Graeme Horrell Consultancy Limited

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Assessment of the Pinehaven Stream 23 July 2009 flood peak.

1 Back ground

You have requested me to become familiar with the information you have sent, and provide a check on the GWRC flow record of the 23 July 2009 event measured at Pinehaven Stream opposite Chatsworth Road: stage, gaugings, rating curve and rating curve extension to peak stage measured. Provide my opinion on the peak discharge and ARI findings in a letter.

My understanding of your requirements is that GWRC has used the 23 July 2009 flood event to calibrate a model which has been used to show the flood extent of a 100 year design flood on the community in Pinehaven. You are requesting an independent assessment of the 23 July 2009 event in terms of flood peak and return period.

2 Rating curve extension issues

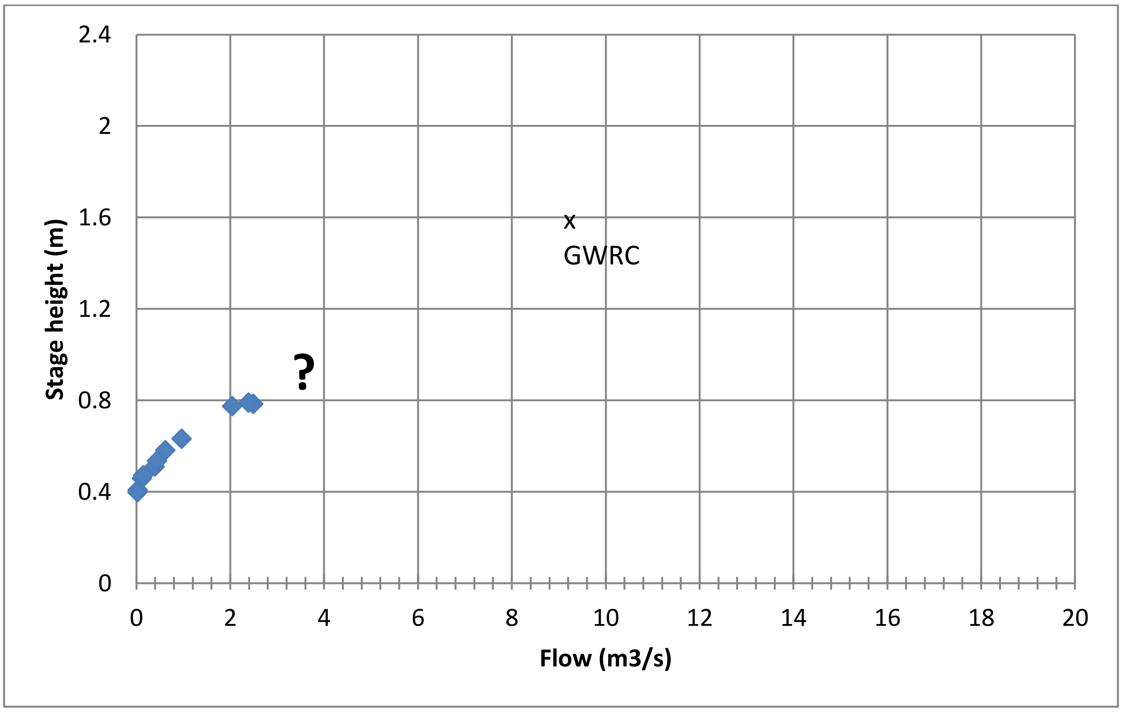

Figure 1: Flow gaugings available and the problem with extending the rating curve without high flow gaugings.

The problem for the GWRC hydrology team was how to extend the rating curve from 0.8 m to 1.6 m Figure 1, due to the lack of high flow measurements. The lack of any flood measurements or mapped flood marks during the peak of the 23 July 2009 is disappointing as the capture of flood measurements for flood design purposes is the main reason for the flow recorder site on Pinehaven Stream opposite Chatsworth Road.

