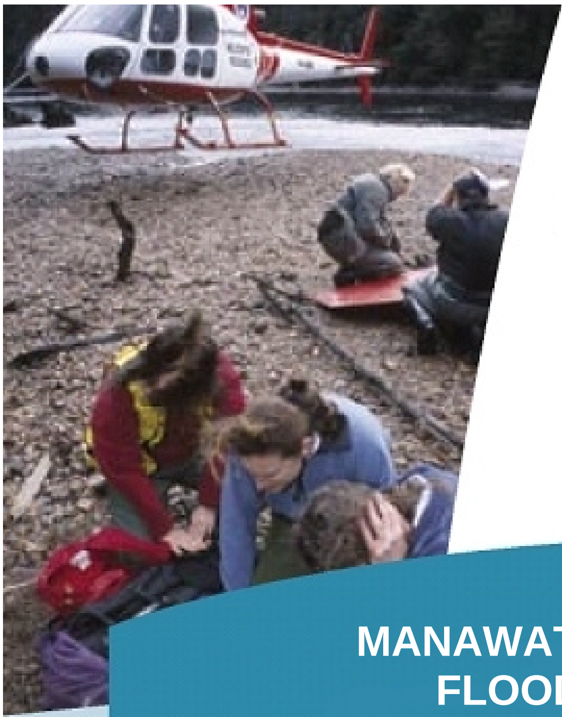
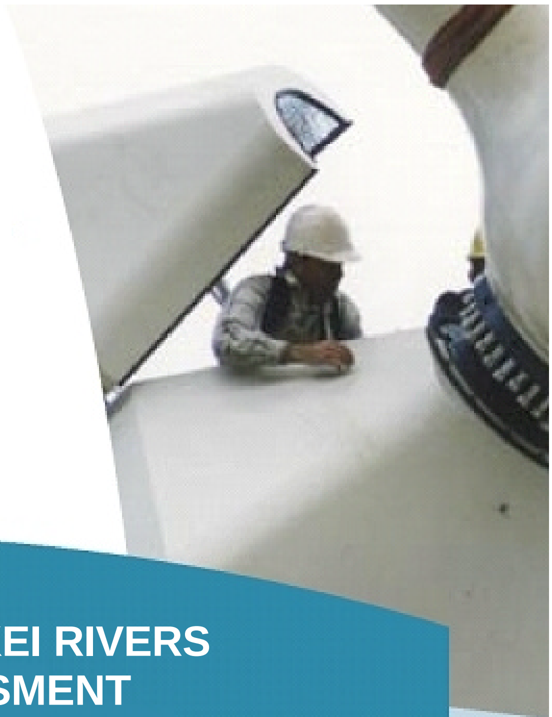
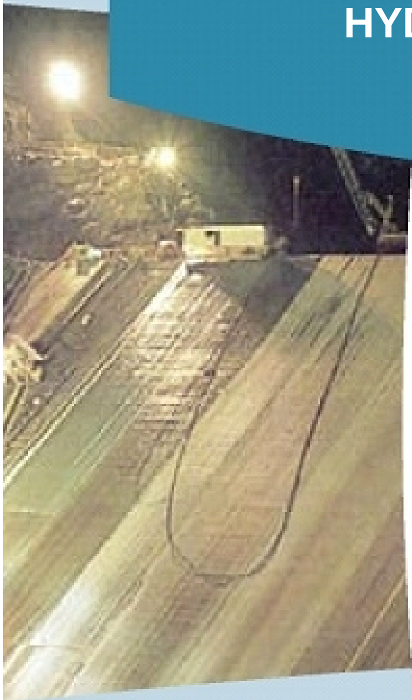


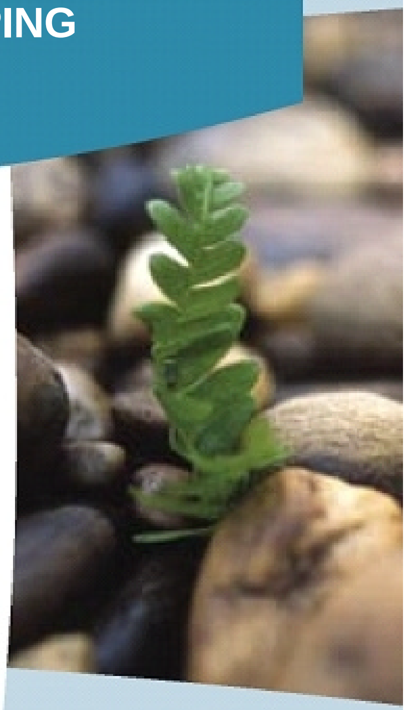


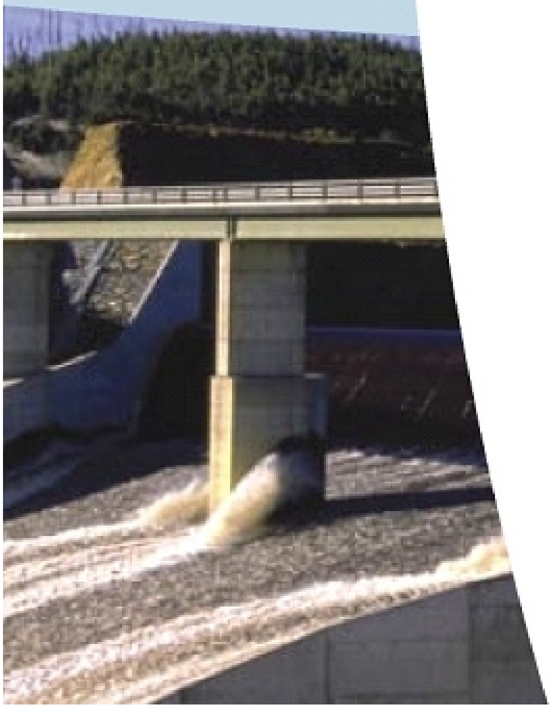
Hydro Tasmania
Consulting

MANAWATU AND RANGATIKEI RIVERS FLOOD HAZARD ASSESSMENT

HYDRAULIC MODELLING AND MAPPING REPORT







Prepared by
Hydro-Electric Corporation
ARBN: 072 377 158
ABN: 48 072 377 158
4 Elizabeth Street, Hobart
Tasmania, Australia

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CONTENTS

1. INTRODUCTION

Hydro Tasmania Consulting (HTC) was commissioned by Horizons Regional Council (HRC) to undertake modelling of several stop bank breach scenarios on the Manawatu and Rangitikei Rivers. The scope of the project involved:

- Hydraulic modelling of seven stop bank breach scenarios, four on the Manawatu River and three on the Rangitikei River.
- Production of electronic flood map data for use by HRC. The parameters for which data was provided include peak water levels, peak water depths, peak velocities and flood hazard.

