Impact of Land Use Change on Floods in the Upper Waikato

ADDENDUM: IMPACT ON FLOODS IN THE POKAIWHENUA RIVER AT SH1

- FINAL REPORT
- 19 January 2010

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Contents

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1. Introduction

Environment Waikato (EW) is concerned about the impact that converting large areas, currently under forest, to grazed pasture will have on floods in the Waikato Catchment and commissioned two independent parallel modelling studies to assess the potential impact. The first model developed by NIWA (2009), followed a continuous simulation approach using the Topnet model with gridded input data. The second model, developed jointly by Sinclair Knight Merz (SKM) and EW (2009), used the HEC-HMS framework and followed a sub-basin approach to simulate floods.

Analyses focused on the change in runoff at a major catchment scale within the Upper Waikato between Lake Taupo and Lake Karapiro. The overall result from both models showed that the impact on the down-gradient receptor, that is the Lower Waikato River, would be small. However, it was acknowledged that locally within parts of the Upper Waikato catchment where a high proportion of particular catchments are planned for conversion, the impact could be significant.

This report provides some insight on the potential impact on local streams, by using the HEC-HMS model to assess the impact that potential land use change would have on floods in the Pokaiwhenua River at the SH1 crossing. This 105 km^2 catchment was selected for analysis because it represents the catchment with the largest proportion of proposed land use change.

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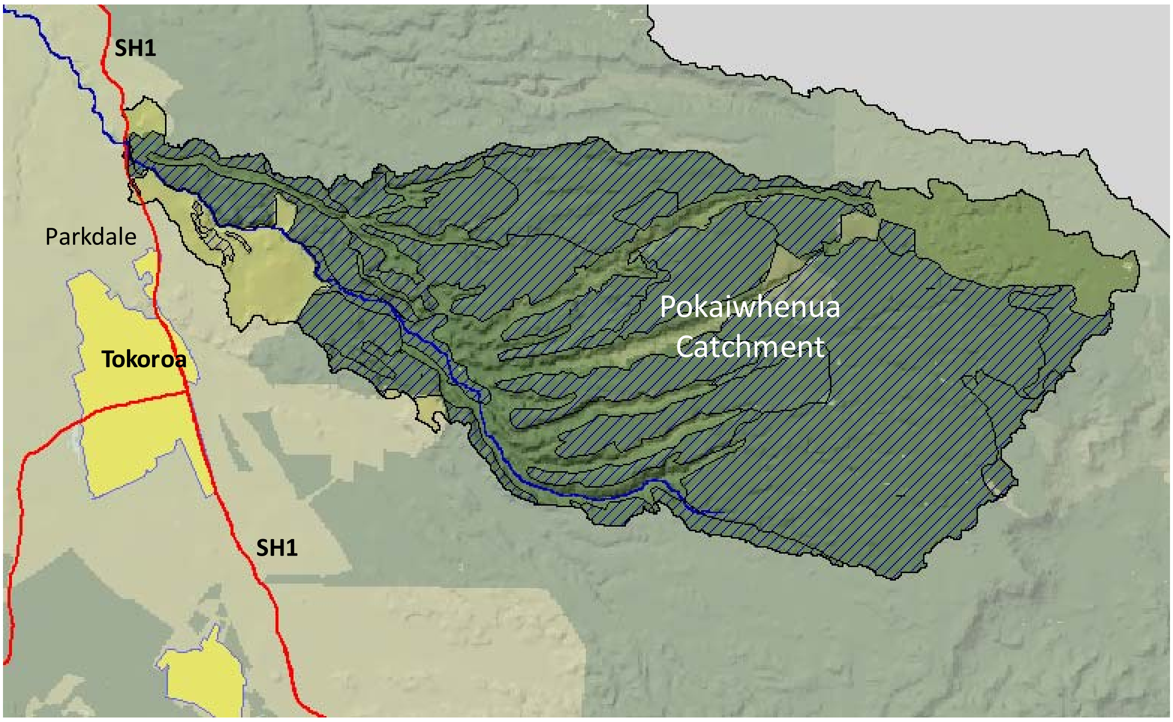
2. Pokaiwhenua at SH1 Model

2.1. Catchment Details and Model Parameters

The Pokaiwhenua Catchment is part of the Karapiro-Right Basin, comprising an area of 105.3 km^2. The river flows from east to west under the SH1 approximately 2.5 km north of Parkdale before flowing into the Waikato River upstream of Lake Karapiro. The study catchment is shown in **Figure 1**.



