Analysis of Rainfall for the storm events of 3rd- 4th June. East Coast Tairawhiti

View of the flooding in the Mangatokerau valley from the roof of the Te Kiri House. 4th June 2018.

Draft report

10 November 2018

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Summary

Introduction

Over the 3rd and 4th of June 2018, a major storm event occurred in the East Coast Tairawhiti District causing significant flooding and damage within the region (Queens Birthday 1 event). While moderate rainfall was widespread across the district, a short duration more intense rain cell occurred in a narrow band in the centre of the region from Pakarae in the south to the Mangaheia River in the north.

This resulted in severe flooding in the Pakarae and Uawa catchments, the mobilisation of a large volume of sediment and woody debris from planation forests and necessitated the dramatic rescue of a family from the Mangatokerau River. The event also re-mobilised woody debris resident on the flood plains of the Uawa Catchment following Cyclone Cook in 2017.

One week later over the 11th and 12th of June 2018, a second major storm occurred but this event exhibited significantly different characteristics (Queens Birthday 2 Event). While peak rainfall intensities were lower than the Queens Birthday 1 storm, the duration of intense rainfall was longer and the distribution more widespread. The Queens Birthday 2 Event is described in more detail in Cave 2018b)

The economic, social and environmental impacts of both storms have been significant and recovery efforts are still continuing some four months later. The flood associated with the Queens Birthday 1 event resulted in around 47,000 m^3 of woody debris being deposited on the beach at Tolaga Bay and at least 400,000 m^3 of debris is estimated to be resident within the catchment in locations vulnerable to remobilisation in a storm event.

Objectives

The objectives of this study are to assess these two rainfall events to establish the following;

1. The duration and intensity of the rainfall events,
2. The distribution of the rainfall event,
3. Unpack the complexity of the rainfall event to aid understanding why it caused such significant impacts,
4. To understand the return period (or average recurrence interval) of the event, and finally,
5. To assess analytical methods and tools to better understand the potential of such storms to cause impacts within a reasonable forecast interval preceding the event.

Data sources

Three separate data sets have been used in this analysis.

1. Rainfall gauges from the Gisborne District Council's (GDC) rain gauges network,
2. Uncalibrated rain gauge data provided by third parties, and
3. Met Service Rain Radar data calibrated by GDC rain gauge data.

Data Quality

The GDC rain gauge data is collected at 10 minute intervals and is then aggregated to provided longer time interval datasets; ie, 1 hour, 12 hour and 24 hour accumulations. There are a number of issues despite the density of data generated.

Firstly, the rain gauge distribution is not perfect with some gauges being located close to each other while in other areas there are large spatial gaps. Secondly, one or more gauges may not have provided accurate readings; for example the Oates Street urban gauge recorded a zero value with other gauges close by recorded meaningful data.

Secondly, the standard of rainfall data reported by the third party gauges is unknown and such data needs to be treated with caution and as such has been omitted from this analysis. Also while there is probably more third party rainfall data available, Council was unable to get these records.

Thirdly, the Met Service rain radar data was supplied as low resolution raster files with no embedded spatial metadata meaning that it could not be directly loaded into a GIS to allow for spatial analysis. Associated digital data, while containing metadata could not be spatially analysed as the attributes required propriety software to allow for it to be analysed. The raster data was manually geocoded (rubber sheeted) to convert it to a form that could be used in a GIS. This process could have produced potential errors but these have not been tested.

Severe Weather warnings

While the available MetService forecast preceding the Queens Birthday storm identified that there would be a weather event, there was no severe storm warning generated and the event's severity came as a surprise **(Figure One**). On the other hand, alternative weather modelling services such as Weatherwatch and MetVUW did suggest that there might be a relatively intense localised weather event within the central area of Gisborne/Tairawhiti (**Figure Two**).

Heavy Rain Watch for Gisborne
Issued 08:32pm Saturday 02 Jun 2018
Heavy Rain Watch Area: Bay of Plenty west of Whakatane, including Rotorua and the Kaimai range. Also ranges of Gisborne north of Tokomaru Bay. Valid: 27 hours from 6:00am Sunday to 9:00am Monday Forecast: Periods of heavy rain with thunderstorms possible. Rainfall amounts may approach warning criteria.

Heavy Rain Watch for Gisborne
Issued 09:23pm Sunday 03 Jun 2018
Heavy Rain Watch Area: Bay Of Plenty east of Te Puke including Rotorua, and Gisborne north of Tokomaru Bay Valid: 14 hours from 9:00pm Sunday to 11:00am Monday Forecast: Periods of heavy rain with thunderstorms possible. Rainfall amounts may approach warning criteria.

Heavy Rain Watch for Gisborne
Issued 10:24am Monday 04 Jun 2018
Heavy Rain Watch Area: Bay Of Plenty east of Te Puke including Rotorua, and Gisborne north of Tokomaru Bay Valid: 16 hours from 9:00pm Monday to 1:00pm Tuesday Forecast: Heavy rain has eased early this morning, but should return tonight with possible thunderstorms. Rainfall amounts may approach warning criteria, especially during Tuesday morning.

Figure One. *Heavy rain Watches for Gisborne Queens Birthday Weekend.*

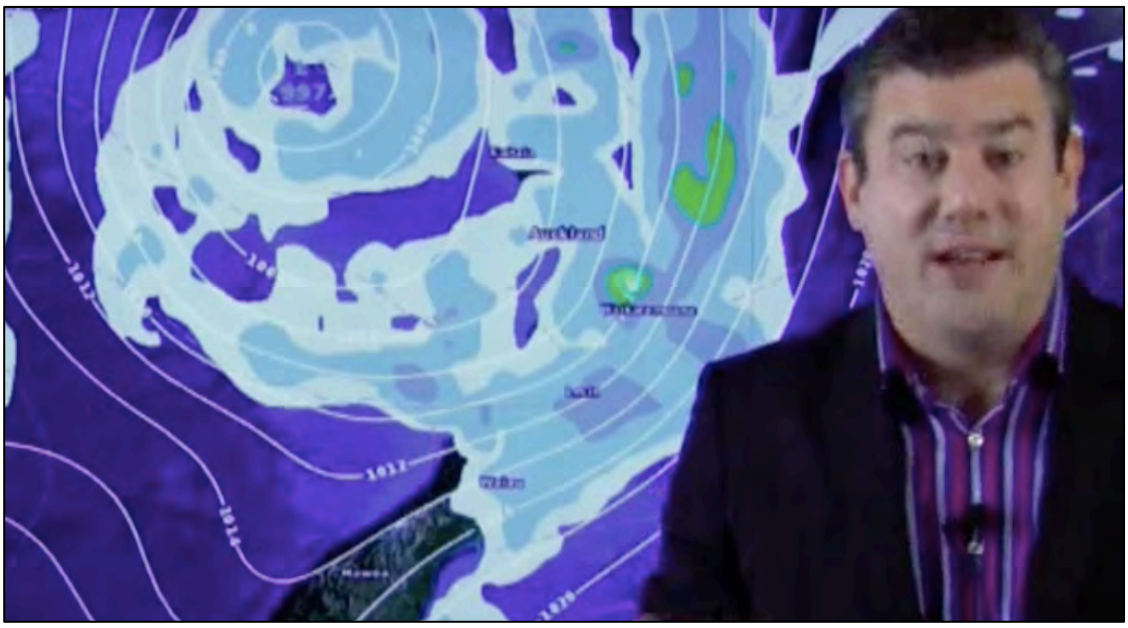

Figure Two. *Weatherwatch Forecast for Sunday 3rd showing intense rainfall cell over central East Coast/Tairawhiti (forecast dated 1 June).*

Situation

The weather event was atypical for the region in having a northwesterly aspect which rarely results in severe weather (*Hall, Bosworth 2018 internal GDC report*). The MetService forecasts suggested some heavy rain and general wet weather with some strong winds around the East Coast. The analysis charts on the MetService news service showed a cell of more intense rainfall moving

down centred offshore East Coast over this time but not making landfall (**Figure Three**).

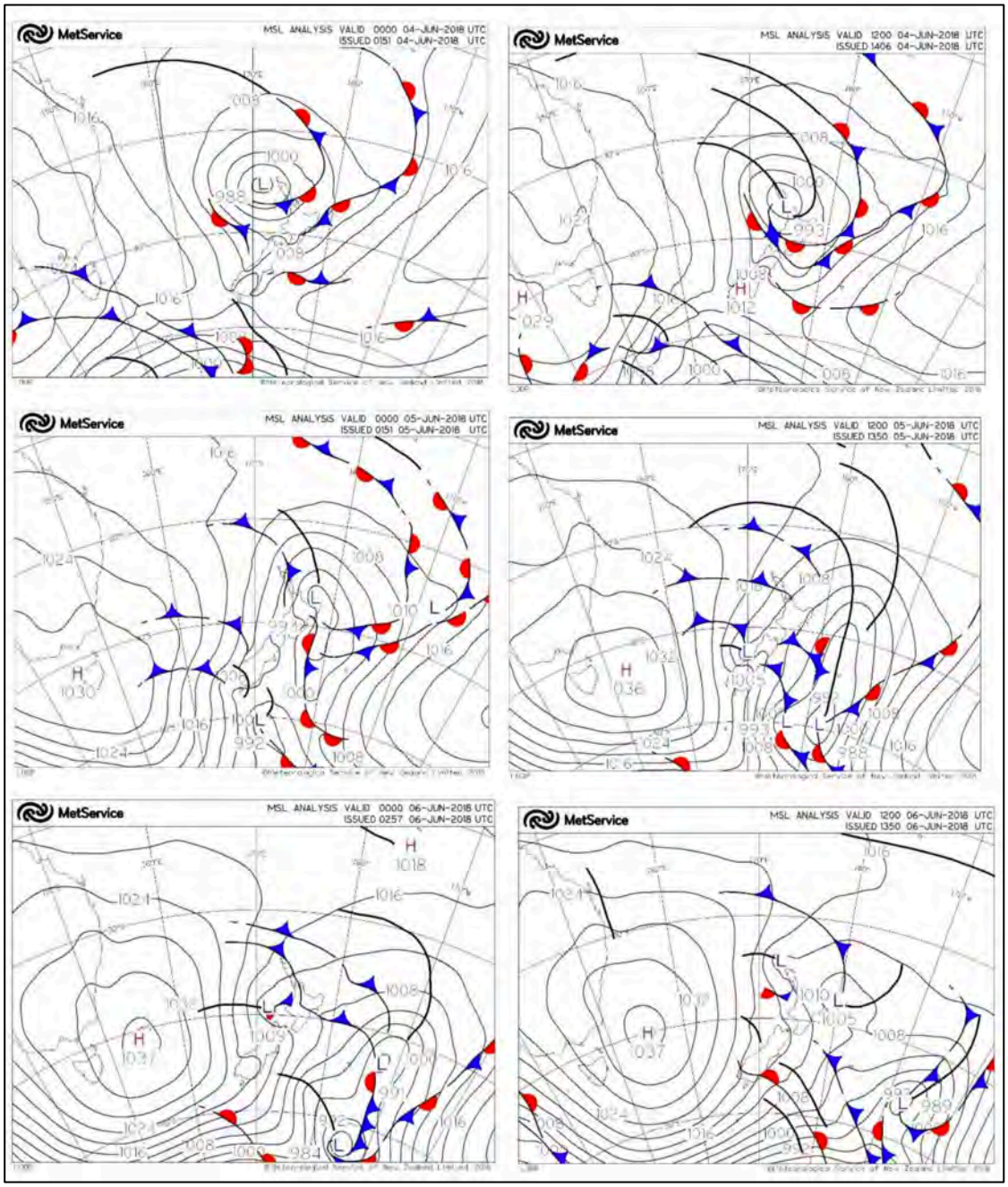

Figure Three. MetService analysis charts for the Queens Birthday One storm.

The severe weather outlook for New Zealand issued by the MetService on the afternoon of the 3rd June appeared to signal heavy rainfall with low confidence for the 5th and 6th of June but no equivalent map was generated for the period 3rd to 4th June (**Figure Four**).

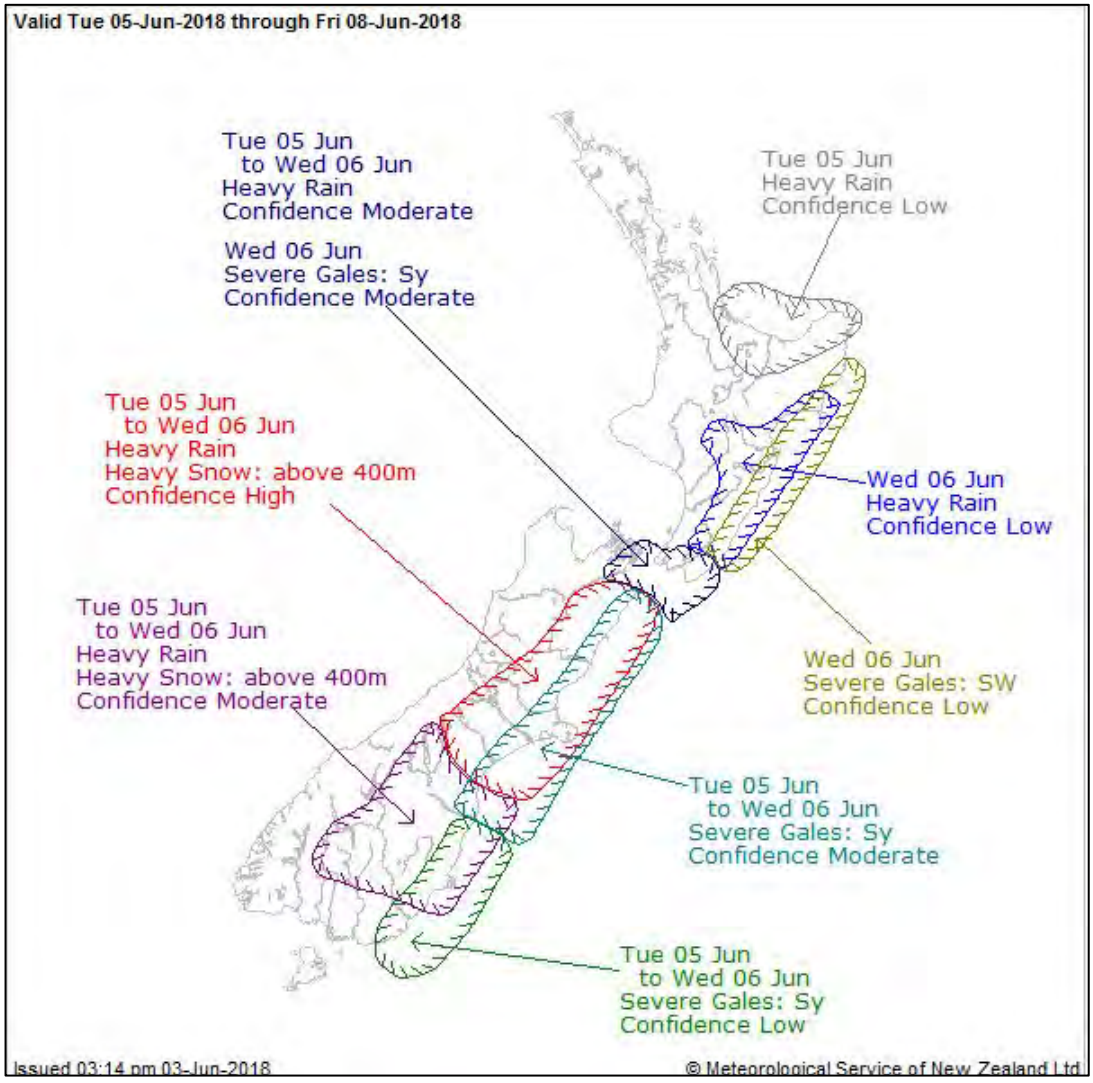

Figure Four. *MetService outlook map dated 03:14pm 3rd June 2018 which forecast low confidence heavy rain for Bay of Plenty and northern East Coast/Tairawhiti on the 5th of June.*

Rainfall Data

This analysis of rainfall data for the East Coast Tairawhiti Region is based on 59 rain gauges distributed across the area from Hicks Bay in the north to the top of the Wharerata in the south. There is a gap in coverage in the west while coverage to the north may be too coarse to adequately define rainfall distribution across the area (**Figure Five**). Raw rainfall data is presented as **Appendix One**.

