Greater Wellington Regional Council

Pinehaven Stream Flood Hydrology

4 November 2008

Quality Assurance Statement	
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Revision Schedule

Rev No	Date	Description	Prepared By	Reviewed By	Approved By

Executive Summary

This report presents the results of a flood hydrology investigation into the Pinehaven Stream catchment in Upper Hutt City. Greater Wellington Regional Council (GWRC) has commissioned MWH to complete this study.

The Pinehaven catchment has a total area of approximately 4.7 km^2 and rises to an elevation of 380 m. The stream originates at the boundary with the Mangaroa catchment with major tributaries flowing down the Pinehaven Rd and Elmslie Rd valleys, before reaching lower gradient residential areas of Pinehaven and Silverstream. The aim of this investigation is to undertake a flood hydrology assessment of the Pinehaven Stream and derive design flood flows for use in a hydraulic model. The design flood estimates presented in this report are for the Pinehaven Stream opposite Chatsworth Rd (catchment area of 4.4 km^2).

Design rainfall estimates are derived for the 2-year to 100-year Average Recurrence Interval (ARI) and Probable Maximum Precipitation (PMP) is estimated using standard New Zealand based methodology.

There is very limited recorded flow data in the Pinehaven Stream. Flood frequency analyses are therefore carried out using three regional methods. The rational method is also used as a check on the results.

A rainfall-runoff model is developed for the catchment. Limited calibration data is available – only one flood event was available to be used to calibrate the model. The design rainfall totals are input to the rainfall-runoff model with an appropriate temporal pattern, and modelled flood estimates and hydrographs are output for locations along the catchment.

Despite the lack of calibration data available for the model the results 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.

It is recommended that the rainfall-runoff model results be adopted as the design flood estimates.

Table E1 details the recommended design flood estimates for the Pinehaven Stream at Chatsworth Rd.

Table E1. Final Design Flood Estimates for the Pinehaven Stream

ARI (Years)	Flow (m^3/s)
5	15
10	16
20	18
50	20
100	22
PMF	86

After publication of this report in November 2008, the rainfall-runoff model was able to be updated with newly collected flood data on the Pinehaven Stream. Design flood estimates presented have been updated as a result. Table E1 details the updated results while Appendix B contains the relevant updated Sections (6, 7 and 8) of this original report.

Greater Wellington Regional Council

Pinehaven Stream Flood Hydrology

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1 Introduction

This report presents the results of a flood hydrology investigation into the Pinehaven Stream catchment in Upper Hutt City. Greater Wellington Regional Council (GWRC) has commissioned MWH to complete this study.

1.1 Objective

The aim of this study is to undertake a flood hydrology assessment of the Pinehaven Stream and derive design flood flows for use in a hydraulic model.

Various flood frequency methods are used on the available rainfall and flow data, and a rainfall-runoff model was developed to produce design flood hydrographs at various points in the catchment. The design hydrographs for specific return periods are to be used in subsequent hydraulic modelling of the Pinehaven Stream flood hazard.

1.2 Scope

To develop the required design hydrographs, the following components of work were completed:

i.) Relevant rainfall and flow data was obtained from databases operated by GWRC, Upper Hutt City Council (UHCC) and NIWA.

ii.) An analysis of rainfall records in the area was undertaken to develop an understanding of spatial and temporal rainfall distribution across the catchment and to establish design rainfall for input to the hydrological model. Frequency analysis of extreme rainfall was carried out to derive design rainfall totals of 30 minutes, 1, 2, 3, 4 and 6 hours duration, with Average Recurrence Intervals (ARI) from 2-years to 100-years. The Probable Maximum Precipitation (PMP) is also calculated for the catchment.

iii.) No recorded flow data exists for the Pinehaven Stream so flood frequency estimates are derived using regional methods (McKerchar and Pearson 1989, Pearson 1990, Pearson 1991). The Rational Method is also used as a check/verification on the results obtained.

iv.) A rainfall-runoff model is developed using the Hydstra Modelling software. Currently there is no continuous flow data available to calibrate the rainfall-runoff model, so previous modelling studies and the experience of MWH hydrological experts are drawn upon to determine suitable model parameters. As this investigation began, GWRC hydrology staff were able to obtain a peak flood flow/level measurement during a rainfall event which is used in the calibration process of the rainfall-runoff model.

v.) The design rainfall totals are used as inputs to the model and design flood hydrographs are output at various points in the catchment.

vi.) The design flood peaks estimated from the regional methods and the hydrological model are compared, and final design flood estimates and hydrographs presented.

2 Catchment Description

The Pinehaven Stream is located in Upper Hutt City and is part of the Hulls Creek catchment that flows into the Hutt River between Silverstream and Stokes Valley.

The Pinehaven catchment (Figure 2-1) is bounded by the Mangaroa catchment to the south, Stokes Valley and the Silverstream landfill to the west, and Trentham to the east/north-east. The Pinehaven Stream flows in a northerly direction before joining Hulls Creek near the Silverstream rail station.

The Pinehaven catchment has a total area of approximately 4.7 km^2 and rises to an elevation of 380 m. The stream originates at the boundary with the Mangaroa catchment in the Blue Mountains area with major tributaries flowing down the Pinehaven Rd and Elmslie Rd valleys, before reaching the lower gradient residential areas of Pinehaven and Silverstream.

The analyses presented in this report are based on the catchment area of the Pinehaven Stream to the point opposite Chatsworth Rd. Below Chatsworth Rd the stream flows through a long section of culverts to Hulls Creek. The catchment area above Chatsworth Rd is 4.4km^2.

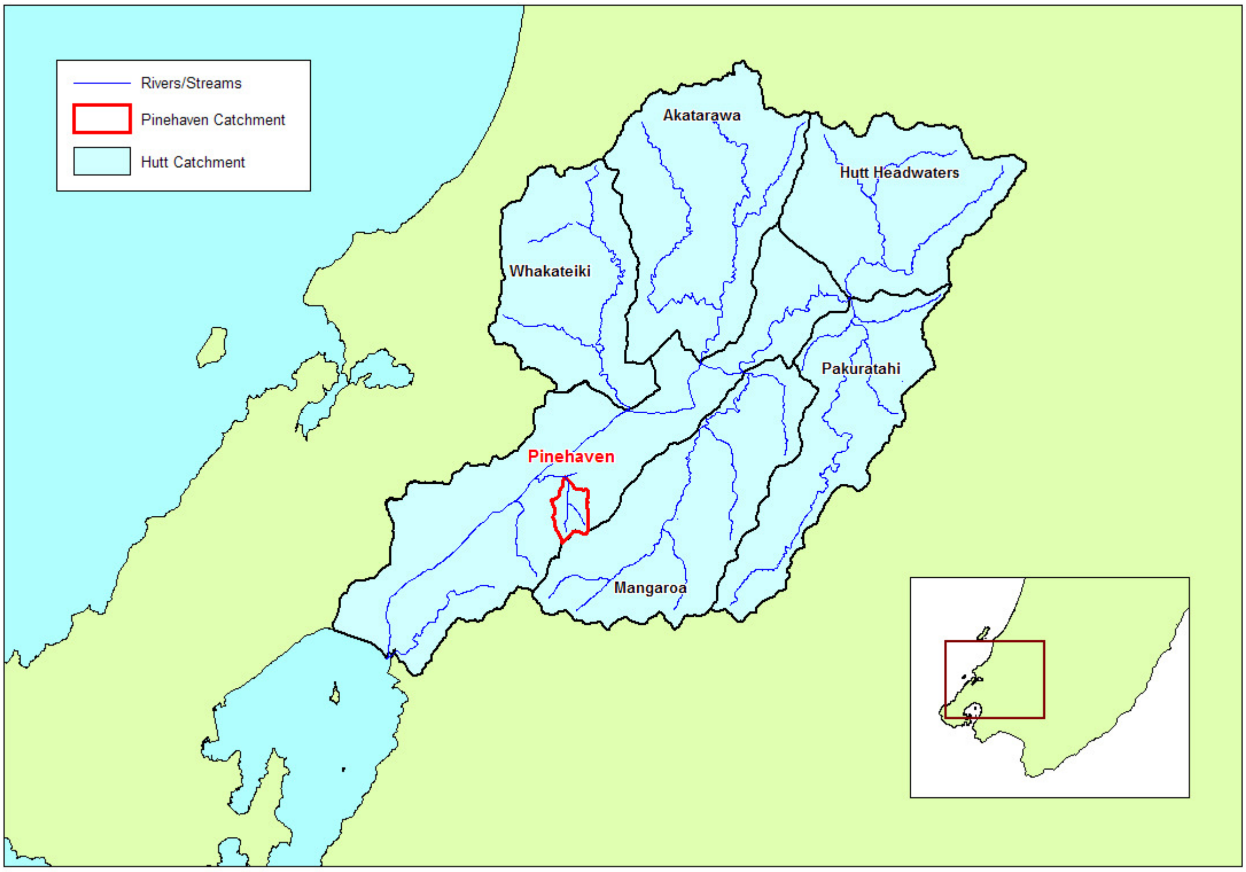


Figure 2-1: Pinehaven Catchment Location

3 Hydrological Data

Rainfall and river flow data used in this report are taken from GWRC, UHCC and NIWA databases.

3.1 Rainfall Data

Table 3-1 details the rainfall data that is available in and around the Pinehaven catchment. The mean annual rainfall for each is also shown. The locations of the raingauges are shown in Figure 4-1.

Table 3-1: Rainfall Stations in and around Pinehaven Catchment

Station	Met No.	Map Reference	Recording Authority	Data Type and Period	Mean Annual Rainfall (mm)
Tasman Vaccine Ltd	E15204	R27:790096	GWRC	Automatic 1980-	1525
Wallaceville	E15102	R27:823061	NIWA	Daily 1939-1985 Automatic 1986-	1300
Pinehaven		R27:785034	UHCC	Daily 1997 Automatic 1998-	1214
Perry St		R27:792050	UHCC	Daily 1997 Automatic 1998-	1240
Heretaunga Dam		R27:807045	UHCC	Daily 1997 Automatic 1998-	1223
Tennyson St	E15104	R27:816073	NIWA	Daily 1954-	1354

The Pinehaven raingauge, operated by UHCC, is ideally located within the study catchment but the length of automatic record is short (approximately nine years) and there are a number of gaps within it.

Wallaceville rainfall data is very similar to the Pinehaven data over the 1998 to 2008 period, and given it's longer length of record and higher data quality it is more useful for rainfall analyses.

The Tasman Vaccine Ltd site is located in the Mangaroa catchment and is more representative of rainfall in the high parts of the Pinehaven catchment.

3.2 Flow Data

There is no recorded flow data within the Pinehaven catchment. GWRC staff carried out a flood gauging measurement of a high flow in the Pinehaven Stream at the Pinehaven Reserve on the 31 July 2008 that is able to be used in the rainfall-runoff model development (Section 6).

The peak flow for the 31 July event was obtained by the 'slope-area' method of estimating flow. The peak water level was marked and surveyed a couple of weeks after the event. The slope-area method allows the flow to be calculated given the stream cross section, slope, peak water level and channel roughness (Manning's n).

GWRC estimate a range of possible peak flows (depending on the channel roughness value used) ranging from 1.8 m^3/s to 5.7 m^3/s. The preferred estimate is 2.5 m^3/s (pers. Comm. J. Marks, GWRC, August 2008).

A more detailed analysis of this flood event is carried out as part of the development of the rainfall-runoff model in Section 6.2.1.

An estimate of peak flow in the Pinehaven Stream resulting from the December 1976 storm exists. Bishop (1997) estimates a flow of 30 m^3/s resulted from an estimated 100 mm of rainfall over three hours, and 180-200 mm over six hours.

It is not known how this peak flow estimate was derived so it must be treated with caution but it was classed as being greater than a 100-year ARI (Bishop 1977).

4 Rainfall Analysis

4.1 Frequency Analysis

Rainfall data from five raingauge sites have been used in frequency analyses to determine high intensity depth-duration frequency totals in and around the Pinehaven catchment. The Event Analysis module within the TIDEDA software was used to carry out the analyses.

Table 4-1 to Table 4-5 detail the depth-duration frequency totals for Tasman Vaccine, Wallaceville, Pinehaven, Perry St and Heretaunga Dam respectively. Results for durations of 30 minutes to 6 hours, and ARI's ranging from 2 to 100-years are presented. The preferred frequency distribution is also shown.

The frequency plots for the analyses and the frequency distributions used are contained in Appendix 1.

The Tasman Vaccine site has the longest available suitable data record (automatic), from 1981 to 2007. Although the Wallaceville site has rainfall data dating back to 1931 it consists of only daily totals until 1985. Therefore, the Wallaceville data used here covers 1986 to 2007. The three UHCC sites – Pinehaven, Perry St and Heretaunga Dam – have suitable data available from October 1998 to the present.

Results from the UHCC raingauges (Table 4-3 to Table 4-5) are similar for durations of 30 minutes to three hours. At the four and six-hour durations the Perry St site displays relatively higher totals for the extreme ARI's.

Table 4-1: Tasman Vaccine Depth Duration Frequency Results (mm) 1981-2007

ARI (Years)	**Duration (Hours)**					
	0.5	**1**	**2**	**3**	**4**	**6**
2	16	22	30	37	42	51
5	22	29	39	47	54	65
10	26	34	44	54	62	75
20	30	39	49	60	70	84
50	35	45	56	69	79	95
100	38	50	61	75	87	104
Distribution	*Gumbel*	*Gumbel*	*Gumbel*	*Gumbel*	*Gumbel*	*Gumbel*

Table 4-2: Wallaceville Depth Duration Frequency Results (mm) 1986-2007

ARI (Years)	Duration (Hours)					
	0.5	1	2	3	4	6
2	12	18	27	33	39	48
5	15	23	33	41	47	60
10	17	26	37	46	53	66
20	18	29	40	50	58	70
50	20	32	44	55	65	76
100	21	34	47	59	69	80
Distribution	*PE3*	*PE3*	*PE3*	*PE3*	*PE3*	*PE3*

Table 4-3: Pinehaven UHCC Depth Duration Frequency Results (mm) 1998-2007

ARI (Years)	Duration (Hours)					
	0.5	1	2	3	4	6
2	12	16	23	30	35	43
5	14	19	29	38	45	53
10	16	23	34	44	51	60
20	18	26	39	50	57	67
50	20	30	46	57	64	76
100	21	33	51	62	70	83
Distribution	*Gumbel*	*PE3*	*PE3*	*PE3*	*Gumbel*	*Gumbel*

Table 4-4: Perry St UHCC Depth Duration Frequency Results (mm) 1998-2007

ARI (Years)	Duration (Hours)					
	0.5	1	2	3	4	6
2	12	17	25	31	35	42
5	14	21	33	41	48	60
10	15	24	38	48	57	72
20	17	26	43	55	65	84
50	18	29	50	64	76	99
100	19	31	55	70	84	111
Distribution	*Gumbel*	*Gumbel*	*Gumbel*	*Gumbel*	*Gumbel*	*Gumbel*

Table 4-5: Heretaunga UHCC Depth Duration Frequency Results (mm) 1998-2007

ARI (Years)	Duration (Hours)					
	0.5	**1**	**2**	**3**	**4**	**6**
2	11	16	25	32	40	49
5	14	20	32	42	52	66
10	15	22	37	48	59	75
20	17	25	41	54	64	82
50	19	28	47	61	71	91
100	20	30	51	67	75	97
Distribution	*Gumbel*	*Gumbel*	*Gumbel*	*Gumbel*	*PE3*	*PE3*

A check of the recorded data shows a high intensity rainfall event on 5 January 2005 that registered at all raingauges but showed much higher totals at the Perry St gauge. Due to the short length of data at the UHCC sites a difference in rainfall totals such as that will cause the frequency analysis results to differ between sites.

The Pinehaven and Wallaceville results are similar. The Tasman Vaccine results are higher and this is to be expected given its location and higher mean annual rainfall.

4.2 Rainfall Distribution

Although the Pinehaven catchment is relatively small there will be a degree of rainfall spatial distribution across it during a high intensity rainfall event.

Mean annual rainfall isohyets are shown for the local area in Figure 4-1. There is a rainfall gradient from the bottom of the Pinehaven catchment and the Wallaceville raingauge up through the catchment to the Tasman Vaccine raingauge. Table 3-1 also shows this with a mean annual rainfall total of 1300 mm at Wallaceville and 1525 mm at Tasman Vaccine.

It is recommended that the Tasman Vaccine results (Table 4-1) be used to represent the rainfall in the upper Pinehaven catchment, and that the Pinehaven/Wallaceville data (

Table 4-2/Table 4-3) is representative of the lower catchment.