- **Figure 1. Pokaiwhenua Catchment**

The catchment was simulated in HEC-HMS as five lumped sub-basins determined on the basis of land use (forest or pasture) and soil type. The sub-basin areas for the current and potential future land use scenarios are summarised in **Table 1**. The potential future land use was based on conversion to pasture of currently forested land with LUC rating of 6 or less.

Catchment characteristic parameters required as input to HEC-HMS are the time of concentration (Tc) and catchment storage coefficient (S). These were calculated using the USSCS formula for Tc and the relationship between S and Tc determined within SKM & EW (2009), where $S = 1.8\,Tc$). For the Pokaiwhenua Catchment Tc = 3.7 hours and S = 6.6 hours.

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Table 1. Summary of sub-basin areas.

Sub-basin	Current Area (km^2)	Potential Conversion to Pasture (km^2)	Future Area (km^2)
Forest Loam	9.12	0.00	9.12
Forest Podzol	3.00	-3.00	0.00
Forest Pumice	87.90	-81.80	6.10
Pasture Podzol	0.00	+3.00	3.00
Pasture Pumice	5.25	+81.80	87.05
Total	105.27		105.27

Model parameters for the sub-basins input to the HEC-HMS Soil Moisture Accounting module were obtained from Table 8 in SKM & EW (2009). These parameters are listed in **Table 2**.

Table 2. Model Parameters for Karapiro-Right Basin.

Parameter	Units	Forest			Pasture	
		LOAM	PODZOL	PUMICE	PODZOL	PUMICE
Infiltration capacity	mm/hr	100	9.3	100	3	15.8
Canopy storage	mm	2.5			2	
Soil zone thickness	mm	791	1066	854	1059	930
Tension zone thickness	mm	383	613	514	625	594
Soil percolation capacity	mm/hr	100	9.3	100	9.3	100
Ground Water 1 Storage	mm	60				
Ground Water 1 Percolation	mm/hr	10				
Ground Water 1 Coefficient	hour	200				
Ground Water 2 Storage	mm	1200				
Ground Water 2 Percolation	mm/hr	0.25				
Ground Water 2 Coefficient	hour	10000				

2.2. Storm Rainfall

Design storm rainfall depths for the 5-year and 100-year rainfall events were determined from the HIRDS database for the catchment centroid. The 5-year rainfall was determined by interpolation using an exponential function fitted through the HIRDS data. The rainfall depths for storm durations from 1 hour to 72 hours are summarised in **Table 3**.

HEC-HMS generates storm hyetograph from storm rainfall following a standard nested hyetograph approach that retains the peak rainfall intensity of the shortest storm duration. This distribution is not appropriate for the analysis as experience shows that longer duration storms tend to be more