Analysis of the rainfall data for all gauges (excluding Panikau-Reed Road and Mangaheia at Willowbank) indicates that much of the 3rd of June had low rainfall of around 4mm per hour but that rainfall steadily increased from around 5pm to 9pm (depending on location) on the 3rd of June peaking between Midnight and 6am on the 4th of June across the region. Peak rainfall maxima for these gauges was under 35mm per hour and for most gauges less than 25mm per hour. Most rainfall had ceased by 9am but a second smaller

peak occurred between 1 and 8 pm in the afternoon with hourly rainfalls peaking at around 10mm or a little above per hour (**Figure Six**).

The key observation based on all of these gauges is that as Peter Hancock (Team leader Environmental Monitoring and Hydrology) [August 2018] noted *"The 3-4 June storm was a relatively small event centred on a narrow band that mainly affected the Uawa and Pakarae catchments. At two sites–Willowbank and Panikau the highest intensity rainfalls of 55mm and 60mm in one hour were recorded–but these don't represent the overall storm size and other gauges in the area recorded much lower rainfall."*

Figure Five. *Location of rain gauges within East Coast/Tairawhiti.*

In some areas, localised short-duration rainfall accumulations occurring prior to the main weather event are evident in the hourly records. The Mangaheia at Willowbank gauge and Hikuwai at No. 3 Bridge recorded 7.5mm and 5mm respectively between 3 and 4pm on the 3rd of June but then just had drizzle until 9pm. A similar pattern occurred at Wharerata, Matawai and Mangapoike Reservoir in the far south of the district.

Rainfall accumulation in the north appears to have started around the same time at 3 to 4pm, with some stations then recording steady rain from then until early in the morning of the 4th of June. In the Waikura Valley, for example, steady rain fell from 4pm, was heavy from 6pm through to 1am on the 4th while Raparapaririki and Ruatoria had steady rain from 4pm until early morning on the 4th. The Mata, Poroporo and Puketoro stations had steady rain from 4pm while at Te Puia steady rain accumulation began at 7pm on the 3rd (**Figure Seven**).

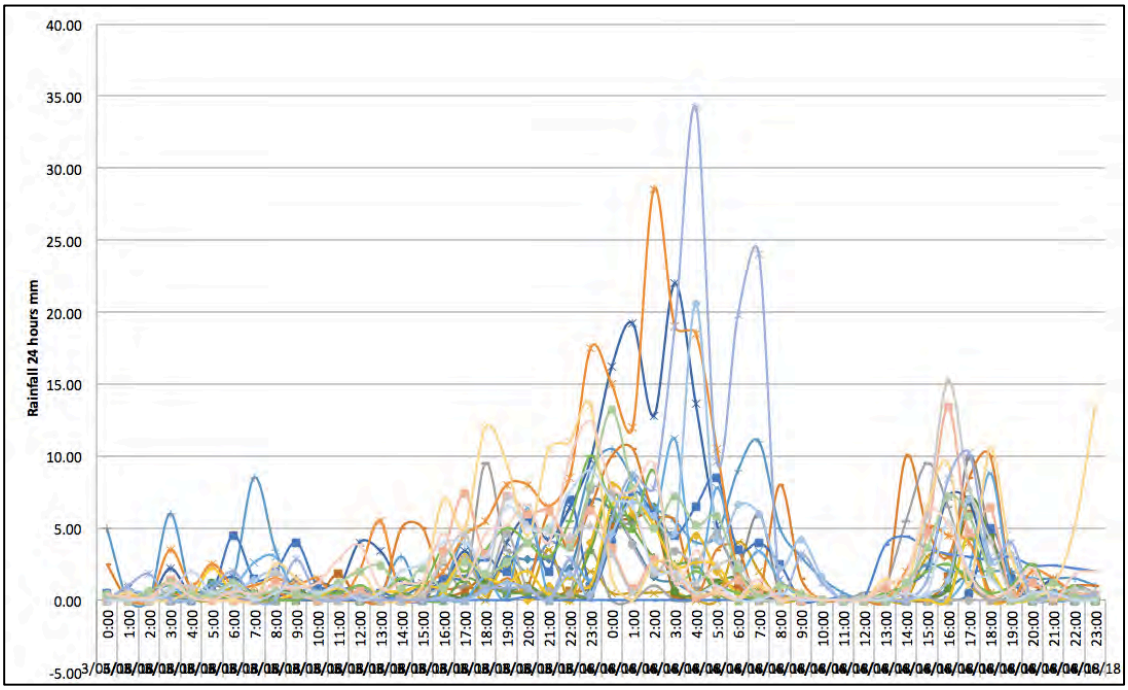

Figure Six. *Plot of all rain gauges (except for Panaikau-Reed Road and Mangaheia at Willowbank) for the 3rd and 4th of June 2018 showi g a relatively small event with a background level of rainfall occurring over much of the 3rd of June with peak accumulations occurring between 10pm on the third and 9am on the 4th of June.*

The data suggests that heavy accumulations started in the far north of the region Waiakura Valley and died away south of Ruatoria by midnight on the 3rd of June. The pattern is the same in the south except for the Wharerata gauge which peaked at 5am on the 4th. Regionally, a storm period starting at c.4pm on the 3rd running to 3pm on the 4th of June fully captures the main storm event and this is the period used for annual recurrence interval estimation (**Table One**).

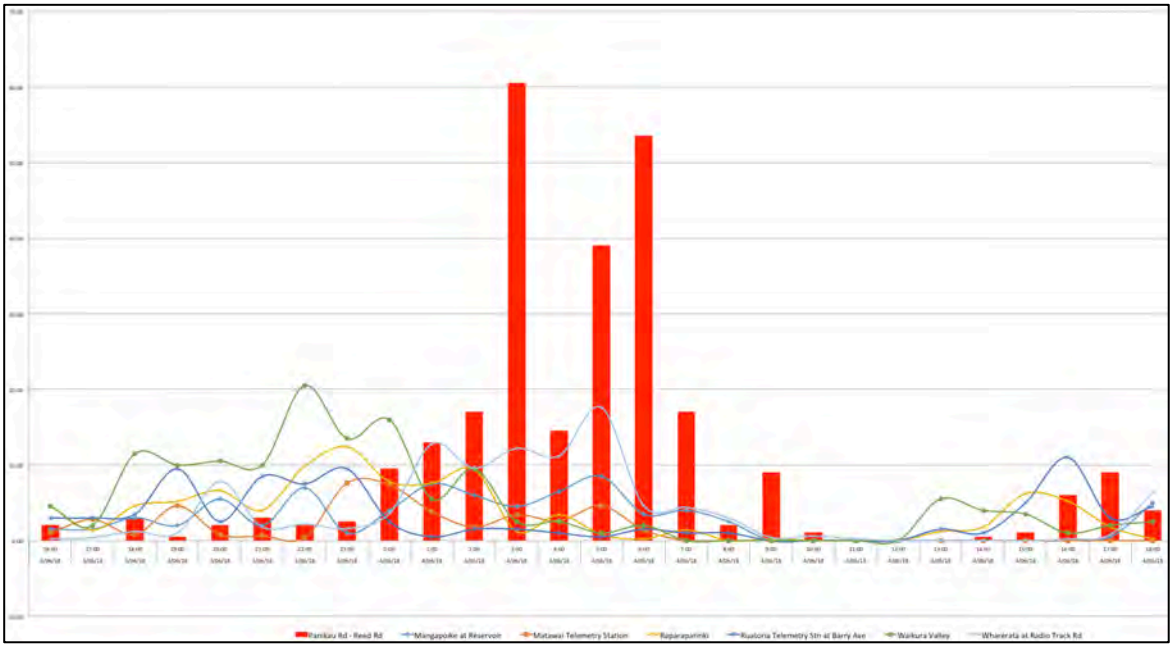

Figure Seven. *Precursor rainfall accumulation for the north of the District (Waikura Valley, Ruatoria, Raparariki) and Mangapoike, Matawai and Wharerata compared with the Panikau at Reed Road Gauge (Red) in the south of the Pakarae Catchment.*

Two sites, Panikau-Reed Road and Mangaheia at Willowbank (**Figure Eight** for locations and **Figure Nine** for rainfall) showed a significantly different pattern. The Panikau-Reed Road gauge is located in the south of the Pakarae Catchment and recorded the highest hourly rainfall for the storm at 60.5mm as well as the highest 24 hour accumulation (266mm on the 4th of June). The Mangaheia at Willowbank gauge is located in the Uawa Catchment and recorded an hourly[1] peak of 55.5mm and a 24 hour accumulation of 234mm (4th June).

The detailed 10 minute rainfall covering the period 1st to 6th of June was also reviewed, particularly for the Panikau-Reed Road and Mangaeia at Willowbank Gauges. The Panikau-Reed Road gauge had a total of 4 hours of heavy rain (+6.5mm per 10min) [total rain 184.5mm] with two nominal hourly peaks, the first between 2:50 and 3:40 (64.5mm) and then again at 5:40 to 6:50 (58.5mm). The Mangaheia at Willowbank gauge also had 2 peaks with the first occurring between 2:30 and 3:20 (55.5mm) and then from 4:20 to 5:30 (79mm) [total rain 150.5mm] but the storm duration was less than at Panikau at 3 hours.

[1] These hourly figures are based on standard hours. Recalculating the data on a nominal hour (ie a 60 minute period not starting at the top of the hour) gives a different value. Using a nominal hour the Willowbank and Panikau had very similar maxima (66.5mm vs 64.5mm) with the most intense rainfall starting 20 minutes earlier at Willowbank.

Station	24 hour	12 hour	6 hour	1 hour (mx)
Arowhana Repeater	37	20.8	3.8	6.8
Caesar Rd No.1 Bore GPG058	25.8	21.4	9.2	5.8
Cameron Rd No.1 Bore GPB099	32.5	29	18	6.5
East Cape at Lighthouse	23	10	7	4
Fernside Station Telemetry Station	130.6	101.4	56	22
Hika No.1 Bore Ferry Road GPE032	27	22.8	10.8	6.4
Hikuwai River at No 4 Bridge	100.5	78	40.5	11
Hikuwai River at Willowflat	85.5	56	19.5	19.5
Karakatuwhero River at SH35 Br	46.5	5	1.5	9.5
Komihana Station	37	29.5	11.5	8
Mangaheia at Willowbank	218.5	202.5	174.5	55.5
Mangapoike at Reservoir	70.5	48	33	8.5
Mangatu River at Omapere Station	29	24.5	8.5	7.5
Maraetaha River at No.3 Br	59	47.4	31.6	11.2
Mata River at Pouturu Br	174.5	124.5	78.5	28.5
Matawai Telemetry Station	43.6	32.6	13.8	7.6
Ngatapa school	39.2	28.6	14	7
Oates St Air Quality	12.4	0	0	4.4
Pakihiroa Telemetry Station	65.5	35.5	14	10
Panikau Rd - Reed Rd	252.5	238.5	201.5	60.5
Parone Rd RG	72.6	67.6	47.8	20.6
Poroporo Fire	61.6	18	7.2	3.4
Poroporo River at SH35 Bridge	56.8	19.4	10.2	7.2
Poroporo Telemetry Station	91	22.5	7	13.5
Pouawa Fire	140.6	134	114.4	34.2
Puketawa Station	81.2	56	25.6	13.2
Puketoro Telemetry Station	64.5	28.5	5.5	9
Raparapaririki	89.8	44.4	16.4	12.4
Ruatoria Telemetry Stn at Barry Ave	65.5	20.5	7	9.5
Stout St RG	44.4	41.2	27.4	9
Tatapouri Hill	57	54.5	42.5	9
Tauwhare Station	42.4	29.6	3.2	14.2
Te Arai River at Pykes Weir	60.5	43.5	25	11
Te Puia	100.5	59	31.5	20.5
Te Rata Telemetry Station	25	17.5	3	5.5
Tuahu Station	91	74.5	37	12.5
Tutamoe Station Telemetry Station	54	39	13.5	12
Uawa River at SH35 Bridge	42.4	29.8	6.2	9.2
Waerenga-O-Kuri	67.4	52.8	36.6	10.4
Waihora River at No.3 Br	25.6	21.8	7.4	6.2
Waikakariki Stream at Kirkpatrick Br	36.5	26.5	12.5	7
Waikanae Creek at Customhouse St Br	40.2	38.4	25.2	6.4
Waikohu River at Mahaki Station	39	31.5	14.5	9
Waikohu River at No.3 Br	32.5	26.5	11	7.5
Waikura Valley	134.5	52.5	17.5	20.5
Waimata River at Goodwins Rd Bridge	73.6	69	47.8	14
Waimata River at Monowai Bridge	48.2	42.4	25.2	9.2
Waingaromia River at Terrace Station	34	28.2	7.2	9
Waipaoa River at Kanakanaia	27	23.5	10.5	8.5
Waipaoa River at Matawhero Bridge	32.8	26.4	12.8	6.6
Waipaoa River at Te Hau Station Rd Br	27.8	24.2	6	7.6
Waipaoa River at Waipaoa Station	27	23	4.5	7.5
Wakaroa Trig	51.8	40.4	21.6	9.6
Whakapunake Trig	18.8	14.8	9.6	3
Wharekahika River at Hicks Bay Rd Br	56.2	8.6	2.8	13.6
Wharekopae River at Rangimoe	44.5	36	16.5	9
Wharekopae School	49.8	35	15.6	9.4
Wharerata at Radio Track Rd	96.4	81.6	59.6	17.6
Wheatstone Rd	42.5	40	29	15

***Table One**. Rain gauge data for the Queens Birthday (3rd-4th June 2018) showing 24 hour (starting 4pm 3rd June), 12 hour (starting 11pm on 3rd June) and 1 hour (maximum hourly rainfall occurring within the 24 hour period starting 4pm on the 3rd of June 2018 (see **Appendix One and Two** for raw data).*