High flow gaugings will give key information for extending the rating curve to provide accurate values of the peak flood. Unfortunately one gauging was completed the day after on 24th July but the flows had receded considerably to only 0.44 m3/s. An attempt was made on 30 August 2009 to measure high flows to define the top end of the rating however stage height levels measured were less than 0.8 m, some 0.77 m less than the 1.577m peak measured on 23 July 2009 peak.

Plots of the 23 July flood hydrograph with the gauging plotted are displayed on Figure 2 and the 30 August peak with three gaugings plotted are shown on Figure 3.

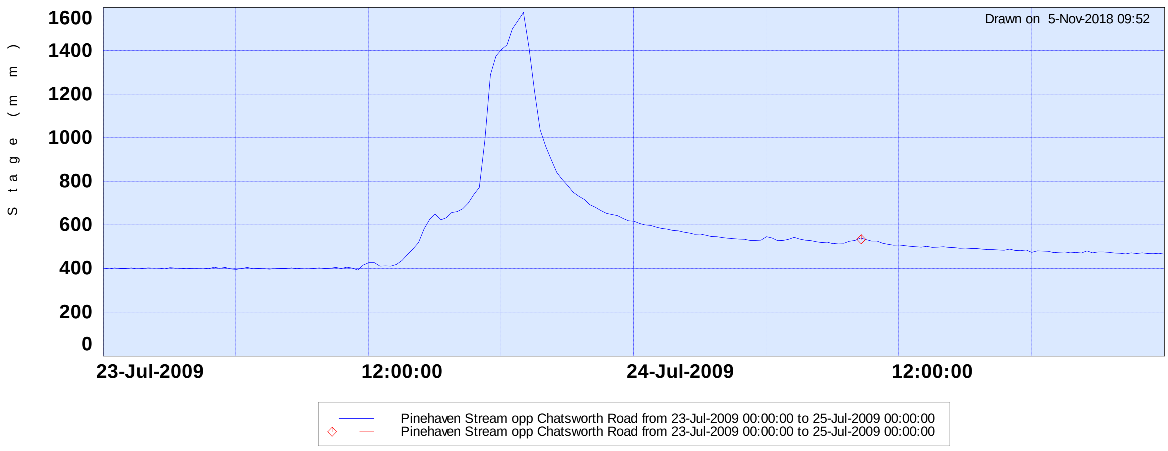

Figure 2: Pinehaven Stream flood hydrograph for 23 July 2009 and single gauging of 24 July 2009 (red diamond).

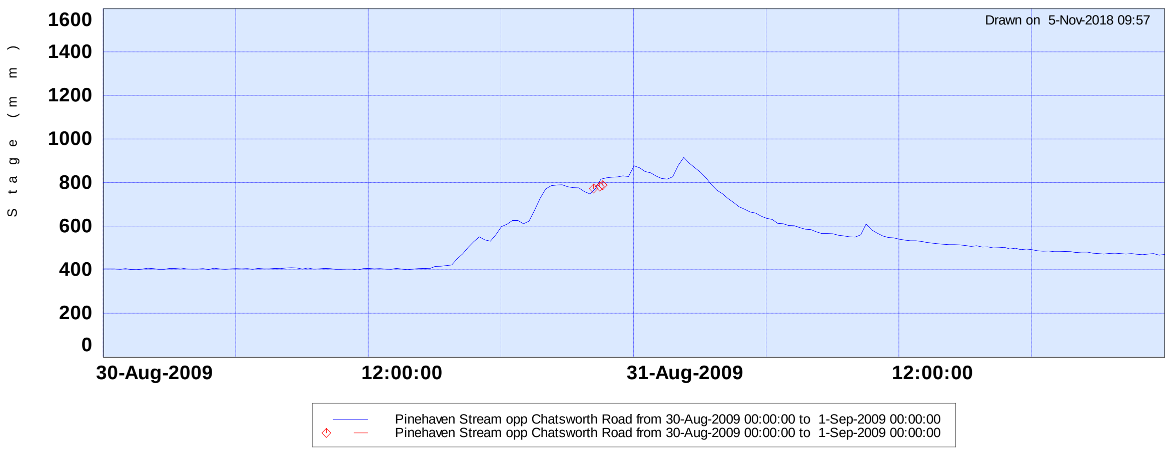

Figure 3: Fresh of 30th and 31st August 2009, 3 gaugings measured are displayed as red diamonds.