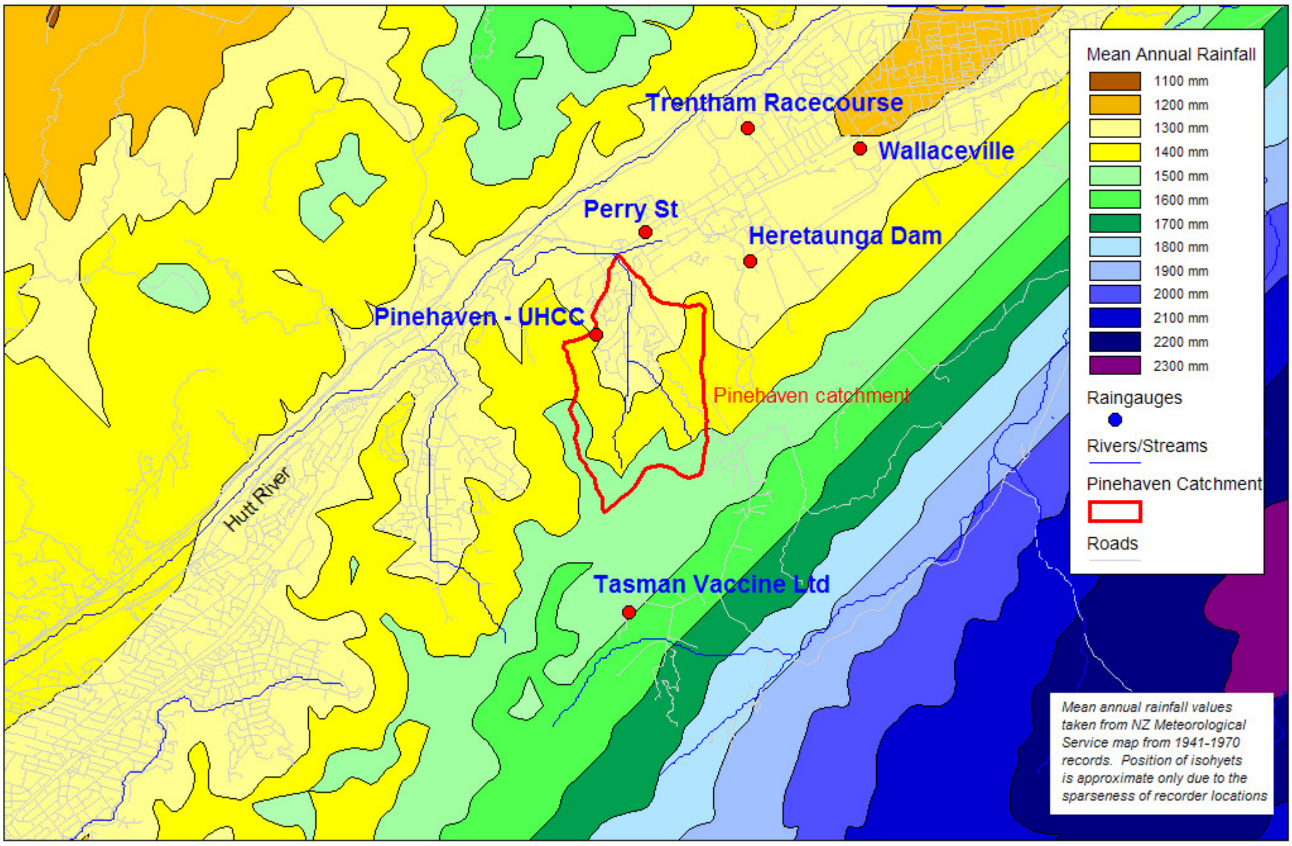


Figure 4-1: Mean Annual Rainfall and Raingauge Locations

4.3 Rainfall Temporal Pattern

Rainfall events tend to exhibit particular temporal characteristics. For example, tropical cyclones tend to distribute rainfall fairly uniformly; severe storms tend to have single peak intensities; while high frequency storms may have several intense rainfall peaks. Thompson and Tomlinson (1992) developed average temporal patterns of rainfall distribution throughout New Zealand based on many recorded storm events which can be used for design rainfalls. An implicit assumption is that design rainfalls of a given return period induce floods of the same frequency and magnitude.

The temporal distribution applied to the design rainfall totals for the Pinehaven catchment is based on the average accumulation during 17 storm events in the Wellington region.

Figure 4-2 details the temporal pattern by the percentage of the rainfall total against the percentage of the rainfall event duration.

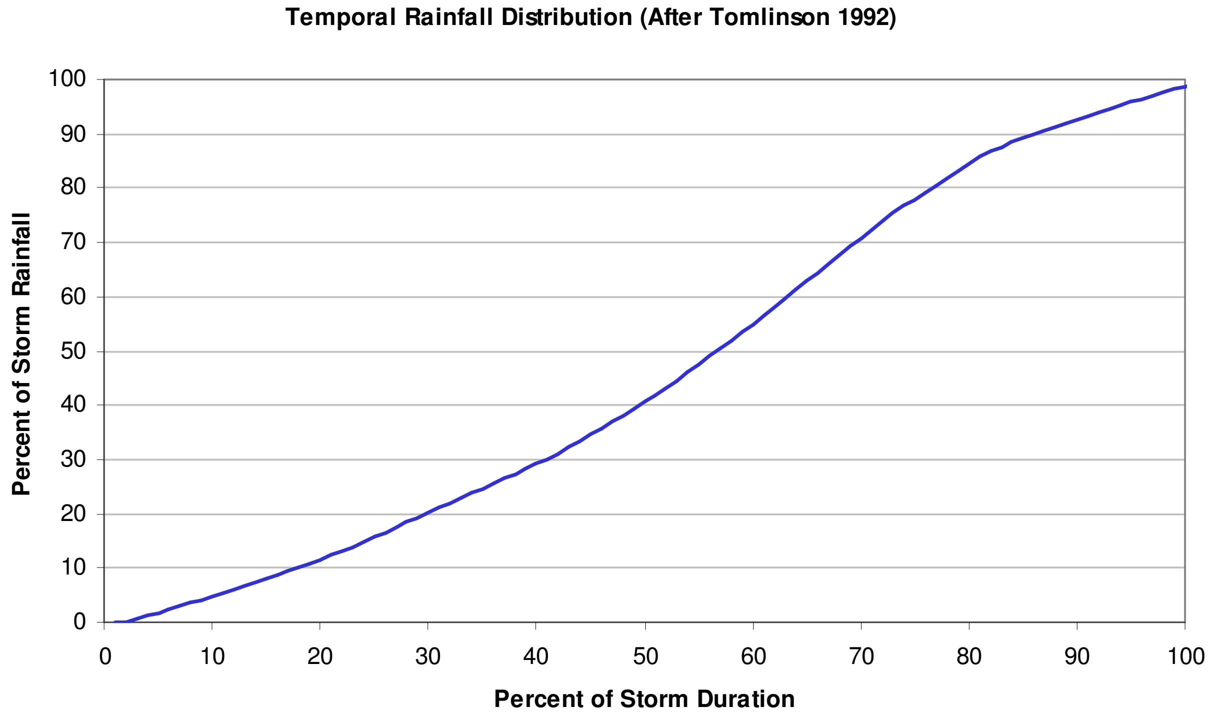


Figure 4-2: Design Rainfall Temporal Distribution

4.4 Probable Maximum Precipitation

Probable Maximum Precipitation (PMP) is defined by the World Meteorological Organisation as the greatest depth of precipitation for a given duration meteorologically possible for a given size storm area at a particular location at a particular time of year. The PMP is an estimate of an upper physical bound to the precipitation that the atmosphere can produce. An estimate of the PMP for the Pinehaven catchment is required so that the probable maximum flood (PMF) can be modelled.

Two PMP methodologies are defined by Thompson and Tomlinson (1993) to estimate PMP in New Zealand. The method of estimating PMP for small areas (less than 1000 km^2) and short durations up to six hours is used here for the Pinehaven catchment.

The 6:1-hour ratio of 3.5 was chosen as this is close to the ratio of 3.62 observed during the December 1976 storm in the Hutt Valley (Watts, 2005).

The PMP results are summarised in Table 4-6.

Table 4-6: PMP Calculation for Pinehaven Catchment

Step	Description	Value						
1	Catchment Area (km^2)	4.4						
	Maximum Altitude (m)	380						
	Mean Altitude (m)	190						
2	Reference 1-Hour Catchment PMP (mm)	202.3						
3	Adjustment for Location (%)	88%						
4	Adjustment for Altitude (%)	100%						
5	Catchment Average 1-Hour PMP (mm)	177						
		Duration (Hours)						
		0.5	**1**	**2**	**3**	**4**	**5**	**6**
6	Depth-duration adjustments (% of 1 hr)	62	100	162	215	263	307	350
7	Catchment PMP (mm)	**110**	**177**	**287**	**381**	**466**	**543**	**620**

5 Flow Analysis

No recorded flow data exists within the Pinehaven catchment. Therefore flood frequency estimates were derived using regional methods and the rational method.

Advice from GWRC (pers. comm. J. Marks, August 2008) is that a flow recorder has been installed in the Pinehaven Stream near Chatsworth Rd since the commencement of this study. The data is unable to provide any useful benefit for this current investigation but it should be continued to be collected and used for any subsequent 2D hydraulic modelling or used to revise this work in the future.

5.1 Regional Flood Frequency Analysis

Two similar applications of regional flood frequency estimation have been used on the Pinehaven catchment:

- *Flood Frequency in New Zealand* (McKerchar & Pearson, 1989) and its subsequent update for the Hutt catchment in *Hutt River Flood Control Scheme Review – Flood Hydrology* (Pearson, 1990)
- *Regional Flood Frequency Analysis for Small New Zealand Basins* (Pearson, 1991)

PMF events cannot be derived using the regional methods.

The analyses are carried out for the Pinehaven Stream at Chatsworth Rd and the catchment area is 4.4 km^2.

5.1.1 Method 1 - McKerchar and Pearson (1989) & Pearson (1990)

The methodology described in *Flood Frequency in New Zealand* (McKerchar & Pearson, 1989) was used to determine peak flows from the mean annual to the 100-year ARI flood event. The regional flood frequency method is widely used throughout New Zealand when no recorded flow data is available and it is based on regionalised actual recorded flood data.

Whereas McKerchar and Pearson (1989) encompassed the entire country, Pearson (1990) focussed on the Hutt River catchment and further defined the mean annual flood statistic ($Q/A^{0.8}$) and flood frequency factor (q_{100}) contour maps for the area.

Table 5-1 details the results of regional flood frequency analyses using the McKerchar & Pearson (1989) methodology for the Pinehaven catchment and the same methodology with the Pearson (1990) updated flood contour maps.

Table 5-1: Regional Flood Frequency Results (m^3/s), Pinehaven Stream at Chatsworth Rd

ARI (Years)	McKerchar & Pearson (1989)		Pearson (1990)	
	Flow (m^3/s)	Standard Error (%)	Flow (m^3/s)	Standard Error (%)
Mean Annual	9.8	±17	9.8	±17
5	13	±17	13	±17
10	16	±20	15	±19
20	19	±22	17	±22
50	22	±26	20	±25
100	25	±28	22	±28

5.1.2 Method 2 - Pearson (1991)

The methodology described in *Regional Flood Frequency Analysis for Small New Zealand Basins* (Pearson, 1991) was used to determine peak flows for the 5-year to 100-year ARI flood events. This regional flood frequency method, while based on many of the same principles as that in Section 5.1.1, is targeted at small catchments (<10km^2).

Following the prescribed procedures in Pearson (1991), the Pinehaven catchment can be classified into two separate flood frequency groups depending on whether rainfall data from Wallaceville (Group 1) or Tasman Vaccine (Group 3) is used to determine the 5-year ARI 24-hour total. Results from both are presented.

Table 5-2 details the results of regional flood frequency analyses using the Pearson (1991) methodology for the Pinehaven catchment.

Table 5-2: Pearson (1991) Regional Flood Frequency Results (m^3/s), Pinehaven at Chatsworth Rd

ARI (Years)	Flow (m^3/s)			
	Flood Frequency Group 1	Flood Frequency Group 3		Weighted Flood Frequency
Mean Annual	9.8	9.8		9.8
5	14	14		14
10	17	19		18
20	22	23		22
50	27	28		28
100	32	32		32

The procedure to derive weighted flood frequency estimates when two or more groups are relevant (Pearson 1991) is followed and the results are details in the fourth column.

5.2 Rational Method

The rational method is a standard method for calculating the peak runoff rate for a given catchment or parcel of land and is commonly used in New Zealand and around the world. The rational method is based on assumptions that the peak runoff at any design location is a function of the average rainfall intensity during the time of concentration to that location, - the time of concentration being the time required for the runoff from the most remote part of the drainage area to flow to the point under design. The rational method is particularly suited to small catchments.

Table 5-3 details the results of applying the rational method to the Pinehaven Stream catchment at Chatsworth Rd. The time of concentration for all catchments is taken as 60 minutes and a runoff coefficient of 0.5 is used. The runoff coefficient was derived from basic GIS analysis of areas of different runoff characteristics within the catchment and weighting them. The catchment area is 4.4 km^2.

Rainfall intensities from the Tasman Vaccine and Wallaceville raingauges are used. The rainfall data from these two sites has been used to interpolate a set of approximate catchment average design rainfall intensities (intermediate rainfall in Table 5-3) for use in the rational method.

Table 5-3: Rational Method Flood Frequency Results (m^3/s), Pinehaven Stream at Chatsworth Rd

ARI (Years)	Tasman Vaccine Rainfall	Wallaceville Rainfall	Intermediate Rainfall
2	13	11	12
5	18	14	15
10	21	16	18
20	24	18	21
50	28	20	23
100	31	21	24
PMF	108	108	108

6 Rainfall-Runoff Modelling

A rainfall-runoff model was developed for the Pinehaven catchment to produce design hydrographs for specified return period (ARI) events from the design rainfall inputs. The model is an Initial Loss - Continuing Loss type and has been built using Hydstra Modelling software. Hydstra Modelling has been used in many hydrological applications in New Zealand and around the world for rainfall-runoff and design flood modelling. It has been used for a number of GWRC flood modelling and flood design investigations.

6.1 Model Configuration

The Pinehaven catchment was divided into nine sub-catchments (P1 to P9) for the rainfall-runoff modelling (Figure 6-1). The most downstream point of the model is opposite Chatsworth Rd before the stream enters into a long culvert. The catchment area to this point is 4.4 km^2.

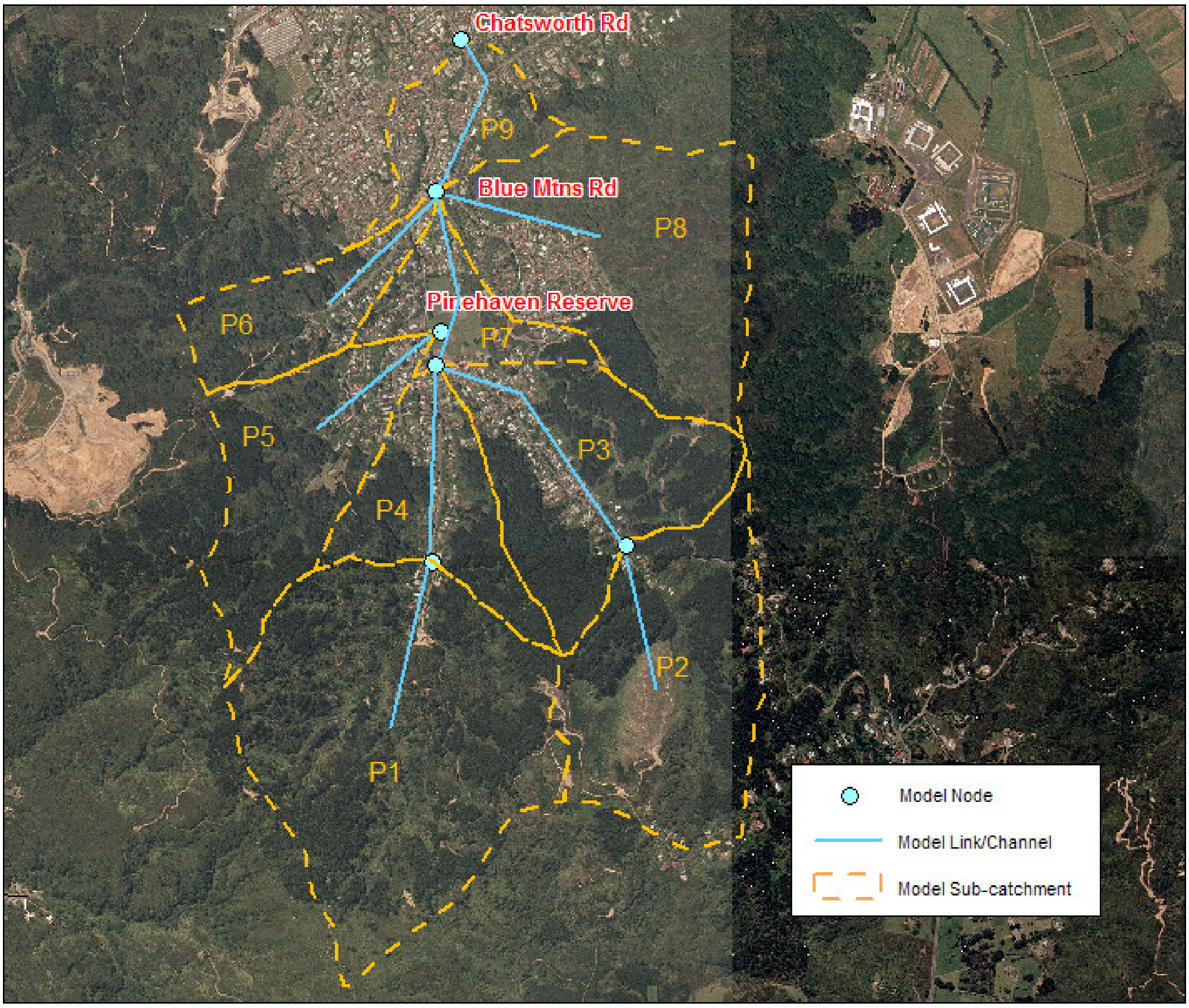


Figure 6-1: Pinehaven Rainfall-Runoff Model Delineation

Sub-catchment delineation and channel lengths were derived from GIS based contour and aerial photograph information, as well as maps presented in the Upper Hutt City Council District Plan (2004).

