greater WELLINGTON
REGIONAL COUNCIL

The 4 - 7 July 2006 storms in the Wellington region

Hydrology and meteorology

FOR FURTHER INFORMATION

Laura Watts
Environmental Monitoring and Investigations
P O Box 11646
Wellington
Phone 04 802 0339

Mike Gordon
Environmental Monitoring and Investigations
34 Chapel Street
Masterton
Phone 06 370 5650

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1. Introduction

During the period 4-7 July 2006 two storms brought widespread rainfall to the Wellington region, producing an extended period of high river flows. This report summarises the meteorology and hydrology of the storms. The report gives an overview of the weather patterns, quantifies rainfall and river flows, and provides a frequency analysis. The hydrological data used in this report is from Greater Wellington Regional Council's environmental monitoring network, supplemented with data provided by NIWA, MetService, National Rural Fire Authority, and Wairarapa landowners.

During the storms surface flooding and slips caused damage and disruption in many parts of the region, in particular throughout the Wairarapa and in Wainuiomata, the Hutt Valley, and Wellington city. However, this report is a hydrological analysis and does not describe the effectiveness of flood protection measures, the damage that occurred or the civil defence response.

2. Event description

The following description of the meteorological situation was provided by MetService Ltd:

The heavy rain experienced over the Wellington region during the period 4- 7 July 2006 was the result of two separate low pressure systems which brought two distinct periods of rain to the southern North Island.

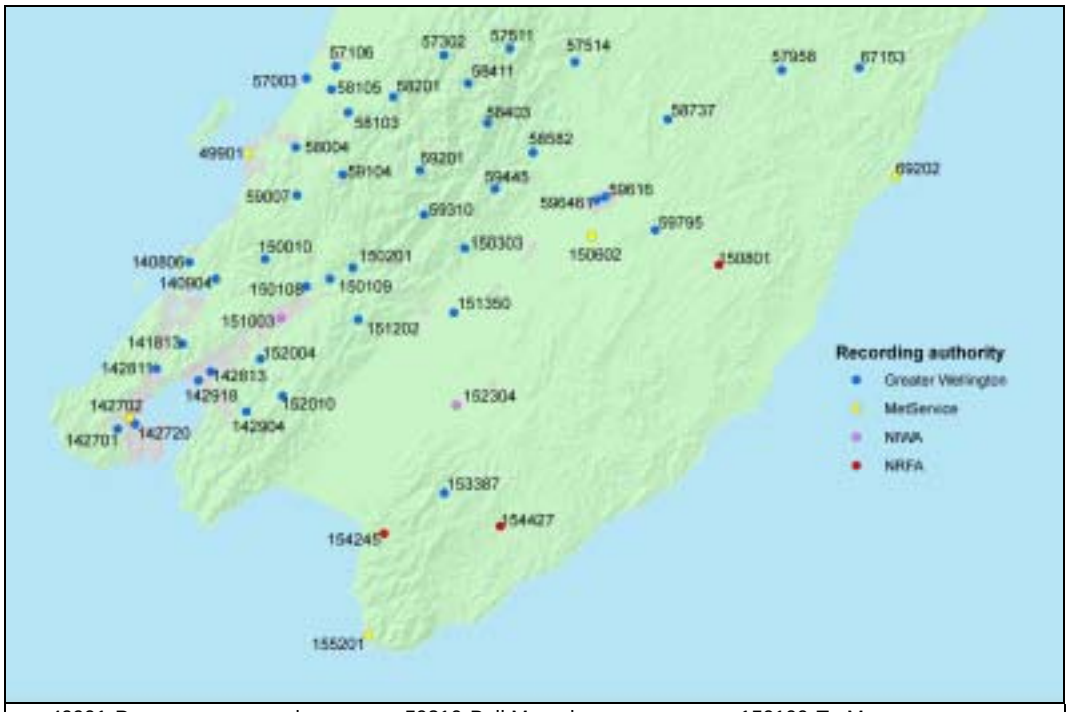
The first period of rain was associated with a complex area of low pressure which developed over central New Zealand during Tuesday 4 July. This system contained two low centres, one each east and west of the southern North Island. Between the two low centres, a strong moist south-easterly flow developed around Cook Strait along with a very slow-moving band of rain. This rain band brought widespread rain to the Wellington area from Tuesday afternoon (4 July) through to Wednesday evening (5 July). The first rain band then weakened and moved away to the south of Wellington on the evening of 5 July.

At about the same time, a second low pressure system developed north of the North Island. This low deepened overnight on Wednesday (5 – 6 July) and moved southwards to lie over the southern North Island on Thursday 6 July. A rain band associated with this new low brought a second period of widespread rain across the southern North Island. This rain affected Wellington and Wairarapa from early Thursday morning (6 July) through to Friday morning (7 July).

The synoptic weather maps for the events are contained in Appendix 1.

3. Rainfall analysis

Figure 1 shows automatic rainfall stations in the Wellington region; data was obtained from most of these stations for analysing this storm event. Greater Wellington has 42 automatic rainfall stations, and the data from these stations was supplemented with data from automatic stations operated by MetService, NIWA and the National Rural Fire Authority (NRFA). Daily rainfall totals were also obtained from about 60 privately-operated manual rain gauges, most of which are in the eastern Wairarapa hills.



49901 Paraparaumu aerodrome	59310 Bull Mound	150109 Te Marua
57003 Sims Road	59445 Valley Hill	150201 Kaitoke Headworks
57106 Otaki Depot	59616 Wairarapa College	150303 Phelps
57302 Oriwa	59795 Te Weraiti	150602 East Taratahi
57511 Bannister	67153 Tanawa Hut	150801 Ngaumu
57514 Mt Bruce	69202 Castlepoint	151003 Wallaceville
57958 Castlehill	140806 Whenua Tapu	151202 Centre Ridge
58004 Water Treatment Plant	140904 Snodgrass	151350 Alloa
58103 Transmission Lines	141813 Waynes Mistake	152004 Tasman Vaccine Limited
58105 Centrepoint	142701 Karori Reservoir	152010 Orongo Swamp
58201 Taungata	142702 Kelburn	152304 Martinborough
58403 Angle Knob	142720 Regional Council Centre	153387 Iraia
58411 Carkeek	142811 Seton Nossiter Park	154245 Haurangi
58582 Waingawa	142813 Shandon Golf Course	154427 Stony Creek
58737 Waihi	142904 Wainuiomata Reservoir	155201 Ngawihi
59007 Warwicks	142918 Birch Lane	596461 Masterton Office
59104 Kapakapanui	150010 Blue Gum Spur	
59201 McIntosh	150108 Cemetery	

Figure 1: Automatic rainfall stations in the Wellington region

3.1 When did it rain?

As mentioned in Section 2, there were two distinct periods of rainfall associated with the storms. The intensity and duration of the rainfall resulting from the two low pressure systems varied across the region (Figure 2).

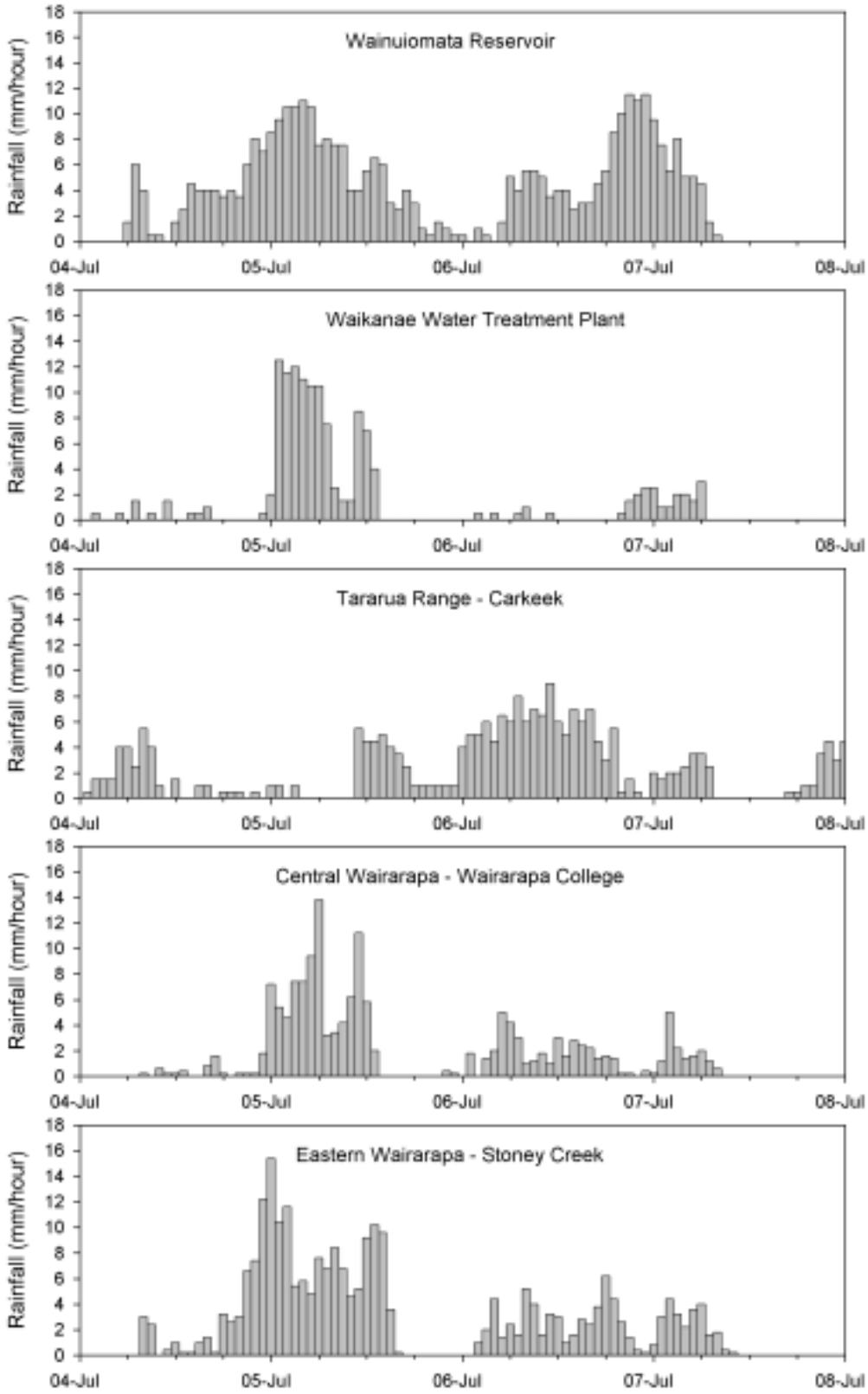
In **Wainuiomata**, the **Hutt Valley**, **Porirua** and **Wellington city** (as indicated by *Wainuiomata Reservoir* in Figure 2), rain began at about midday on 4 July and continued through until the afternoon of 5 July. The second period of rainfall began at about midday on 6 July and lasted until mid-morning on 7 July. The heaviest rainfall occurred in the early hours of 5 July, and between about 9 pm on 6 July and 1 am on 7 July. The peak intensity at *Wainuiomata Reservoir* was about 12 mm/hour.