It is not common to gauge a river on the peak; however gaugings below the peak are often achieved and used to extend the rating curve to derive the peak flow.

It is standard practise to extend the top end rating curve using an area curve to develop a stage versus mean velocity curve Figure 4. A recorder cross-section is surveyed and a stage versus area curve developed. A recorder cross-section is available (perhaps at downstream weir which is acceptable). For this site the area curve will be accurate as I believe degradation or aggregation of the bed during the flood event on Pinehaven Stream will be minimal, at other natural river sites this can be large e.g. braided rivers. The area curve is used and divided by the measured flow for each completed gauging to develop a stage versus mean velocity curve (Figure 4).

Some knowledge of what will happen to velocities at higher stage values is required. For example if the river were to break out over a flood plain the velocities may become slower as the stage height increases, this will not happen here (until perhaps 2.5 m stage height). From experience (there are many exceptions) the maximum mean velocity for most rivers is between 3 - 4 metres per second. The channel is very smooth and downstream of a steep slope and could be higher than this, only measurements will answer this, but none are available which seriously detracts from this rating curve extension method.

With the lack of higher flow gaugings, extending the velocity curve is difficult, see Figure 4 below.

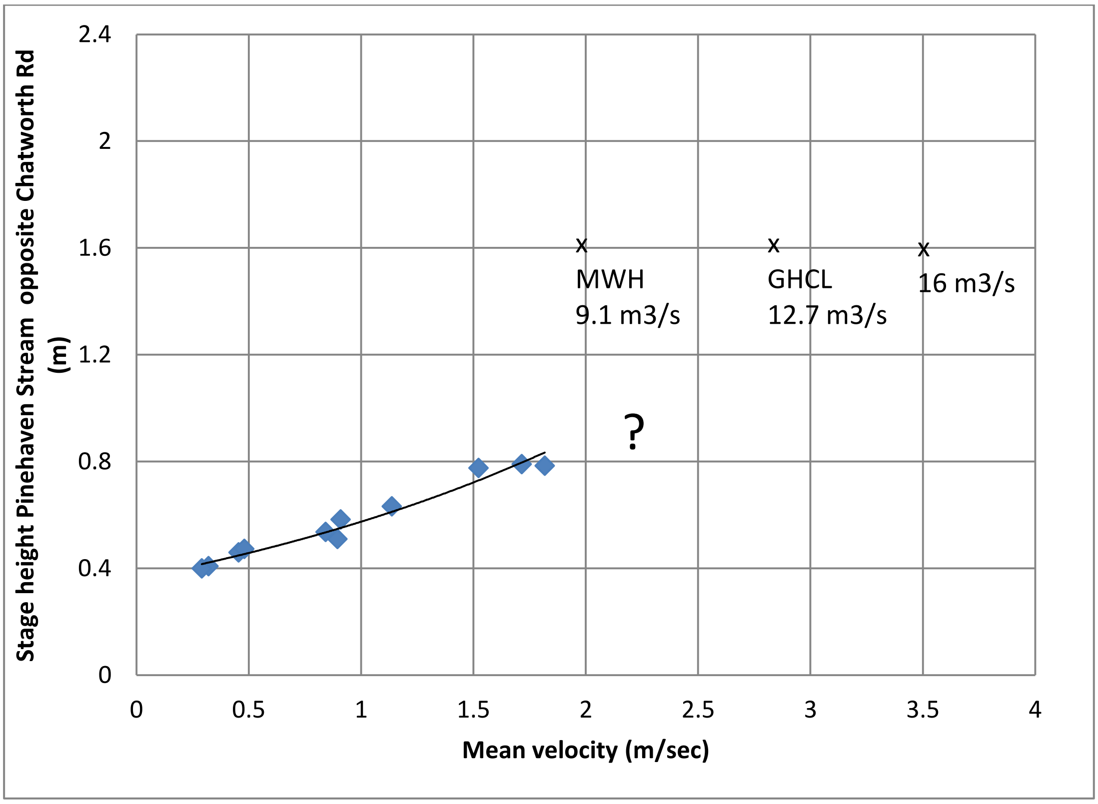

Figure 4: Pinehaven Stream at Chatsworth road stage height versus mean velocity curve