Figure 6-2 shows a schematic of the rainfall-runoff model. Modelled flow hydrographs are output at Pinehaven Reserve, Blue Mountains Rd, and Chatsworth Rd. However, output can be determined from any of the other nodes if required for hydraulic modelling purposes. Sub-catchments P1 and P2, originating on the higher catchment divides, use Tasman Vaccine rainfall as an input. All other sub-catchments use the Wallaceville/Pinehaven rainfall as input.

The catchment areas draining to the Pinehaven Reserve and Blue Mountains Rd sites are 3 km^2 and 4.2 km^2 respectively.

The model is setup to run at 15 minute intervals.

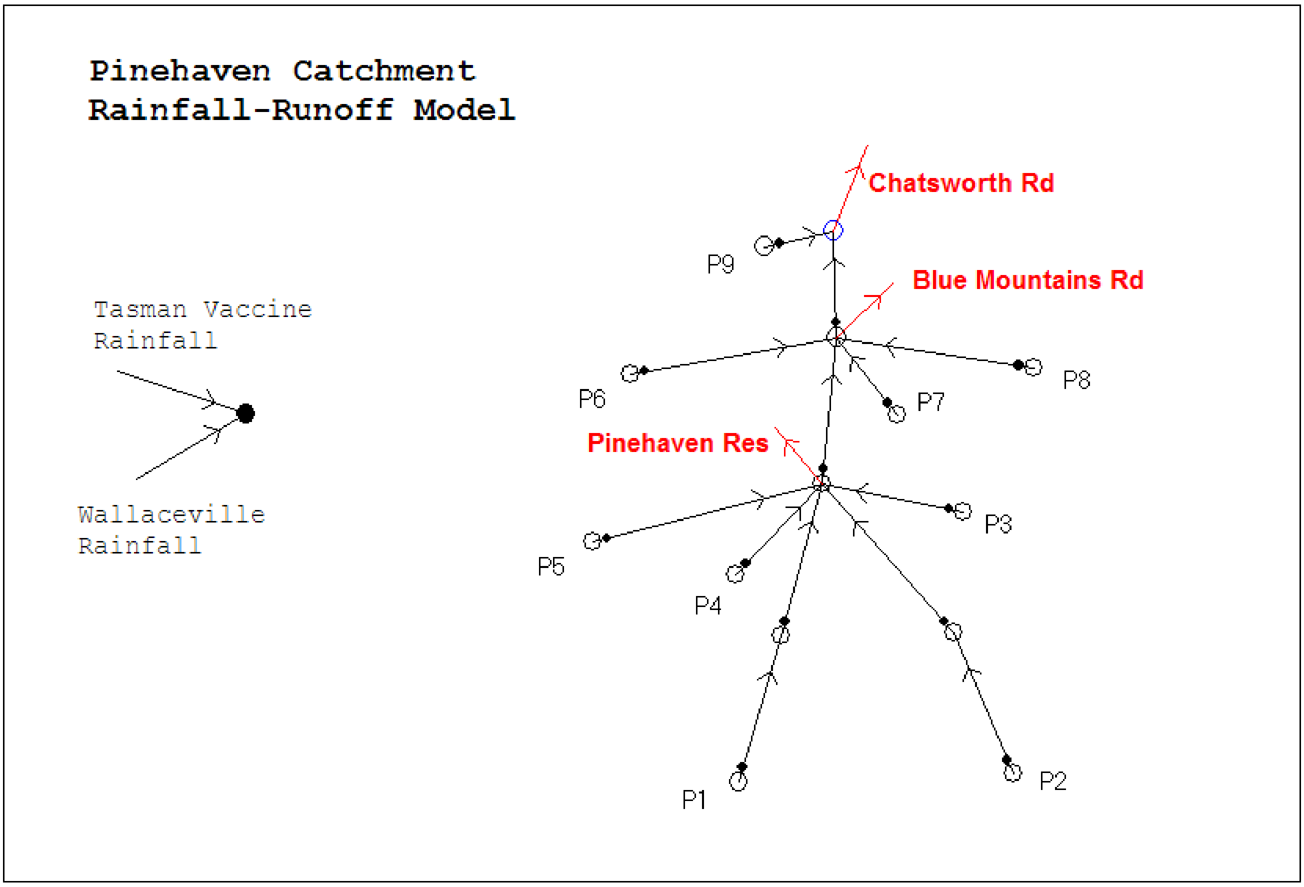


Figure 6-2: Pinehaven Model Schematic

6.2 Model Calibration

At the time of commencing this flood study there was no recorded flood flow data for the Pinehaven catchment. GWRC installed a flow recorder on the Pinehaven Stream at Chatsworth Rd in August 2008 but no suitable data is available for this study.

GWRC hydrology staff pegged out the peak water level of a small flood event that occurred on 31 July 2008. The peak levels, cross sections and slope have been surveyed and used to derive a peak flow estimate (Section 6.2.1) for this event.

This flood estimate is the only calibration data available for the modelling process.

6.2.1 31 July 2008 Flood Estimate

GWRC hydrology staff computed a standard slope-area discharge measurement for the 31 July 2008 event using surveyed peak water levels at the Pinehaven Reserve.

As is often the case with the slope-area method the choice of Manning's n (roughness coefficient) was difficult to accurately assess. Two follow up flow gaugings were carried out at lower flows to assess the actual Manning's n value, however as the flow was contained within the normal stream bed the results are representative of that only and not the banks or berms.

A range of Manning's n values were used that were representative of the channel and berms, or parts thereof. This resulted in a range of peak flow estimates from 1.8 m^3/s (using a Manning's n value of 0.616 - obtained from follow up flow gaugings) to 5.7 m^3/s (using a Manning's n value of 0.02 - taken from literature).

To obtain a reliable peak flow estimate, MWH has used the surveyed cross section and slope data to create a MIKE11 hydraulic model. The Manning's n value is able to be varied across the cross sections within MIKE11 and can therefore replicate the actual channel and berms roughness far more accurately than the slope-area method which can only use a single Manning's n value.

A number of MIKE11 model runs were completed with Manning's n values ranging from 0.06 for the gravel channel (as derived from GWRC follow up flow gaugings) to 0.03 for the grassy berms (derived from literature). A steady-state constant flow was used as the input to the MIKE11 model and numerous iterations carried out by varying this flow input magnitude until the peak modelled water levels approximated those surveyed after the flood event.

The resulting peak flow estimate for the 31 July 2008 event is 2.8 m^3/s.

This is not a major flood event and the rainfall totals suggest it is probably an annual, or possibly more frequent, event. Rainfall totals for the event range from one-third to two-thirds of a 2-year ARI event.

6.2.2 Calibrating Rainfall-Runoff Model to Flood Estimate

The rainfall-runoff model was calibrated using the 31 July 2008 peak flow estimate and recorded rainfall data from the Tasman Vaccine and Wallaceville raingauges for that event.

Table 6-1 details the parameters used in the rainfall-runoff model. The initial loss (IL), continuing loss (CL), α and n parameters are adjusted during the calibration process. These values are "global" and are therefore assumed constant over the catchment.

Table 6-1: Calibration Parameters for Rainfall-Runoff Model

Parameter	Description
Initial Loss (IL) - mm	Amount of water lost before rainfall becomes effective runoff
Continuing Loss (CL) - mm/hr	Continuing loss rate applied to rainfall after IL is satisfied
α	Channel lag parameter for channel routing
n	Non-linearity parameter for channel routing
Area - km^2	Sub-catchment area
L - km	Channel length

The calibration process consisted of using the recorded rainfall data and varying the IL, CL, α and n parameters.

The calibration was carried out by a visual assessment of the magnitude and shape of the hydrograph at the Pinehaven Reserve site as compared to the 31 July 2008 flood estimate. Only the magnitude of the modelled peak can be compared directly. Hydrological practice and judgement was used to ensure a valid hydrograph shape was produced.

Figure 6-3 shows the final calibration hydrograph produced for the 31 July 2008 event from the Hydstra Modelling software. The y-axis flow units are m^3/s and the time interval (x-axis) is 15 minutes. The red line is the estimated 2.8 m^3/s magnitude of the estimated flood peak. Recorded rainfall at Tasman Vaccine and Wallaceville is shown along the bottom axis.

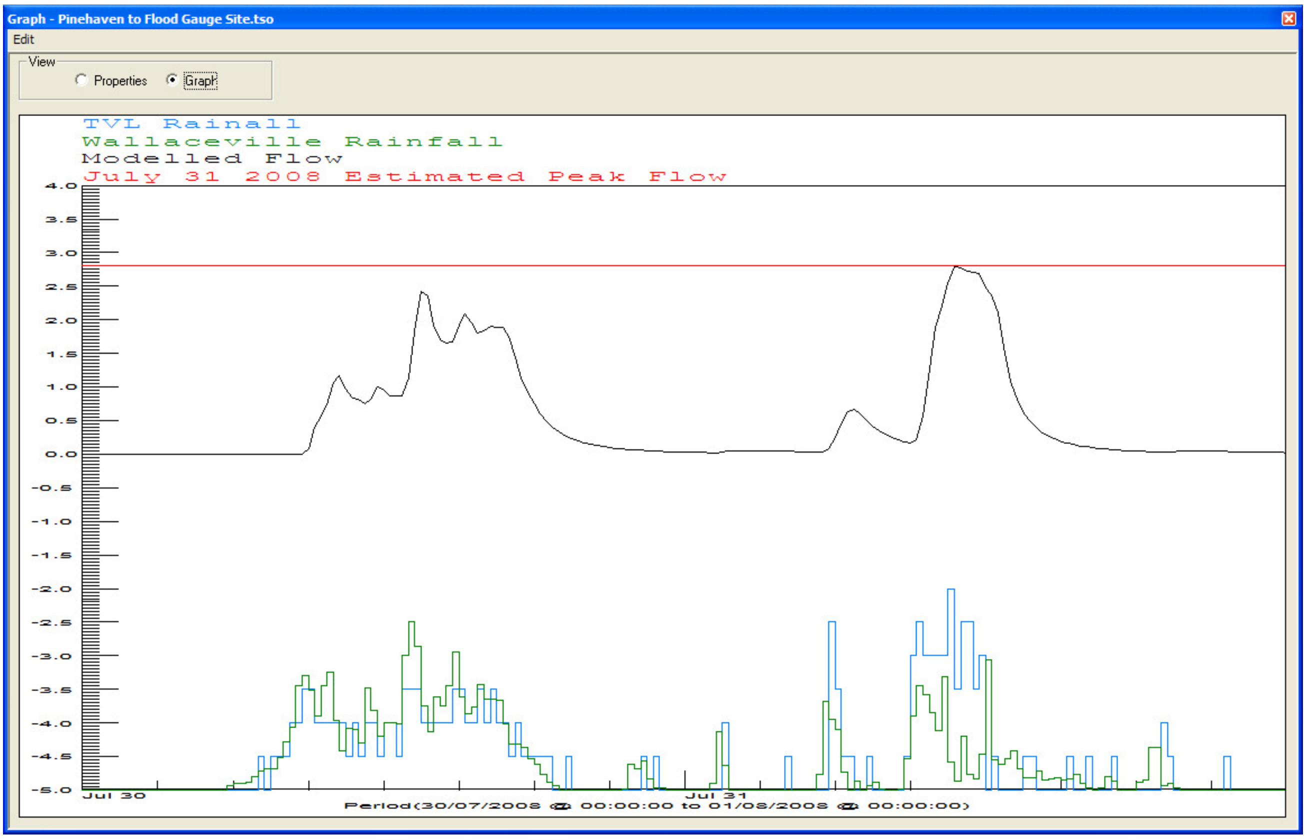


Figure 6-3: 31 July 2008 Calibration Event at Pinehaven Reserve (Hydstra Modelling output)

Table 6-2 details the final model parameters adopted.

Table 6-2: Pinehaven Stream Model Calibration Results

Parameter	Best Fit Value
Initial Loss (IL)	5 mm
Continuing Loss (CL)	2 mm
α	0.9
n	0.72

Comparison was made to other nearby flood modelling results such as the Mangaroa River (Watts, 2005), Waiwhetu Stream (Watts, 2004), Mangaone Stream (MWH, 2002) and Karituwhenua Dams (MWH, 2008) to ensure values for the model parameters were realistic.

The channel lag component (α) is considered reasonable due to the way the Pinehaven Stream flows through many residential property back yards, under bridges and through culverts on its way down catchment.

The calibration flood event of 2.8 m^3/s on 31 July is not a major flood event. It is estimated to be an annual event at the most. There are uncertainties in calibrating a rainfall-runoff model to just one single peak value that is not a major flood peak. 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.

6.3 Design Flood Hydrographs

The design rainfall events for the 2 to 100-year ARI and PMP were input to the rainfall-runoff model to produce design flood hydrographs throughout the catchment.

Figure 6-4 shows the 100-year ARI design hydrographs for Pinehaven Reserve and Chatsworth Rd. The one and two-hour events for each are given.

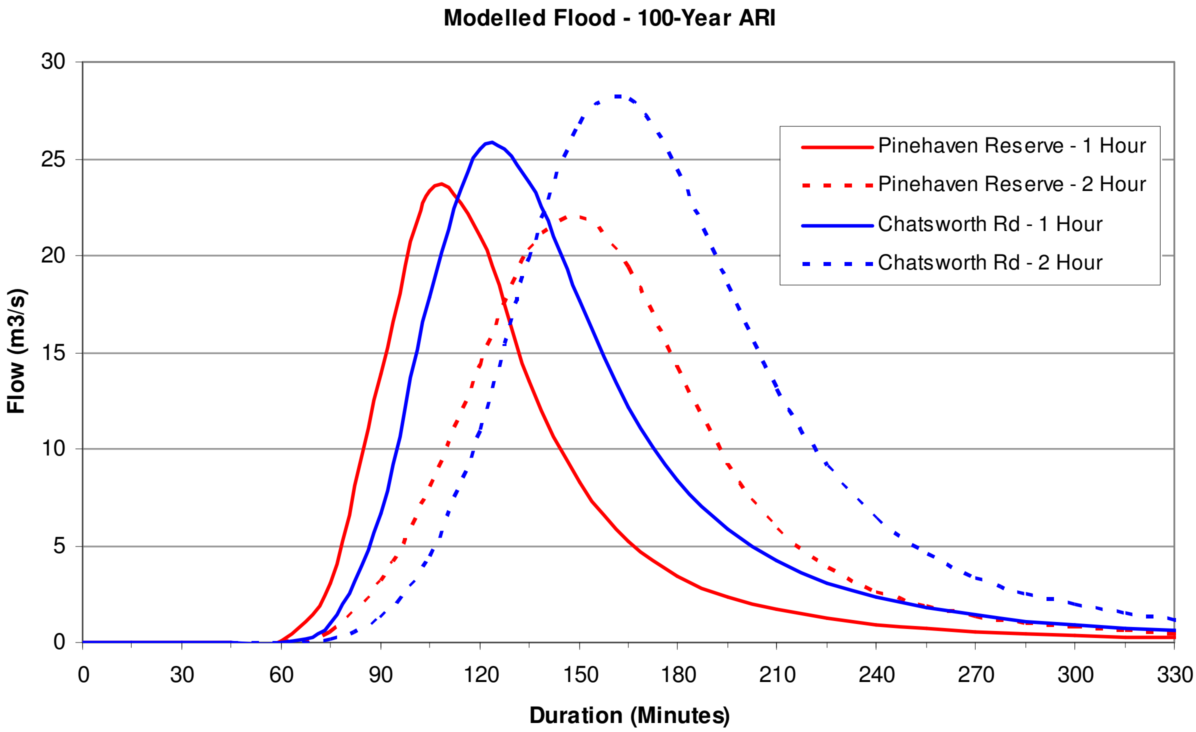


Figure 6-4: Design 100-year ARI Hydrographs

The critical duration 100-year ARI flood event is a one hour duration storm for Pinehaven Reserve and a two hour duration for Chatsworth Rd.