This report briefly summarises the hydraulic modelling that was carried out for the development of the electronic flood map data.

2. HYDRAULIC MODEL SET-UP

2.1 Introduction

This project involved the setup and running of six stop bank breach computational hydraulic models. The location of these models is shown in Figure 2-1. Model areas 1 and 2 were combined into a single model, since the outflow from the breaches in Model 1 have an effect on the flooding extent in Model 2.

For four of the six hydraulic models run, the software package MIKE 21 (version 2005b) was used. This software is appropriate for the modelling of floodplains where there are no significant or well defined flow paths and no hydraulic structures affecting flow through the area of interest.

For the other two models, MIKEFLOOD (version 2005b) was used. This software package combines both the MIKE 11 1D and MIKE 21 2D software packages into a single model, where the river channel or hydraulic structure is modelled using MIKE 11 cross-sections and out of channel flooding is modelled using the MIKE 21 grid.

Maps showing the location of the breaches within each model area are presented in Appendix A.

The names chosen for the model areas are as follows:

- Model 1 & 2 – Aokautere/Whakarongo (MIKEFLOOD)
- Model 3 – Poplar Road
- Model 4 – Moutoa Floodway (MIKEFLOOD)
- Model 5 – Dalrymple Road
- Model 6 – Flock House
- Model 7 - Tangimoana

2.2 General Set-up

The most critical part of any hydraulic model is the model geometry. HRC provided extremely accurate Lidar data for the creation of the model bathymetries. The Lidar data provided by HRC, which had a very high resolution, was resampled to create a digital elevation model (DEM) with the appropriate grid size using ARC GIS software. To ensure the flow of water across the floodplain reflects real life as much as possible, stop bank banks, creeks and roads were enforced into the DEM from the Lidar data.

For all models other than Model 1 & 2 – Aokautere/Whakarongo, a 10 m grid size was adopted, as the inundated land is mostly rural, with little population located within the flooded extent. A larger grid size can significantly reduce run times, but this come at the expense of model accuracy. For Model 1 & 2 – Aokautere/Whakarongo, a 7.5 m grid size was adopted, as this gives better resolution for the results in urban areas.

For Model 1 & 2 – Aokautere/Whakarongo, the MIKEFLOOD model made use of an existing MIKE 11 model of the Manawatu River supplied by HRC. The MIKE 11 model was linked to a 7.5 m grid size MIKE 21 model, which was developed using Lidar data provided by HRC. The 7.5 m grid size provides enough resolution to give a good model accuracy, while minimising the run time. The supplied MIKE 11 model was modified by removing all branches representing the floodplain flow, moving bank markers to the top of stop banks and by reducing the dx[#] of the MIKE 11 network to 7.5 m to match the MIKE 21 grid size. Branches representing Stoney Creek and Aokautere Stream were also added to the MIKE 11 as model these contribute to the floodplain flows during significant flood events. The cross sections for these branches were taken from the Lidar data.

For Model 4 – Moutoa Floodway, MIKE FLOOD was used, as there is a bridge under State Highway 1 that has an effect on flooding upstream. The bridge was modelled in MIKE 11 and linked to MIKE FLOOD using a structure link.

Models run times ranged from less than one day for models 6 and 7 to eight days for Model 3.

2.3 Roughness and Manning's Values

The roughness and equivalent Manning's values for the MIKE 21 grids were based on land use information provided by HRC. Similar land use types were grouped, producing five roughness categories. The adopted values are based on prior experience. The values are shown in Table 2-1.

Table 2-1: MIKE 21 Roughness and Manning's Values

Land Type	Roughness Mannings M	Equivalent Manning's n 1/Roughness
Built Up Areas	6	0.167
Roads	56	0.018
Waterways	35	0.029
Open Space/Light Vegetation	27	0.037
Dense Vegetation	15	0.067

[#] dx is the maximum distance between calculation points

Roughness values were varied by ± 10% to verify the sensitivity of Model 1 and 2 to change in adopted roughness. The results showed an increase in water levels and extents for increased roughness values and a decrease in water levels and extents for lower roughness values. The difference, however, was considered minor, so the adopted roughness values were used for all models. This sensitivity was assumed to hold true for all models.

2.4 Boundary Conditions

The locations as which the stop bank breaches occur were provided by HRC and are shown in Table 2-2. These inflows are the "upstream" boundaries for each of the MIKE 21 models and Model 4. The breach hydrographs used for the flood events are provided in Appendix B.

Table 2-2 Stop bank Breach Locations

Model	Easting (m)	Northing (m)
Model 1 & 2		
Breach 1	2743800	6096100
Breach 2	2741200	6094600
Breach 3	2740800	6094600
Breach 4	2740100	6095000
Breach 5	2739500	6094300
Model 3	2718246	6081932
Model 4	2080667	6076324
Model 5	2707390	6104766
Model 6	2705300	6101336
Model 7	2702109	6098139

The upstream boundary for Model 1 and 2 was a flood hydrograph with peak of 4,500 m^3/s. This hydrograph is provided in Appendix B.

Downstream boundary conditions for the MIKE 21 models were taken as constant water levels at the lowest point of the model These water levels are described in Table 2-3. For Model 1 and 2, a flow-depth relationship was provided by HRC with the Manawatu River MIKE 11 model. This relationship can be found in Appendix B. For model 4, no downstream boundary was used as the water was completely contained within the model.

Table 2-3 Downstream Boundary Water Levels

Model	Downstream Boundary Constant Water Level (m)
Model 1 & 2	Q-H relationship
Model 3	0.0
Model 4	-
Model 5	0.0
Model 6	0.0
Model 7	0.0

2.5 Link Structures in Model 1 & 2 Aokautere/Whakarongo

81 links were set-up for transfer of flow between the MIKE 11 cross-sections and the MIKE 21 grid in Model 1 & 2. The link structure type used for all the links is summarised in Table 2-4.

2.6 Link Structures in Model 4 Moutoa Floodway

Two links were set-up for transfer of flow between the MIKE 11 bridge structure and the MIKE 21 grid in Model 4. The link structure parameters used for both links is summarised in Table 2-5.