On the **Kapiti coast**, most rainfall was received during the first storm. At *Water Treatment Plant* (Figure 2) and *Transmission Lines* rainfall began late on 4 July and relatively heavy rain occurred there for about six hours. The second low pressure system – on 6 and 7 July – brought relatively little rain to the Kapiti coast.

In the **Tararua Range**, as indicated by *Carkeek* in Figure 2, the second low pressure system brought significantly more rain than the first. Although parts of the ranges received rain throughout the day on 4 July, the rain was relatively light. Heavier rain, with intensities of 6 to 10 mm per hour, occurred throughout 6 July.

In **central and eastern Wairarapa**, as on the Kapiti coast, the first low pressure system brought heavier rainfall than the second storm of 6 and 7 July. As indicated by *Wairarapa College* and *Stoney Creek* in Figure 2, rain began in these areas late in the evening on 4 July and continued until about midday on 5 July. After a brief respite, rain occurred throughout the day on 6 July but generally less rain was received during this period.

Figure 2: Storm hyetographs for selected rainfall stations, 4 – 8 July 2006



3.2 Rainfall across the region

To show how rainfall was distributed across the region during the storms a 3-day rainfall map has been produced. To allow inclusion of rainfall readings supplied by Wairarapa farmers, the rainfall total for the period 9 am on 4 July to 9 am on 7 July 2006 is mapped in Figure 3. The data used to create this rainfall map, and daily rainfall totals where available, are shown in Appendix 2.

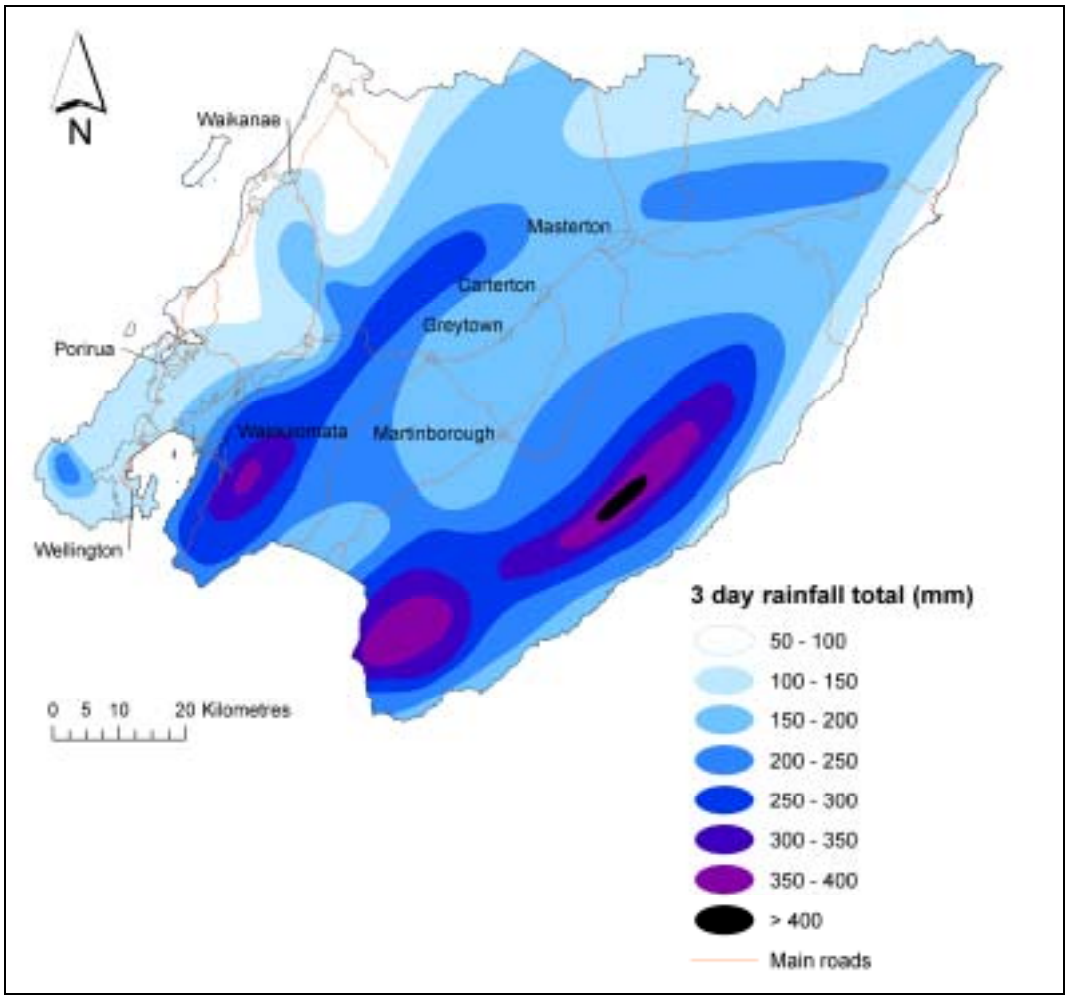


Figure 3: Accumulated rainfall from 4 July 2006, 9 am until 7 July 2006, 9 am

The highest rainfall totals for the storms, possibly over 400 mm in the three days, occurred in the eastern Wairarapa hills, in an area around Hinakura (east of Martinborough) in the mid-Pahaoa catchment. The data was supplied by local farmers and Greater Wellington does not have any gauges in the area to confirm the totals.

Very high 3-day totals were also recorded in the Aorangi Range, Orongorongo Range, and Wainuiomata. The highest confirmed rainfall totals from automatic rainfall stations are 345 mm at *Wainuiomata Reservoir* and 328.6 mm at *Haurangi* in the southern Aorangi Range. The valley floor areas of the Wairarapa and the Hutt generally received between 150 and 200 mm of rain over the three days, which are relatively high rainfall totals for these areas. The

northern Kapiti coast, western Tararua Range, and north eastern Wairarapa coast received considerably less rainfall than other parts of the region.

3.3 Rainfall frequency analysis

Table 1 shows the rainfall maxima for various durations at selected rainfall stations in the Wellington region. The corresponding estimated return periods were derived by fitting an EV1 or EV2 distribution to the annual maxima record for the site. For those stations with an insufficient length of data to perform a reliable frequency analysis, return periods were estimated using HIRDS version 2.0 (NIWA, 2002). The estimated return periods should be treated with caution, and are subject to change in the future as rainfall records are extended. Note that the return period relates to the annual probability of occurrence by the equation: 1/(return period). For example, a 5-year return period rainfall or river flow has a probability of 0.2 (or 20% chance of occurring) in any one year.

The return periods in Table 1, shaded in yellow for 2 to 4 years and blue for greater than 5 years, highlight that the storms produced significant rainfall depths in many parts of the region. The long duration of the rainfall (the effect of two storms combined) is evident, with significant return periods particularly for the durations of 24 to 72 hours. The high number of stations that also had significant rainfall depths for the 6 to 12 hour durations shows how the rainfall was sustained at moderate intensities within the storms. However, the rainfall was not unusually heavy, as indicated by the totals for the 1 to 2 hour durations.

The areas of most significant 72-hour rainfall depths – estimated to have return periods equal to or greater than 30 years – were central Wairarapa valley (as indicated by *Wairarapa College* and *Alloa*), Mangaroa Valley (*Tasman Vaccine Ltd*), and the southern Aorangi Range (*Haurangi*). The 72-hour totals were also very significant, with return periods of 10 to 30 years, in Wainuiomata, Orongorongo Range, Porirua, and eastern Wairarapa. Note that the return period for the *Haurangi* 72-hour rainfall may be greater than 50 years, but data records are insufficient to perform an accurate depth-duration-frequency analysis for this area.

The rainfall map in Figure 3 shows that the highest rainfall totals for the 3 days were in the eastern Wairarapa hills around the Hinakura area, in the mid-reaches of the Pahaoa catchment. There are no long-term automatic rainfall records for this area and so an accurate depth-duration-frequency analysis cannot be performed. However, daily rainfall has been measured at *Hikawera* since 1948 and the record is stored in the National Climate Database. The 3-day rainfall total over 4 to 7 July 2006 at *Hikawera* (283 mm) has an estimated return period of **80 years**, and is the highest on record. It can be assumed that this return period applies to the general area of the mid-Pahaoa catchment.