Table 6-3 details the results for all durations and ARI magnitudes for the Pinehaven Stream at Chatsworth Rd. The critical duration event for each ARI is highlighted.

The 100-year ARI modelled design peak flow for the Pinehaven Stream at Chatsworth Rd is 28 m^3/s.

Table 6-3: Modelled Design Peak Flows for Pinehaven Stream at Chatsworth Rd (m^3/s)

ARI (Years)	Duration (Hours)					
	0.5	1	2	3	4	6
2	4	7	11	14	14	10
5	6	12	15	15	14	13
10	9	14	18	18	17	15
20	11	19	22	22	21	17
50	13	22	25	25	24	20
100	15	26	28	28	26	21
PMF	124	189	207	199	190	174

6.4 Rainfall-Runoff Model Limitations

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. This uncertainty is reduced by comparing modelled output with peak estimates from other methods as summarised in Section 7.

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.

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.

7 Summary of Flood Estimates

A summary of the derived flood estimates for the Pinehaven Stream is detailed in Table 7-1.

Table 7-1: Pinehaven Stream at Chatsworth Rd Flood Estimates (m^3/s)

ARI (Years)	Regional Methods			Rational Method	Rainfall-Runoff Model
	McKerchar and Pearson (1989)	Pearson (1990)	Pearson (1991)		
2	9.8	9.8	9.8	12	14
5	13	13	14	15	15
10	16	15	18	18	18
20	19	17	22	21	22
50	22	20	28	23	25
100	25	22	32	24	28
PMF	-	-	-	108	207

The first three result columns detail the estimates derived from the regional flood frequency methods. Of the three methods, Pearson's (1991) method can be considered as the preferred regional method as it is directly applicable to small catchments less than 10 km^2 in area. The Pinehaven catchment is 4.4 km^2 to the Chatsworth Rd site.

The rainfall-runoff model results are similar to Pearson (1991) for all but the 2-year ARI event. It is the extreme ARI events that will be used for design purposes so the slightly conservative model results for lower ARI events are acceptable.

The rainfall-runoff results are also similar to those derived using the rational method.

7.1 Comparison to 1976 Peak Flow Estimate

As described in Section 3.2, an estimate of the flood magnitude in the Pinehaven Stream during the December 1976 extreme storm was presented by Bishop (1997). The peak flow was estimated at 30 m^3/s and this was assigned an ARI of greater than 100-years, matching the estimated ARI of the rainfall event.

Although the exact method of derivation of this estimate is not known it provides a reference point for the results presented here, and is in fact similar to the 100-year ARI estimates as shown in Table 7-1.

8 Recommended Design Flood Estimates

Based on the results obtained in this investigation it is recommended that the rainfall-runoff model results and hydrographs be adopted for design flood purposes.

Table 8-1 presents the recommended design flood estimates for the Pinehaven Stream at Chatsworth Rd.

Table 8-1: Pinehaven Stream Design Flood Estimates

ARI (Years)	Flow (m^3/s)
2	14
5	15
10	18
20	22
50	25
100	28
PMF	207

9 Further Work

Climate change scenarios should be investigated and design rainfall estimates for 2030 and 2080 derived. These can be input to the rainfall-runoff model to provide ‘future proofed’ hydrographs for the Pinehaven Stream.

The GWRC water level/flow recorder recently installed in the Pinehaven Stream should continue to be operated. While it was too late to be of benefit to this study, the data collected will provide vital information for any subsequent 2D hydraulic modelling.

The recorded flow data will also be useful to review and revise the findings presented here as well as providing further calibration data for the rainfall-runoff model after a period of time or sizable flood events.

It may be of interest to extract rainfall data for the December 1976 storm event and apply these to the rainfall-runoff model and derive a peak flow estimate.

10 References

Bishop, R.G., 1977. *Report on Storm of 20 December 1976*. Wellington Regional Water Board, Wellington, 66p

GWRC, 1995. *Hydrology of the Hutt Catchment - Surface Water*. Prepared by the Hydrological Services Group, Greater Wellington Regional Council

McKerchar, A.I., and Pearson, C.P., 1990: *Flood Frequency in New Zealand.* Publication No.20 of the Hydrology Centre, DSIR, Christchurch.

MWH, 2002: *Mangaone Stream Flood Hazard Assessment Hydrology Report*. Report Prepared for Greater Wellington Regional Council

MWH, 2008: *Karituwhenua Detention Dams Hydrological Modelling*. Report prepared for Barnett and MacMurray Ltd

Pearson, C.P., 1990: *Hutt River Flood Control Scheme Review – Flood Hydrology*

Pearson, C.P., 1991: *Regional Flood Frequency Analysis for Small New Zealand Basins: 2.Flood Frequency Groups.* Journal of Hydrology (NZ) 30(2):77-92

Pearson, C.P., and McKerchar, A.I., 1999. *An Update of the Hutt River Flood Frequency*. Prepared by NIWA for Greater Wellington Regional Council

Tomlinson, A.I. and Thompson, C.S., 1992. *Probable Maximum Precipitation in New Zealand. The Development and Application of Generalised Methods to Provide Nationwide Estimates of PMP*. Report prepared for ECNZ by NZ Meteorological Service.

Thompson, C.S. and Tomlinson, A.I., 1993. *Probable Maximum Precipitation in New Zealand for Small Areas and Short Durations.* Journal of Hydrology (NZ) 31(2):78-90

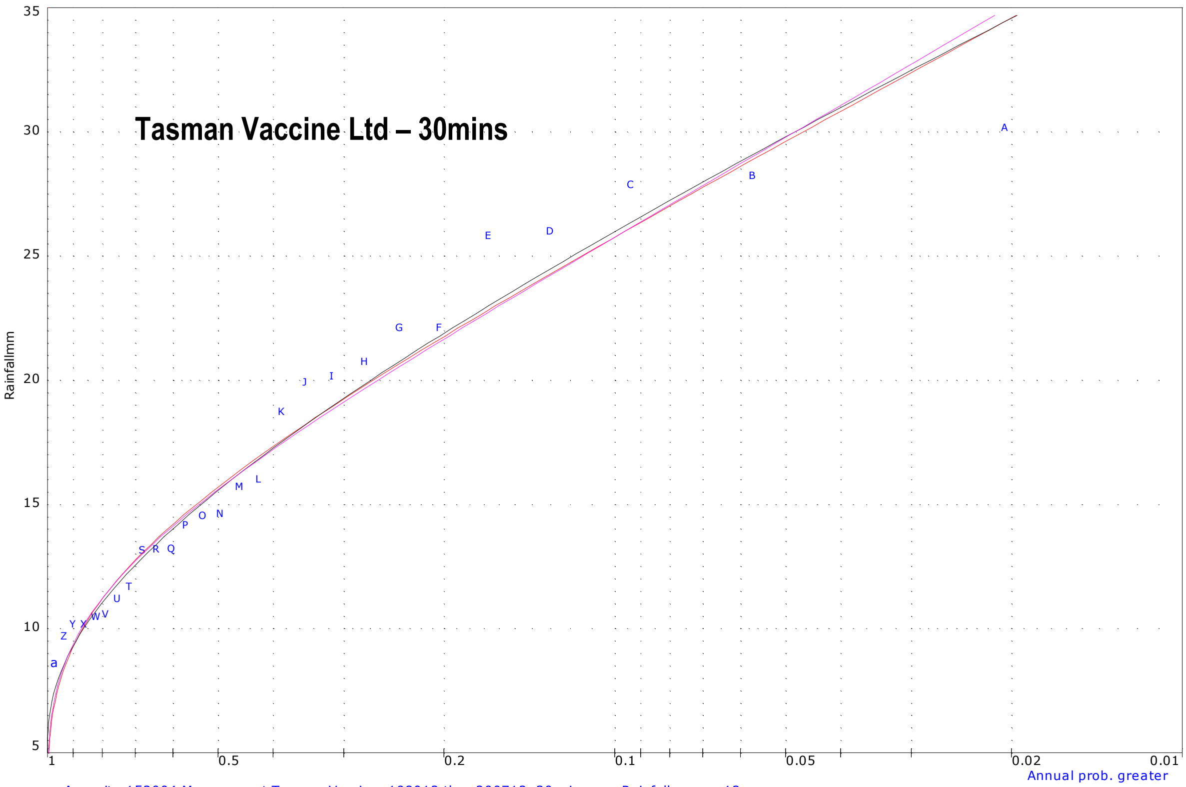
Thompson, C.S. and Tomlinson, A.I., 1995. *A Guide to Probable Maximum Precipitation in New Zealand*. NIWA Science and Technology Series No. 19.

Watts, L., 2004: *Flood Hydrology of the Waiwhetu Stream*. Greater Wellington Regional Council, Resource Investigations Department Technical Report.

Watts, L., 2005: *Flood Hydrology of the Mangaroa River*. Greater Wellington Regional Council, Resource Investigations Department Technical Report.

UHCC, 2004: *Upper Hutt City Council District Plan*. Upper Hutt City Council

Appendix A Rainfall Frequency Analysis Plots



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Gumbel Distn. Location & Scale= 13.75 5.340
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PE3 Distn. Location, Scale & Shape= 16.84 6.828 1.133
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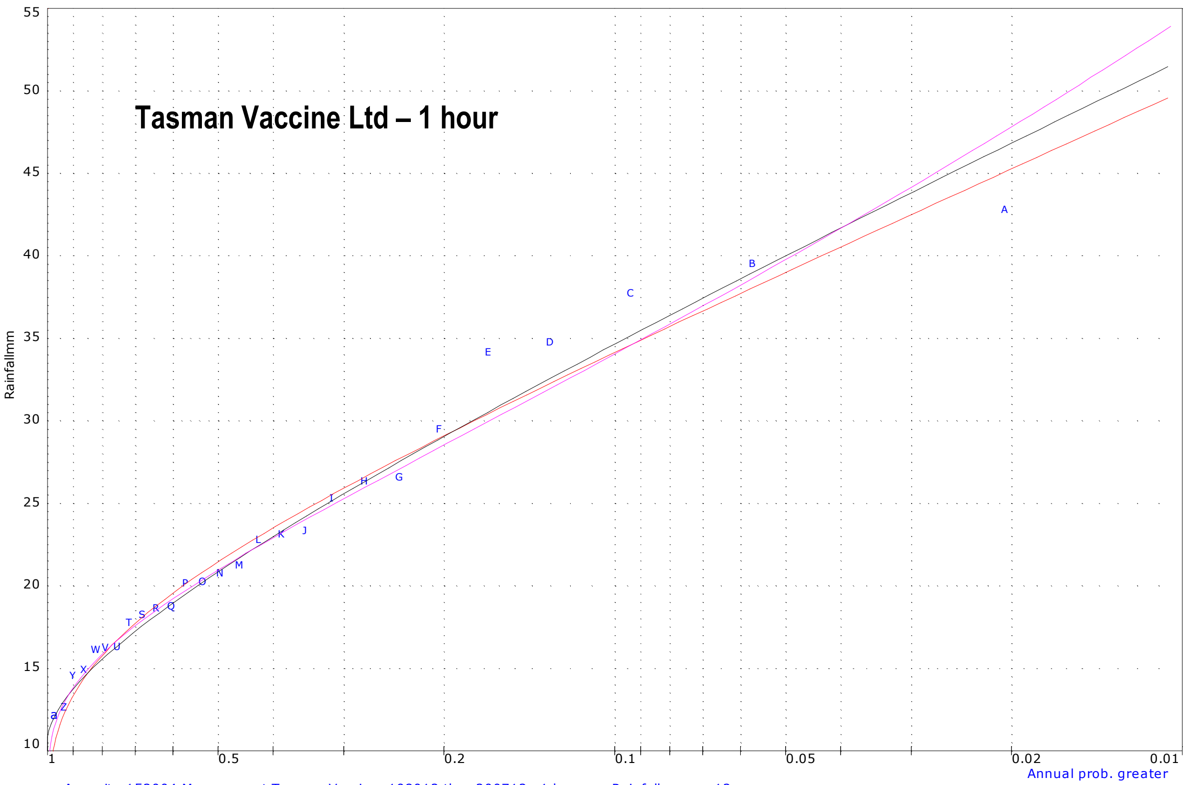
GEV Distn. Location, Scale & Shape= 13.69 5.209 -.2634E-01



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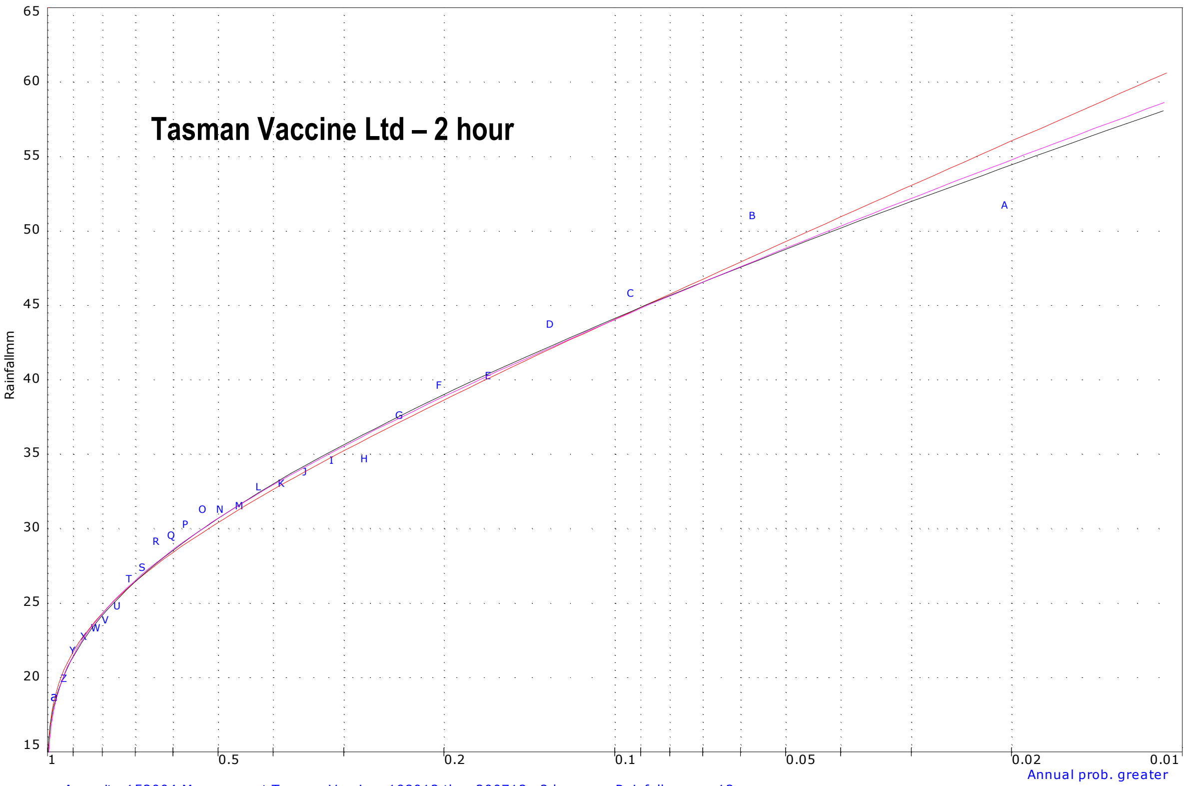

