	8:00		40.0	8.0	158.0	185.0	28.0	4.0
A Sturme	941 Edgecumbe Rd SH2	V15: 4407 5309			40.0	5.0	160.0	68.0	25.0	4.5
D Jenkins	34 Rimu St	V15: 4606 5042	8:00		31.0	15.0	141.0	95.0	21.0	4.0
D Kendell	19 Puriri Cres	V15: 4620 5173	9:00		34.0	9.0	150.0	43.0	57.0	4.0
J Gibbons-Davies	9 Totara St	V15: 4629 5075			41.0	10.0	112.0	110.0	25.0	8.0
I Beasley	517 Greig Rd	V15: 4475 5946	7.00		35.0	19.0	70.0	172.0	21.0	3.0
J Gow	30 Colebrook Rd	V15: 4513 5526	8.00		35.0	8.5	150.0	137.0	22.0	14.0
P Gow	396 Westbank Rd	V15: 4703 5506	8.00		34.0	27.0	172.0	69.0	6.0	5.0
A Moore	Moore Rd	V15: 4937 5845	18.00	0.0	29.0	23.0	127.0	61.0	6.0	7.0
I Blackwood	84 Hallett Rd	V15: 4038 4966	8.00		48.0	11.0	155.0	20.0	25.0	
H Whyte	Hallett Rd	V15: 4028 4851					40.0	306.0	18.0	4.0
E Roe	588 Braemar Rd	V15: 3854 5273	08:30		45.0	10.0	155.0	190.0	38.0	13.0
J Woodrow	820 Braemar Rd	V15: 3699 4996	07:30	0.0	43.0	12.0	150.0	107.0	31.0	14.0
B Comyns	2060 Manawahe Rd	V15: 2875 4960			25.0	12.0	100.0	72.0	26.0	26.0
C Mountfort	583 Herepuru Rd	V15: 3570 5851			46.0	24.0	225.0	90.0	20.0	20.0
Ouwehand	808 Herepuru Rd	V15: 3405 5849			51.0	8.0	170.0	130.0	24.0	30.0
ENVIRONMENT BOP Automatic Raingauges										
Mimiha Upper		V15:3494 6146	0:00	1	35	21	238	37	22	2
Ohinekoao		V15: 3618 5932	0:00	1	44	40	250	44	33	2
Tumurau Lagoon		V15: 383 523	0:00	2	51	38	275	33	24	1
Tarawera at Awakaponga		V15: 415 555	0:00	1	40	39	302	29	11	1
Rangitaiki at Thornton		W15: 507 576	0:00	1	29	29	110	50	3	6

APPENDIX 2 – MATATA FLOODING 18 MAY 2005: METEOROLOGY (UPDATED 13 DECEMBER 2019)

Matata Flooding 18 May 2005: Meteorology Update

Peter Blackwood[1] and Tom Bassett[2]
13 December 2019
File

Introduction

This report updates the report entitled "Matatā Flooding 18 May 2005: Meteorology", Peter Blackwood, 28 June 2005, File 5810 03 2005-06-28. The update focusses on the updated rainfall frequency information now available, and the latest information on climate change estimates. All the other information in the 2005 report is repeated largely unaltered for completeness of this report. Some further detail on the rainfall intensities has been added.

Synoptic Situation

This event was an extreme case of severe convection. The heavy rain was not driven by broadscale dynamic processes, and certainly no large scale orographically enhanced precipitation. The actual cause seems to have been a combination of abnormally warm, moist air, very unstable conditions and most importantly of all, a near stationary convergence line along the coastal fringe from Eastern Coromandel to Bay of Plenty (the trigger mechanism for the convection).

The convergence was between the weak northeast flow just offshore of the coastline and a weak southeast flow over the land. The convergence was considered weak, but remained slow-moving along the coastal fringe for much of the 18th May. It basically enabled the torrential downpours and thunderstorms to continue to re-form in the same area over many hours, rather than move away in half an hour or so which is the usual case.

The significantly lower rainfall amounts about the main ranges of Bay of Plenty (and other inland areas) can be accounted for, by the fact that this convergence did not spread that far inland (Andrew Downs, New Zealand MetService forecaster, pers comm 2005).

Peak Rainfalls

Peak rainfall intensities are presented in the appended tables. Unfortunately there were no automatic or manual rain gauges in the storm centre. The closest automatic gauge is at Awakaponga some 5 km SSE of Matata. This recorded:

- an event total from 17 to 19 May of 367.5 mm
- peak 30 minute 58 mm
- peak one hour 94.5 mm
- peak two hour 132.5 mm
- peak 24 hour 307.5 mm.

Table One below presents depth-duration-frequency data for rainfall at Awakaponga based on the High Intensity Rainfall Design System (HIRDS) Version 4, together with the recorded rainfall depths on 18 May.

The HIRDS Version 4 software is documented in the publication "High Intensity Rainfall Design System Version 4", Prepared for Envirolink, January 2018, Trevor Carey-Smith, Roddy Henderson, Shailesh Singh, National Institute of Water & Atmospheric Research. The HIRDS software uses a regionalised index frequency method, and incorporates all available historical records and the available rainfall measurements to early 2017 gathered from multiple agencies. It produces

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[2] Water Engineering Consultant, Tonkin & Taylor Ltd

estimates of high intensity rainfall at ungauged catchments for a range of return periods and event durations.

Table One:
Rainfall Depths in 18 May 2005 Storm and HIRDS V4 Design Rainfall Estimates (mm)

AEP (percent)	Return Period (years)	Rainfall Duration			
		30 minutes	**1 hour**	**2 hours**	**24 hours**
1	100	61.3	84.6	113	241
0.4	250	71.8	99	132	279
18 May 2005 depths		58	94.5	132.5	307.5

These rainfall figures show the one and two hour rainfalls are around 12 to 18% higher than the current 1% AEP (1 in 100 years) estimates and close to the 0.4% AEP (1 in 250 years) estimates. The 24 hours rainfall estimates are 28% higher than the 1% AEP estimates and 10% higher than the current 0.4% estimates. The rainfall return periods for this duration are higher than others because of an earlier 10 hour band of rain between 2200 hours on 17 May 2005 and 800 hours on 18 May 2005 – some 6 hours before the severe storm which commenced at 1600 hours.