Table 1: Maximum rainfall depths (mm) and estimated return periods, 4 – 7 July 2006

	Station (number) (catchment)		1 hour	2 hours	6 hours	12 hours	24 hours	48 hours	72 hours
	Wainuiomata Reservoir (142904) (Wainuiomata)	Depth (mm)	12	23.5	63	106.5	162	247	354
		Return period	< 2 years	2 years	4 years	5 years	7 years	10 years	18 years
	Orongo Swamp (152010) (Orongorongo)	Depth (mm)	13	24.5	62	106	156	259	347
		Return period	< 2 years	< 2 years	< 2 years	3 years	3 years	7 years	13 years
	Seton Nossiter Park (142811) (Porirua)	Depth (mm)	6.4	11	24.8	46.8	77	107.4	144
		Return period	< 2 years	< 2 years	< 2 years	< 2 years	3 years	5 years	10 years
	Karori Reservoir (142701) (Karori)	Depth (mm)	7.4	13	26.8	40.8	55.2	95	126.2
		Return period	< 2 years	< 2 years	< 2 years	< 2 years	< 2 years	3 years	5 years
Kapiti Coast	Water Treatment Plant (58004) (Waikanae)[1]	Depth (mm)	13.5	25.5	69.5	97	105	113.5	131
		Return period	< 2 years	< 2 years	15 years	15 years	8 years	8 years	4 years
	Transmission Lines (58103) (Mangaone)	Depth (mm)	13	25	56	69	70.5	82.5	99.5
		Return period	< 2 years	< 2 years	2 years	2 years	< 2 years	< 2 years	< 2 years
Hutt catchment	Birch Lane (142918) (Waiwhetu)	Depth (mm)	8	14.5	41	70	101.5	136.5	192.5
		Return period	< 2 years	< 2 years	< 2 years	3 years	4 years	4 years	n/a
	Warwicks (59007) (Akatarawa / Waikanae)	Depth (mm)	15	25.5	57.5	85.5	97	141.5	172.5
		Return period	< 2 years	< 2 years	< 2 years	< 2 years	< 2 years	< 2 years	2 years
	TVL (152004) (Mangaroa)	Depth (mm)	10	17.5	46	83	144	188.5	268
		Return period	< 2 years	< 2 years	< 2 years	4 years	12 years	15 years	40 years
Tararua range	Angle Knob (58403) (Waingawa)	Depth (mm)	8.5	15.5	41	75.5	126.5	157	182
		Return period	< 2 years	< 2 years	< 2 years	< 2 years	< 2 years	< 2 years	< 2 years
	Bull Mound (59310) (Hutt)	Depth (mm)	10	19.5	46.5	86.5	144	215	273.5
		Return period	< 2 years	< 2 years	< 2 years	< 2 years	< 2 years	< 2 years	< 2 years
Western Tararua foothills	Mt Bruce (57514) (Ruamahanga)	Depth (mm)	8	12.5	26	48.5	65.5	103	118.5
		Return period	< 2 years	< 2 years	< 2 years	< 2 years	< 2 years	< 2 years	< 2 years
	Valley Hill (59445) (Mangatarere)	Depth (mm)	11	19.5	53	96.5	117.5	180.5	221
		Return period	< 2 years	< 2 years	< 2 years	5 years	2 years	5 years	8 years
	Kaituna (58582) (Waingawa)[1]	Depth (mm)	11.5	20	50	85.5	98.5	151.5	176.5
		Return period	< 2 years	< 2 years	< 2 years	3 years	< 2 years	3 years	3 years
Central Wairarapa	Wairarapa College (59616) (Ruamahanga)[1]	Depth (mm)	14.4	23.2	48	83.4	96.2	133.2	153.2
		Return period	2 years	4 years	10 years	30 years	15 years	25 years	30 years
	Alloa (1513501) (Tauherenikau)[1]	Depth (mm)	8.6	15.8	40.4	67.6	85.2	138.4	164.4
		Return period	< 2 years	< 2 years	4 years	7 years	5 years	22 years	30 years
Eastern Wairarapa	Tanawa Hut (67153) (Whareama)	Depth (mm)	19	35.5	60	74	79	154	162
		Return period	3 years	5 years	4 years	4 years	< 2 years	4 years	3 years
	Castlehill (57958) (Tauweru)	Depth (mm)	13	25	55	70.5	74.5	119	135.5
		Return period	< 2 years	4 years	6 years	4 years	2 years	5 years	6 years
	Stoney Creek (154427) (Awhea)[1]	Depth (mm)	15.4	27.6	63.6	102.6	162	206.8	249.8
		Return period	3 years	5 years	15 years	20 years	22 years	21 years	25 years
	Ngaumu (150839) (Wainuioru)[1]	Depth (mm)	17.6	26.2	50.4	88.6	107.2	177.4	189.4
		Return period	3 years	5 years	5 years	10 years	5 years	12 years	10 years
	Haurangi (154245)[1]	Depth (mm)	9.6	19.2	49.8	87.6	141.8	224	333
		Return period	< 2 years	< 2 years	5 years	9 years	15 years	35 years	50+ years

[1] Return periods estimated using HIRDS v2.0 (NIWA, 2002)

The 15-16 February 2004 storm was a similarly long-duration event, which produced record rainfall depths in many areas. Because the 4-7 July storms were a result of two separate low-pressure systems, the rainfall was sustained for a longer period and therefore higher 72-hour rainfall totals were received. However, in general the February 2004 storm resulted in heavier rain throughout the Wellington region for the durations less than 72 hours. The exceptions are the Aorangi Range, which received higher 24 and 48-hour totals in July 2006 than in the February 2004, and the Wairarapa plains.

Table 2 compares Masterton's recorded rainfall depths from the 4-7 July 2006 storms with rainfall maxima recorded during other long-duration storms of recent years. The July 2006 event resulted in greater rainfall depths for all durations compared to during the storms of February and August 2004. However, Masterton did not receive as much rain as during the storm of 30-31 March, except for the 72-hour duration. Once again, this highlights the unusually long duration of the July storm event.

Table 2: Maximum rainfall depths in Masterton (***Wairarapa College***) during significant storms since 2004

Event date:		1 hour	2 hour	6 hour	12 Hour	24 hour	48 hour	72 hour
15-16 February 2004	Rainfall (mm)	11.4	19.6	40.2	63.6	81.8	94.4	105.8
	Return period	< 2 years	< 2 years	5 years	9 years	5 years	3 years	3 years
17-18 August 2004	Rainfall (mm)	7	13	30.4	48.4	69.2	91	104.6
	Return period	< 2 years	< 2 years	< 2 years	2 years	3 years	5 years	4 years
30-31 March 2005	Rainfall (mm)	19.6	29.4	56	88.2	143.4	147	147
	Return period	8 years	12 years	20 years	40 years	80 years	40 years	25 years
4-7 July 2006	Rainfall (mm)	14.4	23.2	48	83.4	96.2	133.2	153.2
	Return period	2 years	4 years	10 years	30 years	15 years	25 years	30 years

4. River flows and Lake Wairarapa

Figure 4 shows the river level monitoring stations in the Wellington region. The peak stage heights and river flows recorded during the storms are shown in Table 3. The return periods were derived using published flood frequency tables where available, or by fitting an EV1 distribution to the annual flood maxima series.

Table 3: Flood peaks in Wellington region's rivers, 4 – 7 July 2006

River	Date & time of peak	Peak stage (m)	Peak flow (m^3/s)	Estimated return period (years)
Hutt River @ Birchville	7/7 01:15	4.609	573	< 2
Hutt River @ Taita Gorge	7/7 02:00	27.681	596	< 2
Mangaroa River @ Te Marua	6/7 23:45	3.563	166	3
Akatarawa River @ Cemetery	7/7 00:45	1.967	117	< 2
Waiwhetu Stream @ Whites Line East	7/7 00:45	1.603	12.0	2
Wainuiomata River @ Manuka Track	7/7 00:00	1.266	45.8	4
Wainuiomata River @ Leonard Wood Park	7/7 00:15	2.733	134	15
Porirua Stream @ Town Centre	5/7 09:30	0.984	20.2	< 2
Otaki River @ Pukehinau	5/7 07:30	1.920	242	< 2
Waitohu Stream @ Water Supply Intake	5/7 06:00	0.790	21.1	< 2
Mangaone Stream @ Ratanui	Not available due to site damage during the event			
Waikanae River @ Water Treatment Plant	5/7 07:45	3.531	124	< 2
Ruamahanga River @ Mt Bruce	6/7 17:30	1.934	116	< 2
Ruamahanga River @ Wardells	5/7 16:00	4.351	519	3
Ruamahanga River @ Gladstone	5/7 16:15	3.523	922	6
Ruamahanga River @ Waihenga	5/7 17:15	5.050	1501	9
Kopuaranga River @ Palmers	6/7 23:00	3.767	32	< 2
Whangaehu River @ Waihi	5/7 13:30	3.207	35	4
Waipoua River @ Mikimiki	6/7 18:00	1.537	115	< 2
Waingawa River @ Kaituna	6/7 18:00	1.911	114	< 2
Mangatarere Stream @ Gorge	5/7 09:00	1.597	34	< 2
Tauweru River @ Te Weraiti	5/7 19:15	12.285	395	12
Waiohine River @ Gorge	6/7 19:45	2.148	288	< 2
Huangarua River @ Hautotara	5/7 10:45	4.497	295	n/a
Otukura Stream @ Weir	7/7 02:15	1.477	17.3	15+
Tauherenikau River @ Gorge	6/7 19:45	2.060	149	< 2
Whareama River @ Waiteko	5/7 14:45	12.226	515	6
Kaiwhata River @ Stansborough	6/7 17:00	3.413	242	5
Pahaoa River @ Hinakura	5/7 16:30	9.561	1169	20