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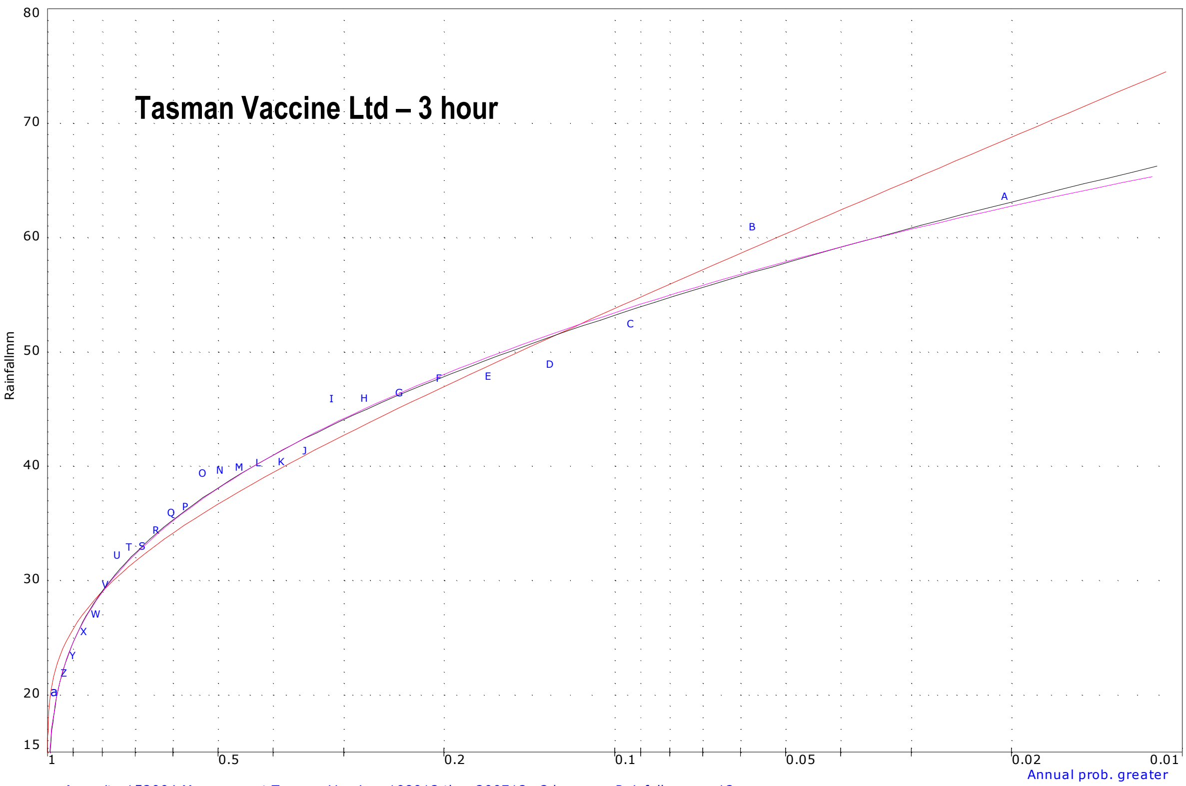

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site 152004 Mangaroa at Tasman Vaccine 198012 thru 200712 3 hrs max. Rainfallmm m=12
PE3 Distn. Location, Scale & Shape= 38.63 11.17 0.2662
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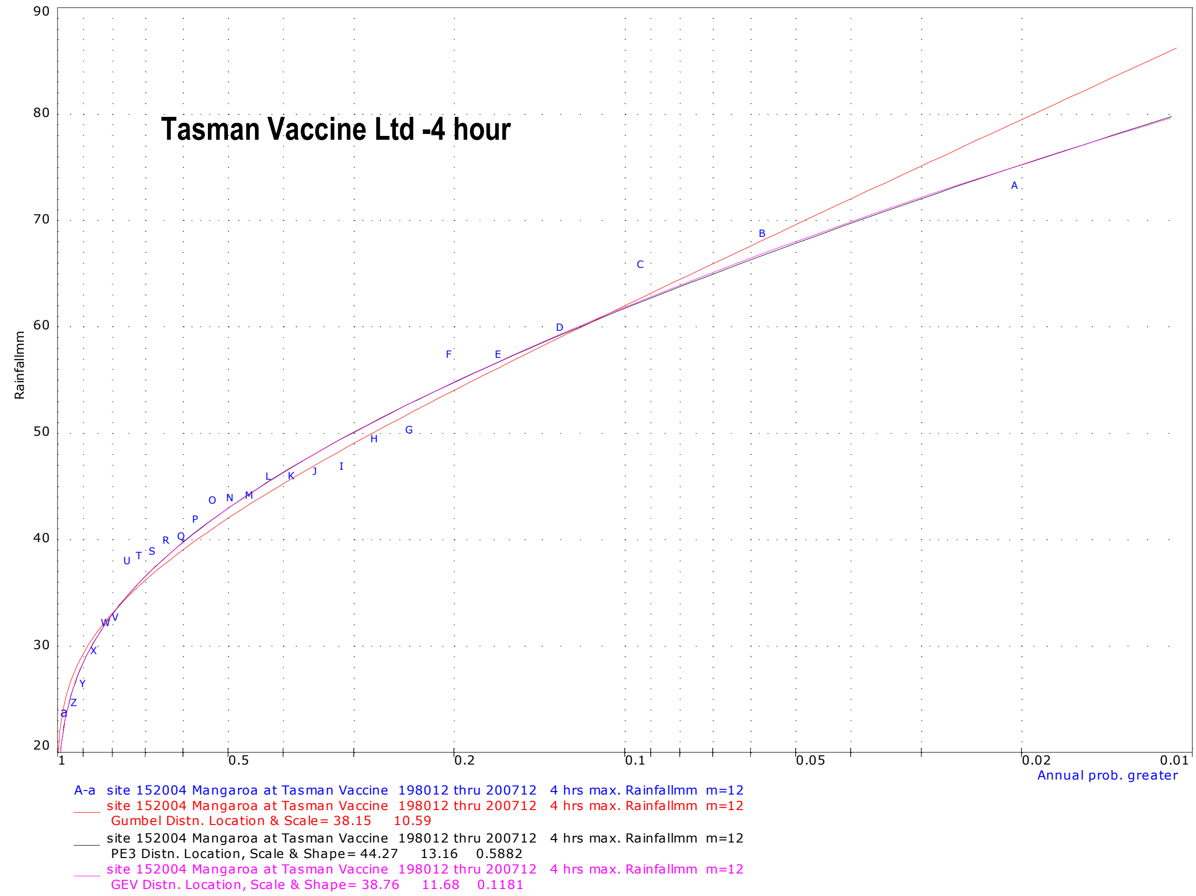
Tasman Vaccine Ltd -4 hour
Rainfallmm
Annual prob. greater
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PE3 Distn. Location, Scale & Shape= 44.27 13.16 0.5882
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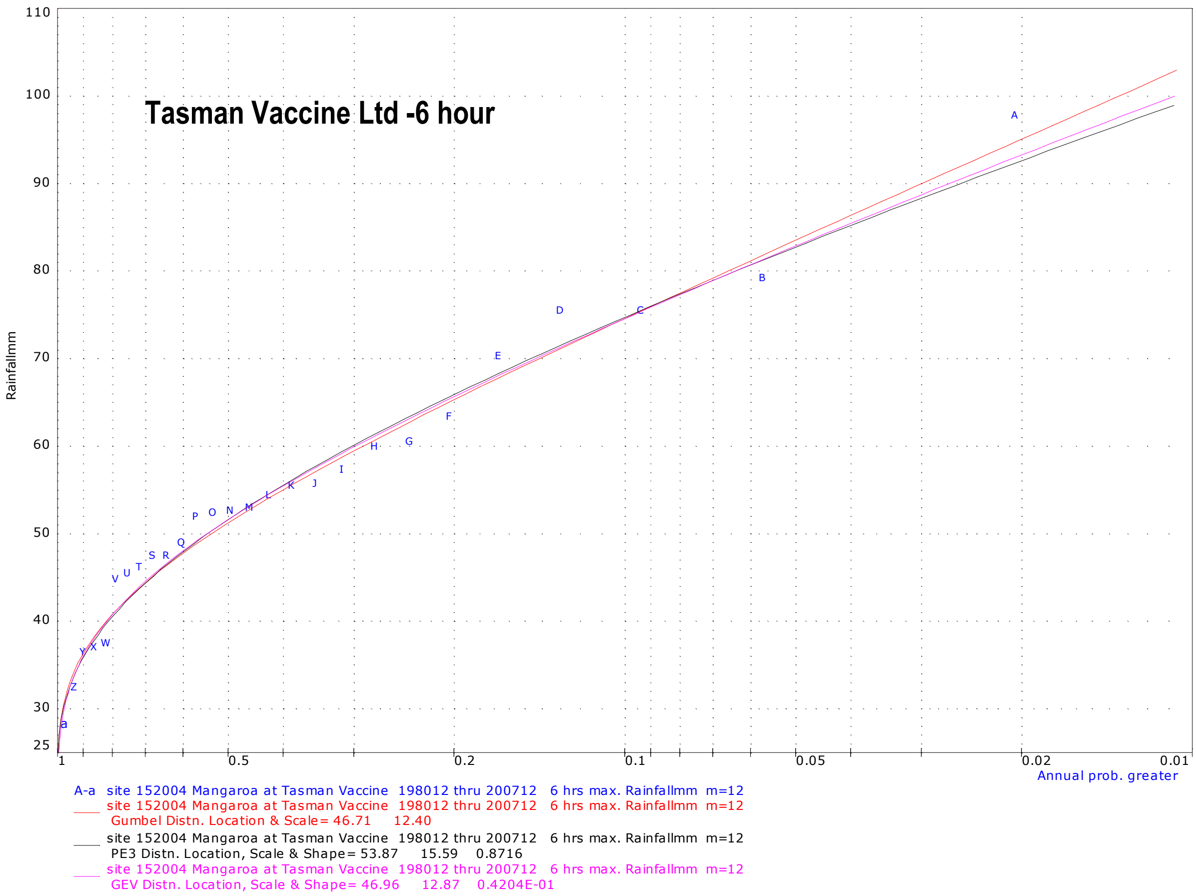
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Rainfallmm
Annual prob. greater
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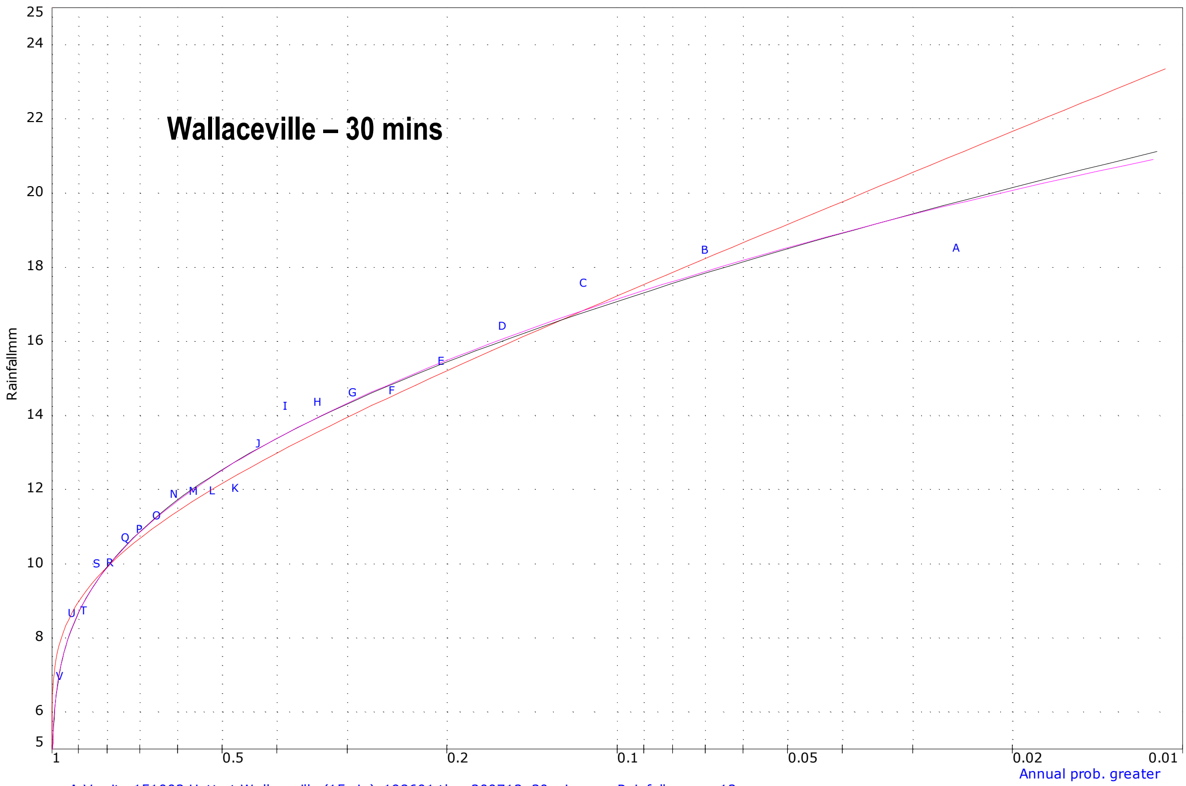

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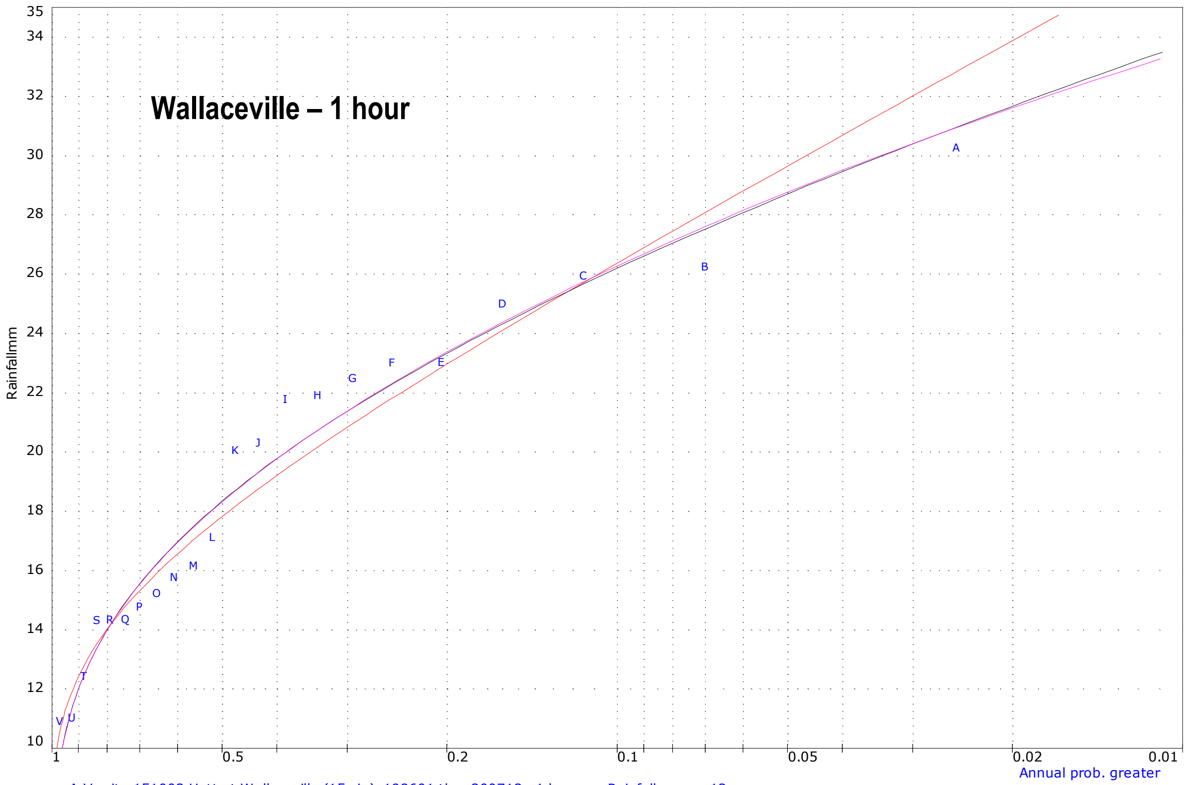