Table 2-4: Link Structure Details (Common for all 81 links)

Method	Cell to cell	**Comment**
Type	Weir 1	$Q = W \cdot C \cdot (H_{us} - H_w)^k \cdot \left[1 - \left(\frac{H_{ds} - H_w}{H_{us} - H_w}\right)^k\right]^{0.385}$ Refer to MIKE 11 reference manual for details.
Source	HGH	Maximum of MIKE 11 cross-section level and MIKE 21 grid cell level used as invert level for the link.
Depth Tolerance	0.1m	For model stability.
Weir C	1.838	Default discharge coefficient.
Manning's n	0.05	Adopted value.

Table 2-5: Link Structure Details

Parameter	Value	Comment
Type	Structure(E)	Refer to MIKE FLOOD reference manual for details.
Momentum Factor	1.5	Default value.
Extrapolation Factor	1.0	Default value.
Depth Adjustment	No	Default value.
Exponential Smoothing Factor	1.0	Default value.

2.7 Other Parameters

Other critical parameters adopted for all six models are provided below:

- Calculation time-step: 1 second.
- Flooding and drying enabled:
    - Drying depth: 0.02m.
    - Flooding depth: 0.03m.
- Eddy viscosity: 0.1m^2/s.

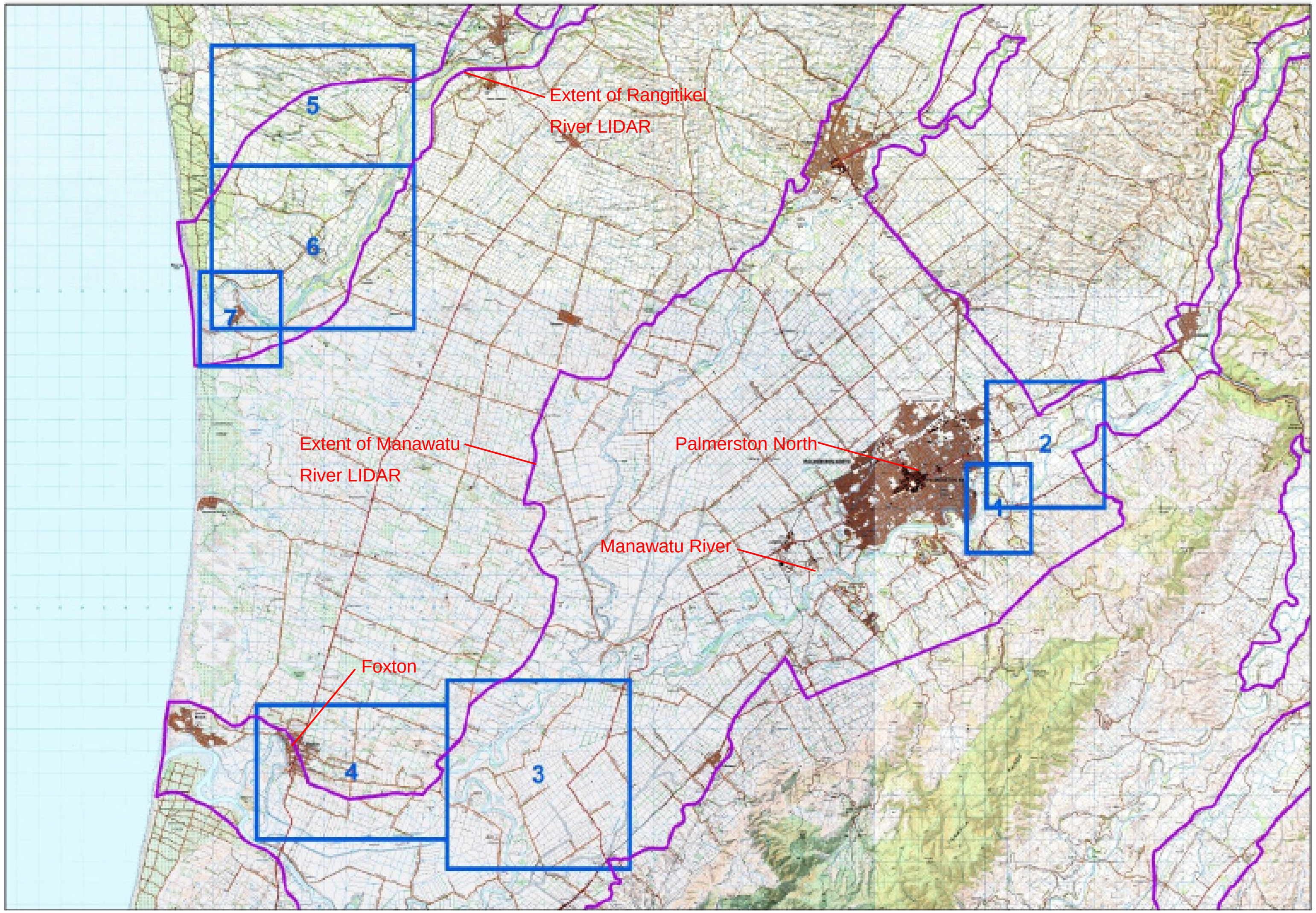


Figure 2-1 Map Showing Locations of Model Areas

3. HYDRAULIC MODEL RUNS

3.1 Model Outputs

The MIKE 21 and MIKEFLOOD models were used to develop a set of electronic peak flood depth, peak water surface, peak flow velocity, and hazard maps for the stop bank breach scenarios provided by Horizons Regional Council (HRC). These maps were provided to HRC electronically in ARC GIS format. A list of electronic map data supplied is provided in Appendix C. Hydraulic modelling files have also been provided.

3.2 Flood Hazard

3.2.1 Flood Hazard Criteria

"Flood hazard varies with both time and space across the floodplain. Floodwaters flow swift and deep at some locations, while in others, they are shallow and slow moving. The variation of hazard and flood behaviour across the floodplain needs to be understood by flood-prone landholders, floodplain managers and flood emergency staff" (CSIRO, 2000).

Hazard criteria are defined in the publication "Floodplain Management in Australia – Best Practice Principles and Guidelines" (CSIRO, 2000). This publication states that the factors affecting the "hazard and disruption caused by a flood can be grouped into four broad categories:

- flood behaviour (i.e. severity, depth, velocity, rate of rise, duration)
- topography (i.e. evacuation routes, islands)
- population at risk (i.e. number of people, number of developments, type of land use, flood awareness)
- emergency management (i.e. flood forecasting, flood warning, flood response plans, evacuation points, recovery plans)."