Conversely the 30 minutes rainfalls are just below the 1% AEP estimates.

The Awakaponga hyetograph is appended (Appendix One). It is clearly evident that at this site rainfalls were extreme for a period of 1.5 hours. The conclusions from the above data are that the significant rainfall had return periods between 200 and 500 years on known extreme value statistics, but could be more frequent as they are perhaps part of a different distribution of storms that we know little about. It is wisest to regard them as around 12 to 18 Percent greater than the 1% AEP rainfall intensities.

The one hour figure plots just below an envelope curve of New Zealand Record Rainfalls (NZ Meteorological Service Provisional List, October 1972). Whilst this curve would require some updating (the one hour record value has only increased to 107 mm, cf. Leigh, 30 May 2001), clearly this Matatā event is extremely rare in New Zealand experience.

Morphological evidence (of extreme flows based on scour that occurred) at both Matata and the lower Manawahe area strongly indicates that rainfall intensities in the storm centre were somewhat higher again.

Other points evident from the rainfall records (refer Appendix Two) are:

1. The line of high intensity rainfall peaked just inside the coastline and travelled to at least Tumurau Lagoon (71 mm in one hour). The high intensity rainfall is evident from Tauranga Airport (58 mm in one hour) and Te Matai (57.7 mm in one hour). The Tauranga at Airport one hour rainfall is around 4% AEP and Te Matai figure is around 5% AEP (HIRDS V4).

2. The band of very intense rain was narrow at Matata. It was described by Mr R. Williamson whose residence in Herepuru Road is 5.1 km from the coast, as heavy, but not unusual. Mr C. Mountfort, at 583 Herepuru Road (almost directly across the road from the Williamson house and 4.8 km from the coast) recorded 225 mm for the 18th of May. Mr J. Ouwerhand further up the road at number 808 (5.5 km from the coast) recorded 170 mm that day and 130 mm the next day. The Ohinekoao automatic rain gauge (4.1 km from the coast) recorded a peak one hour fall of 44.5 mm and 24 hour fall of 250 mm. These indicate decreasing 24 hour/daily rainfalls with distance from the coast.

3. A curious fact is that, neglecting the one hour peak, the rainfall for the 18th May at the Awakaponga, Tumurau and Ohinekoao gauges is very similar, at around 210 mm. Whilst the rainfall outside the peak period was similar, during the peak intensities the particularly extreme

rainfall was confined to a relatively small area along and to the south of the Matata escarpment. The high intensities were clearly not observed at the Ohinekoao gauge, nor those in Herepuru Road (both referenced in point 2).

4. However, in the Pikowai and Manawahe catchments the width of the band of rain reaches the divide, several kilometres inland. Maybe the steep increase in terrain at the Matata catchments focussed the rain – particularly during the 1.5 hours at the peak of the storm.

5. Similarly, behind Te Puke, there was a significant one hour fall of 74 mm at Mangorewa. Whilst, HIRDS V4, attributes this to be a 2% AEP event, it was the second such rainfall in six years. A rainfall frequency assessment of the 24 years of annual maxima data recorded by Bay of Plenty Regional Council concludes a frequency midway between 5% AEP and 2% AEP.

Design Rainfalls

Design rainfalls should be based on HIRDS Version 4, modified by orographic enhancement factors not included in the HIRDS database. These factors have proven necessary in past designs, after inspection of generated peak flows. They have been implemented after discussion with Dr C.Thompson, NIWA, who was a principal developer of the HIRDS database.

Dr Thompson advised that HIRDS produces site data through a Gaussian interpolation between relevant rain gauges. In the case of the Matata catchments the relevant gauges are located at Thornton (10 km east on the coast), Mahoetahi (20 km inland in the Rotoeuhu forest) and Pongakawa (20 km west). This interpolation process takes no account of the significant orographic uplift at the high cliffs in the vicinity of Matata.

Whilst orographic enhancement is a very small component in convective (thunderstorm) rainfalls, it is clear that there is a very steep rainfall gradient immediately inland from the coast that is not represented in the HIRDS dataset. Thus, based on catchment location, it is considered that the HIRDS rainfalls should be increased by the following factors:

- Catchments immediately inland of the Matata Coast 1.30
- Awakaponga Stream catchment 1.15

Global Warming

The impact of global warming includes both increases in sea levels and rainfall intensities. Whilst the increase in sea levels has been measurable for several decades and is forecast to accelerate, the increase in rainfall intensities had up until comparatively recently been less accurately forecast. Environment Bay of Plenty included a factor of 10 percent in the design of the Lake Rotorua outlet control structure, during its design in 1989. However, now much more detailed information is available and is presented in the HIRDS V4 database.

This information is presented for four scenarios for New Zealand, which align with those in the IPCC Fifth Assessment Report. Information on these scenarios is presented in several publications including those produced by the Ministry for the Environment, and specifically including the summary document "Climate Projections for New Zealand: Snapshot", June 2016, Ministry for the Environment, attached as Appendix Three.

These pathways are known as Representative Concentration Pathways (RCPs). They describe four alternative futures, in which scenarios of human activities result in different concentrations of greenhouse gases in the atmosphere. The four pathways are abbreviated as RCP2.6, RCP4.5, RCP6.0 and RCP8.5 and are:

- a low emissions, mitigation scenario (RCP2.6) in which global carbon dioxide emissions stop after 2080, after which some is actually removed from the atmosphere;
- a high emissions, business as usual scenario (RCP8.5); and
- two middle scenarios (RCP4.5 and RCP6.0) which represent futures where global emissions stabilise at different levels.

Global Warming Impacts on Storm Rainfalls

The impacts on storm rainfalls are presented in Table 5 of the HIRDS V4 publication. This is presented in Table Two.