Figure 4 displays the problem with extending the stage/velocity curve between 0.8 m and 1.6 m. The MWH approach was to adopt 2 m/sec at stage 1.6 m. However this is only a 10 % increase in mean velocity from the stage of 0.8 m. This is not plausible in such a smooth bedded and smooth walled channel. My estimate is 2.8 m/sec which would result in a 12.7 m3/sec flow at 1.6 m, however for a flow of 16 m3/s a mean velocity of 3.51 m/sec would be required.

My estimate of the flow peak at 1.577 m on 23 July 2009 is 12 m3/s, however future high stage gaugings to define the stage/mean velocity curve would provide higher confidence to estimates. I consider the 8.8 m3/s an underestimate. Interestingly the SKM (2010) report of modelling the 23 July 2009 event shows a peak discharge of approximately 11.8 m3/s, but unfortunately their depth at the staff gauge is 400 mm less than that actually measured (the only actual measured data point in their modelling), a gross error. This highlights the risk of using just one single event to calibrate the rainfall runoff model, which then feeds inputs into the hydraulic model. Multiple flood events should have been used in the calibration with additional floods for the testing/verification phase.

3 Pinehaven Stream design flood estimates

ARI (Years)	Harkness 2009 (Rainfall runoff model) 3 methods (m3/s)	$Horrell_1$ 2020 Pearson (1990), Henderson & Collins 2016 (m3/s)	$Horrell_2$ 2020 5 years data Henderson & Collins 2016 (m3/s)	$Horrell_3$ 2020 5 years data McKerchar & Pearson (1989) Pooling, Henderson & Collins 2016 (m3/s)	Henderson 2018 Henderson & Collins (2016) Regional flood study (m3/s)	Bob Hall 2020 Mangaroa, Runoff coefficient ratio and NIWA 2018 (m3/s)
Mean annual flood	9.8	6.5	5.04	5.69	7.39	6.2
5	15	8.6	6.6	7.6	9.8	8.5
10	16	10.3	8.0	9.1	11.8	9.9
20	18	12.0	9.3	10.6	13.7	11.4
50	20	14.3	11.1	12.5	16.3	13.4
100	22	15.9	12.3	13.9	18.1	15.0
PMF	86	-			-	

Table 1: Pinehaven Stream design flood estimates.

i) It should be noted that to give reliable estimates of the return period of the 23 July 2009 flood event, a continuous flow record of Pinehaven Stream is required. If for example 100 years of flow record existed then the estimate of the return period for this event would be very reliable.

ii) The next best estimate would be if there were some years of continuous flow records, say 10 or 20 years; and the annual maximum floods can then be used to calculate the mean annual flood. This is then applied to the ratio for specific annual return intervals e.g. 5 year, 10 year. The ratio is provided from regional flood studies, McKerchar and Pearson (1989), or the recent Henderson and Collins (2016). This method is commonly used by hydrologists and engineers for design purposes as hydrological records are usually collected. However this method was not available to GWRC as the Pinehaven site was only operating from 2008 to 2013 and the high flow part of the stage/discharge rating curve was not defined by measurements as described above.
It is unthinkable that a key site for design purposes is closed. I have been informed by Mike Harkness (GWRC) by email that no further site was installed.

iii) The next best method is when just 5 years of data is collected at the Pinehaven site, as occurred. The McKerchar and Pearson (1989) regional flood study provided a method to include the mean annual flood estimate from the 5 years of measurements and combine these with their method to estimate a mean annual flood when no data exists. This is a pooled estimate. Results are shown in Table 1.