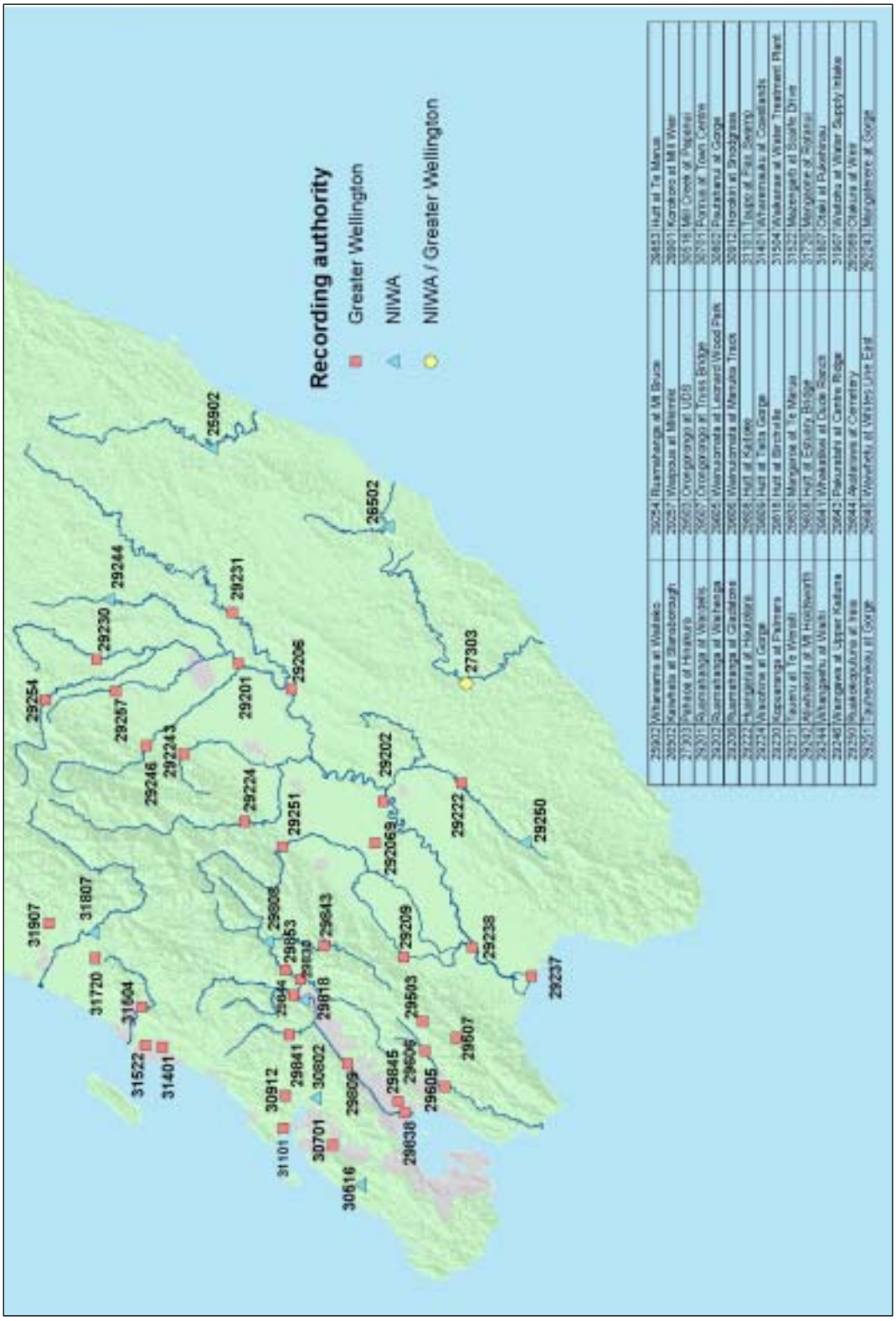


Figure 4: River level monitoring stations in the Wellington region

The storms of 4-7 July 2006 produced significant flood peaks in several rivers of the region. Of those waterways that are monitored, the most significant floods in terms of estimated return period occurred in Wainuiomata River, Pahaoa River, and Otukura Stream. The return periods are estimated to be 15 years or greater. Less significant peak flows, with return periods in the range of 3 to 12 years, were recorded in Mangaroa, lower Ruamahanga, Whangaehu, Tauweru, Whareama, and Kaiwhata Rivers.

The table of flood peaks highlights the effect of the storms in parts of the region exposed to southerly and southeasterly flows. All major eastern Ruamahanga River tributaries, with the exception of the Kopuaranga River, reached significant flood levels. This is also true for eastern tributaries of the Hutt River (Waiwhetu Stream, Mangaroa River). It is likely that the Orongorongo River, and other eastern rivers that are not monitored by Greater Wellington, also reached high levels. The relatively high flows in the Ruamahanga River, particularly at *Waihenga*, were mainly a result of high flows from the eastern tributaries and runoff from the valley and surrounding foothills.

The Waikanae River reached a peak flow less than the mean annual flood, despite the significant rainfall recorded at *Waikanae Water Treatment Plant* (return period of 15 years for the 6 and 12-hour rainfall depths). The reason for the relatively low peak flow was that rainfall in the upper reaches of the catchment was less significant (as indicated by *Warwicks* in Table 1).

In general all the monitored rivers had lower flood peaks than during the storm of 15-16 February 2004, because in most parts of the Wellington region the rainfall over shorter durations (1 to 12 hours, the range in which most catchment time of concentrations will fall) was heavier in February 2004. The two exceptions are Otukura Stream and Pahaoa River, which highlights the significance of the rainfall during the period 4-7 July 2006 on the Wairarapa plains and in the eastern Wairarapa hills around Hinakura (see Section 3).

The peak flows in the south-eastern Wairarapa rivers – the Huangarua, Pahaoa and Kaiwhata Rivers – reached higher levels in the event of 30-31 March 2005 than during this July 2006 event. *Ruamahanga at Waihenga* reached a slightly higher peak of 1530 m^3/s in March 2005 but the flow remained high for a much shorter duration. The peak flow at *Wainuiomata at Leonard Wood Park* on 7 July 2006 is the second highest on record since 1977, and is about equal to the flood that occurred on 10 June 2003.

Surface flooding in the central Wairarapa valley was more severe during the July 2006 storms than in March 2005, despite the rainfall in this area being more significant in March 2005 (as shown in Table 2). The greater amount of surface flooding in July 2006 is a result of the wet antecedent conditions, due to the timing of the event in winter, and the long duration of the storms.

The shapes of the river flow hydrographs reflect the relative intensity and rainfall distribution of the two storm events. As shown by Figure 5 and Figure 6, rivers in the areas where the first low pressure system brought the most intense rainfall (eastern Wairarapa and Waikanae) peaked on 5 July 2006. The

Wainuiomata River, the Hutt catchment, and rivers fed from the Tararua Range had higher flow peaks as a result of the second storm, on 6 and 7 July 2006.