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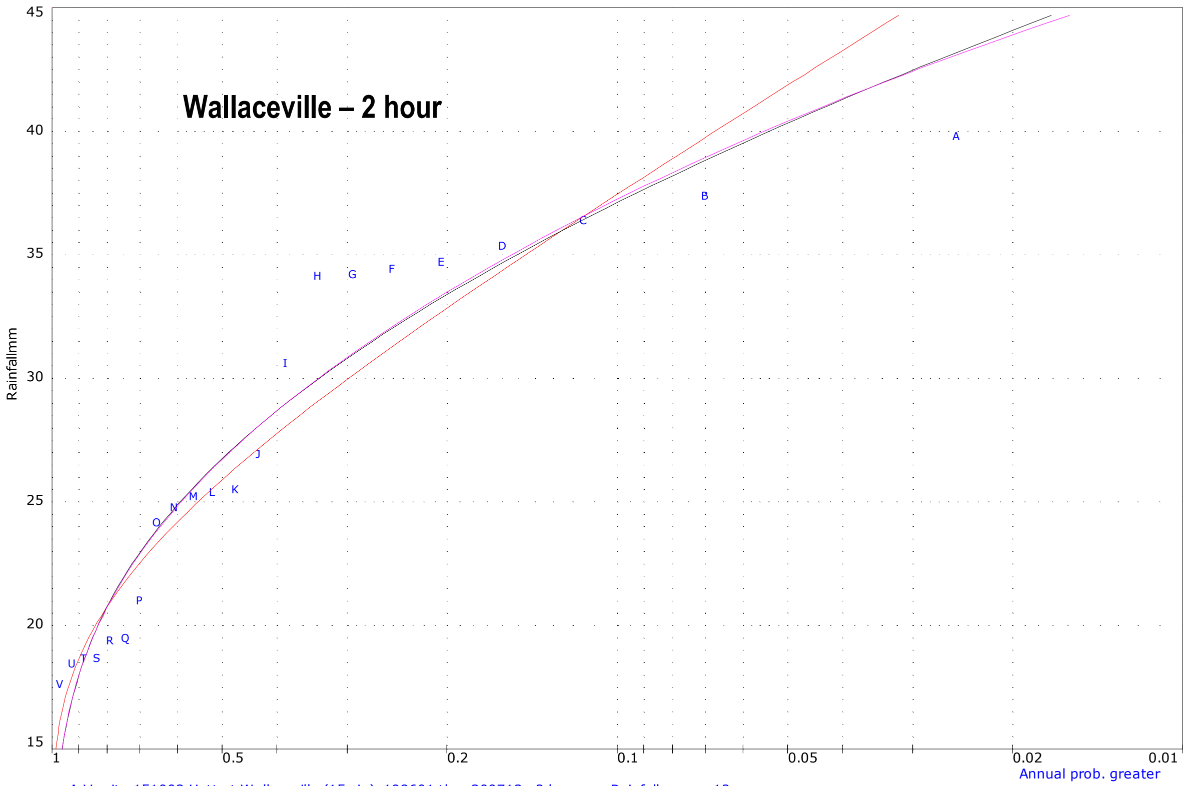

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PE3 Distn. Location, Scale & Shape= 27.19 7.562 0.3460
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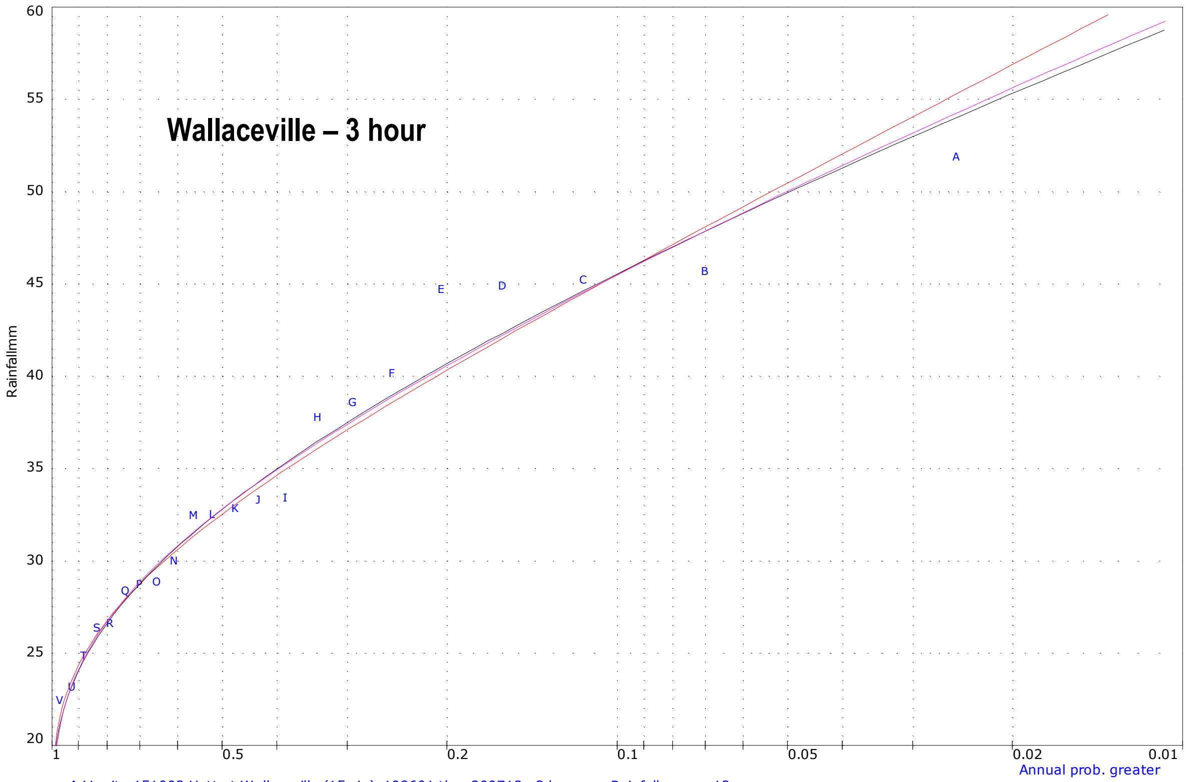

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Gumbel Distn. Location & Scale= 30.00 6.891
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PE3 Distn. Location, Scale & Shape= 33.98 8.650 0.8311
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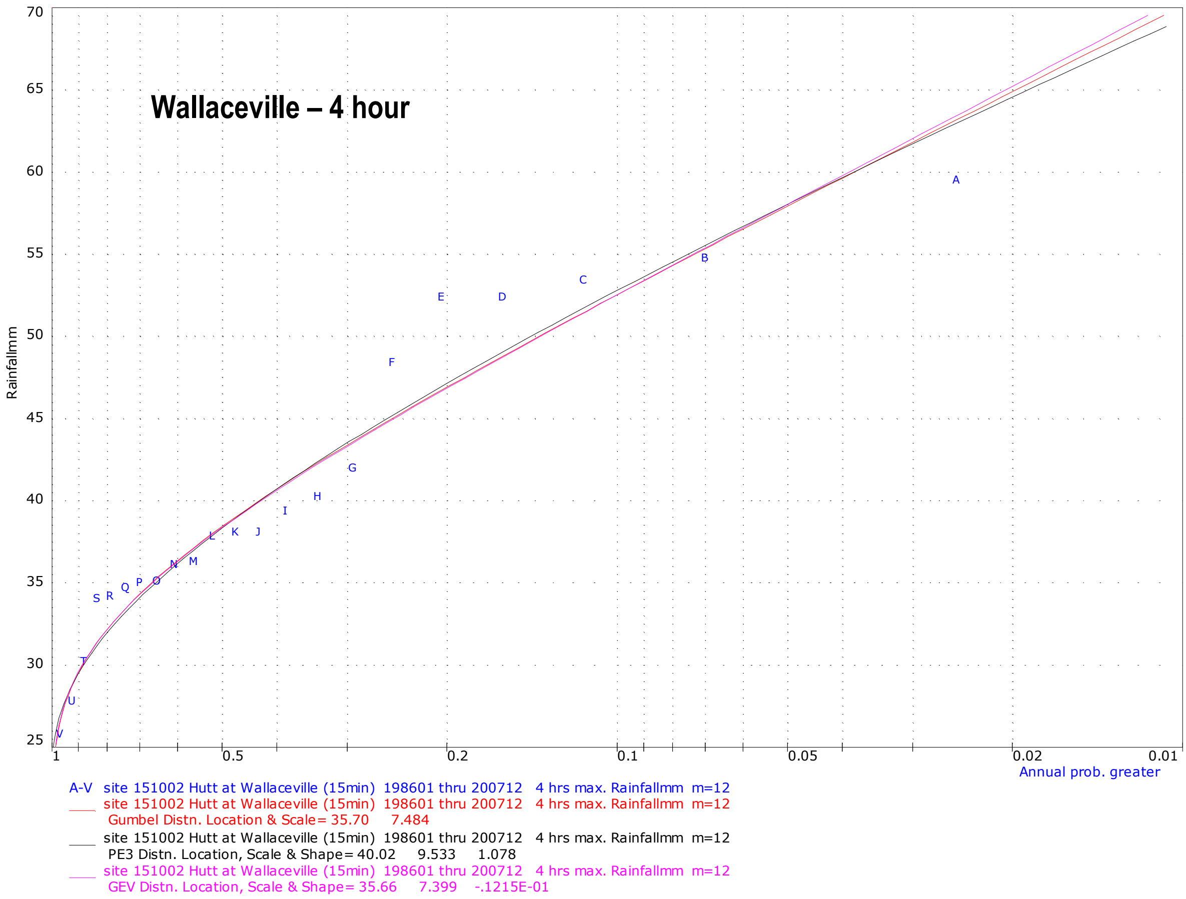

Wallaceville – 4 hour
Rainfallmm
Annual prob. greater
70
65
60
55
50
45
40
35
30
25
1
0.5
0.2
0.1
0.05
0.02
0.01
A-V site 151002 Hutt at Wallaceville (15min) 198601 thru 200712 4 hrs max. Rainfallmm m=12
site 151002 Hutt at Wallaceville (15min) 198601 thru 200712 4 hrs max. Rainfallmm m=12
Gumbel Distn. Location & Scale= 35.70 7.484
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PE3 Distn. Location, Scale & Shape= 40.02 9.533 1.078
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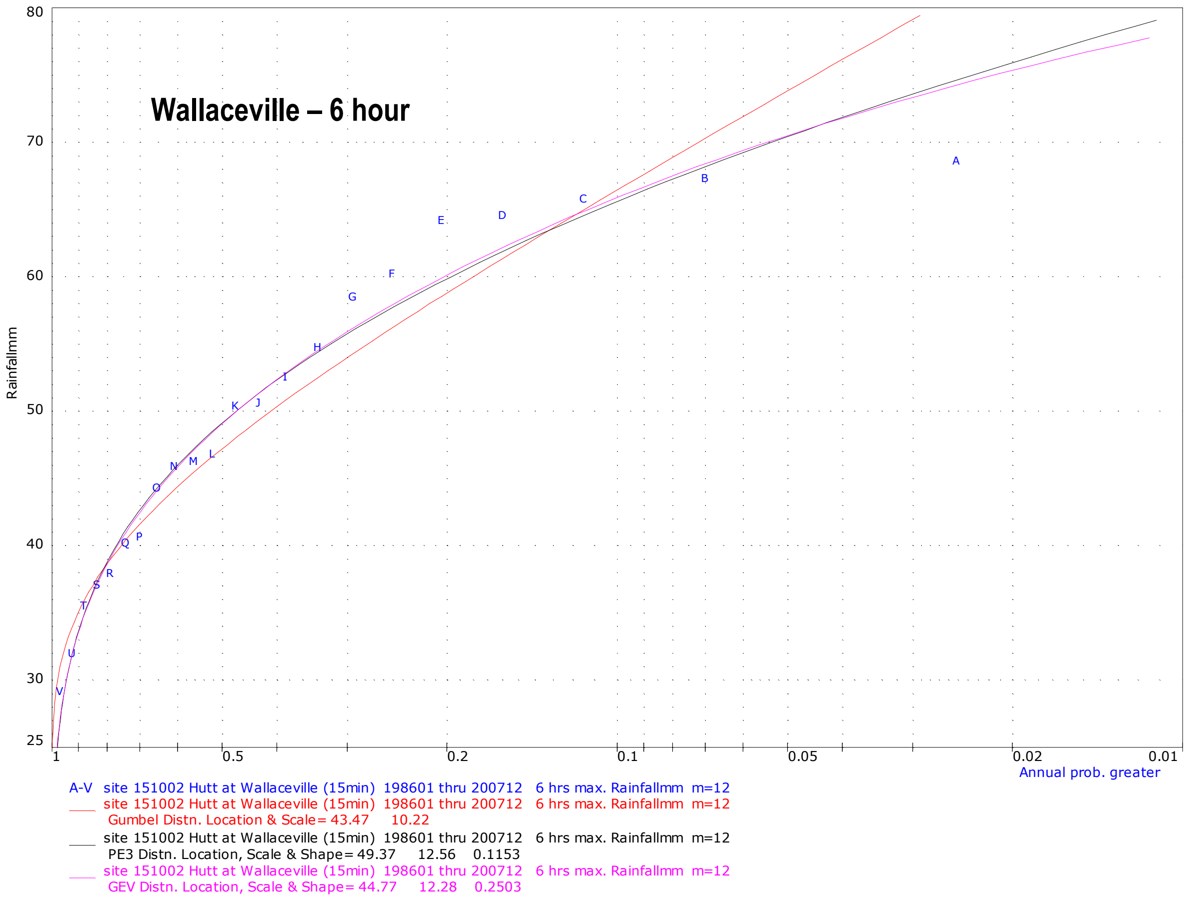

Wallaceville – 6 hour
Rainfallmm
Annual prob. greater
80
70
60
50
40
30
25
1
0.5
0.2
0.1
0.05
0.02
0.01
A-V site 151002 Hutt at Wallaceville (15min) 198601 thru 200712 6 hrs max. Rainfallmm m=12
site 151002 Hutt at Wallaceville (15min) 198601 thru 200712 6 hrs max. Rainfallmm m=12
Gumbel Distn. Location & Scale= 43.47 10.22
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PE3 Distn. Location, Scale & Shape= 49.37 12.56 0.1153
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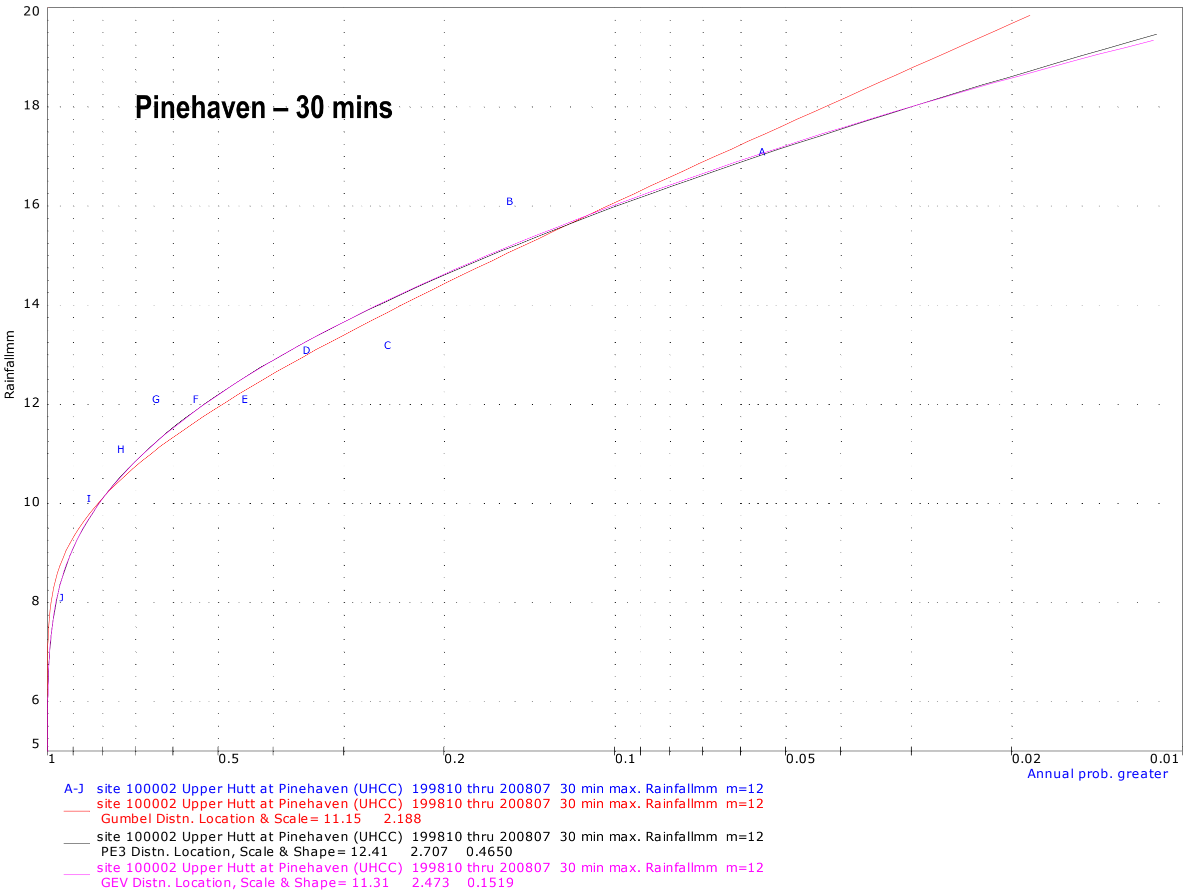