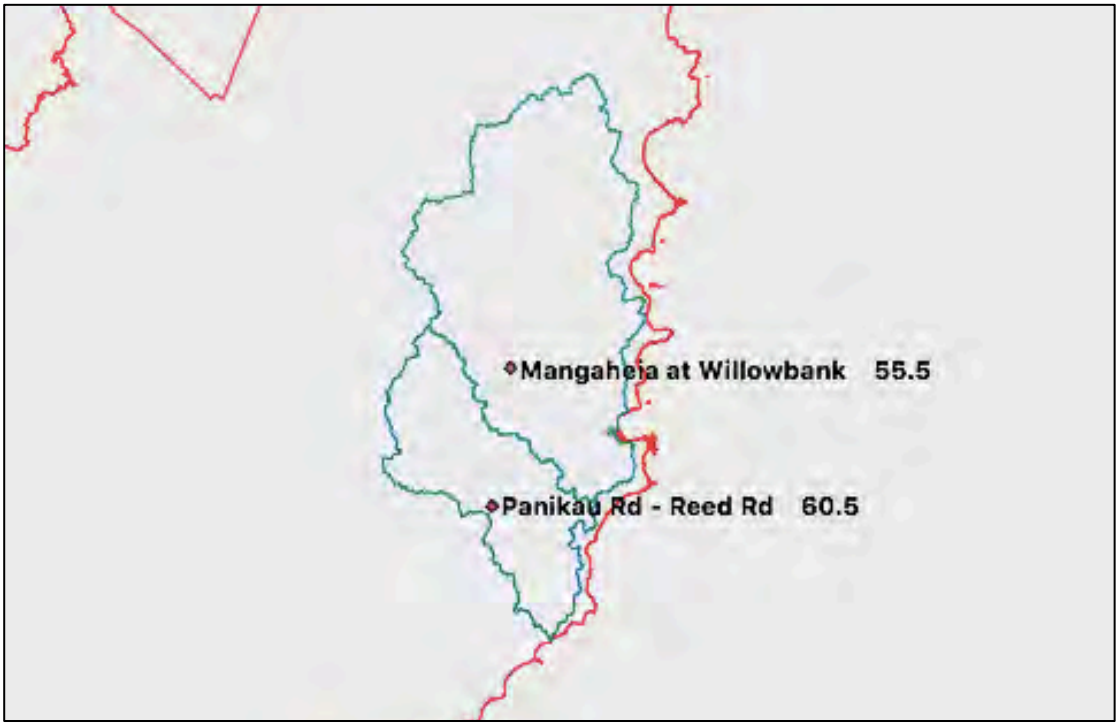

***Figure Eight**. Map of the central part of the Gisborne/Tairawhiti Region showing the Pakarae and Uawa Catchments and the location of the Panikau-Reed Road and Mangaheia at Willowbank rain gauges.*

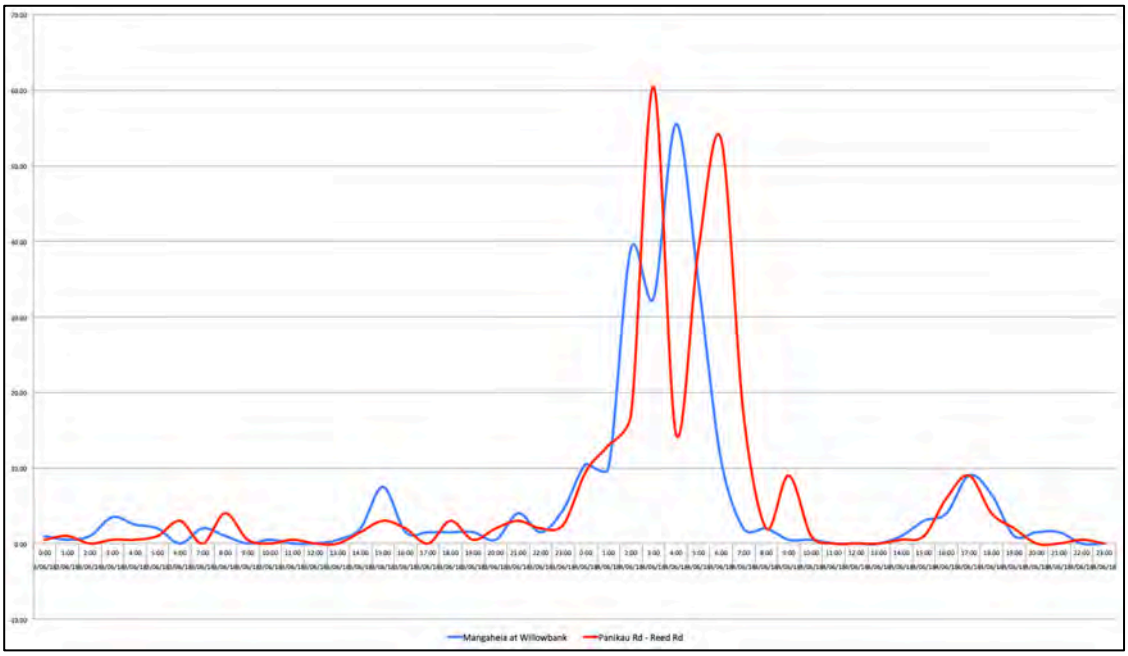

***Figure Nine**. Rainfall accumulation for the Panikau-Reed Road (red) and Mangaheia at Willowbank (Blue) Gauges. Note that the scale on the left (in mm) indicates that peak accumulation was about twice that of other gauges (see **Figure Six**).*

The data suggests that an intense short-duration rain cell hit at Mangaheia slightly earlier (2:30am) than at Panikau (2:50am) but didn't last as long. Total rainfall at Mangaheia was also lower at 150.5mm for the intense storm interval

compared with 184.5mm at Panikau for the same period. Excluding these two gauges, the event rainfall had a maximum peak intensity of 35mm/hour with this peak occurring from 3-4 am on the 4th. The Queens Birthday storm was thus quite complex with what appeared a relatively small event with rainfall spreading from north to south colliding with a secondary orographic rain cell between Gisborne City and Uawa. This rain cell caused intense rain that was fortuitously captured by the Panikau-Reed Road and Mangaheia at Willowbank gauges (**Figure Ten**).

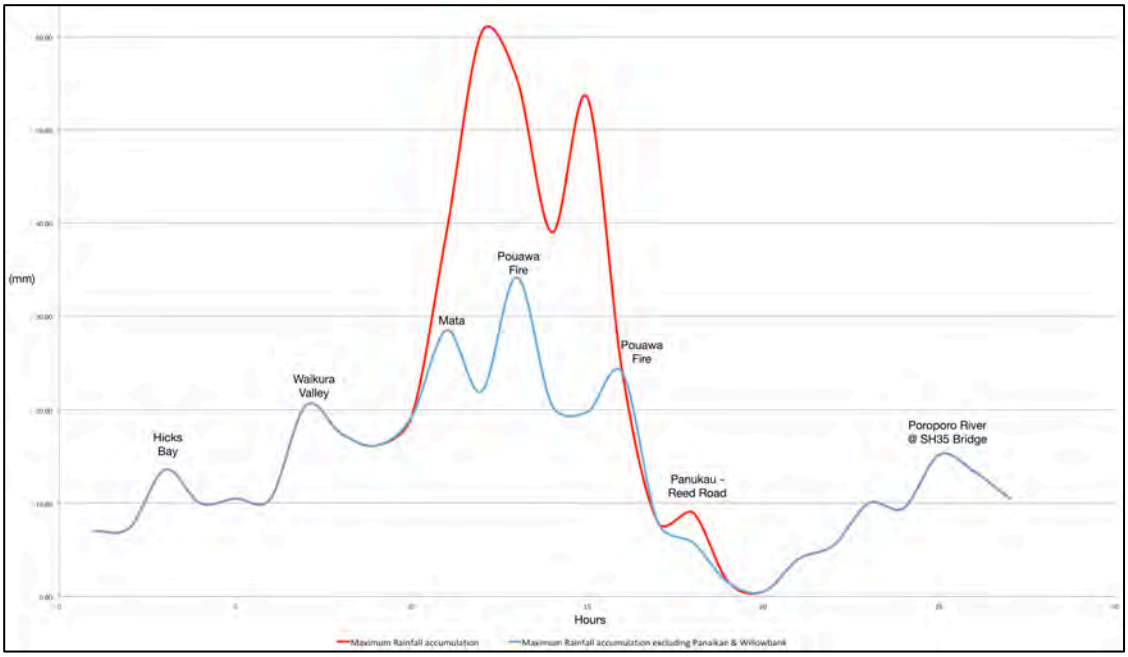

***Figure Ten**. Maximum hourly rainfall accumulation for the Panikau-Reed Road Gauge (red) superimposed on the background Queens Birthday rainfall event (Blue). The background rainfall suggests heavy rain started in the north and then moved south through Mata. Note the Pouawa Fire peaks occurring slightly later than the overall maxima recorded at the Panikau Reed Road Gauge.*

Rain Radar

To better understand the nature of the event, rain radar data was provided by the MetService. The MetService 24 hour rain radar data is calibrated with the rain gauge data and shows that a relatively narrow band of more intense rain occurred in the central part of the region starting in the Glenroy Road area in the south and extending north to around the Mangatokerau tributary of the Uawa (**Figure Eleven**).

Not surprisingly, this is consistent with the rain gauge data. The radar also suggests that the high rainfall band extended further north but with overall lower rainfall intensities. Secondary rain concentrations occurred in the Wharerata and possibly in the Wharekopae. Because, however, this rain radar dataset shows a 24 hour accumulation for a storm that lasted a relatively short

period, it does not accurate view of the 6 hour period when the most intense rain fell.

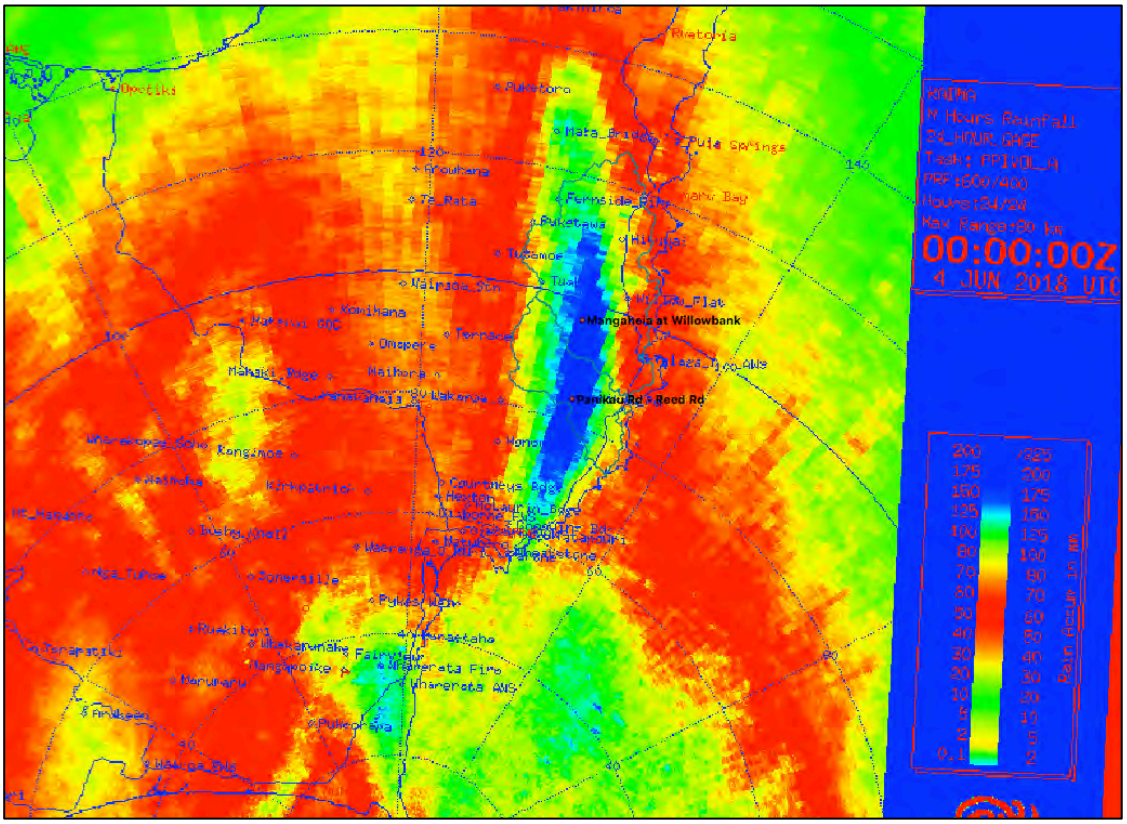

Figure Eleven. Geo-corrected 24 hour Rain Radar data for the Queens Birthday 1 storm based on MetService radar (00 hours UTC midday 4th June standard hours).

The MetService also provided 12 hour rain radar data covering the period 21:00:00 hours UTC on 3rd of June. The difference between UTC time in New Zealand and standard time is 12 hours (in winter) and thus this rain radar image covers the 12 hour period before 9am on the 4th of June.

The 12 hour radar image is consistent with the 24 hour data. Significantly it shows that the rainfall over the previous 12 hours (i.e., encompassing the 6 to 8 hour rainfall event indicated on rain gauge data) is tightly confined to a narrow band starting at the southern boundary of the Pakarae catchment in the south and terminating at the Mangaheia at Willowbank rain gauge (**Figure Twelve**).

Heavy but not as intense rainfall occurred immediately north of Mangaheia at Willowbank as well as immediately south beyond Panikau-Reed Road gauge extending into the Pakarae catchment is evident in the detail of the 1 hour rain radar image (**Figure Thirteen**).

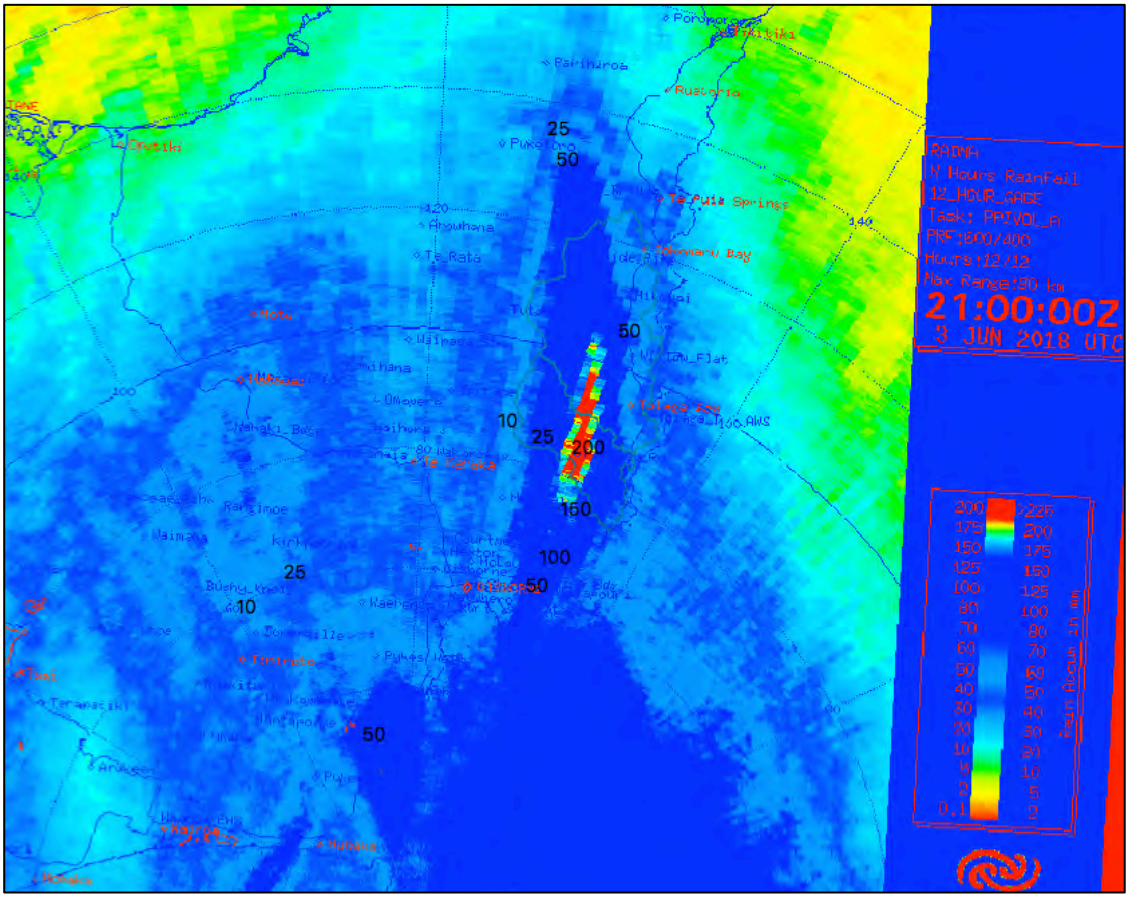

Figure Twelve. Geo-corrected 12 hour Rain Radar data for the Queens Birthday 1 storm based on MetService radar (21 hours UTC 9am 4th June standard hours).