Table Two: Percentage change factors per degree Celsius to project rainfall depths derived from the current climate to a future climate

DURATION/ARI	2 YR	5 YR	10 YR	20 YR	30 YR	40 YR	50 YR	60 YR	80 YR	100 YR
1 HOUR	12.2	12.8	13.1	13.3	13.4	13.4	13.5	13.5	13.6	13.6
2 HOURS	11.7	12.3	12.6	12.8	12.9	12.9	13.0	13.0	13.1	13.1
6 HOURS	9.8	10.5	10.8	11.1	11.2	11.3	11.3	11.4	11.4	11.5
12 HOURS	8.5	9.2	9.5	9.7	9.8	9.9	9.9	10.0	10.0	10.1
24 HOURS	7.2	7.8	8.1	8.2	8.3	8.4	8.4	8.5	8.5	8.6
48 HOURS	6.1	6.7	7.0	7.2	7.3	7.3	7.4	7.4	7.5	7.5
72 HOURS	5.5	6.2	6.5	6.6	6.7	6.8	6.8	6.9	6.9	6.9
96 HOURS	5.1	5.7	6.0	6.2	6.3	6.3	6.4	6.4	6.4	6.5
120 HOURS	4.8	5.4	5.7	5.8	5.9	6.0	6.0	6.0	6.1	6.1

Note this table is from Table 5 of the report "High Intensity Rainfall Design System Version 4 – Prepared for Envirolink", NIWA, April 2018.

Based on the catchment times of concentration for the Te Awatarariki catchment of 35 minutes (as per Mr PM West's detailed design flow estimates assessed in 2005) the increases will be around 13.6 percent per degree of climate change. Thus, design rainfalls and flows will markedly increase in the future, and storms of the nature of 18 May 2005 will occur more frequently.

Table Three presents details of the changes in the 1% AEP rainfalls to the period 2081-2100 for the one hour and two hour durations for the various future concentration pathways.

Table Three: Forecast changes in the 1% AEP design rainfalls (mm) to the period 2081-2100

Climate Change Scenario	Rainfall Duration	
	1 hour	2 hours
18 May 2005 Depths	94.5	132.5
Current Climate	84.6	113
RCP2.6	91.4	122
RCP4.5	98.6	131
RCP6.0	103	137
RCP8.5	114	151

Table Four presents details of the changes in frequency of the 18 May 2005 rainfalls to the period 2081-2100 for the one hour and two hour durations.

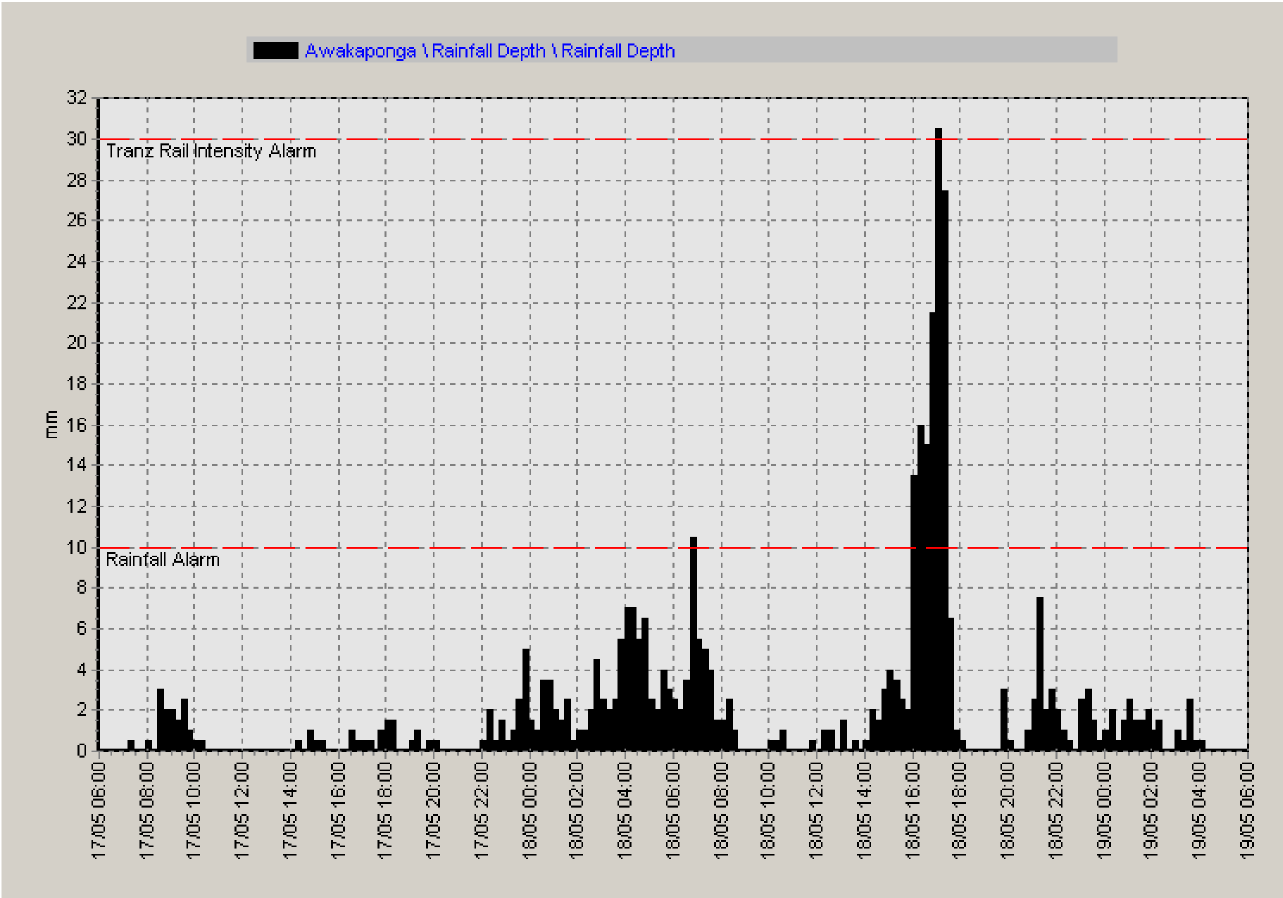
Table Four:
Forecast changes in frequency (years) of the 18 May 2005 rainfalls to the period 2081-2100

Climate Change Scenario	Rainfall Duration	
	1 hour	2 hours
Current Climate	200-500	200-500
RCP2.6	100-150	150-250
RCP4.5	80	100
RCP6.0	60	80
RCP8.5	40	50

Thus, it is plain that rainfall events of nature that occurred at Matatā on 18 May 2005 will occur much more frequently. By the end of this century, under RCP 8.5 scenario these storms could be expected to occur on a 40 to 50 year return period, under RCP 6.0 on a 60 to 80 year return period.