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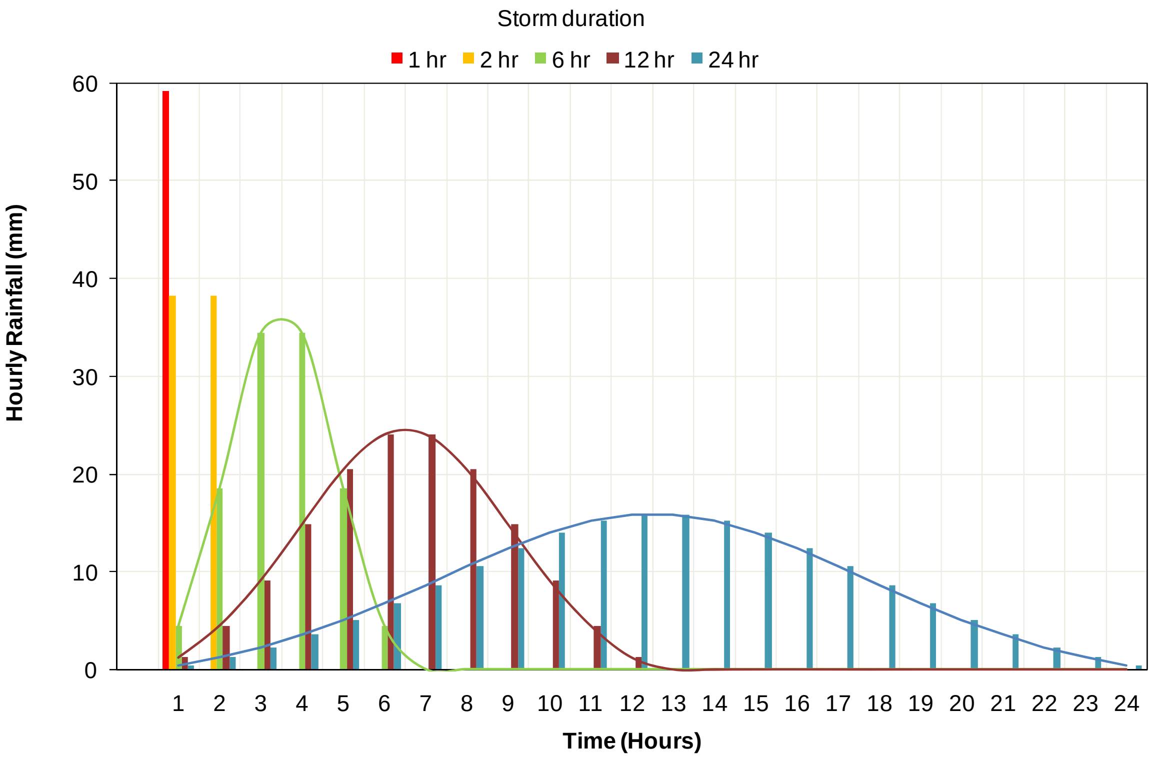
uniform in nature. Accordingly a distribution is required that distributes rainfall more evenly over the storm duration. The distribution of the design storm rainfall shown in **Figure 2** was determined using a relationship determined from analysis of storm rainfall data carried out for previous studies by SKM. This distribution is considered suitable for the analyses to assess the impact on floods of land use change in the Pokaiwhenua River at SH1.

- **Table 3. Storm Rainfall for the Pokaiwhenua Catchment (from HIRDS)**

Return Period (Years)	Storm duration (hours)						
	1	2	6	12	24	48	72
5	30.2	39.7	60.9	79.9	104.8	127.1	142.3
100	59.2	76.5	114.9	148.4	191.8	230.3	256.3



- **Figure 2. Distribution of Design Rainfall over Storm Duration**

2.3. Historic Rainfall time series

An historic rainfall time series for the study catchment was required for input to HEC-HMS to determine suitable anticedent soil moisture conditions for the flood analysis. This time series was generated by averaging the NIWA grid rainfall time series at hourly resolution for all grid points located in the study catchment (grid rainfall time series 199188, 200188 and 201188).

3. Flood Analysis

The HEC-HMS model was used to generate flood hydrographs in the Pokaiwhenua River where it passes under the SH1 for return periods of 5-years and 100-years and a range of storm durations between 1-hour and 72-hours. The simulations were carried out for both the current land use and projected future land use to assess the impact that conversion of forest to pasture is likely to have on the flood peaks and volumes.

3.1. Anticedent Conditions

Anticedent conditions in the catchment will impact on both the flood peak discharge and volume from a design storm over the catchment. Furthermore the impact of anticedent conditions on flood runoff will not be the same for forest and pasture catchments. Assuming very wet anticedent conditions resulting from exessive rainfall prior to the design storm would give extreme flood runoff that is also expected to mask the impact of land use change. Conversely, assuming very dry anticedent conditions would have the opposite affect on the results.