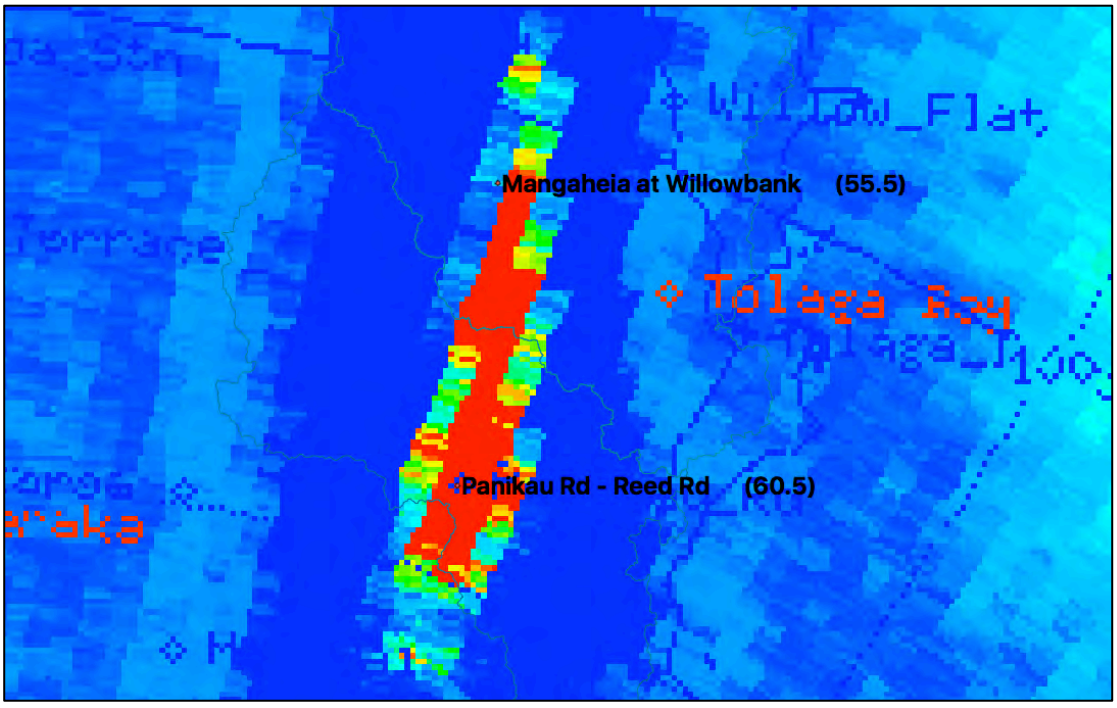

Figure Thirteen. Detail of the geo-corrected 12 hour Rain Radar data for the Queens Birthday 1 storm shown in Figure Twelve) showing the area of highest intensity rainfall in the 12 hours before 9am on the 4th of June 2018.

Combining Rain Gauge and Rain Radar Data

All rain gauge data for all sites has been aggregated to give a contour of total rainfall depth over an 8 hour period (**Figure Fourteen**). The 8 hour period was selected as it encompassed the duration of the peak event recorded at the Panikau-Reed Road and Mangaheia at Willowbank sites plus a tail either side. Overall, however, the majority of that rainfall accumulation occurred within a 6 hour window that moved north to south over time.

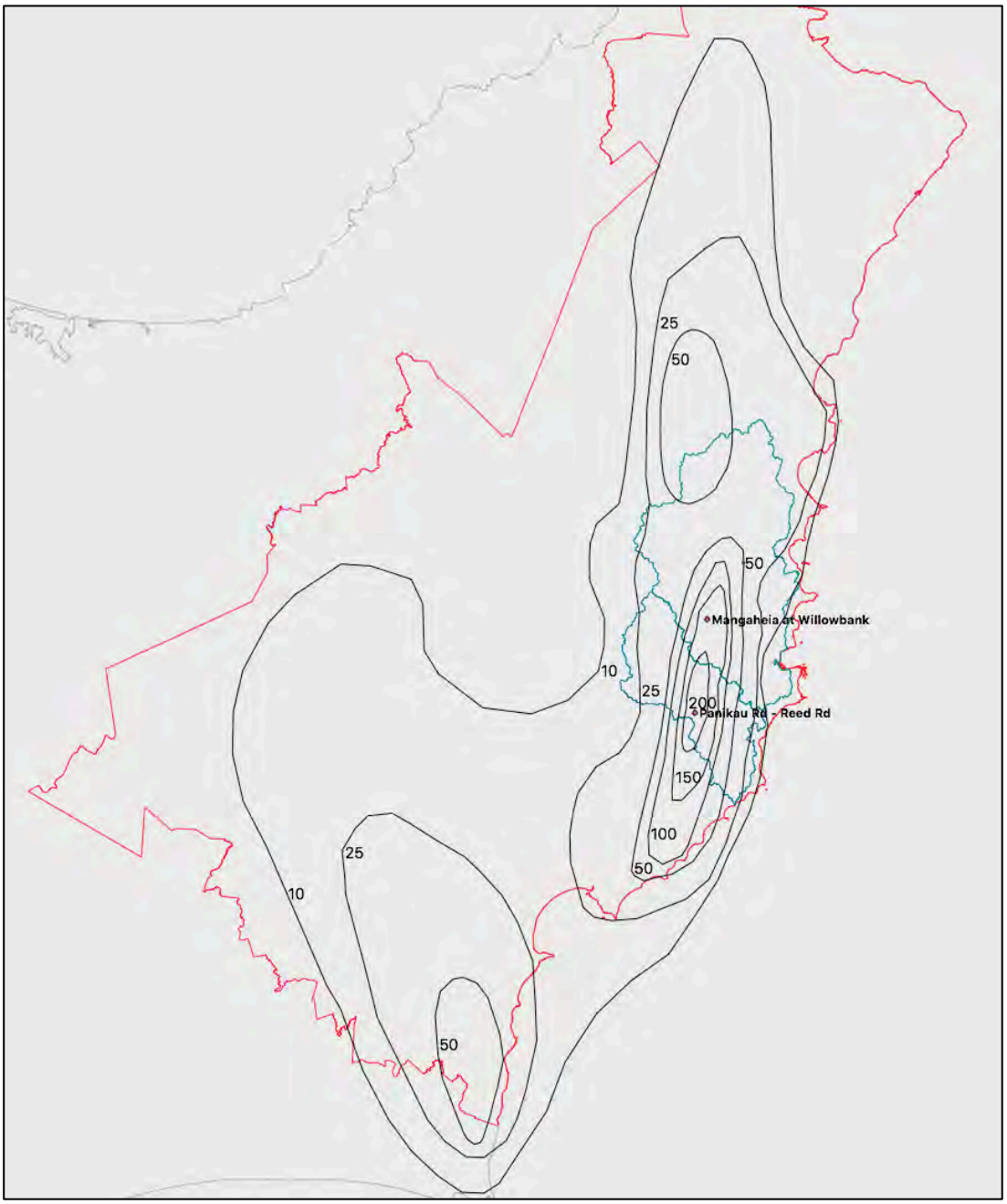

Figure Fourteen. Contoured rain gauge data covering a 8 hour period encompassing all of the main storm event as recorded at Panikau-Reed Road and Mangaehia at Willowbank. This contour plot is based on raw rainfall data and interpolation between adjacent gauges. The data shows a narrow band of intense rain centred on the Panikau-Reed Road extending north to Mangaheia at Willowbank. Gauge data suggests a secondary cell of heavy but not intense rain over the Wharerata and in the north around Fernside Road.

The rain radar was calibrated using the GDC gauges and thus the two datasets should therefore be consistent. This was confirmed with the combined rain radar and contoured rainfall being well aligned although the contour data was better able to delineate rainfall distribution within the area of most intense rainfall shown in the rain radar (**Figure Fifteen**). When viewed in isolation, the contoured rainfall suggested a narrow north-south oriented band of rain centred around Panikau and extending north to Mangaheia at Willowbank with a secondary much smaller cell further north centred on Fernside. It is, however, possible to infer from the rain radar that the two cells are connected.

Either interpretation could be valid. A second cell centred on Fernside would, however, be more consistent with the level of infrastructure damage observed in the Fernside area than a heavy rainfall band extending north of Willowbank.

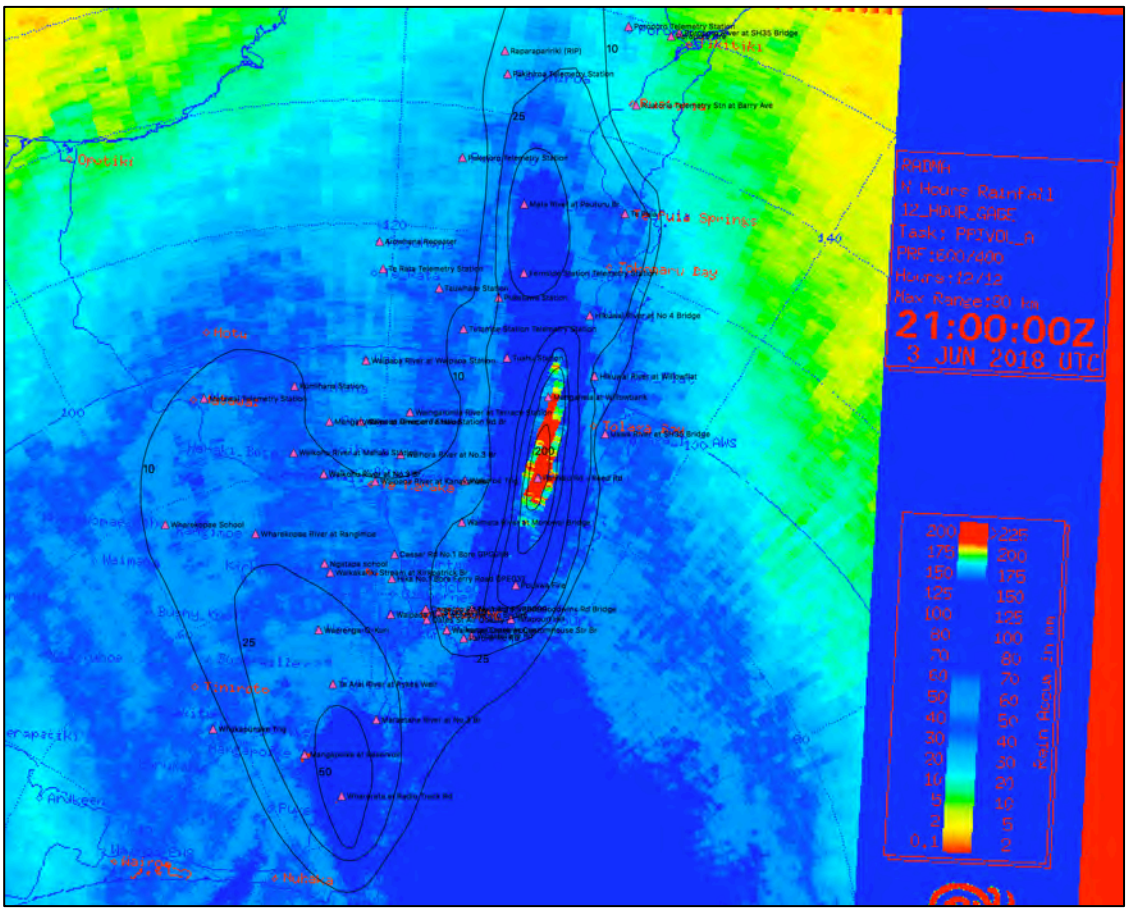

Figure Fifteen. Map overlaying the 12 hour rain radar with the 8 hour rain gauge contours.

Rainfall Accumulations by Catchment

Since the storm caused significant impacts in the region, the relationship between rainfall accumulation and catchments and from there to harvest areas is a key element that needs addressing. As can be seen in **Figures Sixteen and Seventeen**, the heaviest rain accumulation occurred in the Pakarae Catchment but there was also heavy rain in the southern part of the Uawa Catchment, in the Waiomoko, Pouawa and Turihaua catchments.

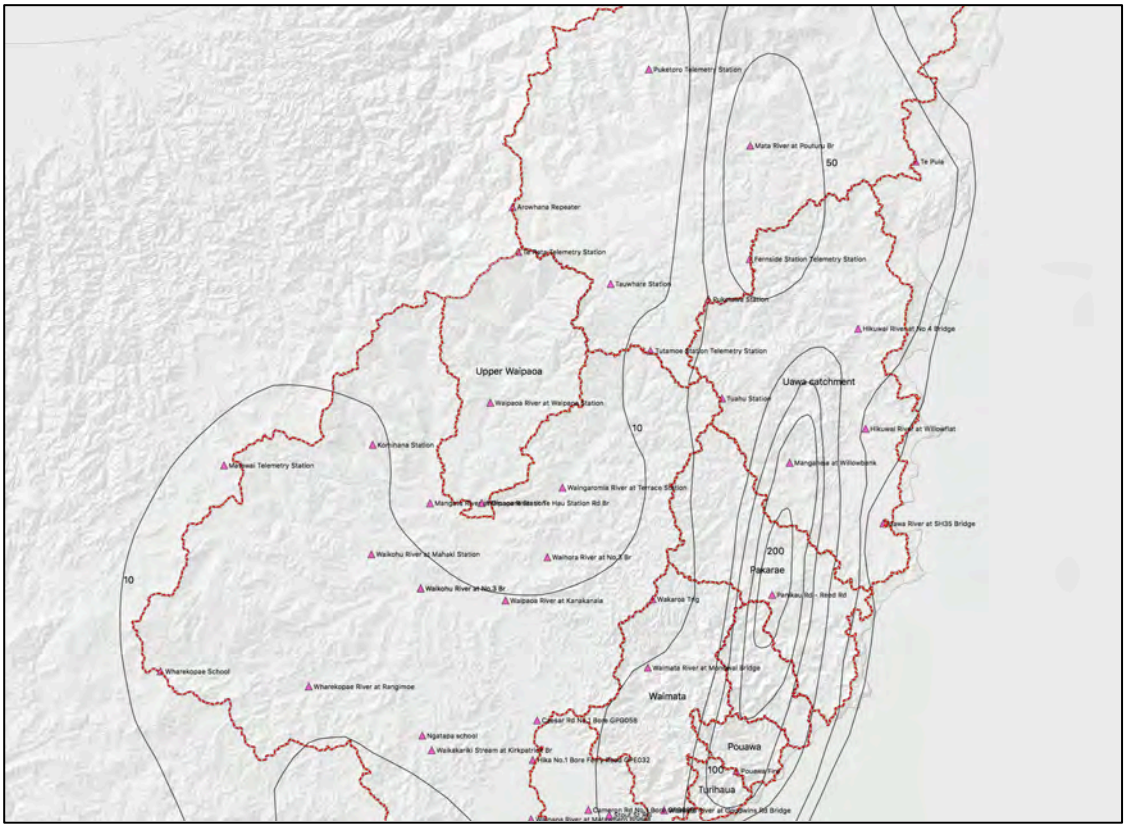

Figure Sixteen. Map showing rainfall distribution over the 8 hour high intensity rainfall event showing the distribution relative to catchments.