APPENDICES

APPENDIX ONE: Hyetograph of rainfall at Tarawera at Awakaponga Site over 17-19 May 2005



APPENDIX TWO: Rainfall Recorded at Automatic and Public Rain Gauges over 17-19 May 2005

	Rainfall (mm) Recorded at Automatic Gauges										
	17-May-05				18-May-05				19-May-05		22-May-05
Site	15 min maximum	30 min maximum	1 hour maximum	24 hour total	15 min maximum	30 min maximum	1 hour maximum	24 hour total	24 hour total	Event total	24 hour total
Western Bay Catchments											
Tuapiro	6.5	10.0	13.0	70.5	3.0	4.5	7.0	25.0	11.0	106.5	24.5
Waipapa	2.5	4.0	7.5	42.5	3.5	3.5	5.0	31.0	10.5	84.0	41.0
Tauranga Airport	-	-	3.0	14.0	-	-	58.0	346.2	5.4	365.6	-
Kaituna Catchment											
Whakarewarewa	1.5	2.0	2.5	8.0	2.0	3.5	6.0	33.0	4.0	45.0	11.0
Rotorua Airport	-	-	3.6	12.8	-	-	8.4	62.2	3.2	78.2	
Kaharoa	3.0	4.5	7.5	37.5	4.0	5.5	9.0	65.5	12.5	115.5	31.0
Mangorewa	3.0	5.0	8.5	32.5	22.0	41.0	73.0	220.0	12.5	265.0	34.5
Te Matai	4.0	7.0	9.5	36.0	4.0	34.5	57.5	216.0	9.5	261.5	15.5
Te Puke AWS	-	-	5.0	25.2	-	-	24.4	158.0	4.8	188.0	-
Central Catchments											
Pongakawa	4.5	7.0	12.5	31.5	11.5	12.5	16.5	126.5	15.5	173.5	34.0
Ohinekoao	6.0	9.5	12.5	39.5	13.0	23.5	44.5	250.0	44.0	333.5	36.0
Plains											
Tumurau Lagoon	4.0	7.0	9.5	37.5	21.0	39.0	71.0	274.5	33.0	345.0	40.5
Awakaponga	5.0	7.5	9.0	39.0	30.5	58.0	94.5	307.5	20.5	367.0	25.0
Thornton	2.5	4.5	8.0	28.5	17.5	32.5	44.0	109.5	22.5	160.5	24.0
Whakatane Airport	-	-	6.8	22.6	-	-	28.2	80.4	10.8	113.8	-
Rangitaiki Catchment											
Kokomoka	1.0	1.5	1.5	8.0	1.5	2.0	3.0	17.5	2.0	27.5	18.5
Whirinaki	2.0	3.5	4.5	13.5	12.0	16.5	20.5	76.5	8.5	98.5	11.5
Aniwhenua	3.0	4.0	6.0	19.5	7.0	11.0	15.5	109.5	12.0	141.0	26.0
Waimana Catchment											

Huiarau	2.0	3.5	6.5	21.5	7.5	11.0	14.0	47.5	8.5	77.5	27.5
Ranger Stn	1.5	3.0	5.5	13.0	4.0	5.0	6.5	37.5	6.0	56.5	50.0
Waioeka Catchment											
Koranga	1.0	2.0	3.5	14.5	1.0	2.0	3.0	12.0	2.0	28.5	33.5
Cableway	1.5	2.0	3.0	9.0	3.0	4.0	5.5	20.0	4.5	33.5	56.5
Mouth of Gorge	1.0	2.0	3.0	6.0	7.0	10.5	13.5	22.5	8.0	36.5	38.5
Otara Catchment											
Pakihi	1.0	2.0	3.0	4.5	2.0	3.0	4.0	9.0	4.5	18.0	45.5
Tutaetoko	1.0	2.0	3.5	9.0	6.5	8.5	12.0	21.5	3.5	34.0	37.0
Browns Bridge	1.0	1.5	2.5	5.0	4.5	5.5	7.5	15.0	6.0	26.0	38.5
Opotiki Wharf	1.0	1.0	1.5	4.0	4.0	7.0	7.5	19.0	9.0	32.0	26.0

2005 FLOOD EVENT

Name		NZMS260 Map Ref	Time	15-May	16-May	17-May	18-May	19-May	20-May	21-May	22-May	23-May	Total 18 - 19 May inclusive	
Public Rain gauges	**Address**													
D Beattie	16 Kauri St	V15: 4618 5117	8:00		40.0	8.0	158.0	185.0	28.0	4.0	0.0	30.0	343.0	
A Sturme	941 Edgecumbe Rd SH2	V15: 4407 5309			40.0	5.0	160.0	68.0	25.0	4.5		30.0	228.0	
D Jenkins	34 Rimu St	V15: 4606 5042	8:00		31.0	15.0	141.0	95.0	21.0	4.0	2.0	24.0	236.0	
D Kendell	19 Puriri Cres	V15: 4620 5173	9:00		34.0	9.0	150.0	43.0	57.0	4.0	0.0	26.0	193.0	
J Gibbons-Davies	9 Totara St	V15: 4629 5075			41.0	10.0	112.0	110.0	25.0	8.0	1.0		222.0	
I Beasley	517 Greig Rd	V15: 4475 5946	7.00		35.0	19.0	70.0	172.0	21.0	3.0	0.0	27.0	242.0	
J Gow	30 Colebrook Rd	V15: 4513 5526	8.00		35.0	8.5	150.0	137.0	22.0	14.0	4.5	29.0	287.0	Between 1500 & 1630 82mm recorded
P Gow	396 Westbank Rd	V15: 4703 5506	8.00		34.0	27.0	172.0	69.0	6.0	5.0	24.0	1.0	241.0	
A Moore	Moore Rd	V15: 4937 5845	18.00	0.0	29.0	23.0	127.0	61.0	6.0	7.0			188.0	
I Blackwood	84 Hallett Rd	V15: 4038 4966	8.00		48.0	11.0	155.0	20.0	25.0				175.0	
H Whyte	Hallett Rd	V15: 4028 4851					40.0	306.0	18.0	4.0	1.0		346.0	
E Roe	588 Braemar Rd	V15: 3854 5273	08:30		45.0	10.0	155.0	190.0	38.0	13.0	10.0	38.0	345.0	
J Woodrow	820 Braemar Rd	V15: 3699 4996	07:30	0.0	43.0	12.0	150.0	107.0	31.0	14.0	2.0	42.0	257.0	
B Comyns	2060 Manawahe Rd	V15: 2875 4960			25.0	12.0	100.0	72.0	26.0	26.0	1.0	33.0	172.0	
C Mountfort	583 Herepuru Rd	V15: 3570 5851			46.0	24.0	225.0	90.0	20.0	20.0	22.0	40.0	315.0	
Ouwehand	808 Herepuru Rd	V15: 3405 5849			51.0	8.0	170.0	130.0	24.0	30.0			300.0	
ENVIRONMENT BOP Automatic Raingauges														
Mimiha Upper		V15:3494 6146	0:00	1	35	21	238	37	22	2	26	0	274.0	
Ohinekoao		V15: 3618 5932	0:00	1	44	40	250	44	33	2	36	0	294.0	
Tumurau Lagoon		V15: 383 523	0:00	2	51	38	275	33	24	1	41	0	308.0	
Tarawera at Awakaponga		V15: 415 555	0:00	1	40	39	302	29	11	1	25	0	331.0	
Rangitaiki at Thornton		W15: 507 576	0:00	1	29	29	110	50	3	6	24	0	160.0	