The current guidelines for determining flood hazard provide four degrees of hazard.

- Low – there are no significant evacuation problems. If necessary, children and elderly people could wade to safety with little difficulty. Maximum flood depths and velocities are low. The warning time is long and allows evacuation routes to remain trafficable for at least twice as long as the time required for evacuation. Evacuation is possible by small vehicles.
- Medium – fit adults can wade to safety but children and the elderly may have difficulties Maximum flood depths and velocities are greater.

Evacuation routes are longer. Evacuation is possible by sedan type vehicles in the initial stages of the flood and later by 4WD vehicles or trucks. The evacuation routes remain trafficable for at least 1.5 times as long as the necessary evacuation time.

- High – wading evacuation routes are longer again. Fit adults have difficulty in wading to safety. Maximum flood depths and velocities are greater (up to 1.0 m and 1.5 m/s respectively). Motor vehicle evacuation is possible only with 4WD vehicles or trucks and only in the early stages of flooding. Boats or helicopters may be required. Evacuation routes remain trafficable only up to the minimum evacuation time.
- Extreme – boats or helicopters are required to evacuation. Wading is not an option because of the rate of rise and the depth and velocity of the floodwaters. Maximum flood depths and velocities are over 1.0 m and 1.5 m/s respectively. (CSIRO, 2000)

Figure 3.1 below indicates the criteria adopted for determining the flood hazard rating of a particular location.

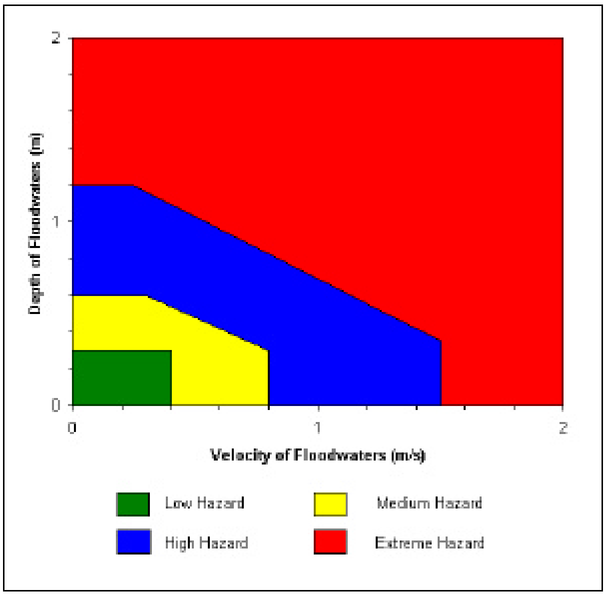


Figure 3.1 Adopted Hazard Ratings

3.2.2 Estimation of Maximum Hazard Category Data

The first task in preparing a floodplain hazard map for a flood event is to determine the maximum hazard category for each grid point in the 2D model over the full simulation period. To achieve this, a Visual Basic software program was developed that would start at the beginning of the flood event and for each of the model grid points:

i) assign an initial value of zero to each grid point,

ii) read the flood depth and fluxes (flow per unit width) in the X and Y model directions,

iii) calculate velocities (= flux/flood depth) in the X and Y directions from the fluxes then calculate the resultant velocity,

iv) assess the hazard category according to the criteria given in Figure 3.1 above then allocate a hazard rating of:

1 for Low hazard

2 for Medium hazard

3 for High hazard

4 for Extreme hazard

v) replace the previous grid point hazard rating with the new rating if it is higher than the previous rating,

vi) repeat steps ii) to v) at a specified time increment until completion of the simulation period.

3.2.3 Hazard Outputs

Peak flood hazard data has been provided in GIS format. In addition, for each stop bank breach scenario, .avi movie files have been prepared that show the changing flood hazard on the floodplain as the flood wave from the stop bank breach progresses along the floodplain in 15 minute increments.

3.3 Summary of Model Results

The following provides a general summary of the stop bank breach flooding for each of the models. Refer to the electronic data (listed in Appendix C) for the detailed modelling results

3.3.1 Model 1 and 2 - Aokautere/Whakarongo

In this scenario, there are six stop bank breaches. Five of the breaches are located on the right bank of the Manawatu River upstream of Palmerston North. Water from these breaches generally travels south west from the breach locations parallel to the Manawatu River. The flooded extent is confined to the south of Napier Road. Floodwaters affect several properties in Palmerston North.

On the left bank, floodwaters overtop the stop bank at Aokautere near Staces Road and inundate the majority of the area between Aokautere Road and the Manawatu River.

Floodplain hazard ranges from Medium to Extreme. Around 50% of the inundated area has an Extreme hazard rating, while 30% had a High hazard rating and 20% Medium hazard rating.

3.3.2 Model 3 – Poplar Road

Floodwaters from the breach of the left bank of the Manawatu River at Poplar Road inundate a large area to the south of the Manawatu River between the Tokomaru River and the Manawatu River. Water generally flows to the south and spreads slowly to the east and west.

Floodwaters from this breach extended much further to the east than expected, so the size of the digital elevation model (DEM) was increased a number of times. Despite this, the water still finds the eastern edge of the model. To minimise the impact of this, when it hits the model boundary, the water is removed from the model. It is expected water will travel approximately 500 m further to the east than is shown by the data, but the flow of this water will be very slow and will not reach great depths. The water also hits the southern boundary near the confluence of the Manawatu and Tokomaru Rivers. In this location, water is expected to reach the stop bank banks for each river and pool behind them to a depth of up to 0.5 m.

The majority of the inundated area resulting from the Poplar Road breach has a high hazard rating. In the centre of the flooded extent is an area of Extreme hazard making up about 25% of the inundated area. Around 65% of the inundated area has a High hazard rating, with the remainder having a Medium hazard rating.

3.3.3 Model 4 – Moutoa Floodway

In this scenario, floodwaters breach the right embankment of the Moutoa Floodway some 500 m downstream of the gate structure. Water flows in a westerly direction following the Moutoa Floodway embankment towards Foxton. Water passes under State Highway 1 before flowing around the end of the stop bank embankment and into the Manawatu River.