Figure 5: Flow hydrographs for selected rivers in the western Wellington region

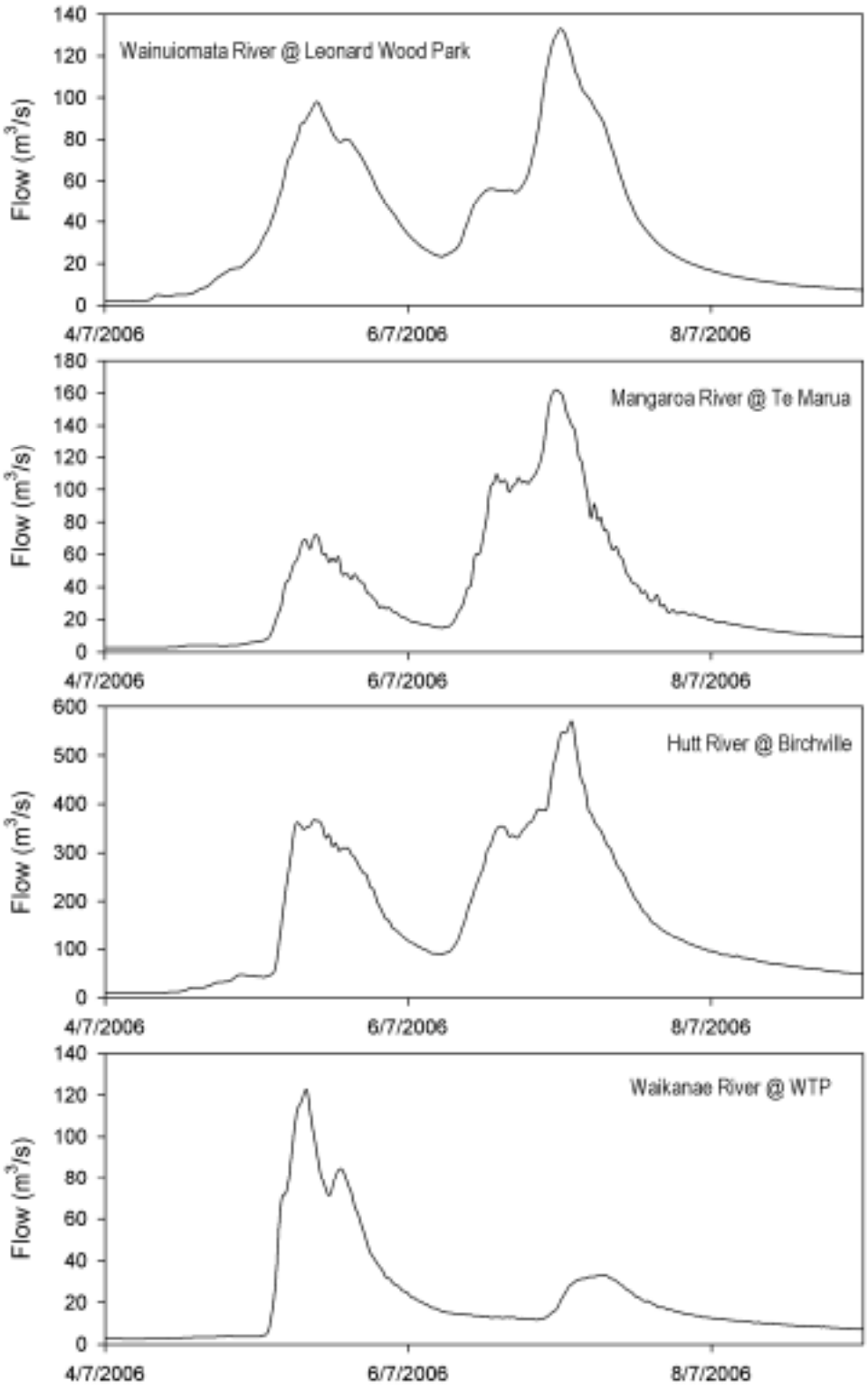
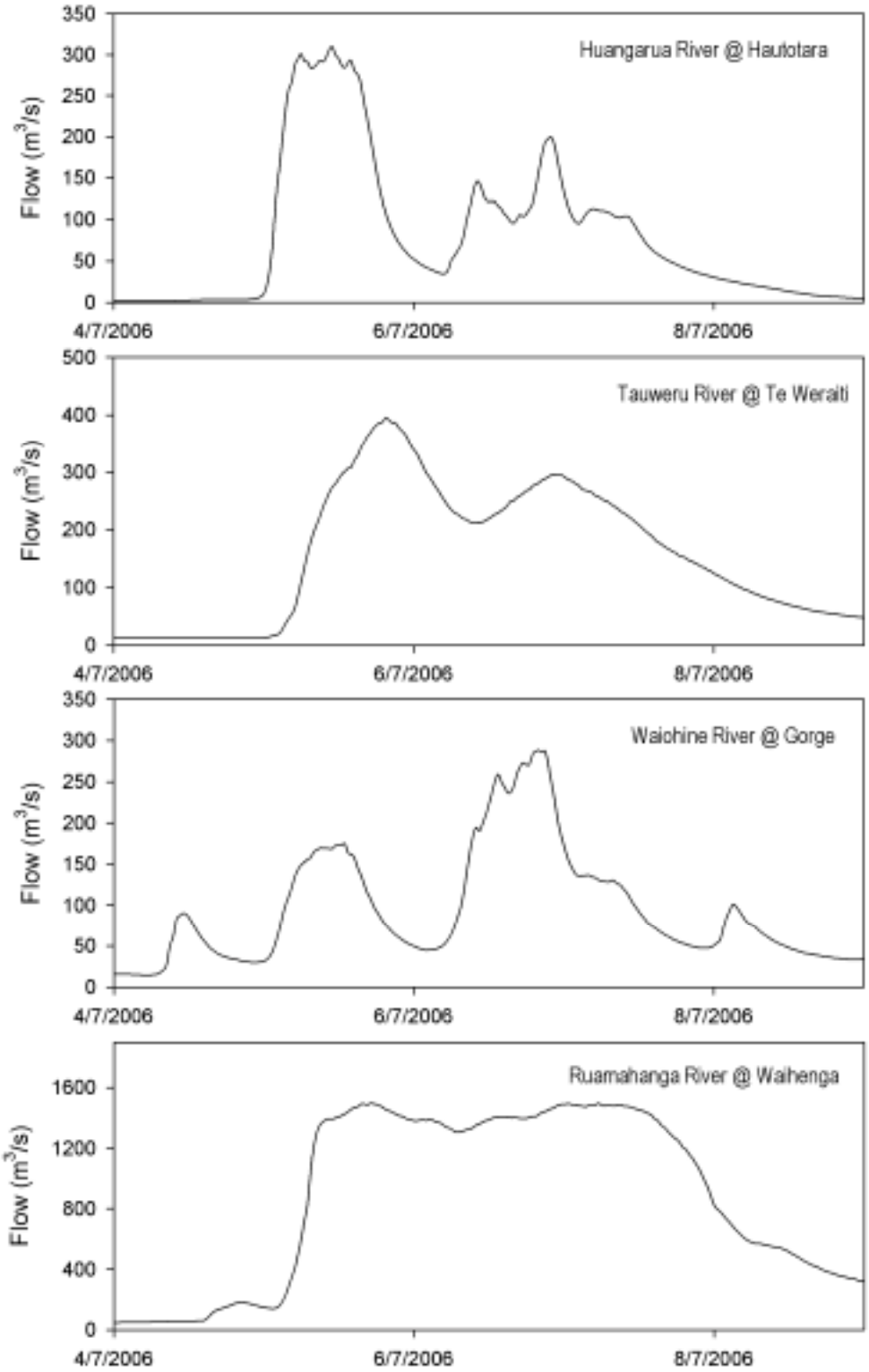


Figure 6: Flow hydrographs for selected rivers in the Wairarapa



4.1 Lower Valley floodways and Lake Wairarapa

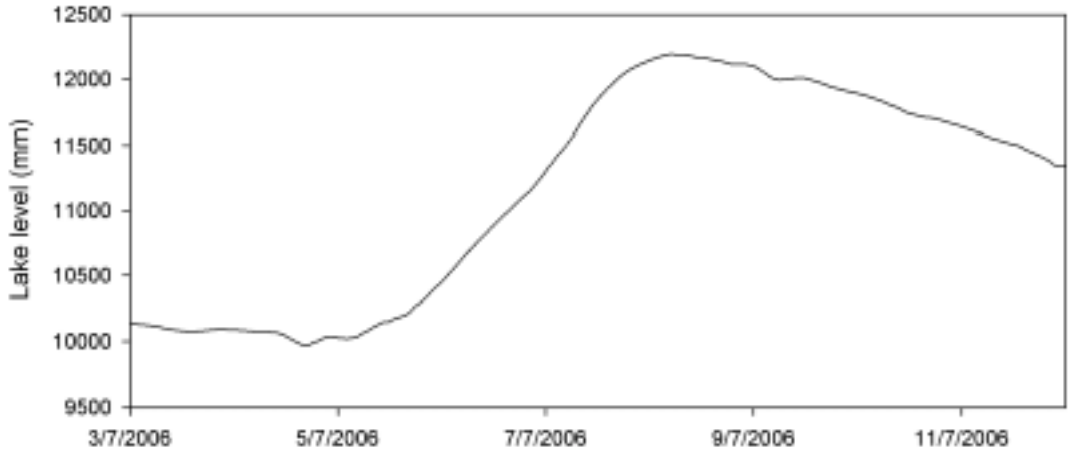
Because the eastern and western Ruamahanga River tributaries had flood peaks that occurred about 24 hours apart, the result at *Waihenga* was a very long duration flow peak (Figure 6). The flow remained above 900 m^3/s, the estimated threshold for the main floodway system to come into operation, for in excess of 64 hours. This is the longest duration for the floodway operation since the early 1980s, when the floodway and stopbanking were completed as part of the Lower Wairarapa Valley scheme. Although the flow on 16 February 2004 was higher (1900 m^3/s) the floodways were only operational in that event for about 38 hours. Therefore the event of 4 – 7 July 2006 has resulted in the largest total volume of water flowing through the floodways on record.

The Lower Valley floodways discharge into Lake Wairarapa. At the beginning of this flood event the lake level was at 10.0 metres, more or less the normal level for this time of year. Over the next three days the lake level rose to over 12.2 metres (Figure 7). This was another record broken by this event, the highest lake level since the Lower Valley diversion and Barrage Gates came into operation around 1976. The lake has an area at 10.0 metres of around 70 km^2 and at 12.2 metres of over 100 km^2. The volume of water this area represents exceeds 180 x 10^6 m^3.

The previous record-high Lake Wairarapa level occurred in February 2004 when the lake reached just less than 12.0 metres. In fact the lake level has not been above 12.0 metres since at least 1966 – 10 years prior to the scheme coming into operation (when it reached 12.5 metres). Historically the highest lake level measured was after the big flood of 1947 when it reached 13.65 metres.

The mouth of the Ruamahanga River through the sand spit at Lake Onoke was open during this event.

Figure 7: Lake Wairarapa at Burlings, 6-hour running average level, 3 – 12 July 2006



5. Summary

During the period 4 – 7 July 2006 two storms brought widespread rainfall to the Wellington region. The storms were the result of two separate low pressure systems which brought two distinct periods of rain to the southern North Island.

The rainfall totals produced over the three day period were highest in the eastern Wairarapa hills, the Aorangi Range, Orongorongo Range and Wainuiomata. Unconfirmed rainfall totals in eastern Wairarapa, to the east of Martinborough (around Hinakura in the mid-Pahaoa catchment), exceeded 400 mm. The estimated return period of the rainfall in this area is 80 years. Totals from automatic gauges indicate at least 330 mm fell in the Aorangi Range and 345 mm in the Wainuiomata catchment.