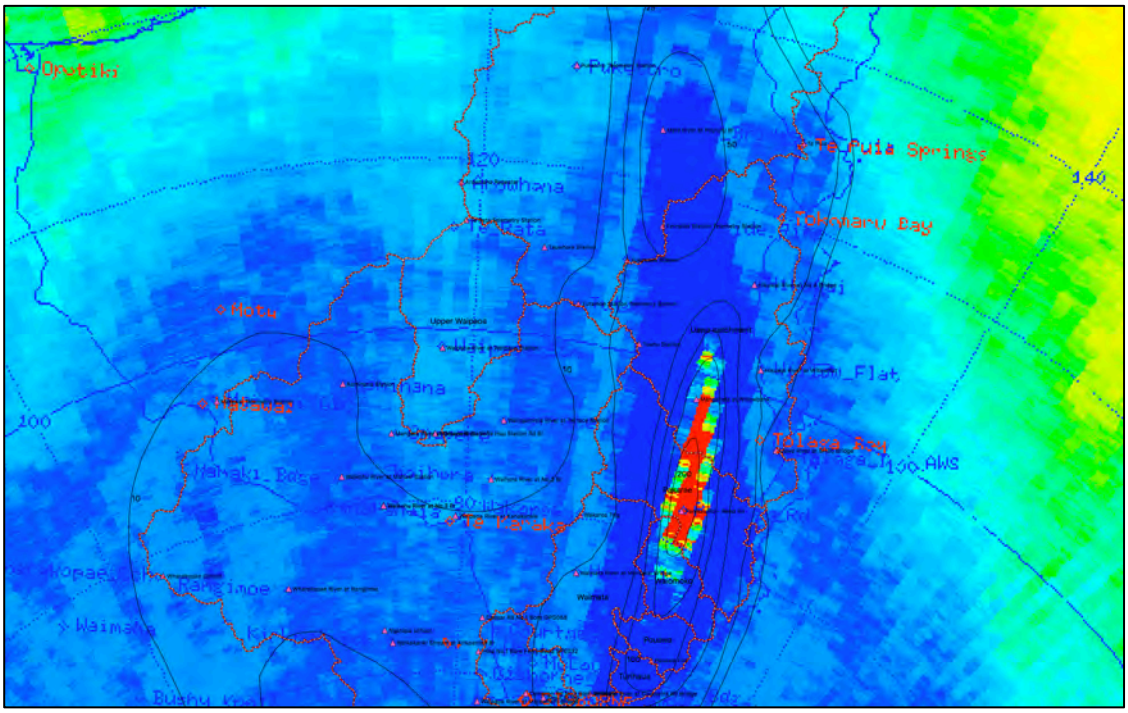

Figure Seventeen. Map showing rainfall distribution over the 8 hour high intensity rainfall event and the 12 hour rain radar data showing the distribution relative to catchments.

Average recurrence Intervals

A limited analysis of the average recurrence interval for the storm has been undertaken (Hancock 2018, *Hall, Bosworth 2018, internal GDC reports*). Hancock (2018) noted *"Although these individual gauge totals were high* [Panaikau- Reed road Mangaheia at Willowbank], *the overall storm size was not that large. Other gauges in the Uawa Catchment recorded much lower rainfall (<2-5 year Average Recurrance Interval), and this is confirmed by the MetService Rain Radar imagery*".

The report went on to note "*The Hikuwai River and Willowflat river site recorded the 3-4 June storm flood as a 5.7 year return period – essentially a one in six year event. Other river gauges in the area <1-2 year flows*."

Hall and Boswell (2018) produced a draft summary of both the Queens Birthday (3-4th June) and Post Queens Birthday (11-12th June) storms. This report remained as an incomplete draft, however, and had a number of caveats noting that many areas required further analysis.

The Hirdsv4 Tool

The Hirdsv4 Tool operated by the National Institute of Water and Atmospheric Research (NIWA) was used to generate indicated average recurrence intervals. The HIRDS tool provides a web map-based interface to enable rainfall estimates to be provided at any location in New Zealand. The web map also displays the locations of all rain gauges used in the HIRDSv4 analysis.

When a gauge is selected, a report can be generated and downloaded as a csv file. Whether a location is selected by clicking on a gauge, clicking anywhere on the map or using the input boxes makes no difference to the way the HIRDS tables are generated.

Rainfall estimates are generated in three steps.

1. *Selecting a location by either:*
   searching using the Address Search
   clicking anywhere on the NZ map
   clicking one of the rain gauge locations
   entering the latitude, longitude and name (WGS84 coordinate system).
2. *Select output format:*
   depth-duration-frequency: returns the amount of rain fallen during the event (in mm).
   intensity-duration-frequency: returns the average rate of rainfall during the event (in mm/hr).

The downloaded data for each site also includes a simple calculator that allows for the ARI to be estimated by typing in the desired duration interval (in this

case 24 hours) and a return period to match the Hirdsv4 data with the rain gauge data.

In this analysis, a suite of reports were generated and downloaded and then compared with actual rain gauge accumulations. Not all Hirdsv4 sites coincided with GDC rainfall gauge sites and where the same sites were used they may use different names; for example Hirdsv4 Pakarae @ Pakerae is the same as GDC Paniakau Reed road.

Because, however, the Hirdsv4 tools allows for the interpolation of data using selecting a specific point on the ground, this option was used as it allowed for the ARI to be estimated at the 59 GDC rain gauge locations (**Table Two**).

For most sites the observed 24 hour rainfall was below the minimum 24 hour value for the site and for these sites the annual recurrence interval was 1. In other words, a 24 hour rainfall accumulation of this amount could be expected at these sites in any one year.

Only a few sites had annual rainfall intervals exceeding 1 year based on a 24 hour rainfall accumulation. The northernmost site was Fernside Station located in the south eastern end of the Mata sub-catchment of the Waiapu and just north of the Ernslaw One's Waiau Forest (ARI 2.75).

Only the Mangaheia and Willowbank site in the Uawa Catchment had an ARI exceeding one (11.7 years). It needs to be noted that NIWA have not used the GDC data to generate an ARI for this location and the return period is based on the interpolation between adjacent sites.

The most significant site was the Panikau-Reed Road site which had a annual recurrence interval of 32 years. The Parone Road rain gauge in outer Kaiti recorded an ARI of 1.4 years.

This analysis confirmed the earlier assessment that the Queens Birthday storm of 3rd and 4th June 2018 was in reality a relatively minor event overall with an overall annual recurrence interval of around 2 years. It must be stressed the ARI estimations are based in part on interpolation which may result in some under reporting of the true ARI.

This is probably particularly the case with the Mangaheia at Willowbank gauge but there cannot be an order of magnitude difference since analysis of landslide scale and frequency in the adjacent farmland does not suggest an overall significant event. In addition, the overprint of the narrow and confined heavy rainfall cell between Mangaehia at Willowbank and Panikau-Reed road adds a complexity to the storm that the Hirdsv4 tool may not be able to accurately accommodate.

Station	24 hour	12 hour	6 hour	1 hour (mx)	Hirdsv4 24 hour Ari
Arowhana Repeater	37	20.8	3.8	6.8	1
Caesar Rd No.1 Bore GPG058	25.8	21.4	9.2	5.8	1
Cameron Rd No.1 Bore GPB099	32.5	29	18	6.5	1
East Cape at Lighthouse	23	10	7	4	1
Fernside Station Telemetry Station	130.6	101.4	56	22	2.75
Hika No.1 Bore Ferry Road GPE032	27	22.8	10.8	6.4	1
Hikuwai River at No 4 Bridge	100.5	78	40.5	11	1
Hikuwai River at Willowflat	85.5	56	19.5	19.5	1
Karakatuwhero River at SH35 Br	46.5	5	1.5	9.5	1
Komihana Station	37	29.5	11.5	8	1
Mangaheia at Willowbank	218.5	202.5	174.5	55.5	11.7
Mangapoike at Reservoir	70.5	48	33	8.5	1
Mangatu River at Omapere Station	29	24.5	8.5	7.5	1
Maraetaha River at No.3 Br	59	47.4	31.6	11.2	1
Mata River at Pouturu Br	174.5	124.5	78.5	28.5	4
Matawai Telemetry Station	43.6	32.6	13.8	7.6	1
Ngatapa school	39.2	28.6	14	7	1
Oates St Air Quality	12.4	0	0	4.4	1
Pakihiroa Telemetry Station	65.5	35.5	14	10	1
Panikau Rd - Reed Rd	252.5	238.5	201.5	60.5	32
Parone Rd RG	72.6	67.6	47.8	20.6	1.4
Poroporo Fire	61.6	18	7.2	3.4	1
Poroporo River at SH35 Bridge	56.8	19.4	10.2	7.2	1
Poroporo Telemetry Station	91	22.5	7	13.5	1
Pouawa Fire	140.6	134	114.4	34.2	5
Puketawa Station	81.2	56	25.6	13.2	1
Puketoro Telemetry Station	64.5	28.5	5.5	9	1
Raparapaririki	89.8	44.4	16.4	12.4	1
Ruatoria Telemetry Stn at Barry Ave	65.5	20.5	7	9.5	1
Stout St RG	44.4	41.2	27.4	9	1
Tatapouri Hill	57	54.5	42.5	9	1
Tauwhare Station	42.4	29.6	3.2	14.2	1
Te Arai River at Pykes Weir	60.5	43.5	25	11	1
Te Puia	100.5	59	31.5	20.5	1
Te Rata Telemetry Station	25	17.5	3	5.5	1
Tuahu Station	91	74.5	37	12.5	1
Tutamoe Station Telemetry Station	54	39	13.5	12	1
Uawa River at SH35 Bridge	42.4	29.8	6.2	9.2	1
Waerenga-O-Kuri	67.4	52.8	36.6	10.4	1
Waihora River at No.3 Br	25.6	21.8	7.4	6.2	1
Waikakariki Stream at Kirkpatrick Br	36.5	26.5	12.5	7	1
Waikanae Creek at Customhouse St Br	40.2	38.4	25.2	6.4	1
Waikohu River at Mahaki Station	39	31.5	14.5	9	1
Waikohu River at No.3 Br	32.5	26.5	11	7.5	1
Waikura Valley	134.5	52.5	17.5	20.5	1
Waimata River at Goodwins Rd Bridge	73.6	69	47.8	14	1
Waimata River at Monowai Bridge	48.2	42.4	25.2	9.2	1
Waingaromia River at Terrace Station	34	28.2	7.2	9	1
Waipaoa River at Kanakanaia	27	23.5	10.5	8.5	1
Waipaoa River at Matawhero Bridge	32.8	26.4	12.8	6.6	1
Waipaoa River at Te Hau Station Rd Br	27.8	24.2	6	7.6	1
Waipaoa River at Waipaoa Station	27	23	4.5	7.5	1
Wakaroa Trig	51.8	40.4	21.6	9.6	1
Whakapunake Trig	18.8	14.8	9.6	3	1
Wharekahika River at Hicks Bay Rd Br	56.2	8.6	2.8	13.6	1
Wharekopae River at Rangimoe	44.5	36	16.5	9	1
Wharekopae School	49.8	35	15.6	9.4	1
Wharerata at Radio Track Rd	96.4	81.6	59.6	17.6	1
Wheatstone Rd	42.5	40	29	15	1

Table Two. Rain gauge data for the Queens Birthday storm (cf Table One) with the Hirdsv4 ARIs.

Analysis of impacts

A detailed analysis of the landslide impacts from this storm is being undertaken by the Institute of Geological and Nuclear Sciences. Google Earth Pro has just been updated, however, and now includes imagery dated the 25th of August 2018. Thus a limited analysis comparing the rainfall accumulation with on the ground impacts can now be provided.

The storm had a significant impact on the region and captured national media attention that is ongoing. Much of the attention has focussed on Tolaga Bay in the Uawa Catchment. In part, this is because of the dramatic rescue of a family from the roof of their house in the Mangatokerau but also because of the visible impacts resulting from 47,000 m^3 of logs clogging Tolaga Beach.

What has faded from many people's minds is that there was a significant impact further south in the Pakarae and Waiomoko Valleys close to the Panikae-Reed Road rain gauge which received the highest rainfall during the event. Although less comprehensively documented that the events in Uawa, an inspection of the Wiaomoko Valley soon after the event, plus several aerial overflights and now satellite imagery dated 25th August 2018 is available. Thus an assessment of the impacts of the storm on forestry at the centre of the storm near the Panikau-Reed Road rain gauge allows for the storm impacts to be put in context (**Figure Eighteen**).