Initially it was intended to determine anticedent conditions by calculating average simulated values over a two year period. This approach does not preserve cross correlation in conditions between the various land use and soil types in the catchment. Accordingly initial conditions were set by simulation using a warm up period.

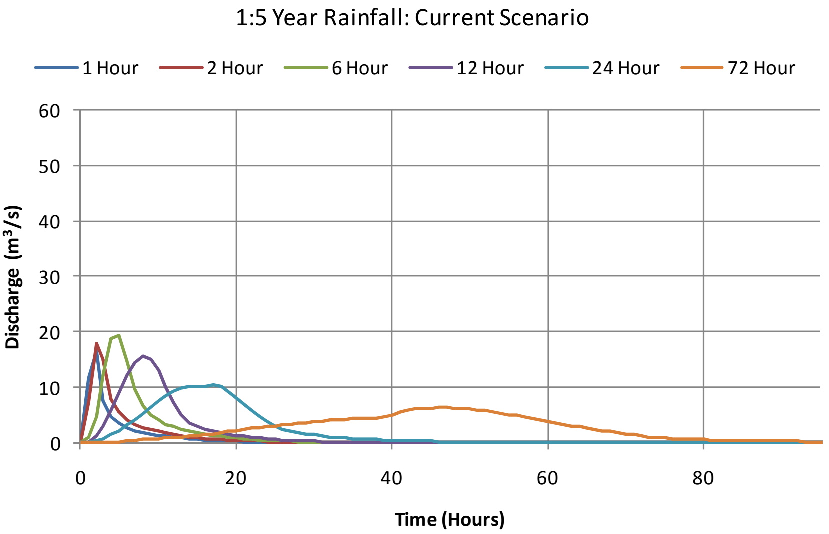
The observed rainfall time series from January 2003 until 11 April 2004 was selected as a warm-up period for the simulations. This was based on inspection of the catchment rainfall time series and simulated flow in the Pokaiwhenua River at SH1. Rainfall did occur on the days preceding 12 April 2004, but this rainfall had negligible effect on runoff from the catchment. The design rainfall was inserted in the observed rainfall time series starting at 01h00 on 12 April 2004.

3.2. Comparison of Flood Hydrographs and Volumes

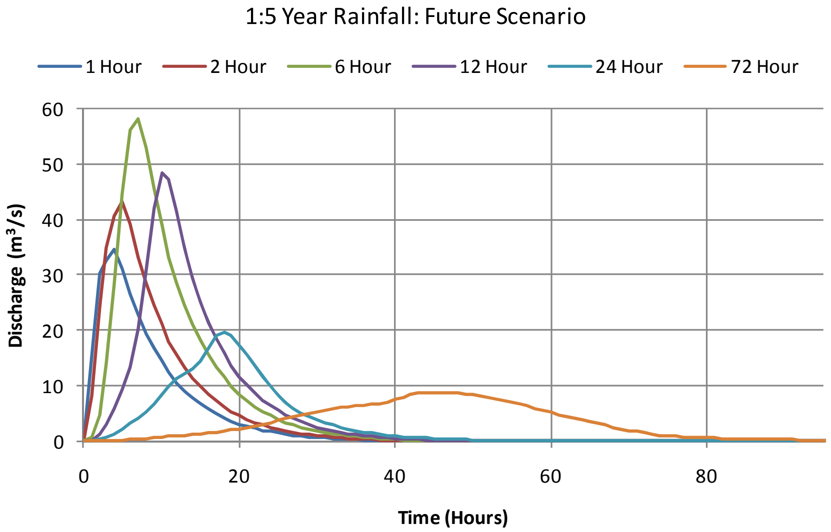
Flood hydrographs were generated for the 5-year and 100-year ARI storm event for storm durations of 1, 2, 6, 12, 24 and 72 hours for the current and future land use scenarios. The results for the 5-year event with current and future land use are presented in **Figure 3** and **Figure 4** respectively and for the 100-year event in **Figure 5** and **Figure 6**.