The return periods of the rainfall were most significant for the durations of 24 to 72 hours, highlighting how these events brought long periods of moderately intense rainfall rather than short, very heavy rain. High river flows occurred as a result of the storms, particularly in the eastern Wairarapa rivers, the streams of the central Wairarapa valley, Wainuiomata River, and Mangaroa River. However, in general the monitored rivers did not reach levels as high as during the event of February 2004, or (in parts of the region) March 2005.

More surface flooding occurred in the central Wairarapa compared to in March 2005, as a result of the storms' timing in winter. Overall the 4-7 July event was characterised by large volumes of water: surface flooding, and record-high volumes of water passing through the Wairarapa floodways into Lake Wairarapa. These effects were the result of two storms occurring within a three day period producing an unusually long period of rainfall, saturated catchment conditions, and an extended period of high river flows.

6. Recommendations

The hydrological analysis in this report highlights the inadequacy of the Greater Wellington monitoring network to detect rainfall in the mid-eastern Wairarapa hills. A gap in the network exists in this area between *Ngaumu* in the north and *Iraia* and *Stoney Creek* in the south. With a predicted increase in the frequency of easterly or southeasterly storms due to a shift in the Interdecadal Pacific Oscillation (Watts, 2005) and an increase in the risk of heavy rainfall events in the future as a result of climate change (Tait *et al*, 2002) it is important that additional rainfall monitoring is conducted in this area.

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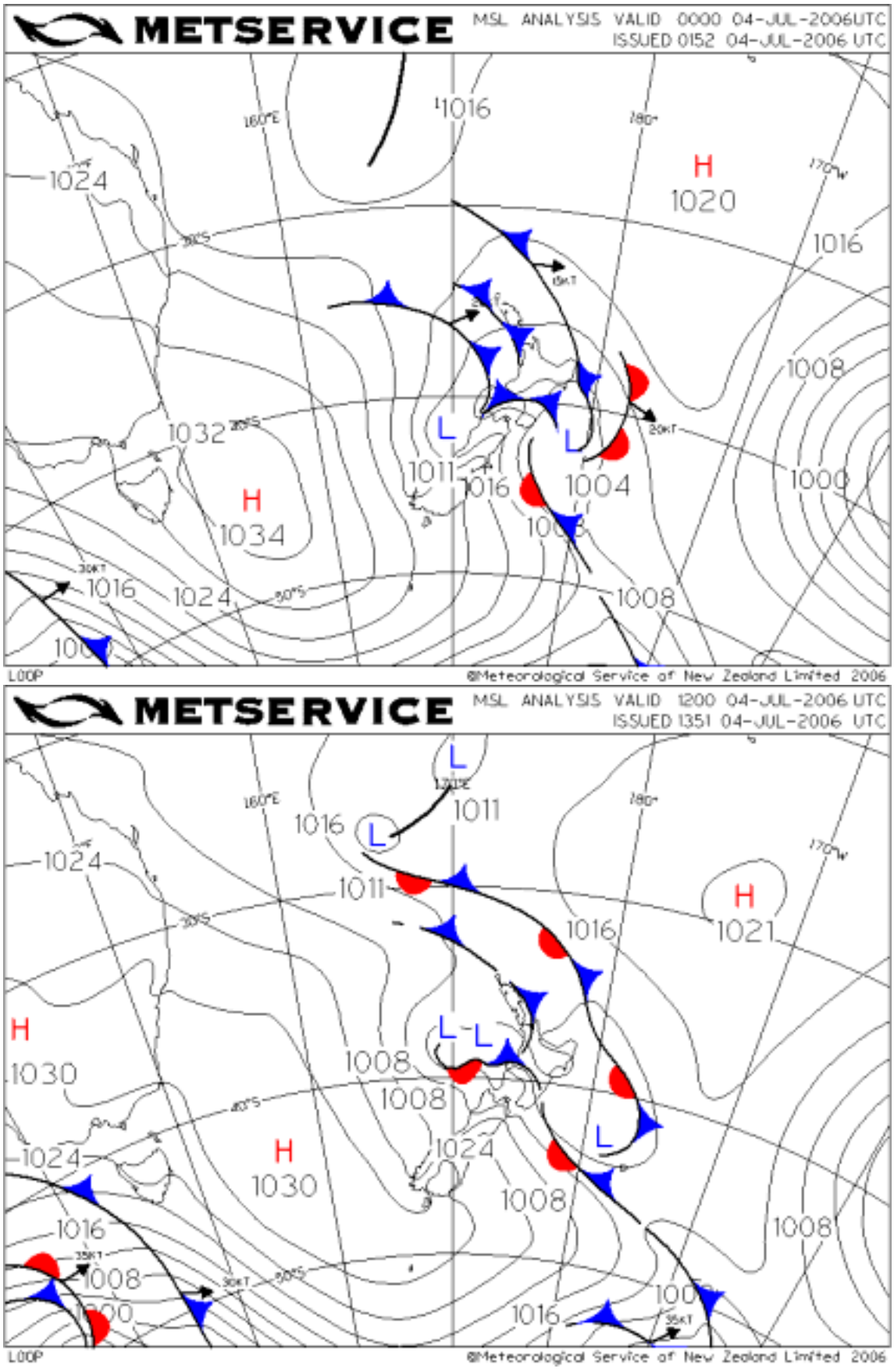
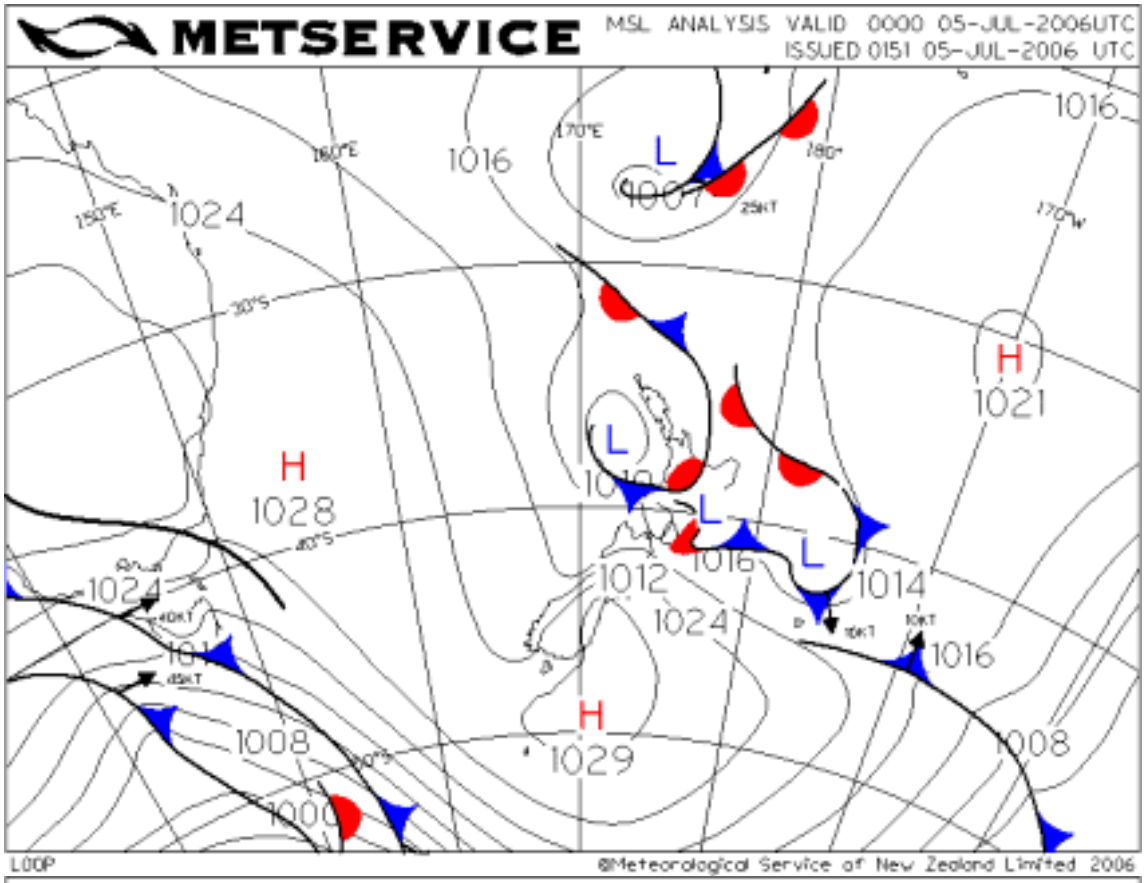
Acknowledgements

Thank you to MetService for providing rainfall data, weather maps, radar images and the description of the meteorological situation.

Useful rainfall data was provided by many Wairarapa farmers. Thank you to the Land Management team for once again collating this information.