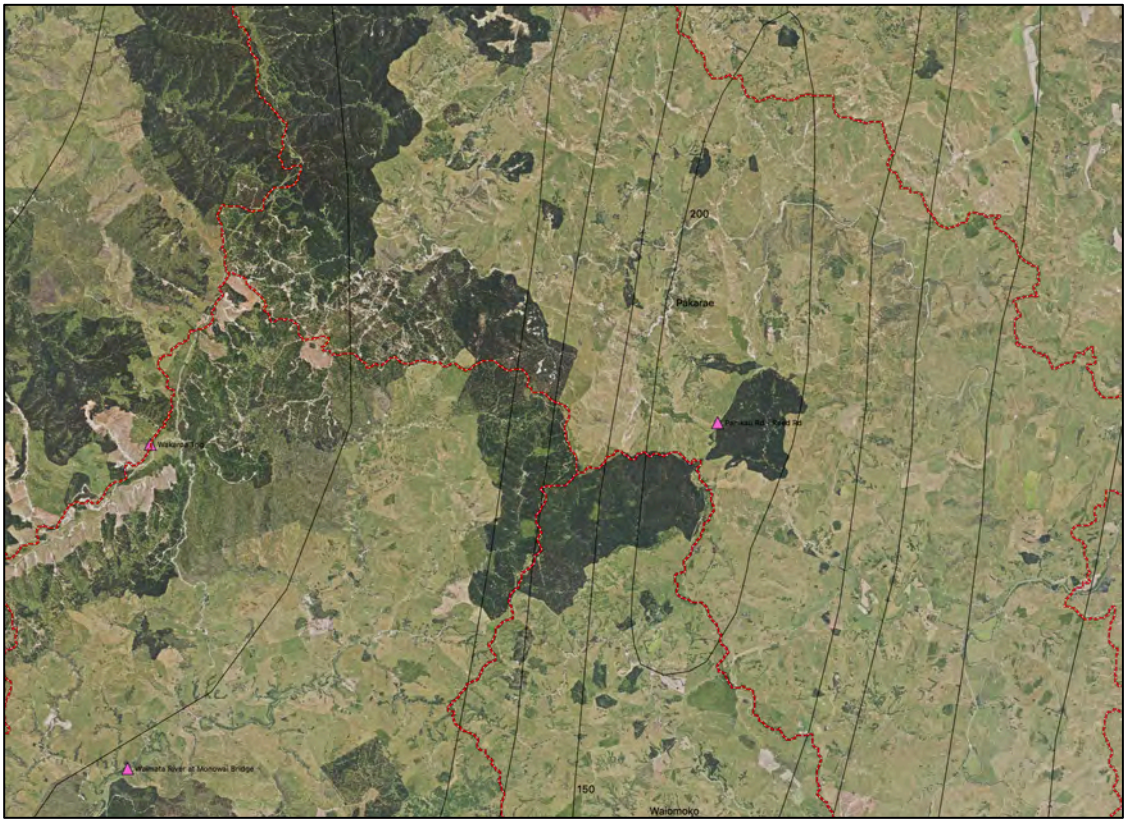

Figure Eighteen. *December 2017 aerial photograph of the Panakau-Reed Road rain gauge site overlain with the catchment boundaries and 6 hour rainfall accumulation. There are two forests immediately adjacent with Baywood forest on the right and Pukerewa on the left.*

Newspaper reports indicated that there was severe flooding in the Waiomoko catchment. Quoted in the Gisborne Herald (6th June 2018), Norm Thomas from Mahana Station at Whangara said "*Any flat paddocks he has on his propertry have lost there riverside fences. For us it's not as bad as Cyclone Bola in terms of the amount of debris left behind, but in terms of the volume and height of floodwaters it was worse*." Mr Thomas also stated that "*farms along the Waiomoko River had also been badly affected by the weather event. They saw extreme river levels that cleaned out floodgates and boundary fences*".

The coincidence of GDC flying new aerial imagery over the summer of 2017-2018 and the new satellite imagery from 25th August 2018 allows us to assess the before and after damage in the affected region. Baywood Forest was at the epicentre of the event situated immediately east of the Panikau-Reed road rain gauge at the southern edge of the Pakarae catchment. The forest falls almost entirely within the area that would have received +200mm of rain over the 6 hours of most intense rain. A view of the forest from the new GDC aerial imagery is shown in **Figure Nineteen** below.

The forest has not been harvested and appears to be in good condition. The age of the forest is uncertain but it has a closed canopy with only a few very small areas of disturbance. The forest appears to be owned by Forest Enterprises Ltd but does not have any current consents.

***Figure Nineteen**. View of Baywood Forest (close up of Figure Eighteen) showing the condition of the forest over the summer of 2017-2018. The forest is unharvested and in good Condition.*

A Google Earth image dated 25th August 2018 is now available for the same area and indicates that the forest has been unaffected by the storm event although there area signs of some slope failure in adjacent pastoral farmland (**Figure Twenty**).

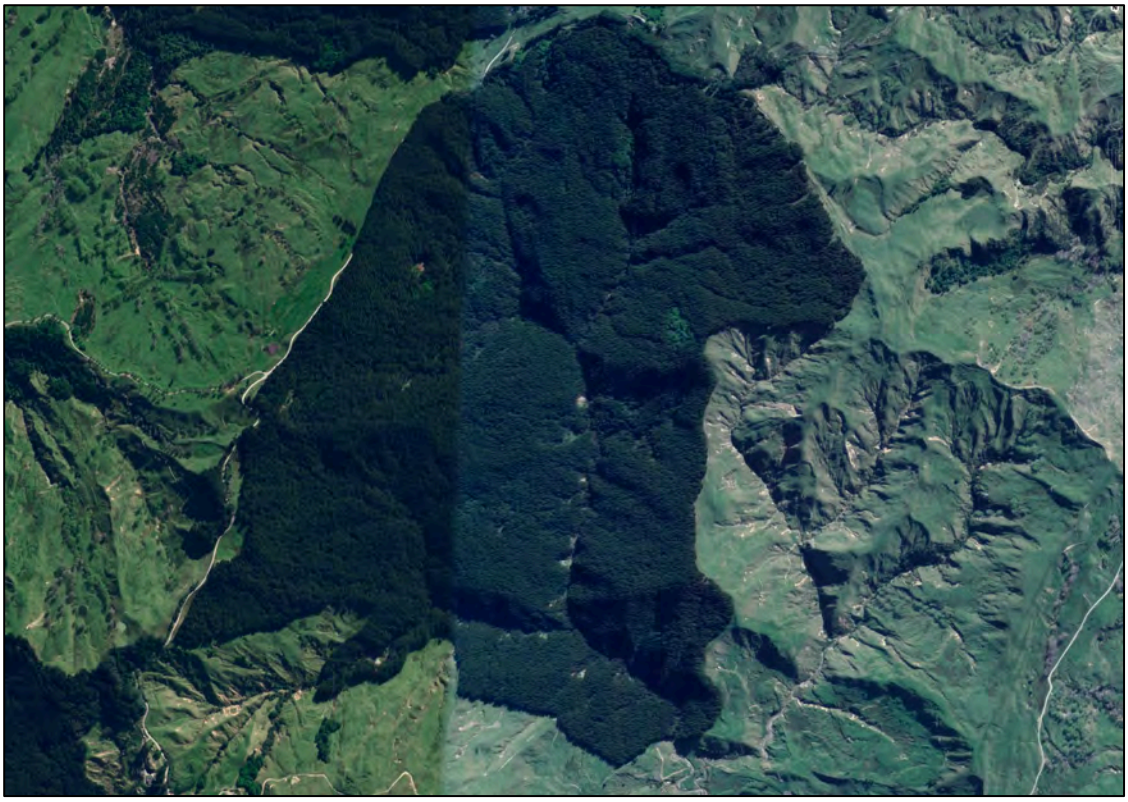

Figure Twenty. *25th August 2018 satellite image of Baywood Forest showing no impact from the Queens Birthday storm but indications of some slipping on adjacent farmland.*

The area east of Baywood Forest has been looked at to assess the scale of slipping on farmland as a result of the storm event (**Figures Twenty One** and **Twenty Two**). Obvious slips present in the 2017-2018 image were digitised and then imported into the August 2018 Google Earth image.

The analysis of the images indicates that there has been a noticeable increase in the number of slips on pasture although the overall scale of slipping is minor compared what has been found in the recently harvested forests further north. Also evident on the Google Earth image is the significant volume of silt that has been deposited on the river flats downstream of the forest (**Figure Twenty Three**). When these flats are examined closely it is clear that some woody debris has been deposited (**Figure Twenty Four**) but the provenance of this material has not been established. The volume of material is low compared with what has been observed in the Uawa catchment which may suggest that this material comprises largely willow and poplar debris.

Overall the assessment indicates that there was significant mobilisation of sediment. The primary source of the sediment appears to be the widespread

slipping of pasture through mid slope failures. Erosion of riverbanks is probably also a contributor. Relatively speaking, however, these mid slope failures do not represent large-scale slope failures such as occurred during Cyclone Bola but do appear to be more prevalent to that observed on farmland further north in the Uawa Catchment. The woody debris present on the river flats have no obvious forestry source and are most likely willow and poplar.

Figure Twenty One. *GDC December 2017 aerial image of the area immediately east of Baywood Forest showing the pre-existing level of slips prior to the Queens Birthday storm.*

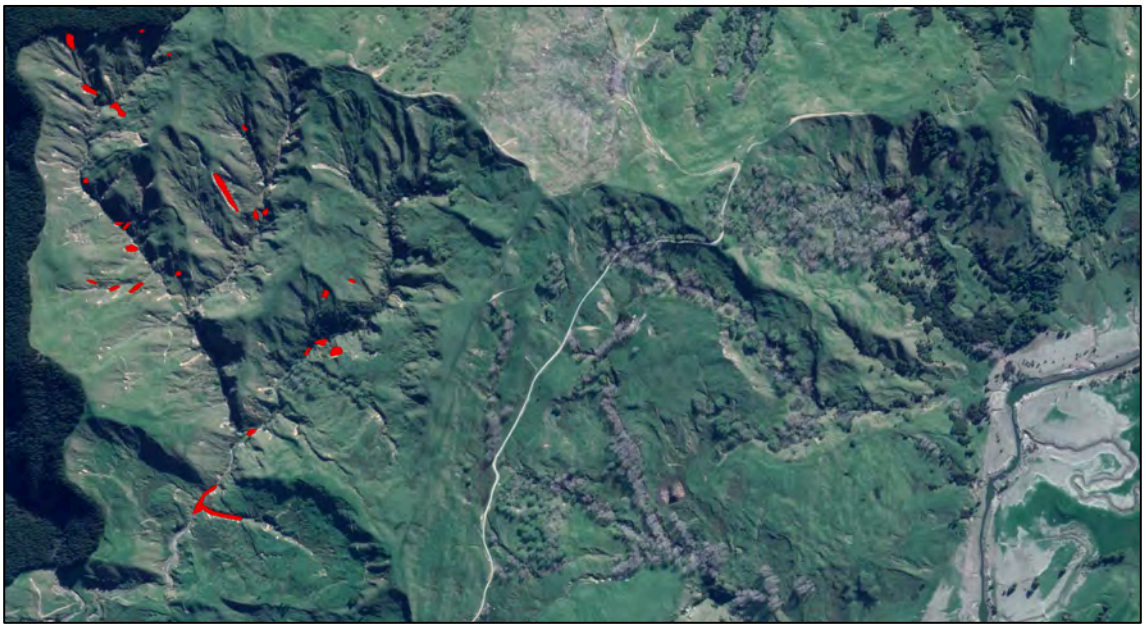

Figure Twenty Two*. Post Queens Birthday storm Google Earth image of the same area as above dated August 25th 2018 showing the pre-exiting slips (red), the extent of new, largely mid slope landslides and the silt deposition on the river flats.*

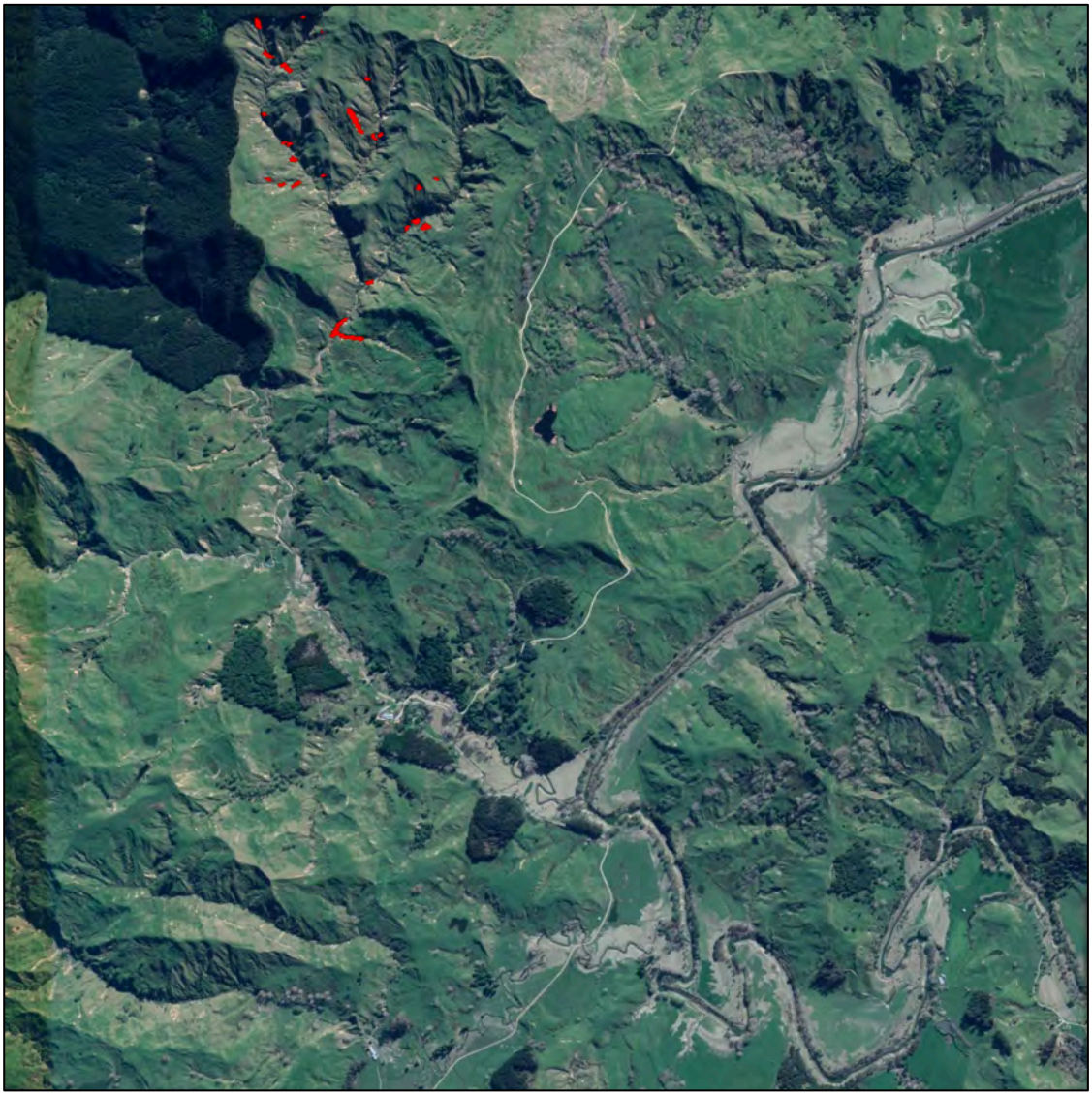

Figure Twenty Three*. View of the catchment east of the Baywood Forest showing the extent of silt deposition on the river flats.*

Figure Twenty Four. *Enlarged view of the river flats showing obvious woody debris deposited on the on the true left bank of the river flood plain (middle left).*

In the Uawa catchment, there was extensive mobilisation of harvest residues from the plantation forests many of which have been in harvest over the last 5 years. The key forests were the Te Mauranga forest owned by Hikurangi Forest Farms (Uawa Forest owned by Timbergrow (Ernslaw), and the Paroa Forest owned by Permanent Forests Ld (PF Olsens).

Te Muranga Forest

The rainfall accumulation contours for the Te Marunga Forest is shown in **Figure Twenty Five** below. This suggests that the forest was north of the main rainfall accumulation with much of it experiencing between 50 and 150mm over a 6-8 hour window. Notably one area that experienced heavy damage (Hesketh Road) occurs in the 50mm band with a significant area occurring within the 100mm band.