To facilitate comparison of the hydrographs for each return period the current and future scenarios are plotted to the same vertical scale. Base flow in the river for the current land use scenario was subtracted from the simulated hydrographs so that the hydrographs represent the additional flow at the SH1 bridge resulting from the event rainfall.

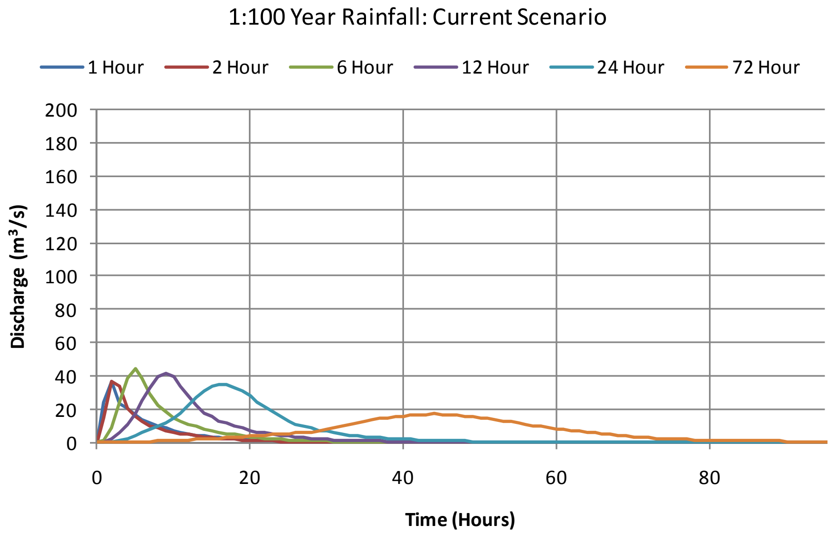
The flood peak discharge and 5-day flood volumes are summarised in **Table 4** and **Table 5** for the 5-year and 100-year return interval storms, respectively and the percentage increase in runoff after conversion is shown in **Figure 7**. Flood volumes were calculated as the additional flow at SH1 bridge due to the event rainfall and limited to the five day period starting at the same time as the event rainfall started.



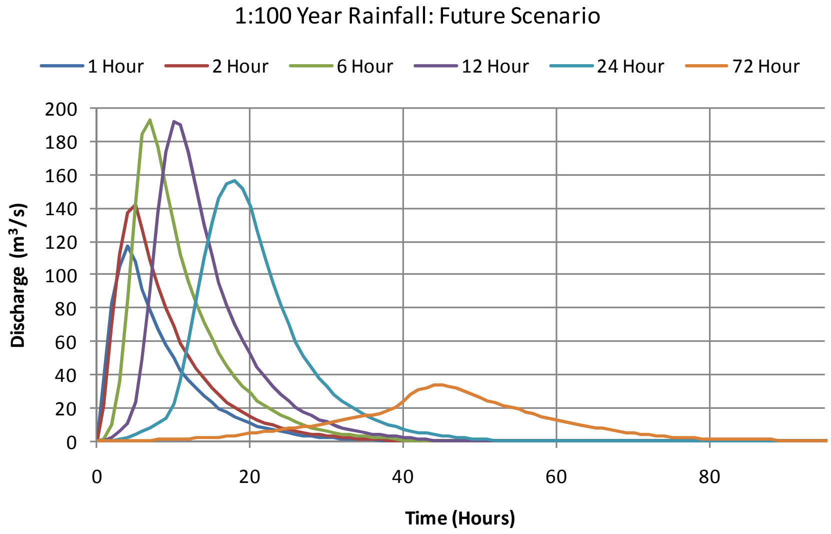
- **Figure 3. 5-year ARI Rainfall – Current Land Use Scenario.**



- **Figure 4. 5-year ARI Rainfall – Future Land Use Scenario.**



■ **Figure 5. 100-year ARI Rainfall – Current Land Use Scenario.**



■ **Figure 6. 100-year ARI Rainfall – Current Land Use Scenario.**

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Table 4. Hydrograph Peak Discharge and 5-Day Volumes (5-year ARI Storm)