Appendix 1: Weather maps

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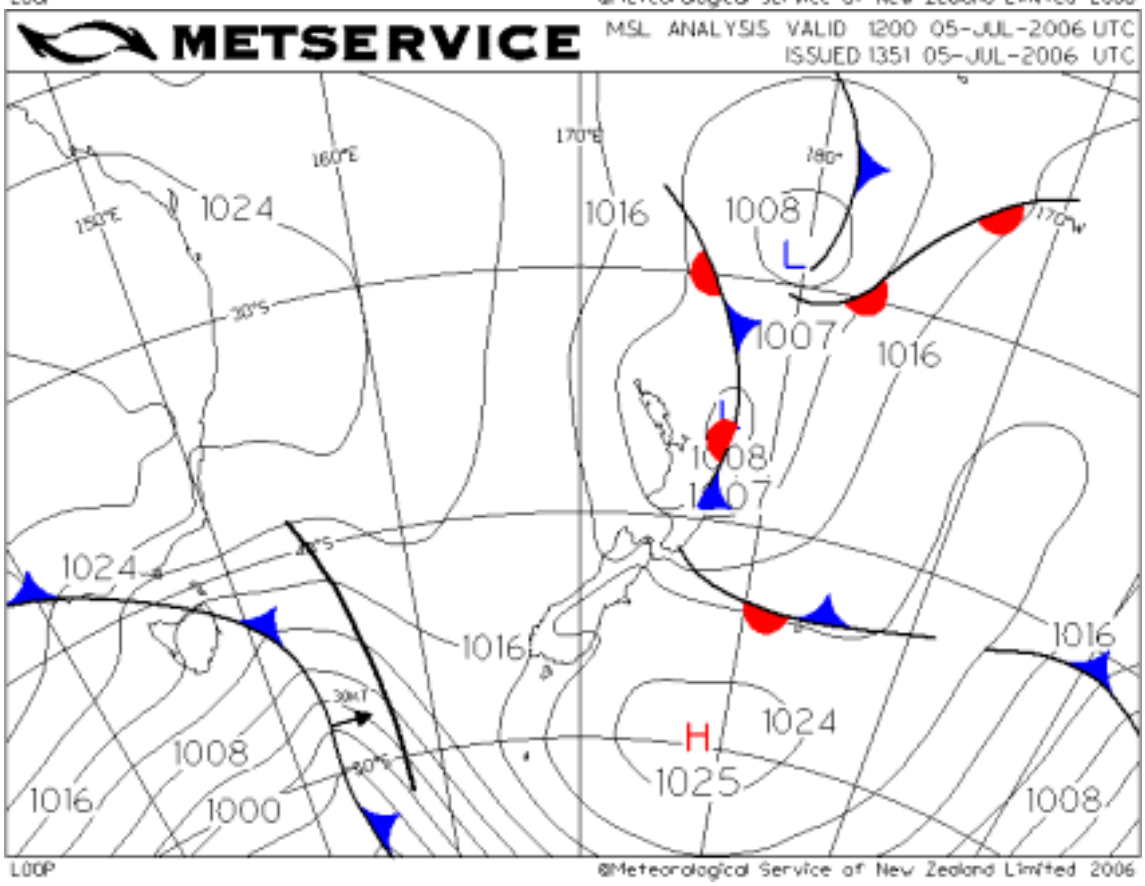
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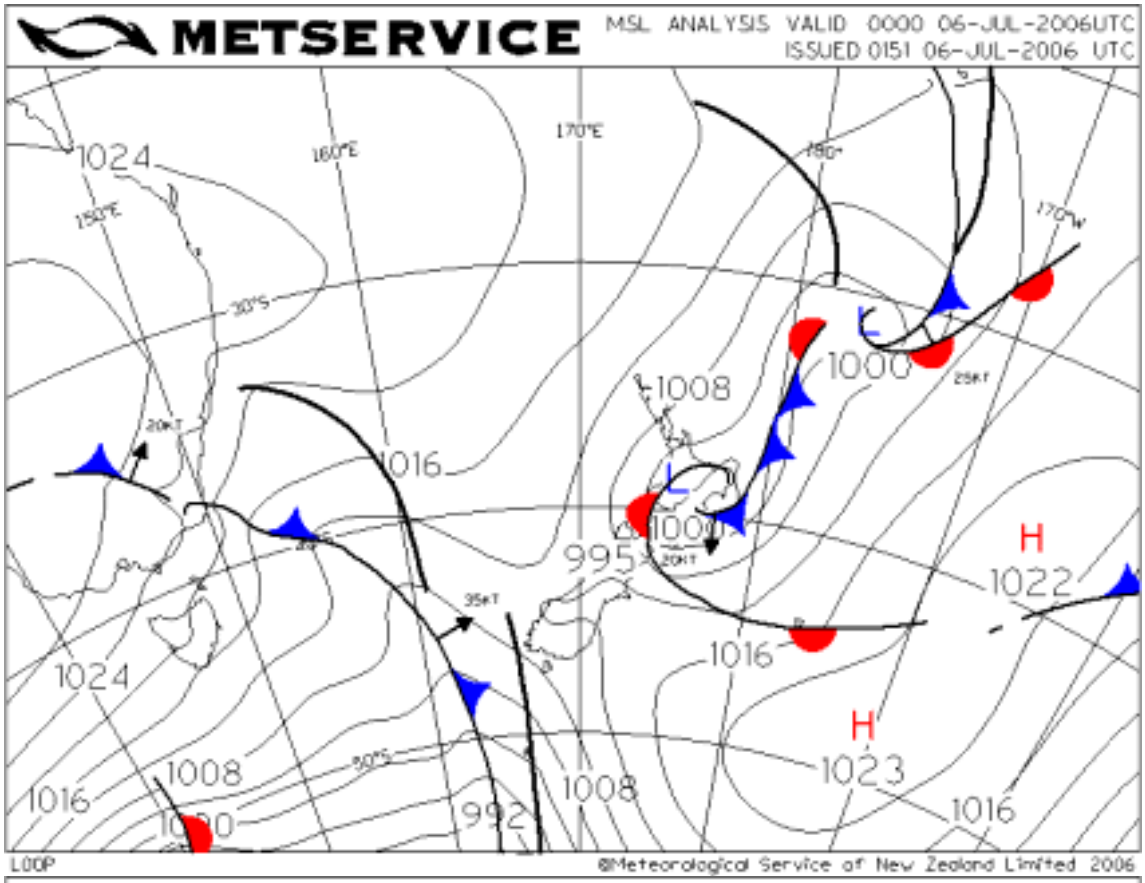
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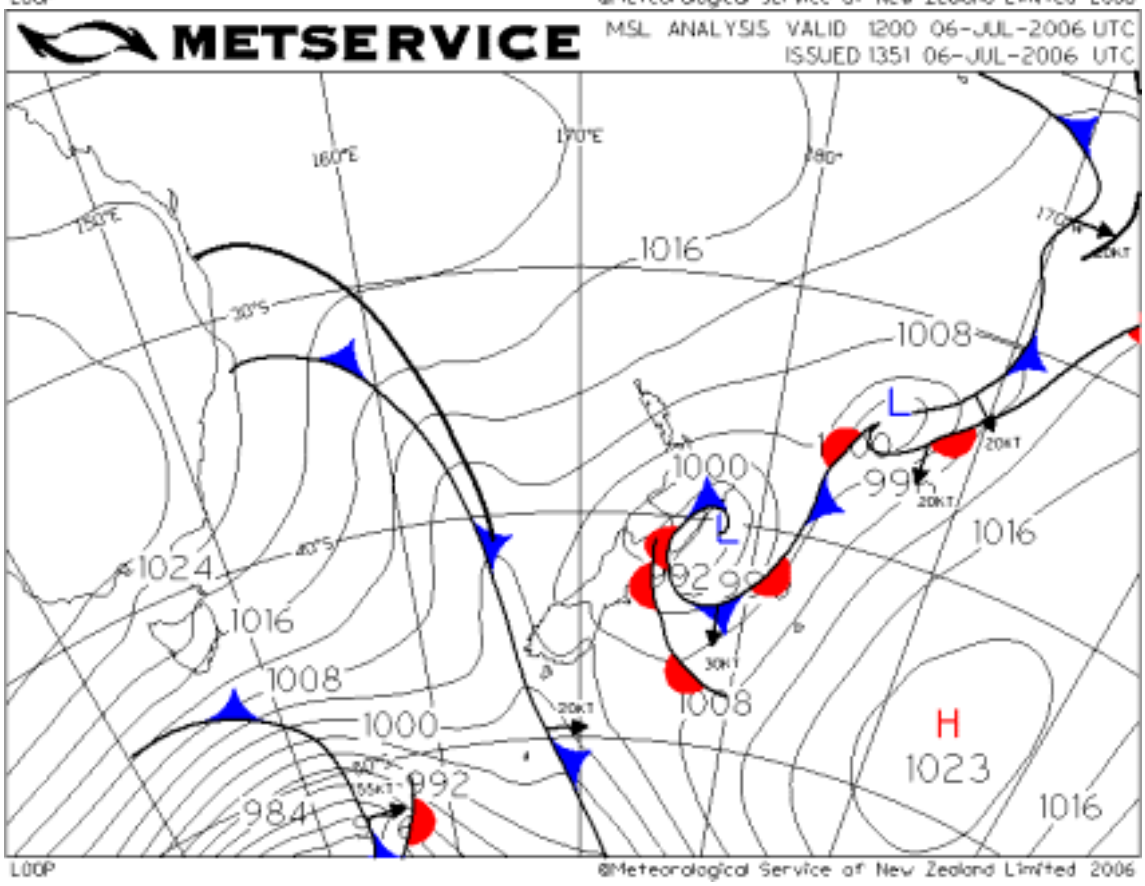
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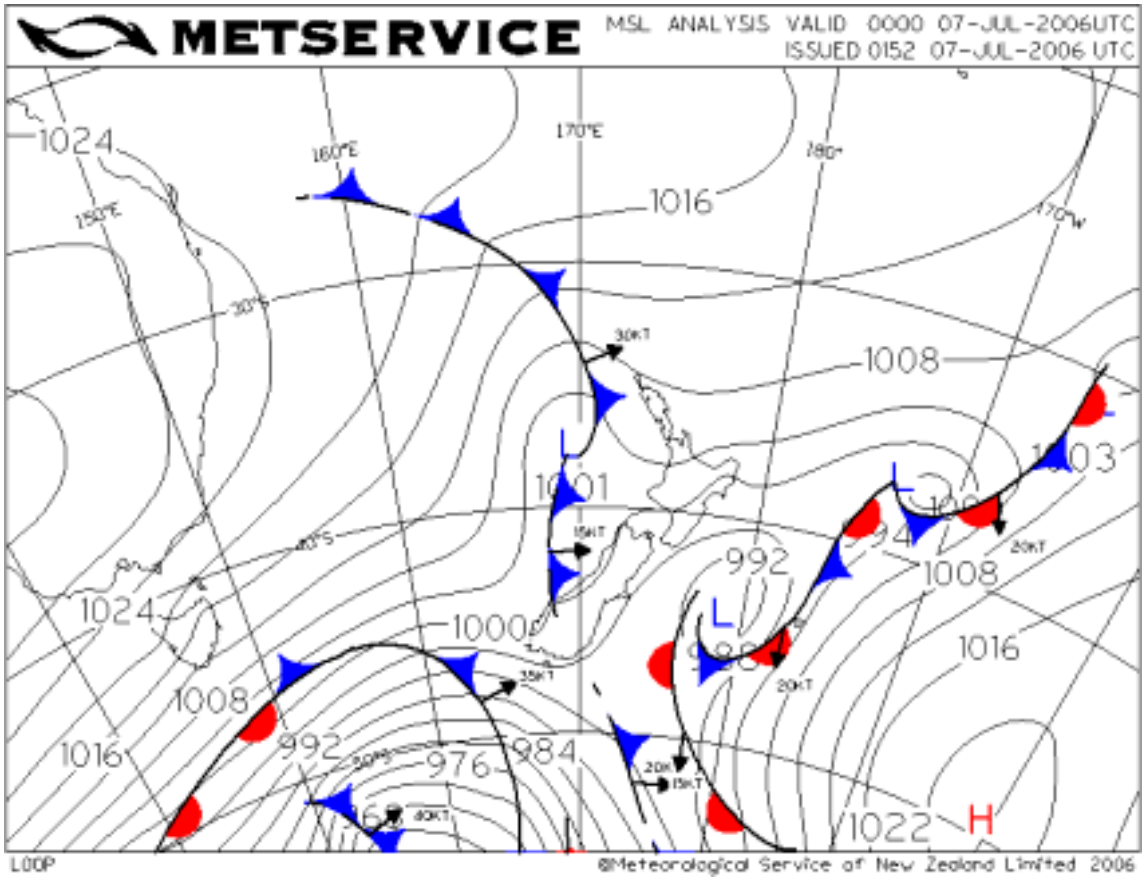
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Appendix 2: Daily rainfall totals 4 – 7 July 2006