APPENDIX THREE: Publication “Climate Projections for New Zealand: Snapshot”, June 2016, Ministry for the Environment

APPENDIX 3 - "CLIMATE PROJECTIONS FOR NEW ZEALAND: SNAPSHOT", JUNE 2016, MINISTRY FOR THE ENVIRONMENT

Ministry for the Environment
Manatū Mō Te Taiao

SNAPSHOT
JUNE 2016
INFO 765

CLIMATE PROJECTIONS FOR NEW ZEALAND

Introduction

The climate is changing. All governments accept that further changes will result from increasing amounts of greenhouse gases in the atmosphere. Reductions of greenhouse gas emissions can slow the rate, but climate change cannot be prevented entirely. In New Zealand, changes in key climate parameters – such as temperature and rainfall – are already occurring. These changes will occur to differing extents in different parts of New Zealand throughout the 21st century and beyond.

This snapshot of climate projections for New Zealand summarises the main elements of a comprehensive technical report: *Climate Change Projections for New Zealand*. It updates the climate projections for New Zealand following the release of the Intergovernmental Panel on Climate Change (IPCC)'s Fifth Assessment Report in 2014. NIWA scientists used a supercomputer to produce climate projections for the New Zealand region on a 5 km grid, based on the results from coarser global climate models. They produced a report for the Ministry for the Environment which addresses possible changes in New Zealand's climate over the next 100 years, and is available in full at: **www.mfe.govt.nz/node/21990**

Current climate variability

New Zealand's climate varies naturally from year to year and from decade to decade. It is the combination of natural variation and human-induced long-term trends that will provide the climate extremes to which future New Zealand society will be exposed. Much of the natural variation is apparently random; however there are some cyclical elements.

In individual years, annual New Zealand-wide temperatures can deviate from the long-term average by up to 1°C (plus or minus). However, despite these fluctuations, there has been a long-term increase of around 0.9°C over the last century. Similarly, annual rainfall can deviate from its long-term average, by about plus or minus 20 per cent.

Key points

According to the 2016 climate projections, New Zealand will likely experience:

> Higher temperatures, with an increase of about 0.7°C (low emissions scenario) and 1.0°C (high emissions scenario) by 2040 and about 0.7°C (low emissions scenario) and 3.0°C (high emissions scenario) by 2090. There will likely be slight gradients from north to south, and from east to west, with the greatest warming experienced in the northeast.

> A change in rainfall patterns – increased summer rainfall in the north and east of the North Island, and increased winter rainfall in many parts of the South Island. Decreased spring rainfall in the north and east of the North Island, and in the south and east of the South Island.

> Increased frequency of dry days for much of the North Island, and for some parts of the South Island. Increased frequency of heavy rainfall events over the South Island and some parts of the North Island.

> Increased frequency and intensity of droughts over time, particularly under a high emissions scenario. The strongest increases are over the northern and eastern North Island and along the eastern side of the Southern Alps.

> Some increase in storm intensity, small-scale wind extremes and thunderstorms is likely to occur. Ex-tropical cyclones will likely be stronger and cause more damage as a result of heavy rain and strong winds.

> Increased northeasterly airflow in summer and stronger westerlies in winter, particularly in the south.

> Increase in the number of hot days, and decrease in the number of frost days and snow days.

Future climate

What our climate looks like in the future depends on the future concentrations of greenhouse gases, and on how the global climate system will respond to these. Our projections are based on several different scenarios ranging from low to high emissions, and include different levels of emissions reductions. Future greenhouse gas concentrations depend on future emissions, which in turn depend on national and international policies, changes in population, economic growth, technology, and energy availability.

Because natural effects cause the New Zealand climate to vary from year to year, the changes are specified in terms of the average change for the twenty-year periods 2031–2050 (referred to in this snapshot as 2040), and 2081–2100 (similarly referred to as 2090), relative to the climate of 1986–2005 (1995).

Emissions scenarios

We consider four scenarios for New Zealand, which align with those in the IPCC Fifth Assessment Report. These pathways are known as Representative Concentration Pathways (RCPs)[1]. The four pathways are abbreviated as RCP2.6, RCP4.5, RCP6.0, and RCP8.5, in order of increasing radiative forcing[2] by greenhouse gases at the end of this century. They are:

> a low emissions, mitigation scenario (RCP2.6), in which global carbon dioxide emissions stop after 2080, after which some is actually removed from the atmosphere

> a high emissions, business as usual scenario (RCP8.5)

> two middle scenarios (RCP4.5 and RCP6.0) which represent futures where global emissions stabilise at different levels.