Pinehaven – 30 mins
Rainfallmm
Annual prob. greater
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Gumbel Distn. Location & Scale= 11.15 2.188
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PE3 Distn. Location, Scale & Shape= 12.41 2.707 0.4650
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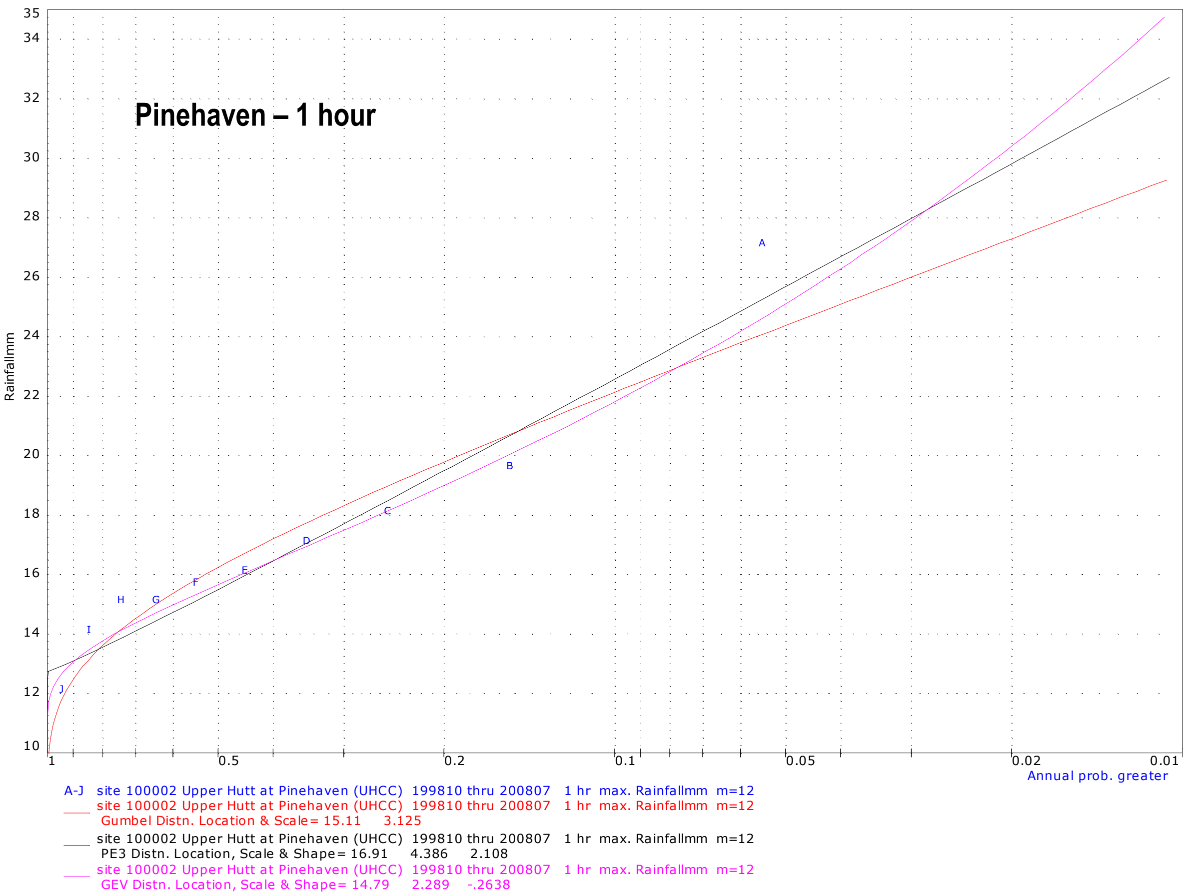

Pinehaven – 1 hour
Rainfallmm
Annual prob. greater
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Gumbel Distn. Location & Scale= 15.11 3.125
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PE3 Distn. Location, Scale & Shape= 16.91 4.386 2.108
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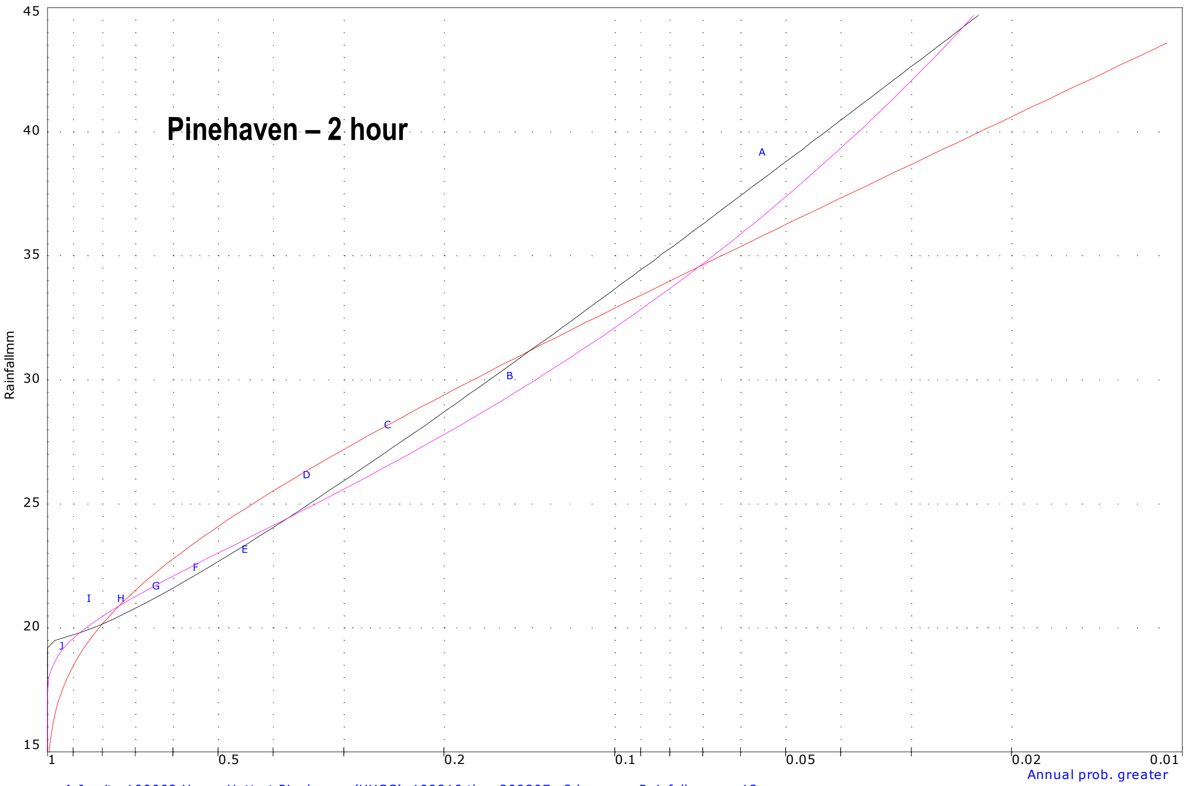

A-J site 100002 Upper Hutt at Pinehaven (UHCC) 199810 thru 200807 2 hrs max. Rainfallmm m=12
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Gumbel Distn. Location & Scale= 22.39 4.670
site 100002 Upper Hutt at Pinehaven (UHCC) 199810 thru 200807 2 hrs max. Rainfallmm m=12
PE3 Distn. Location, Scale & Shape= 25.08 6.815 2.423
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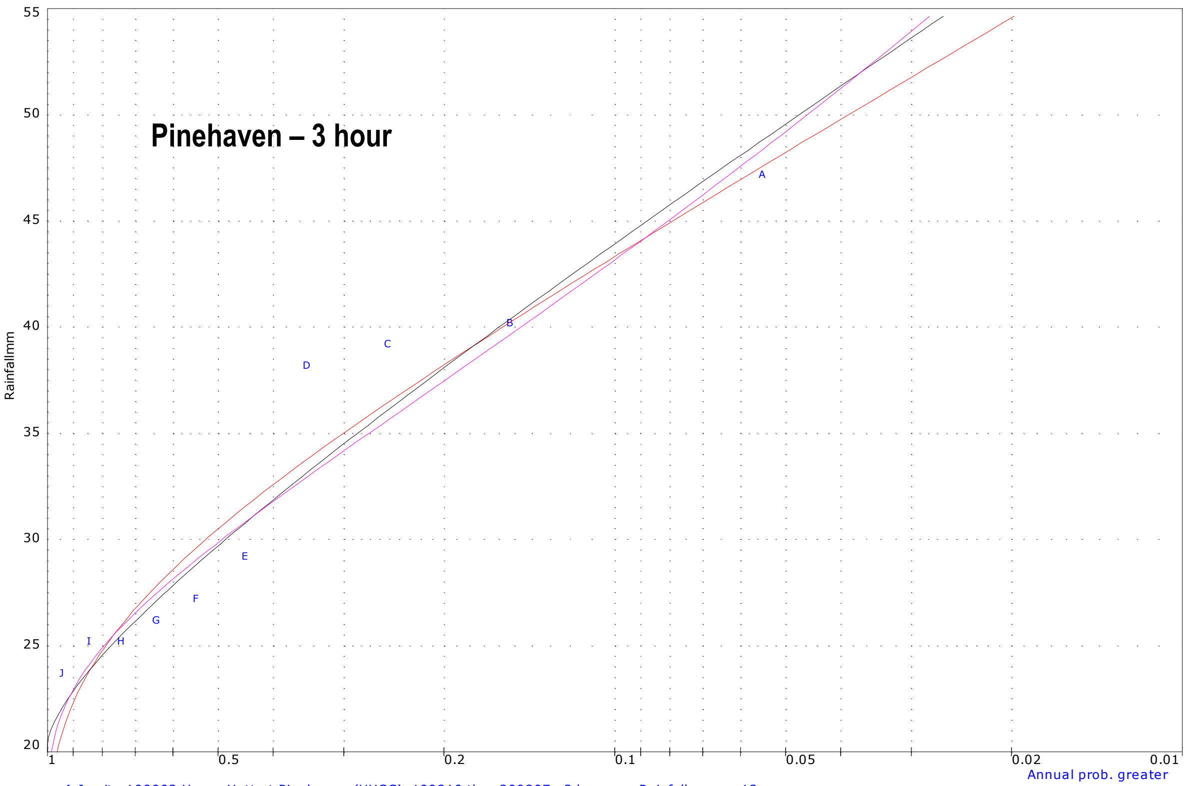
GEV Distn. Location, Scale & Shape= 21.83 3.072 -.3322



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Gumbel Distn. Location & Scale= 28.02 6.805
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PE3 Distn. Location, Scale & Shape= 31.95 9.004 1.552
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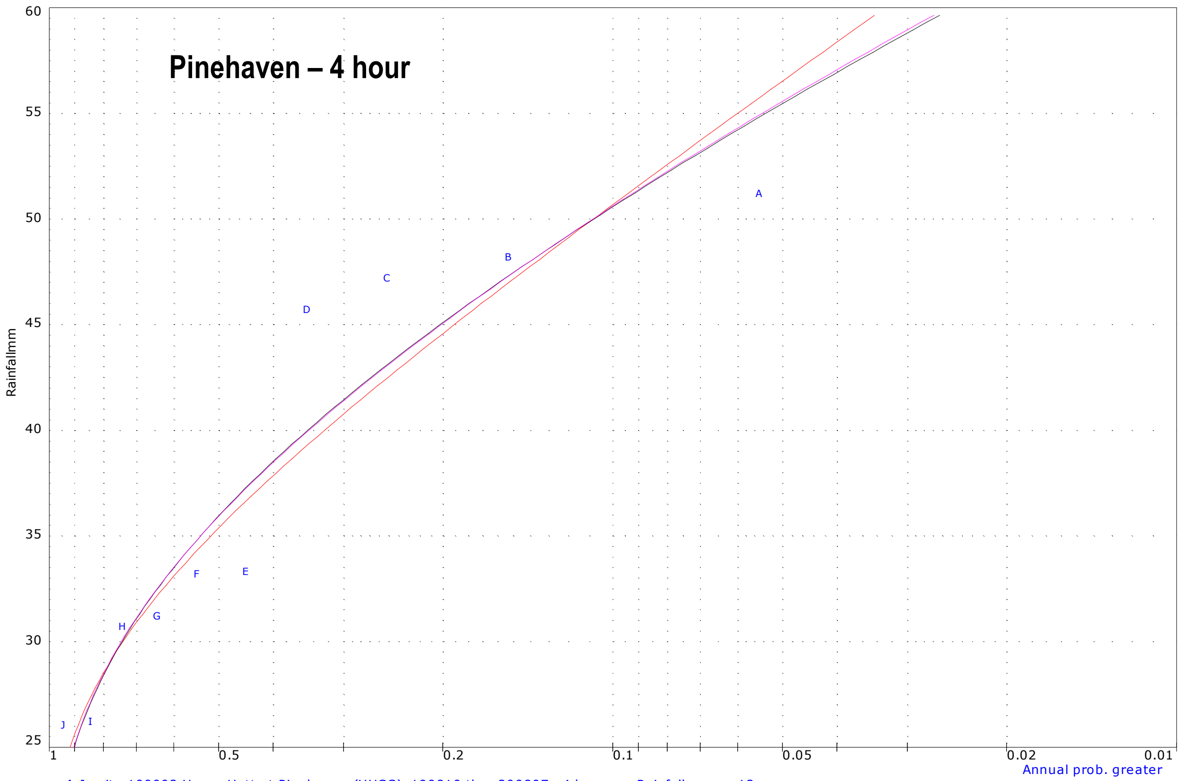

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Gumbel Distn. Location & Scale= 32.41 8.121
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PE3 Distn. Location, Scale & Shape= 37.09 10.12 0.6794
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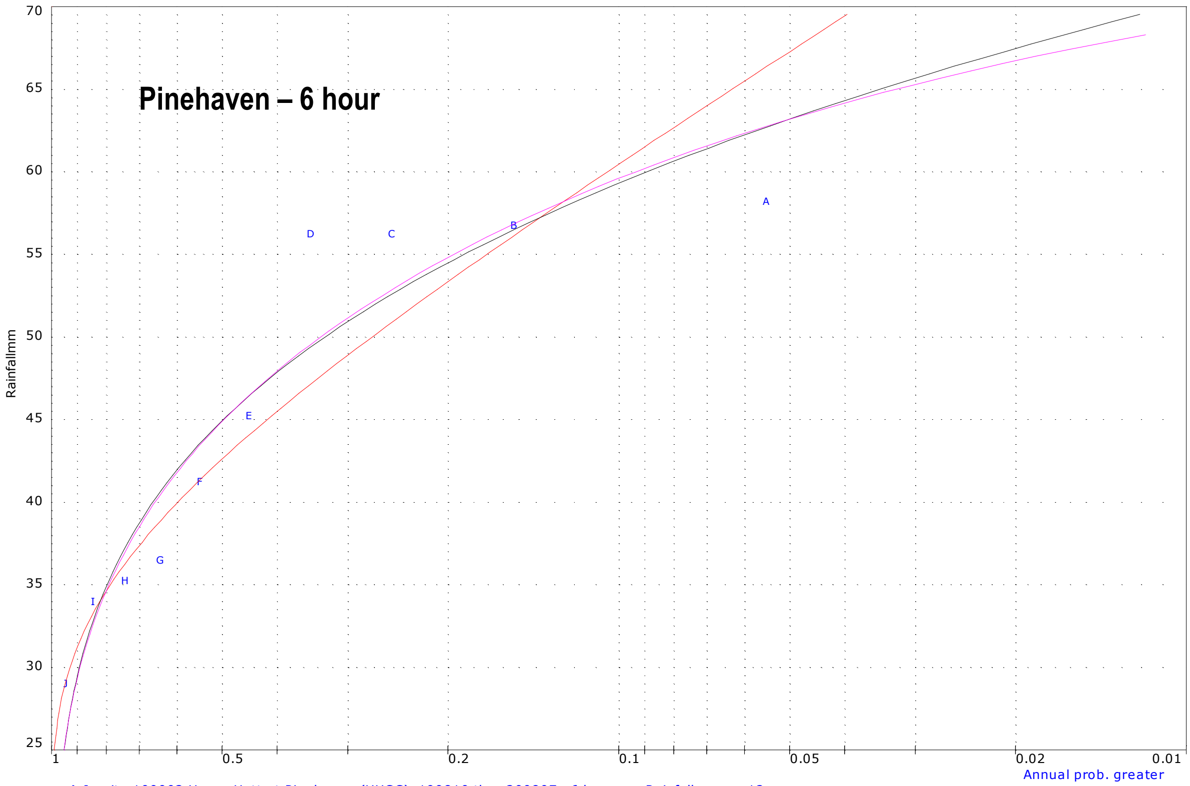

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PE3 Distn. Location, Scale & Shape= 44.62 11.65 -.1678
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GEV Distn. Location, Scale & Shape= 40.81 11.88 0.3335

Appendix B Revision of Rainfall-Runoff Model and Design Flood Estimates, 25 November 2009

Since the publication of the Pinehaven Stream Flood Hydrology report in November 2008, the rainfall-runoff hydrological model has been updated and subsequently the design peak flows presented have changed.

Continuous flow data is now collected on the Pinehaven Stream and as a result the original rainfall-runoff model is able to be calibrated with greater confidence than previously. In addition, a hydraulic model of the catchment has been developed that presents an accurate picture of catchment runoff characteristics that can be used in the calibration process.