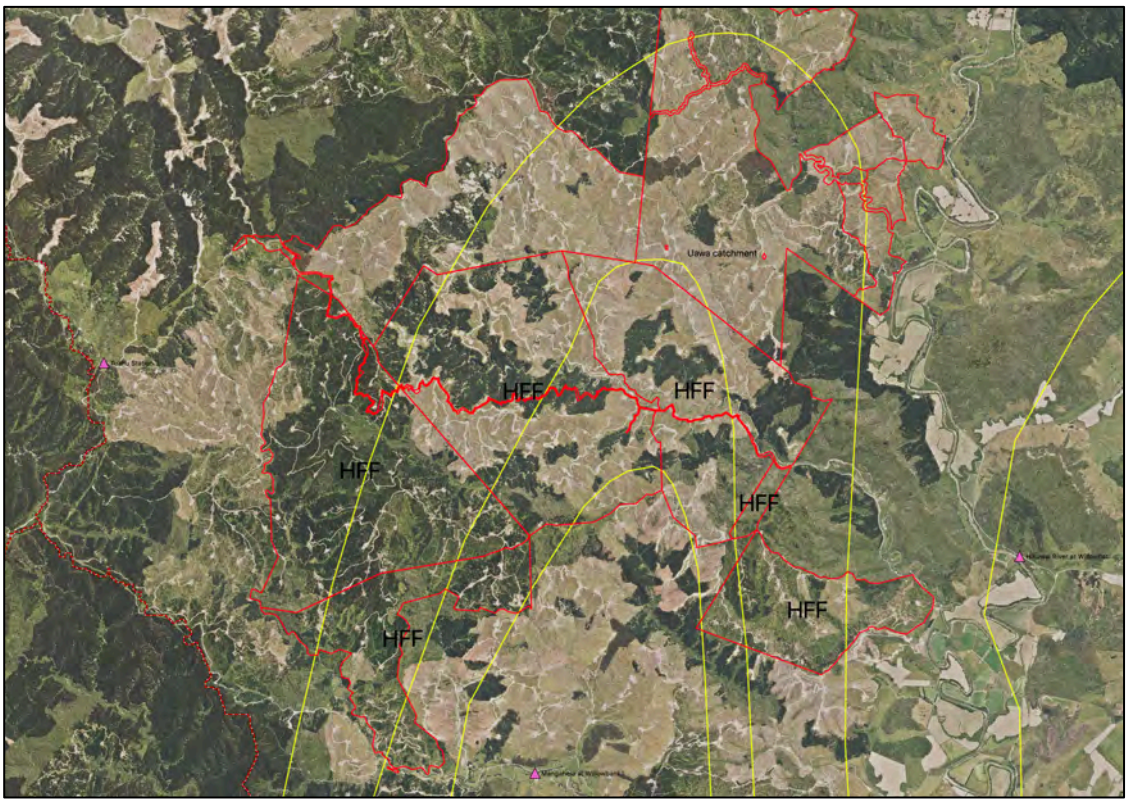

***Figure Twenty Five**. Te Marunga Forest (Hikurangi Forest Farms) showing the rainfall accumulation within the forest (150mm in centre out to 50mm over a large part of the forest.*

When the 12 hour rain radar data is added, a small bright spot is evident in the southern part of the Te Marunga Forest between Spenser and Pa Roads and including Tirohanga and Ira Roads (**Figure Twenty Six**). This area was flown over and photographed on the 6th of June. The images acquired on the sixth did not suggest that the area had suffered an event any different from the surrounding harvest areas. Indeed, if anything, the damage to skid sites in this area was not as significant as elsewhere and the area was subsequently not targeted for detailed site investigation as other areas demonstrated greater damage and were thus more of a focus. The means of aggregating and

calibrating rain radar may cause artefacts to be generated as can a variety of other factors such as topography. Thus this bright spot needs to be treated with caution as it may not reflect on the ground rainfall intensities.

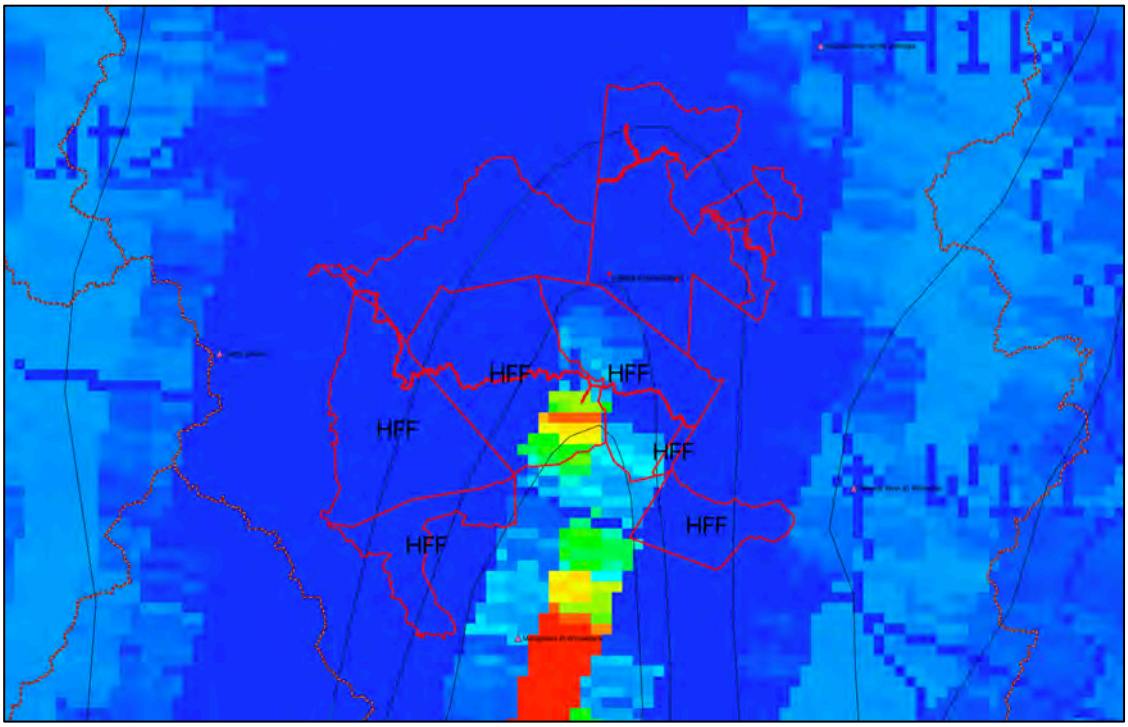

Figure Twenty Six. *Te Marunga Forest (Hikurangi Forest Farms) showing the rainfall accumulation and rain radar reflectance within the forest. The bright spot in the middle of the picture has been compared with field data which does not suggest a significant impact in this area relative to other parts of the forest that experience less intense accumulations.*

Despite the Te Marungi Forest receiving considerably less rainfall than the Baywood Forest adjacent to the Panikau-Reed Road rain gauge, the damage within the harvest area was significant with multiple collapses of landings. To gain an understanding of the impacts, a comparison of the December 2017 GDC aerial imagery with the 25 August 2018 satellite imagery was undertaken (**Figures Twenty Seven** and **Twenty Eight**).

Rather than focus on the entire forest, the Hesketh Road area was selected since the rainfall data suggest the top of the catchment had around <50 mm of rainfall accumulation over a 6 hour period while the lower catchment had between 50 and 100mm over the main period of the storm. Based on Hirdsv4, this suggests that the top of the catchment at Hesketh experienced no more than an annual event while the lower parts of the catchment at Hesketh experienced a storm with a 3 year return period (based on a 6 hour rainfall of 75mm).

The pre- and post-storm images show that extensive landsliding occurred within the top of the Hesketh Road area during the Queens Birthday storm despite this area only experiencing an event with a return period of less than

1.58 years, based on the Hirdsv4 tool. Also significant is that the impacts in this area are significantly greater than occur in the Panakau-Reed Road area which experienced the highest rainfall (see **Figure Twenty Two**). What is also evident is that areas with good closed canopy forest both west and east of the harvest area at Hesketh Road did not experience the same degree of slope failure.

Figure Twenty Seven. *Aerial Photograph of the Hesketh Road area (December 2017) showing the skid locations and ground conditions pre-Queens Birthday Storm. The yellow line is the 50mm rainfall contour.*

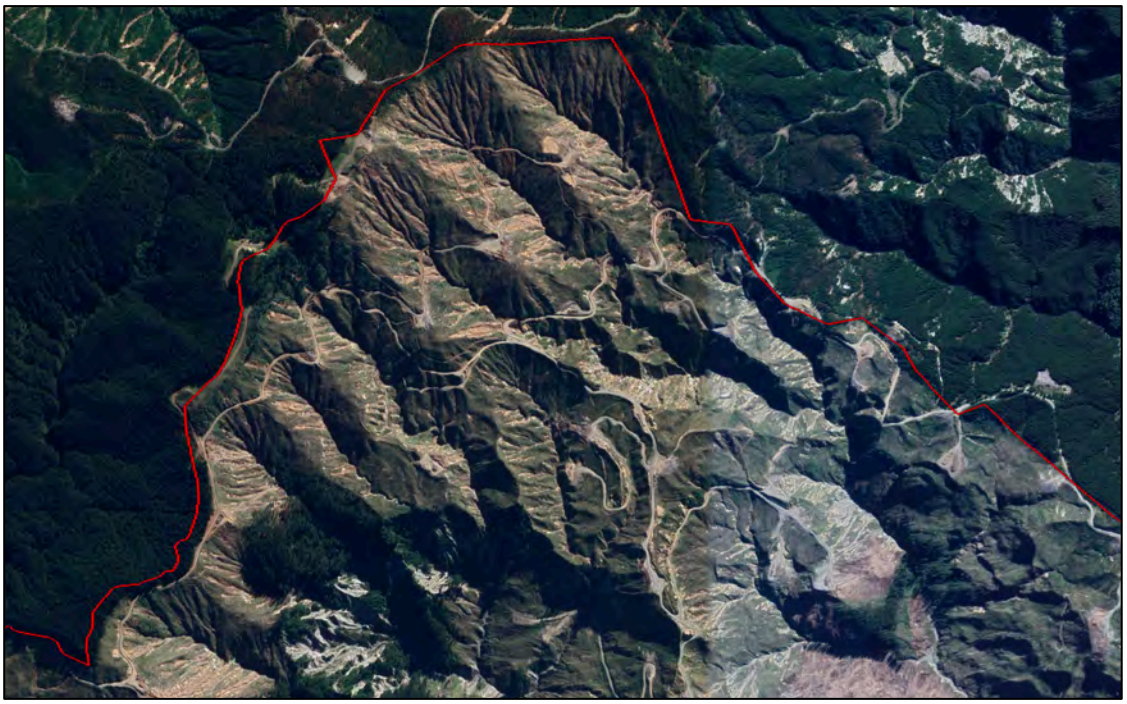

Figure Twenty Eight*. Satellite image of the Hesketh Road area dated 25 August 2018 showing the extensive large scale landsliding that occurred during the Queens Birthday storm.*

Uawa Forest

The rainfall accumulation contours for the Uawa Forest is shown in **Figure Twenty Nine** below. The Uawa Forest is immediately south of Te Marunga and falls largely within the +150mm rainfall accumulation over a 6 hour period. When combined with the rain radar data it suggests that the forest experienced a higher accumulation than the Te Marunga Forest to the north.

This was particularly in the far south of the forest in the lower reaches of Mangatoitoi stream and the south eastern edges of the forest. The rain accumulation contours and the rain radar also suggests that northern and western ends of the forest, for example, Mangateao Stream received lower accumulations within the 100 to 150mm over a 6 hour period. The Hirdsv4 data for Mangaheia at Willowbank estimated a return period of 11.7 years over a 24 hour period accumulation of 2018mm at that gauge but likely to be greater siunce a lot of the rain fell over a shorter period of time. Although the contour plot suggests that the 150mm rainfall accumulation extended north from the Mangeheia at Willowbank gauge, the rain radar drops off very rapidly to the north. This may suggest a strong topographic influence over the rainfall accumulation.

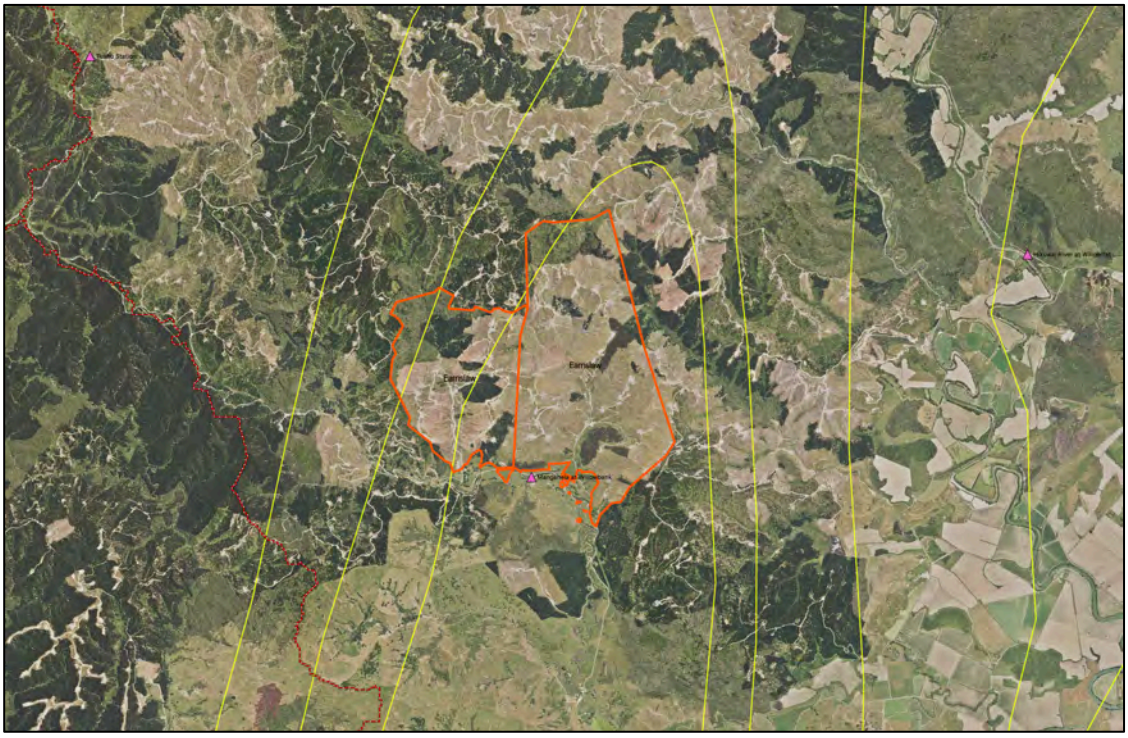

Figure Twenty Nine. Uawa Forest (Timbergrow Ltd-Ernslaw) showing the rainfall accumulation within the forest.

As for the Te Marunga Forest, the pre- and post-storm imagery shows a marked contrast in level of storm damage occurring within recently harvested forest compared with either closed canopy forest or farmland pasture (**Figures Thirty and Thirty One**).