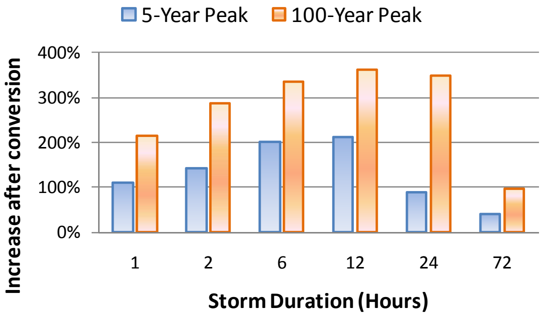
	Land use Scenario	Storm Duration (Hours)					
		1	2	6	12	24	72
Peak Discharge	Current (m^3/s)	16.4	17.9	19.2	15.5	10.5	6.3
	Future (m^3/s)	34.6	43.2	58.2	48.3	19.7	8.8
	Increase (%)	111%	142%	202%	212%	88%	40%
5-Day Flood Volume	Current (10^3m^3)	222	291	430	490	640[1]	894[1]
	Future (10^3m^3)	1187	1523	2077	1811[1]	1071[1]	1169[1]
	Increase (%)	433%	423%	383%	269%	67%	31%

1 Volume is not for the complete hydrograph

Table 5. Hydrograph Peak Discharge and 5-Day Volumes (100-year ARI Storm)

	Land use Scenario	Storm Duration (Hours)					
		1	2	6	12	24	72
Peak Discharge	Current (m^3/s)	37.1	36.6	44.3	41.5	34.9	17.2
	Future (m^3/s)	117.1	142.4	192.4	191.8	156.8	33.7
	Increase (%)	215%	289%	335%	362%	349%	97%
5-Day Flood Volume	Current (10^3m^3)	782	741	1236	1620	2032	2183
	Future (10^3m^3)	3928	4954	6845	7600[1]	7780[1]	3269[1]
	Increase (%)	403%	568%	454%	369%	283%	50%

1 Volume is not for the complete hydrograph



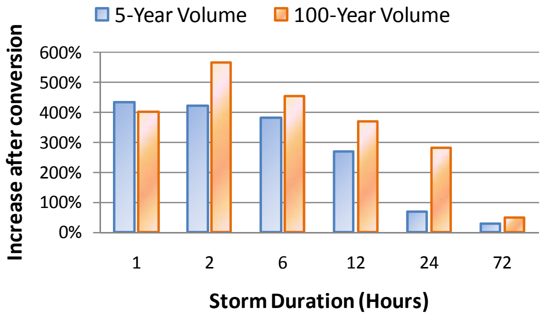


Figure 7. Phokaiwhenua at SH1: Increase in Runoff after conversion

The impact at the SH1 crossing of the Pokaiwhenua Stream of forest to pasture conversion is summarised as follows:

- Flood peaks will increase significantly;
- The highest percentage increase in flood discharge will be for storm duration of approximately 12 hours, twice the catchment time of concentration;
- The percentage increase in peak discharge will be greater for less frequent events; and
- The percentage of rainfall resulting in surface runoff will increase significantly;

The analysis results documented in previous work by SKM & EW (2009) showed that the impact on floods at Lake Karapiro of the proposed land use change would be small for frequent events increasing to the order of 16% for less frequent event. This study shows a similar trend but significantly larger percentage increase in floods. The higher percentage change is because the percentage of the catchment converted will be much higher for the Pokaiwhenua than for the whole Upper Waikato.

4. Conclusions

The analysis results and conclusions apply to a local scale catchment of 105 km^2 where currently 95% of the cachment is forested and after conversion the forested area is likely reduce to 15% (i.e. conversion of 80% of the catcment to pasture). The model results suggest that under these conditions the increase in flood runoff from the catchment will be significant.

5. References

NIWA, 2009. Estimating the Potential Effect of Land Use Change on Waikato Tributary Floods – Topnet Model Development

SKM & EW, 2009. Impact of Land Use Change on Floods in the Upper Waikato, Phase 2: Model Calibration and Flood Hydrograph Generation