iv) The next best method is to obtain a calculated runoff coefficient from a neighbouring catchment which has a long flow record. Fortunately the Mangaroa catchment borders Pinehaven Catchment, and has records from 1977 (42 years), this is a valuable record. This study was undertaken by Bob Hall. This is a good method (pers com, G Griffiths) available to establish what the mean annual flood is (6.2 m3/s) for Pinehaven stream. The ratios as described above can then be applied.

v) Regional flood studies are very useful for providing estimates of the mean annual flood and flood estimates for various annual return intervals where very little or no data exists. The key proviso is that they are estimates only. 'Regional studies can give incorrect estimates in some catchments, but if you have 5 years of data and calculate a pooled estimate, mean annual flood estimates will be more reliable (pers com, C Pearson).

Engineers designing structures for the communities protection, prefer to use hydrological data from their catchment of interest rather than solely from regional studies, however they will often cross check their at site analysis in (i, ii, iii, iv above) with a regional study.

This study $Horrell_1$ (2020) used the Pearson (1990) maps to estimate the mean annual flood and the Henderson and Collins (2016), to estimate the ratio from mean annual flood to selected ARI's.

The additional $Horrell_2$ (2020) study used the 5 years of stage data collected at the site before closure and applied the corrected rating curve described above to estimate the mean annual flood and the Henderson and Collins (2016) to estimate the ratio from mean annual flood to selected ARI's. This method whilst with the advantage of using actually measured flow data from Pinehaven , which no other method includes, however it falls short of the 10 years recommended to establish the mean annual flood flow.

The third method was iii) above $Horrell_3$ 2020 and is considered the most reliable estimate from this study.

The Henderson and Collins 2016 regional study is added to Table 1 and 2 for completeness.

	Harkness 2009	$Horrell_1$ 2020	$Horrell_2$ 2020 (5 years data)	$Horrell_3$ 2020 (5 years data pooled)	Henderson 2018	Bob Hall 2020
ARI of 12 m3/s	3.5	20	80	40	12	28

Table 2: Estimates of the annual return interval (ARI) for the 23 July 2009 12 m3/s peak flow

It is noted the Harkness analysis disagrees considerably with the four other analysis in Table 1 for the ARI for 5 , 10, and 20 years and subsequently in Table 2. It should be noted Harkness (2008 and 2009) did not have the benefit of 5 years of flow measurements at Pinehaven stream.

4 Review of the 'Pinehaven Flood Hydrology' report prepared by Mike Harkness

As requested I have reviewed the Pinehaven Flood Hydrology report prepared by Mike Harkness (4 November 2008 and revised additions 25 November 2009). Listed below in blue are key quotes from the report.

"Limited calibration data is available – only one flood event was available to be used to calibrate the model."

This rainfall runoff modelling if proceeded with will result in large uncertainties.

Typically at least 8 sizable floods (derived from fully developed rating curves, described in 2/ above) are used to determine meaningful design estimates. At least 4 of these floods will be used in the calibration phase of the model and once calibrated the model is tested using the remaining 4 floods.

The Pinehaven design estimates are the result of just one flood with no testing.

Recorded flow data for this flood event have been supplied by GWRC. The peak flow is estimated to be 8.8m3/s. It must be noted that due to the short period of record and lack of certainty about the conversion of high measured water levels to flow (rating curve), the 8.8 m3/s estimate may be revised in the future when new information is available.

Agree with this comment and believe the rainfall runoff modelling should not have proceeded.

There are uncertainties in calibrating a rainfall-runoff model to just a single recorded flood event. Particularly when there is uncertainty associated with the actual flow data due to the short length of record at the site and a lack of other high flow events to confirm the flow rating.

Agree

Ideally a number of recorded flood hydrographs would be available for calibration to provide confidence in the modelled peak flow estimates and hydrographs shapes.
However, it is better to have the one peak flow estimate to calibrate the model to than nothing at all.