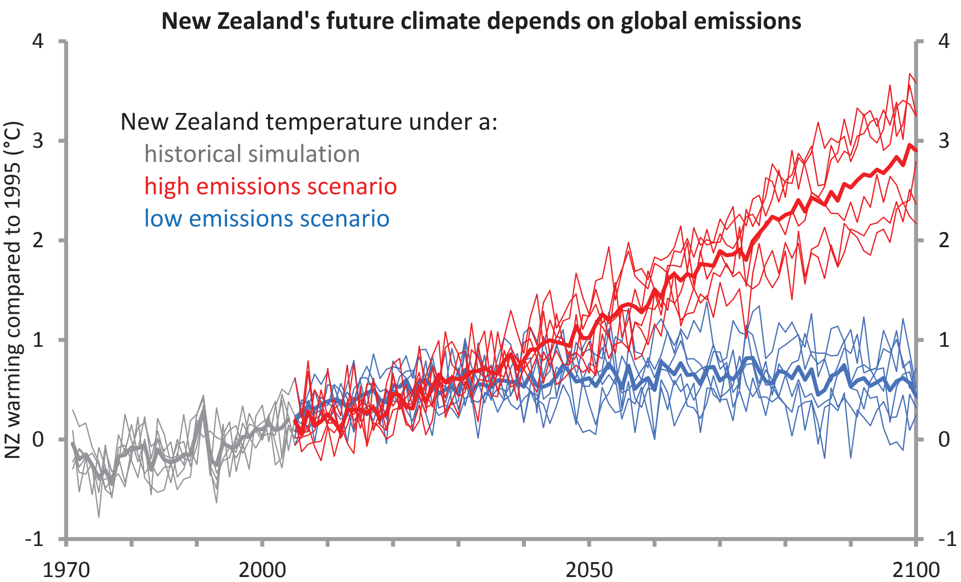
These differ from the scenarios used in the previous climate projections for New Zealand, which were based on the IPCC Fourth Assessment Report (2007). Notably, a new scenario is included which simulates success in limiting global warming to 2°C on pre-industrial levels, the internationally agreed limit. The Paris Agreement also recognises that limiting warming to 1.5°C (on pre-industrial levels) would significantly reduce climate change impacts.

Changes in temperature

According to the projections, by 2040 New Zealand temperatures will warm by about 0.7°C under the low emissions scenario (with an uncertainty range of 0.2-1.3°C) and by about 1.0°C (0.5-1.7°C) under the high emissions scenario, in relation to the 1995 baseline. By 2090, temperatures will increase by about 0.7°C (0.1-1.4°C) under the low emissions scenario and by about 3.0°C (2.0-4.6°C) under the high emissions scenario.

The pattern of annual average warming is expected to be fairly uniform across the country, with slight gradients from north to south and from east to west. The North Island is expected to experience slightly greater warming than the South Island. The warming is generally highest in summer and autumn and lowest in winter and spring.

Figure 1: New Zealand's future temperature depends on global greenhouse gas emissions. The warming will probably lie between the red and blue bands, which represent the extreme high- and low- emissions scenarios modelled in the IPCC 5th Assessment Report (2014). Different models (thin lines) project different amounts of warming under the same scenario, and year-to-year variability will continue as in the past. The thick line shows the average for each scenario, as reported in these new projections.

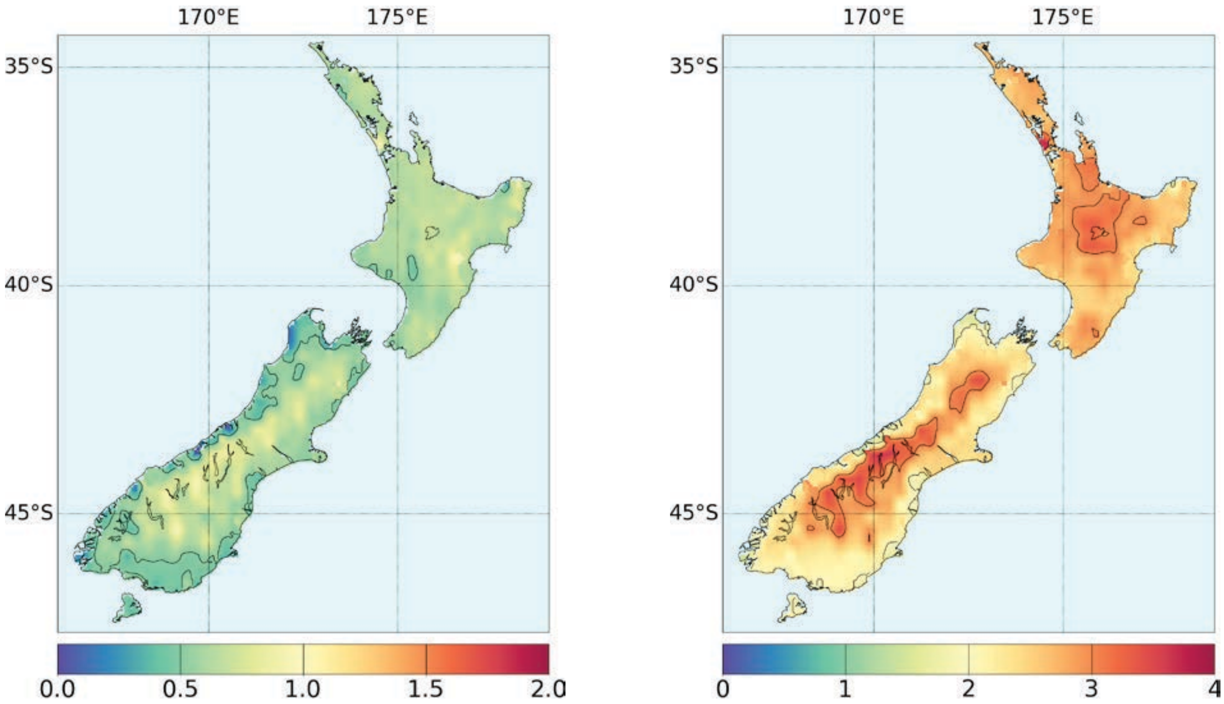


1 The Representative Concentration Pathways (RCPs) are greenhouse gas concentration scenarios adopted by the IPCC for its Fifth Assessment Report. They describe four alternative futures, in which possible scenarios of human activities result in different concentrations of greenhouse gases in the atmosphere.