The majority of the inundated area has an Extreme hazard rating. This is mainly due to the depth of inundation. Areas of High and Medium hazard exist on the northern fringe of the inundated area.

3.3.4 Model 5 – Dalrymple Road

Floodwaters from the breach near Dalyrmple Road on the Rangatikei River flow to the south west parallel to the Rangitikei River. This breach has a relatively low volume and low peak discharge of 36 m^3/s, so the area inundated is not as large as the other breaches modelled on the Manawatu River. Floodwaters generally follow existing drainage paths.

The majority of the inundated area experiences Medium and Low hazard flooding. Areas of High and Extreme hazard exist in watercourses and where deep water flows.

3.3.5 Model 6 – Flock House

In this scenario, floodwaters from the breach near Flock House on the Rangitikei River flow west towards the coast. The flood hazard for this scenario is predominantly Medium, with areas of High hazard in watercourses and Extreme hazard where deep water flows.

3.3.6 Model 7 – Tangimoana

Floodwaters from the Rangitikei River stop bank breach at Tangimoana inundate the entire township of Tangaimoana, flowing in a north westerly direction towards the coast. The high velocity of the flood wave gives the inundated area an Extreme hazard rating.

4. STUDY LIMITATIONS

4.1 General

This project involved hydraulic modelling of hypothetical stop bank breach scenarios where the breach locations, breach sizes and breach outflow hydrographs were provided by Horizons Regional Council along with high resolution LIDAR of the ground surface.

The estimated flood extents, hazards and velocities for the six models are specific to the provided levee breach data, current land use data, as provided by HRC, and catchment conditions at the time the LIDAR was acquired (2006). The flooding that occurs as a result of an actual stop bank breach is dependent on the catchment conditions (land use and terrain characteristics) at the time and the stop bank breach characteristics that occur.

The results from this study provide an estimate of the likely characteristics of the flooding (extent, velocities and hazard) that could occur in the event of a stop bank breach occurring at locations similar to the hypothetical breaches that have been modelled.

4.1.1 Notes for Electronic Maps

The following notes apply to all the electronic results that were provided to HRC:

- Disclaimer - The electronic data is provided on the basis that those responsible for its preparation and publication do not accept any responsibility for any loss or damaged alleged to be suffered by anyone as a result of the publication of the map and the notations on it, or as a result of the use or misuse of the information provided herein.
- The flood extents, depths, velocities and hazards are based on hypothetical scenarios and are not an actual or historical flood event. The flood extent that occurs during a particular flood will depend on earthworks, blockages of structures and drains by debris, further development on the floodplain and stop bank breach characteristics.
- The flood extents shown are a prediction of land affected for the specific level of risk and do not necessarily indicate a threat to buildings located on that land. Flood assessment for particular sites will require more detailed interpretation, survey and hydraulic analysis by qualified and experienced persons.

- The limit of flooding shown is not a boundary between flood prone and flood free land. Larger floods could inundate areas outside the areas shown.

The following note applies specifically to the Model 1 and 2 stop bank breach results:

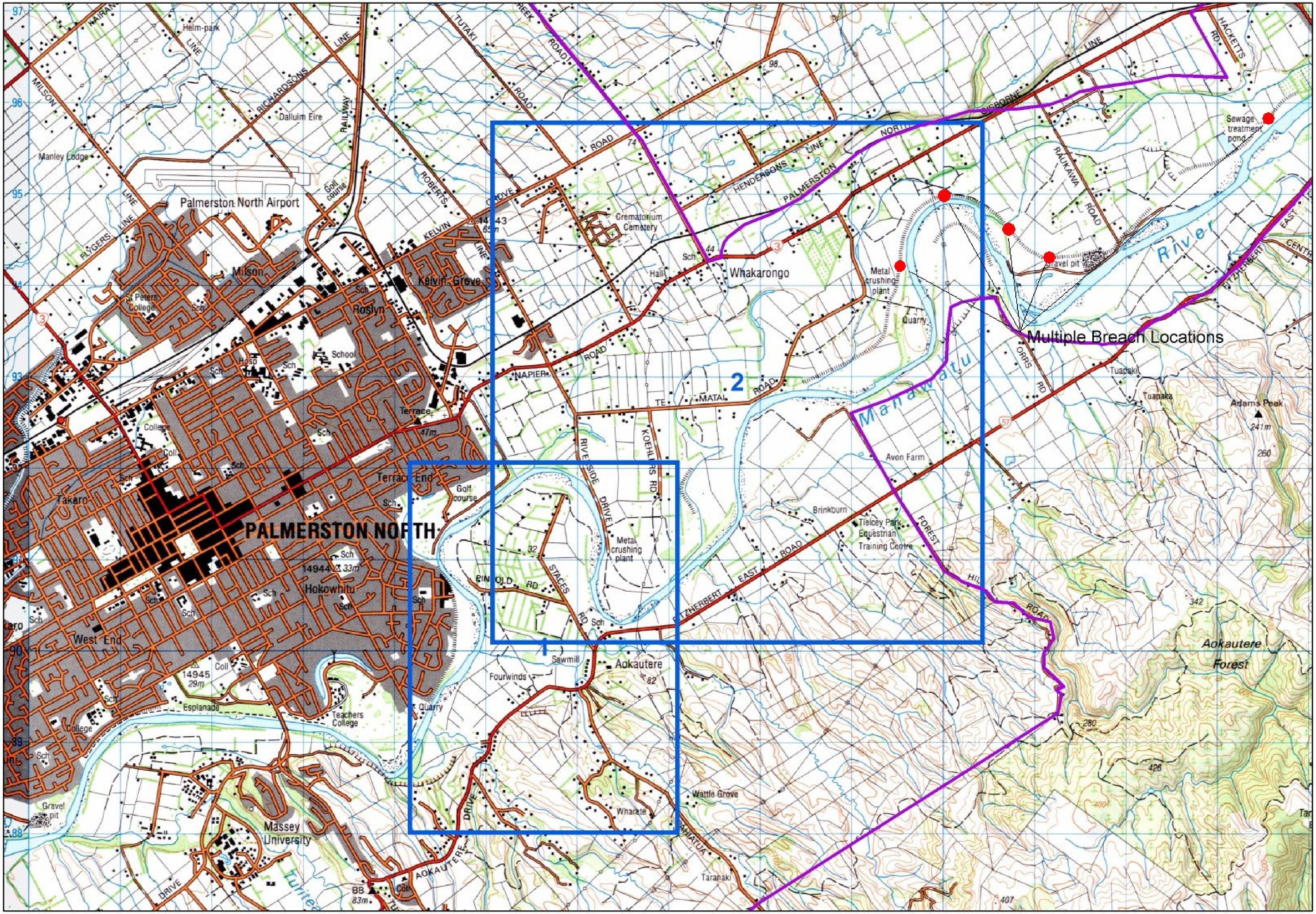
- The modelling assessment is based on a simulated 4500 m^3/s peak flow flood event in the Manawatu River that causes a series of five breaches of the river's stop banks. The location of those breaches are:

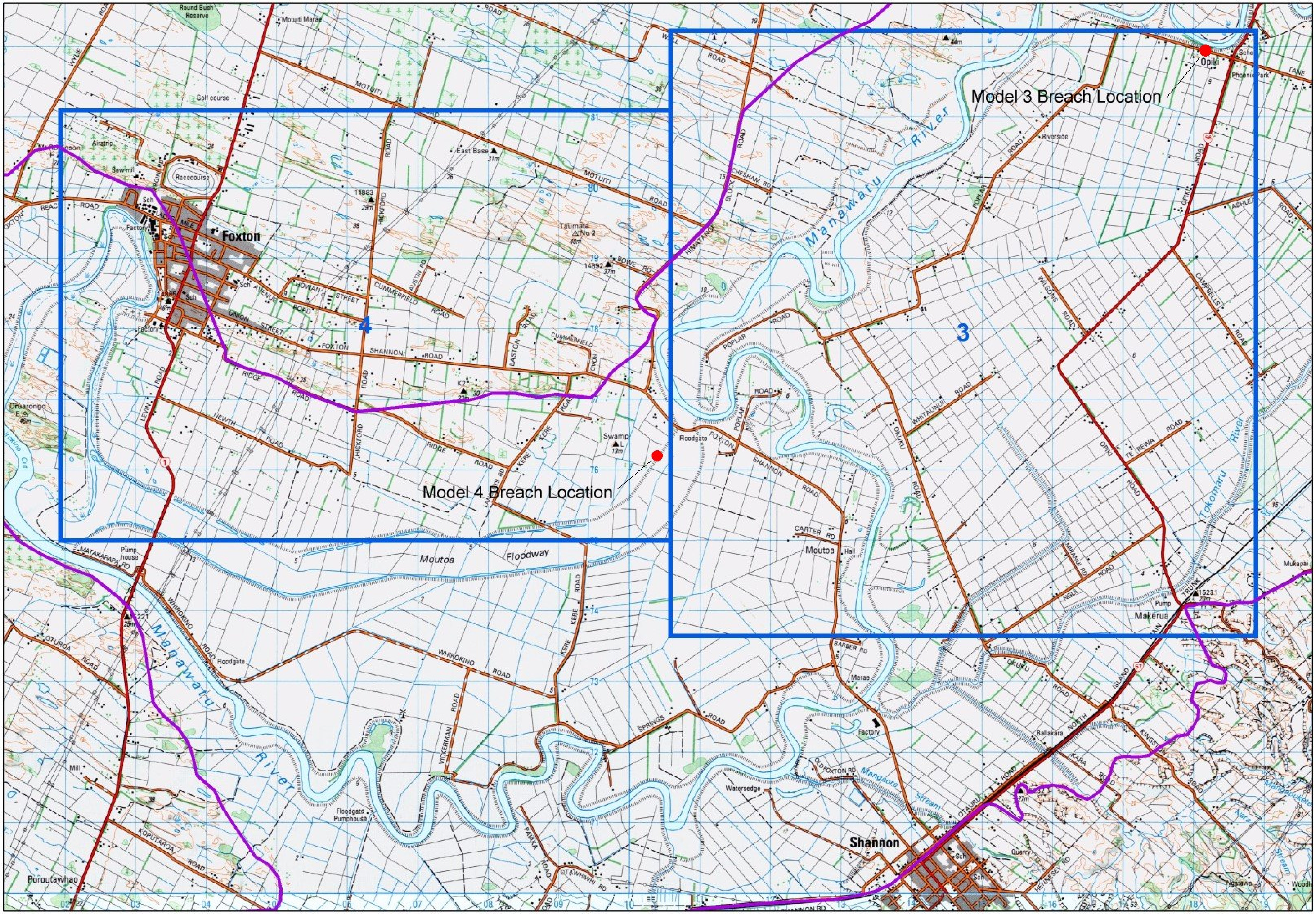
Model	Easting (m)	Northing (m)
Breach 1	2743800	6096100
Breach 2	2741200	6094600
Breach 3	2740800	6094600
Breach 4	2740100	6095000
Breach 5	2739500	6094300