Site Name	Site number	Recording authority	Daily rainfall (mm)			
			4/7 09:00 - 5/7 09:00	5/7 09:00 - 6/7 09:00	6/7 09:00 - 7/7 09:00	Total
Abbotsford		Private landowner				175
Alloa	151350	Greater Wellington	66.6	39.6	58.2	164.4
Angle Knob	58403	Greater Wellington	19.0	55.5	91.5	166.0
Awatoitoi		Private landowner	96	84		180
Beaumaris		Private landowner				112
Birch Lane	142918	Greater Wellington	88.5	34.5	63.0	186.0
Bull Mound	59310	Greater Wellington	67.0	76.0	125.5	268.5
Carkeek	58411	Greater Wellington	9.5	93.5	81.5	184.5
Castlehill	57958	Greater Wellington	71.5	24.0	40.0	135.5
Castlepoint	69202	MetService	20.2	26.0	29.6	75.8
Cemetery	150108	Greater Wellington	42.5	34.0	58.0	134.5
Centre Ridge	151202	Greater Wellington	76.0	46.0	132.0	254.0
Centrepoint	58105	Greater Wellington	39.0	5.0	20.0	64.0
Clifton Grove		Private landowner	122	95	50	267
Craig Morrison		Private landowner	166	76	85	327
D Linton		Private landowner	86	46.4	43	175.4
Daisybank		Private landowner	58	47	32	137
Ditton		Private landowner				245
Drumcairn		Private landowner	116	99	30	245
East Taratahi	150602	MetService	65.2	50.0	34.6	149.8
Eastwood		Private landowner				132
Ekenui		Private landowner	108	58	52	218
Eninga		Private landowner				270
Glenburn Coast		Private landowner	32.7	42.3	52.1	127.1
Glendrynoech		Private landowner	171	120	65	356
Glendu		Private landowner	100+	100+		200+
Gleneden		Private landowner				204
Grassendale		Private landowner	83	49	37	169
Greenfields		Private landowner				195
Greentops		Private landowner	46.8	52.9	66.9	166.6
Haurangi	154245	NRFA	129.4	72.8	126.4	328.6
Highcliffs		Private landowner	87	53	33	173
Hikawera		Private landowner	149	95.3	38	282.3
Homeburn		Private landowner				340
Kaitoke Headworks	150201	Greater Wellington	75.5	61.5	85.0	222.0
Kapakapanui	59104	Greater Wellington	9.5	15.0	36.5	61.0
Karori Reservoir	142701	Greater Wellington	30.4	37.8	49.0	117.2
Kavala		Private landowner				140
Kotu		Private landowner	70	17	22	109
Kouratahi		Private landowner				225
Lagoon Hill		Private landowner	141	93	88	322
Mangapari		Private landowner				220
Martinborough	152304	NIWA	49.4	35.0	37.8	122.2
Masterton Office	596461	Greater Wellington	81.8	51.2	36.2	169.2
McIntosh	59201	Greater Wellington	26.5	70.0	91.0	187.5
Mitchell		Private landowner	100	53	36	189
Moeraki		Private landowner				250+

Site Name	Site number	Recording authority	Daily rainfall (mm)			
			4/7 09:00 - 5/7 09:00	5/7 09:00 - 6/7 09:00	6/7 09:00 - 7/7 09:00	Total
Motuiti		Private landowner	65	55	30	150
Mt Bruce	57514	Greater Wellington	28.0	33.0	50.0	111.0
Ngaipu		Private landowner				440
Ngatapa		Private landowner	120	80	55	255
Ngaumu	150801	NRFA	87.4	54.8	47.2	189.4
Ngawihi	155201	MetService	49.8	88.2	83.2	221.2
Orere		Private landowner	82.5	87	5.5	175
Oriwa	57302	Greater Wellington	14.5	43.5	49.5	107.5
Orongo Swamp	152010	Greater Wellington	130.0	69.0	135.0	334.0
Otaki Depot	57106	Greater Wellington	25.5	6.5	17.0	49.0
Palliser Bay		Private landowner	150	150	75	375
Pirinoa		Private landowner				199
Puke Te		Private landowner	170	-	60	230
Pukeatua		Private landowner	128	82	54	264
Puketawa		Private landowner	49	40	35	124
Regional Council Centre	142720	Greater Wellington	24.8	35.8	38.2	98.8
Riverbend		Private landowner	120	60	50	230
Rocky Hills		Private landowner				330
Rotopai		Private landowner	80	60	63	203
Seaview		Private landowner	60	65	54	179
Seton Nossiter Park	142811	Greater Wellington	56.0	44.0	36.8	136.8
Shandon Golf Course	142813	Greater Wellington	71.5	40.0	46.0	157.5
Snodgrass	140904	Greater Wellington	49.0	18.0	36.0	103.0
Spothill		Private landowner	50	60	48	158
Stoney Creek	154427	NRFA	122.4	64.6	59.6	246.6
Strathearn		Private landowner	72	44	62	178
Sunlay		Private landowner	48	23	32	103
Takapau		Private landowner				490
Tanawa Hut	67153	Greater Wellington	75.5	38.0	48.5	162.0
Tasman Vaccine Ltd	152004	Greater Wellington	92.5	41.0	127.0	260.5
Taungata	58201	Greater Wellington	32.0	23.5	41.0	96.5
Taymor		Private landowner				241
Te Awa		Private landowner	80	34	48	162
Te Haroto		Private landowner	73	75	53	201
Te Maire		Private landowner	93	59	45	197
Te Marua	150109	Greater Wellington	66.0	44.0	71.0	181.0
Te Weraiti	59795	Greater Wellington	86.0	43.0	33.0	162.0
Te Whera		Private landowner	151	49	17	217
The Brocken		Private landowner	90	95	70	255
The Downs		Private landowner	91	61	38	190
Transmission Lines	58103	Greater Wellington	63.5	11.0	23.0	97.5
Tupurupuru		Private landowner	92	48	40	180
Valley Hill	59445	Greater Wellington	97.0	48.5	71.5	217.0
Waihi	58737	Greater Wellington	67.2	46.0	43.6	156.8
Waikoukou		Private landowner	105	65	50	220
Waingawa	58582	Greater Wellington	80.0	41.0	54.5	175.5
Wainuiomata Reservoir	142904	Greater Wellington	144.0	66.5	134.5	345.0
Waiorongomai		Private landowner	78	46	99	223
Wairarapa College	59616	Greater Wellington	72.4	45.4	35.4	153.2
Warren		Private landowner	60	38	29	127

Site Name	Site number	Recording authority	Daily rainfall (mm)			
			4/7 09:00 - 5/7 09:00	5/7 09:00 - 6/7 09:00	6/7 09:00 - 7/7 09:00	Total
Warwicks	59007	Greater Wellington	82.0	32.5	55.0	169.5
Water Treatment Plant	58004	Greater Wellington	85.5	23.5	20.0	129.0
Waynes Mistake	141813	Greater Wellington	35.0	26.0	37.0	98.0
Whakatomotomo		Private landowner	97	51	61	209
Wharepapa		Private landowner	101	-	84	185
Whenua Tapu	140806	Greater Wellington	25.5	10.5	18.5	54.5
White Rock		Private landowner	52	60	53	165