2 Radiative forcing is a measure of the energy absorbed and retained in the lower atmosphere.

Figure 2: Projected annual average temperature changes by 2090 under the RCP2.6 low emissions scenario (left) and the RCP8.5 high emissions scenario (right), relative to the 1995 baseline. Note the colour scales used are different for the two maps, in order to show each scenario more clearly.

Average change in temperature (°C) by 2090 under RCP2.6 (left) and RCP8.5 (right)



Projected changes in rainfall

Rainfall projections are highly variable by region and season. The overall pattern for changes in annual rainfall is a reduction in the north and east of the North Island, and increases almost everywhere else, especially on the South Island West Coast. It is *very likely*[3] that for winter and spring there will be an increase in rainfall for the west of both the North and the South Island, with drier conditions in the east and north. For summer it is *likely* that there will be wetter conditions in the east of both islands, with drier conditions in the west and central North Island.

The largest rainfall changes by the end of the century will be for particular seasons rather than annually.

> In spring, decreases for Northland, Auckland, and Bay of Plenty, and increases for Otago (Queenstown) and Southland.

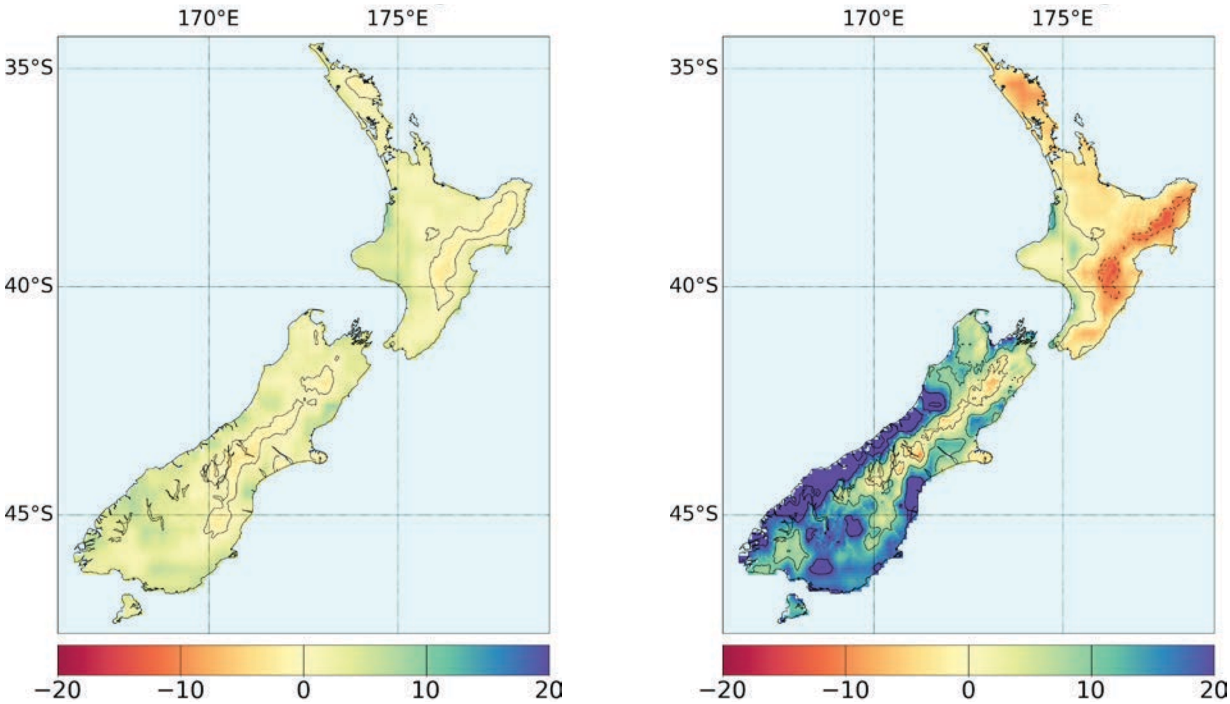
> In winter, decreases for Waikato, Gisborne, Hawkes Bay and Canterbury (Christchurch and Hanmer Springs), and increases for Tasman-Nelson (Nelson), West Coast, Canterbury (Tekapo), Otago (Dunedin), Southland and Chatham Islands.

Changes in ocean and atmospheric circulation patterns projected by the models are consistent with the projected changes in rainfall. Mean sea level pressure is projected to increase over the North Island and east and south of the South Island in the summer season, resulting in more north-easterly airflow and more anticyclonic (high pressure) conditions, consistent with increased rainfall to the northeast. Pressures decrease south of New Zealand in winter, resulting in stronger average westerlies over central and southern New Zealand and increased rainfall in these regions.

3 IPCC terminology for indicating the assessed likelihood of an outcome or result: virtually certain 99–100% probability, very likely 90–100%, likely 66–100%, about as likely as not 33–66%, unlikely 0–33%, very unlikely 0–10%, exceptionally unlikely 0–1%. Additional terms (extremely likely: 95–100%, more likely than not >50–100%, and extremely unlikely 0–5%) may also be used when appropriate. Assessed likelihood is typeset in italics.

Figure 3: Projected annual average rainfall changes (%) by 2090 under the RCP2.6 low emissions scenario (left) and the RCP8.5 high emissions scenario (right), relative to the 1995 baseline.

Annual average change in rainfall (%) by 2090 under RCP2.6 (left) and RCP8.5 (right)



Extreme weather events

Natural variations in our climate will continue to affect the New Zealand climate in the future, and will be superimposed on human-induced, long-term climate change trends. Climate change is expected to shift the *range* of variability and, in some instances, to alter the *patterns* of variability. It will not remove this natural variability. Therefore, the effects of climate change may be felt both through changes in long-term averages and in the changed frequency and intensity of extreme events (such as heavy rainfall, high sea levels brought by storm surges, drought, or very high temperatures). It is this combination of underlying average climate, climate change trends, and natural variations that will provide the extremes that future New Zealand society faces. A small shift in the average climate can cause significant changes in the occurrence of extremes: generally, it is the extreme events that cause damage.