Agree a number of hydrographs are required, however Mike does not know the uncertainties that come with his method, from my experience at least ± 100 %.

6.4 Rainfall-Runoff Model Limitations (2008 version)

The major limitation of the rainfall-runoff modelling process for the Pinehaven Stream is the lack of calibration data. Although a single calibration point was available, it was a relatively minor flood event. The use of the model to simulate extreme flood events will therefore carry relatively high uncertainties.
Agree

A number of recorded flood hydrographs is preferred for calibration purposes to ensure estimates of peak flows and hydrograph shape are as accurate as possible.
Agree

This uncertainty is reduced by comparing modelled output with peak estimates from other methods as summarised in Section 7.
This is somewhat self-fulfilling, as you are effectively using these studies to get an answer, then the model is manipulated/calibrated to get those same results.
MWH 's testing appears to be a comparison with regional flood studies which gave them confidence to recommend to GWRC that hydraulic modelling could proceed. These hydraulic modelling flood inundation outputs will have large uncertainties and are the major cause for disagreement with the locally observed historic flood levels.

"Despite the lack of calibration data available for the model the result obtained are similar to those derived by the regional methods. This provides confidence in the use of the modelled results and the design flood hydrographs for further hydraulic modelling"

This model has not been tested against measured flood events.

Hydstra Modelling has been used in many hydrological applications in New Zealand and around the world for rainfall-runoff and design modelling.

I have no doubt this is an appropriate model to use for this analysis, however it is dependent upon reliable rating curves and multiple floods for calibration and testing, only then will it give reliable estimates.

It is recommended that GWRC make use of data from its recently installed flow recorder on the Pinehaven Stream and check/re-calibrate the rainfall-runoff model after a number of years or flood events have been recorded.
Agree, and disappointing to find the site was closed in 2013.

Rainfall measurements within the Pinehaven Catchment
The rainfall analysis: at site frequency analysis (also Appendix A),rainfall distribution, rainfall temporal pattern and PMP look plausible. However the at site frequency analysis for the UHCC Pinehaven raingauge was over 12 years of data. Since MWH's analysis, NIWA's HIRDS version 3 became available in 2010 followed by HIRDS version 4 in 2018, with more years of data plus the advantage of using regional growth curves to improve the frequency analysis, provides a significant improvement over the MWH frequency analysis. For example this MWH report estimates the Pinehaven 2 hour 100 year return period rainfall as 51 mm (Table 4-3), whereas the more reliable HIRDS v4 estimate is 52 mm for the 2 hour duration with a 30 year return period, a significant difference.

It is disappointing there was no raingauge within the Pinehaven Catchment operating, to provide records for the 23 July 2009 storm event. Unfortunately Upper Hutt City Council (UHCC) removed this Pinehaven raingauge located at map reference R27:785034 in July 2008 at the start of the MWH hydrology study and UHCC only replaced it on 3 August 2010 (operated now on contract by GWRC), after this study was completed. Furthermore this is after SKM finished their flood hazard investigation and published their report on 25 May 2010.

5 Summary

1/ The top end rating curve for Pinehaven stream opposite Chatsworth Road has not been defined due to the poor data collection, even though this site ran for 5 years. It is considered the estimated flood peak of 8.8 m3/s on 23 July 2009 is an under estimation.

2/ My estimate of the 23 July 2009 flood peak is 12 m3/s (based upon an estimate of the peak mean velocity) which is approximately a 40 year ARI.

3/ Relying on a single flood event with an incorrect flow peak coupled with the lack of any Pinehaven catchment rainfall for calibration, followed by the lack of any testing against actual data makes their analysis invalid. Any further use such as inputs into a hydraulic model will result in large errors, as shown in the differences in modelled flood extent maps with those observed by many in the community and water depth at the only water level measuring recorder site in the catchment. This will unfortunately result in unreliable design values for the Pinehaven stream works upgrade.

6 References

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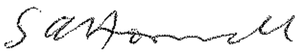
Yours sincerely



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