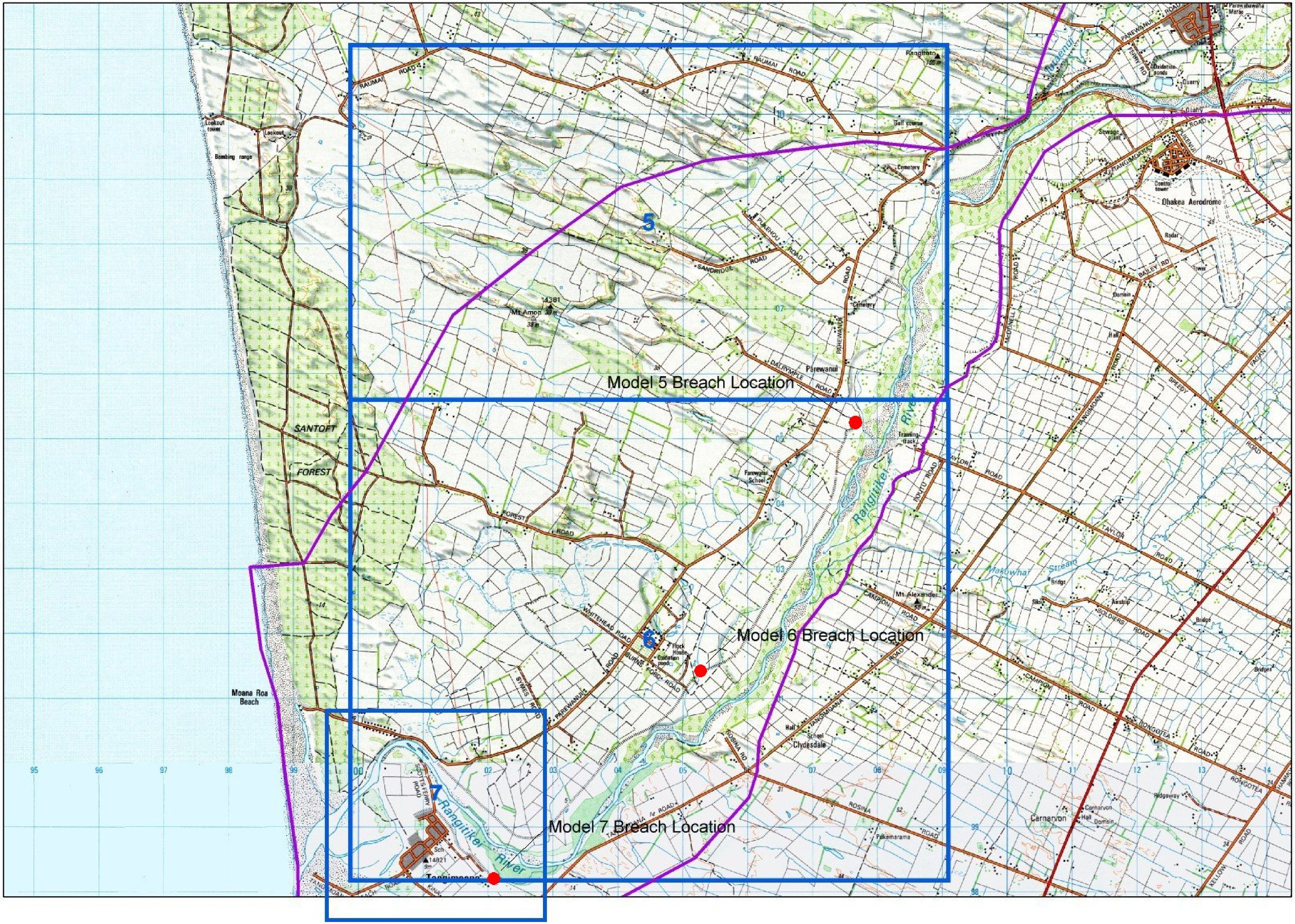
5. REFERENCES

CSIRO (2000), *Floodplain Management in Australia – Best Practices Principles and Guidelines*, CSIRO Publishing.

APPENDIX A: STOP BANK BREACH LOCATIONS


Multiple Breach Locations
1
2
PALMERSTON NORTH
Palmerston North Airport
Whakarongo
Milson
Kelvin Grove
Roslyn
Terrace End
Takaro
Hokowhitu
West End
Aokautere
Massey University
Manawatu River
Sewage treatment pond
Metal crushing plant
Gravel pit
Quarry
Crematorium Cemetery
Avon Farm
Brinkburn
Tielcey Park Equestrian Training Centre
Fourwinds
Sawmill
Wattle Grove
Whareie
Teachers College
Esplanade
Aokautere Forest
Adams Peak
Tuapaka
Fitzherbert East Road
Palmerston Line
Hendersons Line
Kelvin Grove Road
Napier Road
Te Matai Road
Riverside Drive
Kohlers Rd
Stace's Rd
Old Rd
Dalluim Eire
Manley Lodge
Helm-park
St Peters College


Model 3 Breach Location
Model 4 Breach Location
4
3
Foxton
Shannon
Manawatu River
Moutoa
Floodway
Opiki
Makerua


5
Model 5 Breach Location
6
Model 6 Breach Location
7
Model 7 Breach Location
SANTOFT
FOREST
Moana Roa Beach
Ohakea Aerodrome
Rangitikei River
Parewanui
Mt Alexander
Clydesdale
Carnarvon
Tangimoana