Intense rainfall is likely to increase in most areas, except for parts of Northland and Hawke's Bay. Increases are small for the remainder of the North Island and larger for the South Island, with the largest increases being seen in areas where average rainfall is also increasing, such as the West Coast. However, because increases in rainfall intensity do not necessarily imply an increase in annual rainfall totals, heavy rainfall events may increase even in areas where the average rainfall is projected to decrease, because the frequency of storm events may change.

There is a projected increase in the number of dry days for much of the North Island, and for high altitude inland regions in the South Island. The frequency of dry days is expected to decrease along both coasts of the South Island.

Drought frequency and intensity is projected to increase in magnitude in most areas of the country, except for Taranaki-Manawatu, West Coast and Southland. The strongest increases are observed over the northern and eastern North Island and along the eastern side of the Southern Alps, especially later in the century under the highest emissions scenario.

Other climate changes

Projections for other climate changes include:

> increased frequency of high temperatures (days with temperatures of 25°C and above)
> decreased likelihood of frost
> higher snow lines and fewer snow days
> possible increase in strong winds, particularly in eastern regions such as Marlborough and Canterbury
> some increase in storm intensity, local wind extremes and thunderstorms. Ex-tropical cyclones will likely be stronger and cause more damage as a result of greater wind speeds and heavier rainfall.

Significance of climate change versus natural climate variability

What currently is an unusually warm year could be the norm in 30-50 years. In 30-50 years, an unusually warm year is very likely to be warmer than anything we experience at present.

Projected temperatures for the highest emissions scenario out to the end of the century are well outside the values experienced by New Zealand in the 20th century. Unless global emissions are significantly reduced, a hot year in 2090 will be more extreme still.

Summary of projected changes

Table 1 summarises the key findings of the source report. Numerical values refer to model averages.

Table 1: Main features of New Zealand climate change projections

Climate variable	Direction of change	Magnitude of change	Spatial & seasonal variation
Average temperature	Progressive increase with concentration. Only for RCP2.6 does warming trend peak and then decline.	By 2040, from +0.7°C [RCP2.6] to +1.0°C [RCP8.5]. By 2090, +0.7°C to +3.0°C. By 2110, +0.7°C to +3.7°C.	Warming greatest at higher elevations. Warming greatest summer/autumn & least winter/spring.
Minimum and maximum temperatures	As average temperature.	Maximum increases faster than minimum. Diurnal range increases by up to 2°C by 2090 [RCP8.5].	Higher elevation warming particularly marked for maximum temperature.
Daily temperature extremes: frosts	Decrease in cold nights (minimum temperature of 0°C or lower).	By 2040, a 30% [RCP2.6] to 50% [RCP8.5] decrease. By 2090, 30% [RCP2.6] to 90% [RCP8.5] decrease.	Percentage changes similar everywhere, but number of days of frost decrease (hot day increase) greatest in the coldest (hottest) regions.
Daily temperature extremes: hot days	Increase in hot days (maximum temperature of 25°C or higher).	By 2040, a 40% [RCP2.6] to 100% [RCP8.5] increase. By 2090, a 40% [RCP2.6] to 300% [RCP8.5] increase.	
Average rainfall	Varies around the country and with season. Annual pattern of increases in west and south of New Zealand, and decreases in north and east.	Substantial variation around the country, increasing in magnitude with increasing emissions.	Winter decreases: Waikato, Gisborne, Hawkes Bay and Canterbury. Winter increases: Nelson, West Coast, Otago and Southland. Spring decreases: Auckland, Northland and Bay of Plenty.

Climate variable	Direction of change	Magnitude of change	Spatial & seasonal variation
Daily rainfall extremes: dry days	More dry days throughout North Island, and inland South Island.	By 2090 [RCP8.5], up to 10 or more dry days per year (~5% increase).	Increased dry days most marked in north and east of North Island, in winter and spring.
Daily rainfall extremes: very wet days	Increased extreme daily rainfall, especially where mean rainfall increases.	More than 20% increase in 99th percentile of daily rainfall by 2090 [RCP8.5] in Southwest of South Island. A few % decrease in north and east of North Island	Increase in western regions, and in south of South Island. Decrease in extremes in parts of north and east of North Island.
Snow	Decrease.	Snow days per year reduce by 30 days or more by 2090 under RCP8.5.	Large decreases confined to high altitude or southern regions of the South Island.
Drought	Increase in severity and frequency.	By 2090 [RCP8.5], up to 50mm or more increase per year, on average, in July-June potential evapotranspiration deficit (PED).	Increases most marked in already dry areas.
Circulation	Varies with season.	Generally, the changes are only a few hectopascals, but the spatial pattern matters.	More northeasterly airflow in summer. Strengthened westerlies in winter.
Extreme wind speeds	Increase.	Up to 10% or more in parts of the country.	Most robust increases occur in southern half of North Island and throughout the South Island.
Storms	Likely poleward shift of mid-latitude cyclones and possibly also a small reduction in frequency.	(More analysis needed).	(See section 3.7 of full report).
Solar radiation	Varies around the country and with season.	Seasonal changes generally lie between – 5% and +5%. (See section 3.9.1 of full report.)	By 2090 [RCP8.5], West Coast shows the largest changes: summer increase (~5%) and winter decrease (5%).
Relative humidity	Decrease.	Up to 5% or more by 2090 [RCP8.5], especially in the South Island. (See section 3.9.1 of full report.)	Largest decreases in South Island in spring and summer.

FOR MORE INFORMATION:

- about climate change impacts for New Zealand go to: **www.mfe.govt.nz/climate-change/how-climate-change-affects-nz**
- about adapting to climate change go to: **www.mfe.govt.nz/climate-change/adapting-climate-change**
- about the climate projections presented in this snapshot contact: **info@mfe.govt.nz**

New Zealand Government

Published in June 2016 by the
Ministry for the Environment, Manatū Mō Te Taiao,
PO Box 10362, Wellington 6143, New Zealand
Publication number: INFO 765