A high flow event in the Pinehaven Stream on 23 July 2009 is the largest event available to date to use for calibration. Rainfall totals for this event indicate it may have reached a 10-year ARI magnitude within the catchment.

The following sections replace the corresponding sections in the 2008 report.

6 Rainfall-Runoff Modelling

A rainfall-runoff model was developed for the Pinehaven catchment to produce design hydrographs for specified return period (ARI) events from the design rainfall inputs. The model is an Initial Loss - Continuing Loss type and has been built using Hydstra Modelling software. Hydstra Modelling has been used in many hydrological applications in New Zealand and around the world for rainfall-runoff and design flood modelling. It has been used for a number of GWRC flood modelling and flood design investigations.

6.1 Model Configuration

The Pinehaven catchment was divided into 15 sub-catchments (A to O) for the rainfall-runoff modelling (Figure 6-1). The catchment area to Chatsworth Rd is 4.4 km^2.

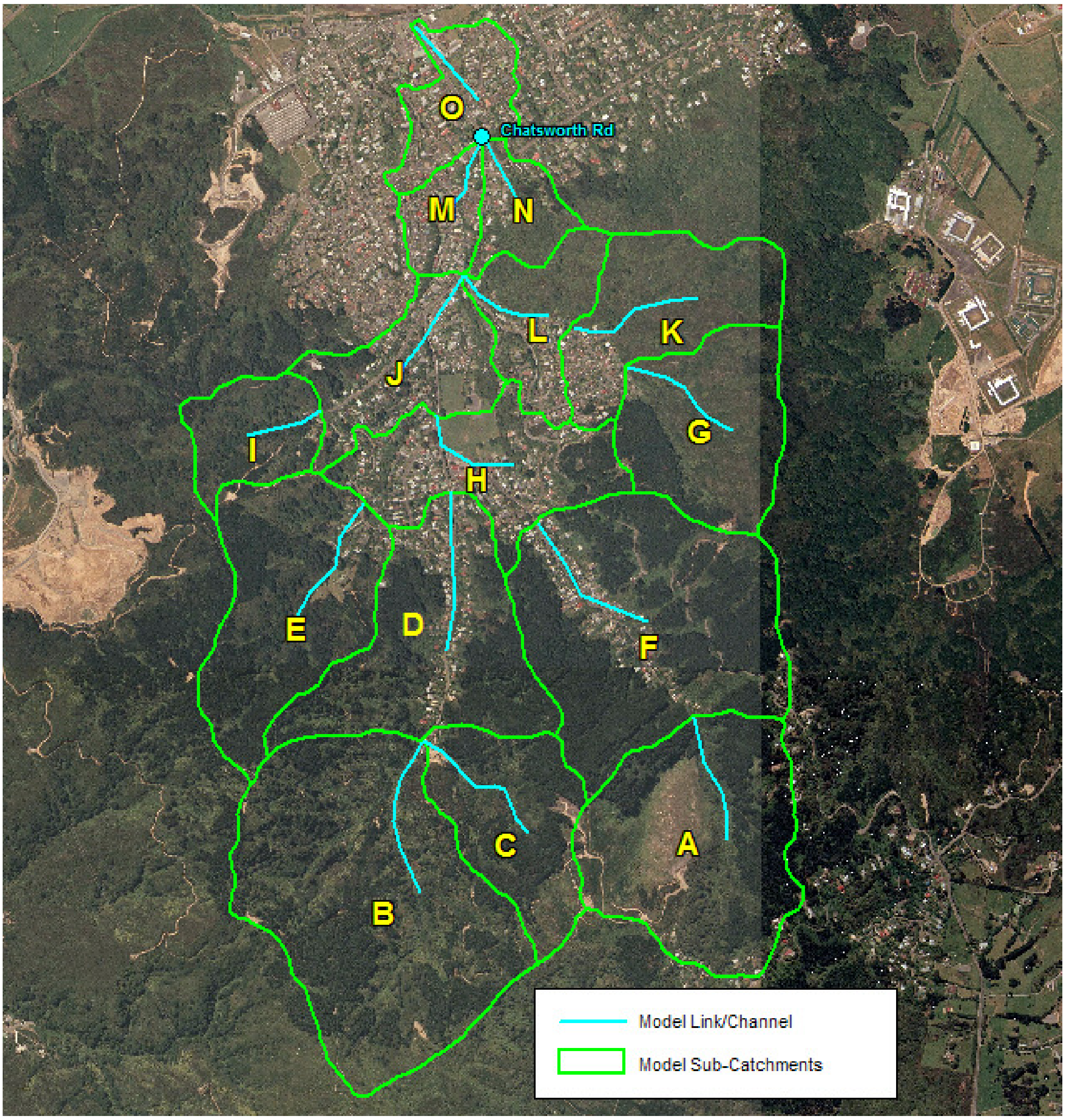

Figure 6-1: Pinehaven Rainfall-Runoff Model Delineation

Sub-catchment delineation and channel lengths were derived from GIS based contour and aerial photograph information, as well as maps presented in the Upper Hutt City Council District Plan (2004).

Figure 6-2 shows a schematic of the rainfall-runoff model. Modelled flow hydrographs are output at Chatsworth Rd. For the subsequent hydraulic modelling process flow hydrographs are output from each sub-catchment.

The model is setup to run with 15 minute intervals.

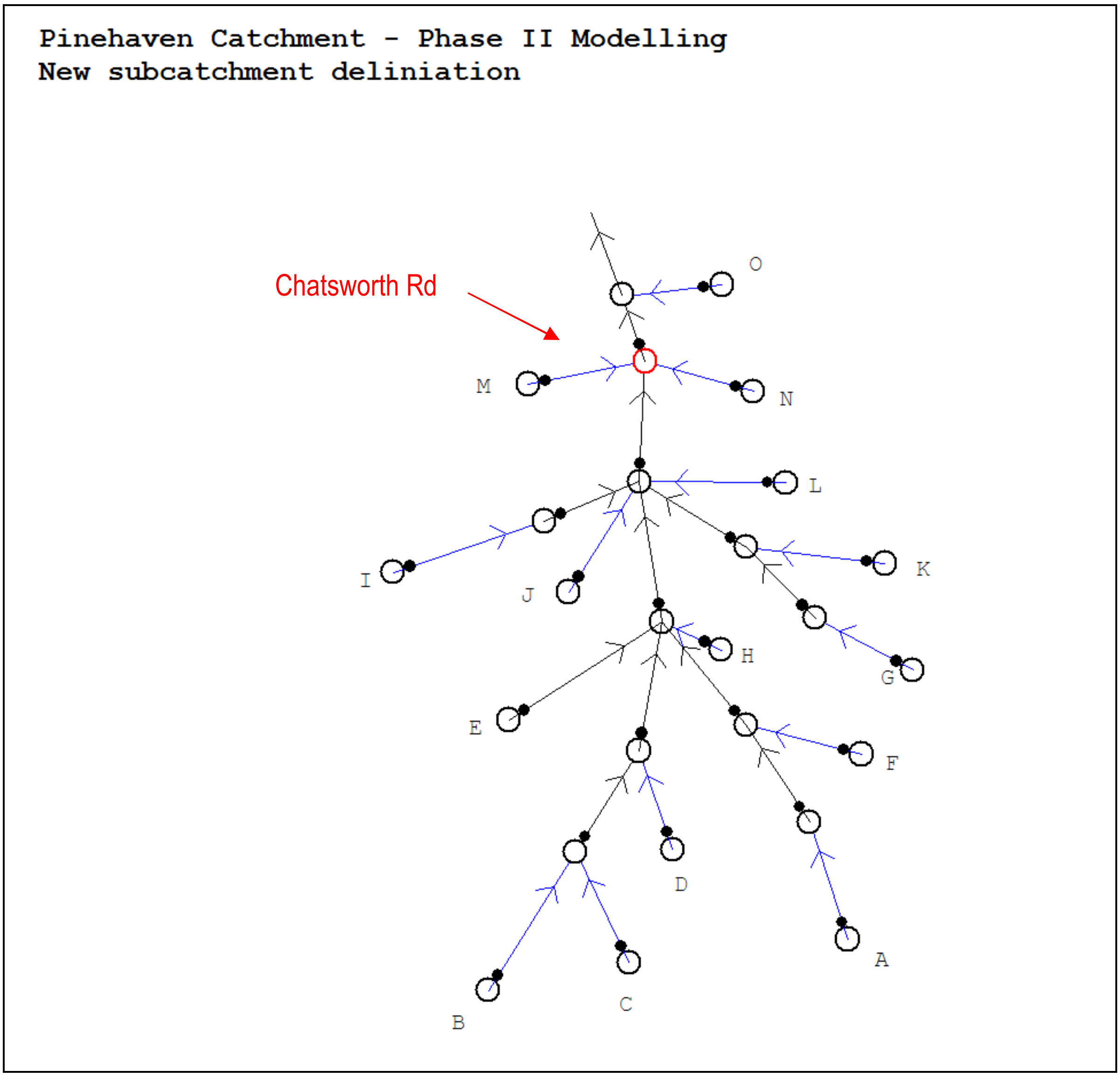

Figure 6-2: Pinehaven Model Schematic

6.2 Model Calibration

At the time of producing this report there was less than one year of recorded flood flow data for the Pinehaven catchment. GWRC installed a flow recorder on the Pinehaven Stream at Chatsworth Rd in August 2008. In this short period of time there has been only one flood event worthy of use for calibration purposes. This event occurred on 23 July 2009.

6.2.1 23 July 2009 Event

Recorded flow data for this flood event have been supplied by GWRC. The peak flow is extimated to be 8.8 m^3/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 m^3/s estimate may be revised in the future when new information is available.

6.2.2 Calibrating Rainfall-Runoff Model to Flood Estimate

The rainfall-runoff model was calibrated against the 23 July 2009 event recorded data as well as output from a hydraulic model of the catchment provided by SKM. Recorded rainfall data from the Tasman Vaccine Ltd and Wallaceville raingauges are used as model inputs.

Table 6-1 details the parameters used in the rainfall-runoff model. The initial loss (IL), continuing loss (CL), α and n parameters are adjusted during the calibration process. These values are "global" and are therefore assumed constant over the catchment.

Table 6-1: Calibration Parameters for Rainfall-Runoff Model

Parameter	Description
Initial Loss (IL) - mm	Amount of water lost before rainfall becomes effective runoff
Continuing Loss (CL) - mm/hr	Continuing loss rate applied to rainfall after IL is satisfied
α	Channel lag parameter for channel routing
n	Non-linearity parameter for channel routing
Area - km^2	Sub-catchment area
L - km	Channel length

The calibration process consisted of using the recorded rainfall data as the input and varying the IL, CL, α and n parameters to match the modelled hydrograph to the calibration data.

Table 6-2 details the final model parameters adopted.

Table 6-2: Pinehaven Stream Model Calibration Results

Parameter	Best Fit Value
Initial Loss (IL)	5 mm
Continuing Loss (CL)	2 mm
α	2
n	1.7

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.

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.

6.3 Design Flood Hydrographs

The design rainfall events for the 2 to 100-year ARI and PMP were input to the rainfall-runoff model to produce design flood hydrographs throughout the catchment.

Figure 6-4 shows the 100-year ARI design hydrographs for Pinehaven Reserve and Chatsworth Rd. The one and two-hour events for each are given.

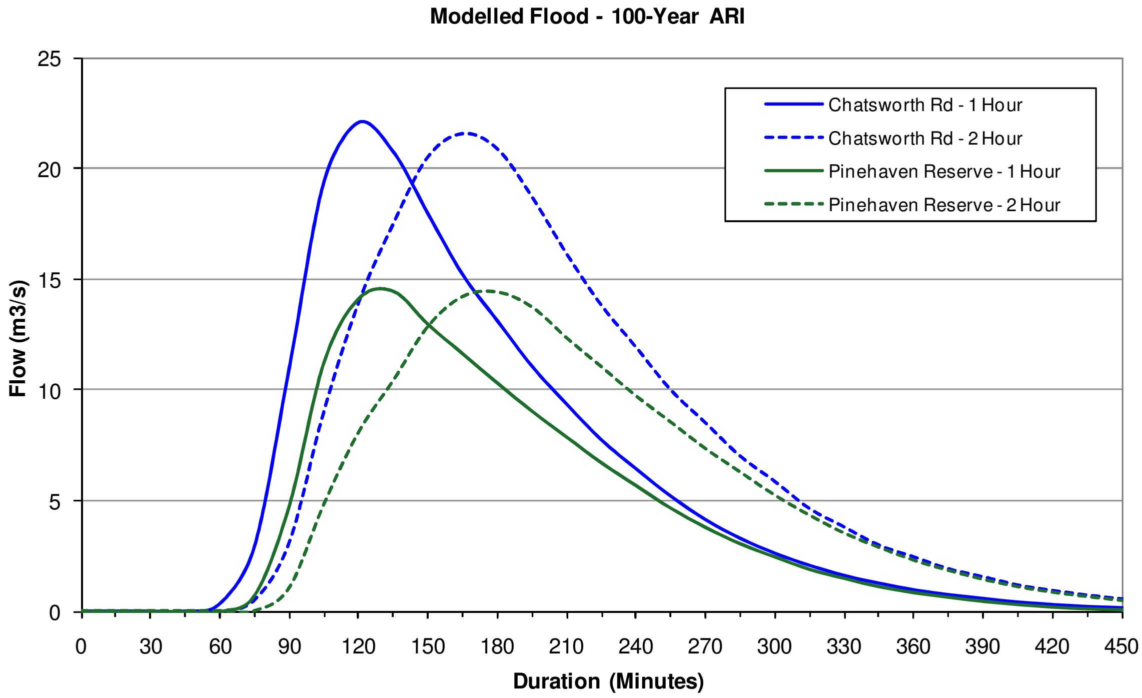

Figure 6-3: Design 100-year ARI Hydrographs

The critical duration 100-year ARI flood event for both locations is a one hour storm. Table 6-3 details the results for all durations and ARI magnitudes for the Pinehaven Stream at Chatsworth Rd. The critical duration event for each ARI is highlighted.

The 100-year ARI modelled design peak flow for the Pinehaven Stream at Chatsworth Rd is 22 m^3/s.

Table 6-3: Modelled Design Peak Flows for Pinehaven Stream at Chatsworth Rd (m^3/s)

ARI (Years)	Duration (Hours)				
	1	2	3	4	6
5	14.4	14.7	14.3	13.8	12.4
10	16.2	16.4	16.1	15.6	14.3
20	18.2	18.0	17.8	17.5	16.0
50	20.3	20.0	20.0	19.5	18.0
100	22.0	21.6	21.6	21.2	19.5
PMF	56	69	76	81	86

6.4 Rainfall-Runoff Model Limitations

The major limitation of the rainfall-runoff modelling process for the Pinehaven Stream is the lack of calibration data. Although one calibration event was available, there are uncertainties around the accuracy of the recorded data as the high flow rating is unconfirmed. The use of the model to simulate extreme flood events therefore carries some uncertainty. This uncertainty is reduced by comparing modelled output with peak estimates from other methods as summarised in Section 7.

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.

Another form of calibration was able to be used here by comparing results to those of a hydraulic model of the catchment.

It is recommended that GWRC make use of data from the flow recorder on the Pinehaven Stream and check/re-calibrate the rainfall-runoff model after a number of years when more flood events have been recorded and there is confidence in the accuracy of measurement.

7 Summary of Flood Estimates

A summary of the derived flood estimates for the Pinehaven Stream is detailed in Table 7-1.

Table 7-1: Pinehaven Stream at Chatsworth Rd Flood Estimates (m^3/s)

ARI (Years)	Regional Methods			Rational Method	Rainfall-Runoff Model
	McKerchar and Pearson (1989)	Pearson (1990)	Pearson (1991)		
5	13	13	14	15	15
10	16	15	18	18	16
20	19	17	22	21	18
50	22	20	28	23	20
100	25	22	32	24	22
PMF	-	-	-	108	86

McKerchar and Pearson (1989) and Pearson (1991) are nationwide regional methods and are applicable to areas greater than 10 km^2 and less than 10 km^2 respectively. The Pinehaven catchment is 4.4 km^2 to the Chatsworth Rd site.

Pearson (1990) uses regional data specifically from the Hutt River catchment and surrounding area.

The rainfall-runoff model results are similar to Pearson (1990) which is based on local flood data. The rainfall-runoff results are also similar to those derived using the rational method.

8 Recommended Design Flood Estimates

Based on the results obtained in this investigation it is recommended that the rainfall-runoff model results and hydrographs be adopted for design flood purposes.

Table 8-1 presents the recommended design flood estimates for the Pinehaven Stream at Chatsworth Rd.

Table 8-1: Pinehaven Stream Design Flood Estimates

ARI (Years)	Flow (m^3/s)
5	15
10	16
20	18
50	20
100	22
PMF	86