Figure Thirty. *December 2017 aerial photograph of the south end Uawa Forest (Timbergrow Ltd-Ernslaw) showing the pre-storm landscape for the Mangaehia River and Mangatoitoi stream (right).*

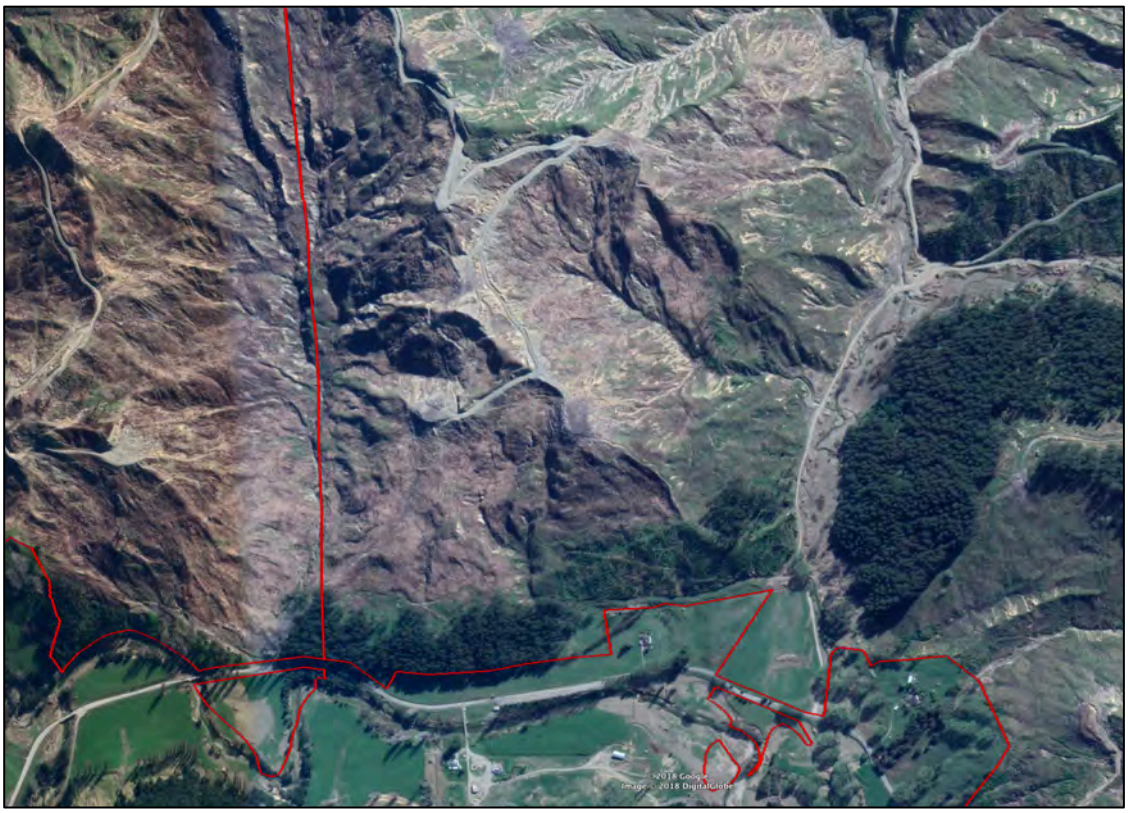

Figure Thirty One*. August 2018 satellite image of the south end Uawa Forest (Timbergrow Ltd-Ernslaw) showing the post-storm landslides the forest. Extensive landslides are evident in recent harvest area while adjacent close canopy forest (right) has remained intact. One small slip is evident on pasture at bottom left.*

Willowbank

The Willowbank Forest is immediately south of the Uawa Forest and is managed by Kontrol Ltd. The forest and adjacent farmland is south of the Mangaheia at Willowbank rain gauge and would have sustained a heavier rainfall accumulation than Uawa Forest.

Although, the Mangaheia River adjacent to Willowbank Forest has clearly sustained a flood event with significant silt deposition, there are no obvious signs of significant landslide activity in either the forest or in the surrounding farmland. As was the case elsewhere, close canopy forest has not experienced any significant impacts while only limited scale landsliding from roadways has occurred within the recently harvested forest.

The pre-storm December 2017 landscape is shown in **Figure Thirty Two** below while the post-storm image showing landslide impacts are shown in **Figure Thirty Three**.

Figure Thirty Two. Willowbank Forest and adjacent farmland. December 2017.

Paroa Forest

The Paroa Forest is located to the east of Uawa Forest and south of Te Marunga. The forest is owned by Permanent Forests Ltd and managed by PF Olsen. The forest is entirely within the Tupae Stream sub-catchment that flows east onto the Uawa flats. This was an area that experienced a significant mobilisation of forestry harvest residues impacting on the adjacent river flats used for intensive pastoral grazing. Around 50% portion of the forest lies within the 50mm rainfall accumulation band with the remainder falling within the 100 to 150mm rainfall band over a 6 hour period (**Figure Thirty Four**).

Using the Hirdsv4 tool, it is estimated that the western side of the forest experienced a 12.5 year return period event while in the east the accumulation was a 2.5 year event.

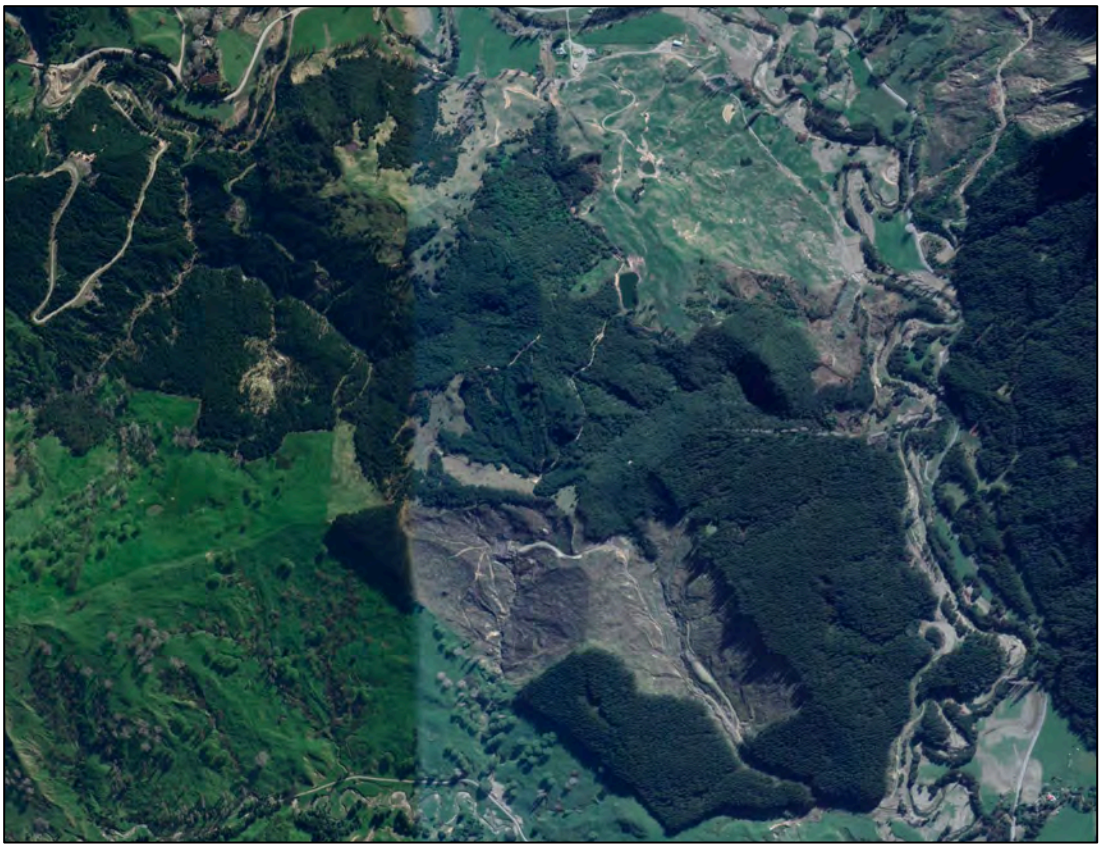

***Figure Thirty Three**. Willowbank Forest and adjacent farmland. August 2018. Silt deposition from flooding in the Mangaheia is evident on the right and in the tributary bottom left but the pasture and closed canopy forest shows little sign of landsliding while within the forest only small failures are roadways are evident relative to other forests.*

The August 2018 satellite imagery does not extend east onto farmland making if difficult to compare the effects of the storm on different land uses such as pasture versus closed canopy forest and recently harvested areas. Within the forest, however, the August 2018 imagery does indicate that closed canopy plantation forestry was not adversely affected by the storm event (**Figure Thirty Five**).

In addition, the satellite imagery gives a clear indication of some of the issues associated with the event. **Figure Thirty Six** shows a large accumulation of harvest residues caught up within the streambed where its been held up by the vegetated riparian margin and the present of steep unbenched batters.

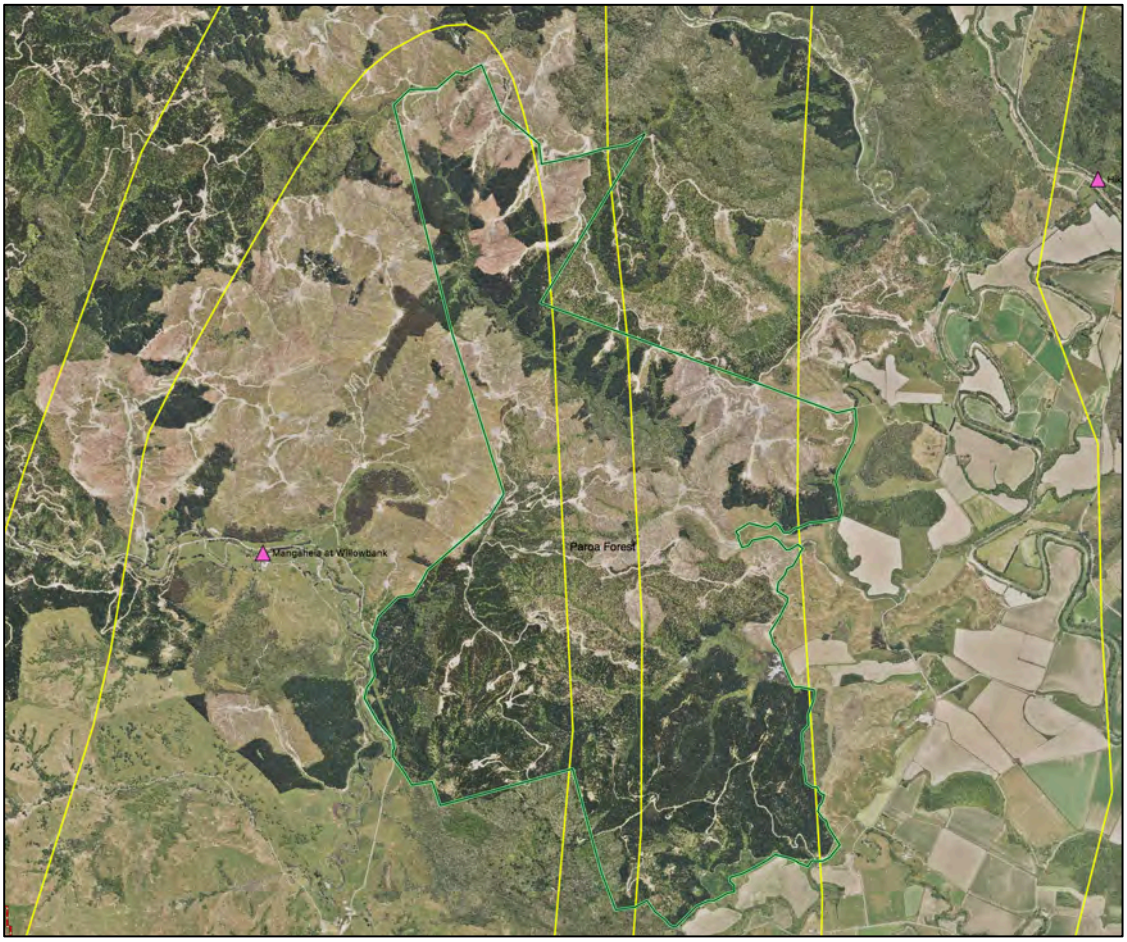

***Figure Thirty Four**. Paroa Forest (Permanent Forests Ltd, PF Olsen) showing the rainfall accumulation within the forest.*

***Figure Thirty Five**. Close up view of Paroa Forest with August 2018 satellite imagery on the left and January 2017 satellite imagery of the right. Extensive landsliding is evident in the recently harvested areas on the bottom left while the closed canopy mature trees at top have remained largely unaffected by the Queens Birthday storm.*

***Figure Thirty Six**. Detailed August 2018 view of part of Paroa Forest showing the location of a large amount of harvest residues in the stream bed (middle) with unbenched batters arrowed.*

Summary and Conclusions

1. The Queens Birthday 2018 storm occurred over the 3rd and 4th of June and was a complex storm apparently having two components;
    a. A northerly front striking first in the north at Waikura Valley-Hicks Bay and moving south with largely steady rain dying out in the north on the 3rd and on the 4th in the south. Rainfalls within this overall event were moderate and generally an event that can be expected every one or two years.
    b. Overprinting this storm and recorded at rain gauges between the Mangeheia at Willowbank in the north and Panikau-Reed Road in the south, was a very narrow north-south oriented intense rain cell which may have been caused by a westerly flow across the Raukumaras which intensified as it collided with the overall storm from moving south.
    c. On a gauge by gauge basis, this intense cell had an ARI of equivalent to a 30 year return period at Panikau-Reed Road rain gauge and 11.7 years at Mangheia at Willowbank rain gauge.
    d. The rain radar which is calibrated with the rain gauge data suggests that this intense storm was sharp edged and the most intense rain did not extend any distance north from the Mangheia at Willowbank rain gauge and dropped off rapidly both east and west.
    e. The intense cell struck first at Mangheia at Willowbank and arrived at Panikau-Reed Road around half an hour later. The system lasted nearly twice

as long at Panikau-Reed Road than it did at Mangheia at Willowbank and the flood levels at the Waiomoko River just south of the Panikau-Reed Road exceeded that recorded during Cyclone Bola but dropped quite quickly.

f. Despite the extensive flooding in the Waiomoko-Pakarae-Whangara area north of Gisborne, landsliding while present was only localised in its effect and there was little or no apparent mobilisation of forest harvest residues and adjacent un-harvested forest came through the storm unscathed.

g. In the Uawa Catchment, however, the impacts of the storm were significant despite the overall size of the event being slightly smaller than in the Waiomoko-Pakarae-Whangara area.

h. In the Mangatokerau tributary an extremely large mass of harvest residues and cut logs travelled down valley with one family rescued after climbing onto the roof of their house in the middle of the night. One other dwelling was knocked off its foundations.

i. An extensive amount of logs and harvest residues were deposited on Tolaga and adjacent beaches as well as along the banks of the Uawa River.

j. Within the Uawa, landsliding was largely confined to recently harvested plantation forest and closed canopy forest, be it plantation or indigenous remained largely unaffected.

k. Equally, pastures on farmland adjacent to the badly affected forest harvest areas showed some signs of landsliding, but at a far less extensive scale to the recent harvest areas.

l. While the event was significant, particularly locally, the differential impacts between recently harvested forest, closed canopy forest and farmlands indicates that factors other than just rainfall accumulation had an impact on this event.