APPENDIX B: MODEL INPUTS

Table B-1 Model 1 & 2 – MIKE 11 Model Inflow Hydrograph

Time (hrs)	Discharge (m^3/s)	Time (hrs)	Discharge (m^3/s)	Time (hrs)	Discharge (m^3/s)	Time (hrs)	Discharge (m^3/s)	Time (hrs)	Discharge (m^3/s)	Time (hrs)	Discharge (m^3/s)	Time (hrs)	Discharge (m^3/s)
0:00	292	13:45	1545	27:30	3779	41:15	3484	55:00	1210	68:45	722	82:30	527
0:15	296	14:00	1602	27:45	3778	41:30	3465	55:15	1177	69:00	717	82:45	524
0:30	298	14:15	1671	28:00	3776	41:45	3444	55:30	1149	69:15	712	83:00	521
0:45	300	14:30	1763	28:15	3774	42:00	3422	55:45	1125	69:30	707	83:15	518
1:00	301	14:45	1850	28:30	3773	42:15	3398	56:00	1106	69:45	702	83:30	515
1:15	301	15:00	1924	28:45	3772	42:30	3376	56:15	1090	70:00	697	83:45	512
1:30	301	15:15	1996	29:00	3773	42:45	3352	56:30	1077	70:15	693	84:00	508
1:45	300	15:30	2080	29:15	3777	43:00	3329	56:45	1066	70:30	689		
2:00	300	15:45	2176	29:30	3783	43:15	3304	57:00	1057	70:45	685		
2:15	299	16:00	2258	29:45	3791	43:30	3279	57:15	1050	71:00	681		
2:30	298	16:15	2333	30:00	3797	43:45	3253	57:30	1044	71:15	678		
2:45	298	16:30	2405	30:15	3802	44:00	3225	57:45	1038	71:30	674		
3:00	298	16:45	2474	30:30	3806	44:15	3192	58:00	1033	71:45	670		
3:15	299	17:00	2540	30:45	3808	44:30	3158	58:15	1029	72:00	667		
3:30	301	17:15	2606	31:00	3809	44:45	3124	58:30	1026	72:15	663		
3:45	305	17:30	2674	31:15	3810	45:00	3091	58:45	1024	72:30	659		
4:00	309	17:45	2751	31:30	3810	45:15	3057	59:00	1022	72:45	656		
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5:00	347	18:45	3021	32:30	3805	46:15	2916	60:00	1015	73:45	642		
5:15	362	19:00	3071	32:45	3802	46:30	2880	60:15	1012	74:00	638		
5:30	378	19:15	3116	33:00	3800	46:45	2844	60:30	1008	74:15	635		
5:45	395	19:30	3158	33:15	3797	47:00	2807	60:45	1004	74:30	632		
6:00	414	19:45	3197	33:30	3794	47:15	2770	61:00	999	74:45	629		
6:15	433	20:00	3234	33:45	3791	47:30	2731	61:15	993	75:00	626		
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7:15	520	21:00	3353	34:45	3781	48:30	2566	62:15	961	76:00	613		
7:30	554	21:15	3378	35:00	3776	48:45	2519	62:30	951	76:15	609		
7:45	595	21:30	3402	35:15	3769	49:00	2472	62:45	941	76:30	605		
8:00	640	21:45	3424	35:30	3759	49:15	2423	63:00	930	76:45	601		
8:15	686	22:00	3446	35:45	3748	49:30	2375	63:15	918	77:00	597		
8:30	731	22:15	3468	36:00	3735	49:45	2323	63:30	906	77:15	593		
8:45	771	22:30	3491	36:15	3739	50:00	2267	63:45	895	77:30	589		
9:00	812	22:45	3513	36:30	3700	50:15	2208	64:00	883	77:45	586		
9:15	853	23:00	3525	36:45	3684	50:30	2146	64:15	872	78:00	582		
9:30	892	23:15	3537	37:00	3669	50:45	2083	64:30	861	78:15	579		
9:45	927	23:30	3548	37:15	3656	51:00	2022	64:45	851	78:30	575		
10:00	960	23:45	3559	37:30	3645	51:15	1966	65:00	841	78:45	572		
10:15	991	24:00	3576	37:45	3636	51:30	1912	65:15	831	79:00	569		
10:30	1021	24:15	3601	38:00	3626	51:45	1860	65:30	822	79:15	566		
10:45	1048	24:30	3633	38:15	3615	52:00	1799	65:45	812	79:30	564		
11:00	1077	24:45	3669	38:30	3603	52:15	1737	66:00	803	79:45	561		
11:15	1106	25:00	3702	38:45	3591	52:30	1682	66:15	794	80:00	558		
11:30	1138	25:15	3729	39:00	3578	52:45	1631	66:30	786	80:15	556		
11:45	1172	25:30	3750	39:15	3566	53:00	1586	66:45	777	80:30	553		
12:00	1207	25:45	3765	39:30	3555	53:15	1535	67:00	769	80:45	550		
12:15	1244	26:00	3776	39:45	3544	53:30	1480	67:15	761	81:00	547		
12:30	1289	26:15	3782	40:00	3535	53:45	1428	67:30	754	81:15	543		
12:45	1338	26:30	3784	40:15	3527	54:00	1379	67:45	747	81:30	540		
13:00	1389	26:45	3784	40:30	3519	54:15	1333	68:00	740	81:45	536		
13:15	1439	27:00	3783	40:45	3513	54:30	1289	68:15	734	82:00	533		
13:30	1499	27:15	3781	41:00	3500	54:45	1246	68:30	728	82:15	530		

Table B-2 Model 1 & 2 - Multiple Breach Location Hydrographs

Hours	Stop bank Breach Discharge (m³/s)				
	Breach 1	Breach 2	Breach 3	Breach 4	Breach 5
0.00	0	0	0	0	0
↓	↓	↓	↓	↓	↓
22.50	0	0	0	0	0
22.75	2	0	0	0	0
23.00	7	0	0	0	0
23.25	15	0	0	0	0
23.50	26	0	0	0	0
23.75	41	0	0	0	0
24.00	56	0	0	0	0
24.25	67	3	0	0	0
24.50	75	11	0	0	0
24.75	80	25	0	0	0
25.00	82	45	0	0	0
25.25	82	70	0	0	0
25.50	82	95	0	0	0
25.75	82	115	0	0	0
26.00	82	129	3	0	0
26.25	82	137	11	0	0
26.50	82	140	25	0	0
26.75	81	139	44	0	0
27.00	81	139	69	0	0
27.25	81	139	94	2	0
27.50	81	138	113	10	0
27.75	81	138	127	22	0
28.00	81	138	135	39	0
28.25	82	138	138	62	0
28.50	82	138	138	84	0
28.75	83	139	139	101	0
29.00	84	141	141	113	4
29.25	84	142	142	121	15
29.50	85	143	143	123	34
29.75	85	144	144	124	61
30.00	85	145	145	124	95
30.25	85	145	145	125	129
30.50	85	145	145	125	156
30.75	85	145	145	125	175
31.00	85	145	145	125	186
31.25	85	145	145	125	190
31.50	84	145	145	125	190
31.75	84	144	144	125	190
32.00	84	144	144	124	189
32.25	83	143	143	124	189
32.50	83	143	143	123	188
32.75	83	142	142	123	188
33.00	82	142	142	123	187
33.25	82	141	141	122	186
33.50	82	141	141	122	185

Hours	Stop bank Breach Discharge (m^3/s)				
	Breach 1	Breach 2	Breach 3	Breach 4	Breach 5
33.75	82	140	140	121	185
34.00	81	140	140	121	184
34.25	80	139	139	120	184
34.50	79	138	138	120	183
34.75	77	136	136	119	182
35.00	76	134	134	118	181
35.25	74	132	132	116	179
35.50	72	129	129	114	176
35.75	70	126	126	111	173
36.00	68	122	122	108	169
36.25	67	119	119	105	165
36.50	66	116	116	103	160
36.75	65	114	114	100	156
37.00	64	112	112	98	152
37.25	62	111	111	97	149
37.50	61	109	109	95	147
37.75	59	107	107	94	145
38.00	58	104	104	92	143
38.25	56	101	101	90	140
38.50	55	99	99	87	136
38.75	54	96	96	85	133
39.00	53	94	94	83	129
39.25	52	92	92	81	126
39.50	51	90	90	79	123
39.75	50	88	88	77	120
40.00	49	87	87	76	118
40.25	48	86	86	75	116
40.50	46	84	84	74	114
40.75	44	81	81	72	112
41.00	43	79	79	70	110
41.25	41	76	76	68	107
41.50	39	73	73	65	103
41.75	37	70	70	63	99
42.00	35	66	66	60	95
42.25	33	63	63	57	91
42.50	31	60	60	55	87
42.75	30	57	57	52	83
43.00	29	53	53	49	79
43.25	28	51	51	46	75
43.50	27	49	49	44	70
43.75	26	47	47	42	67
44.00	24	46	46	41	65
44.25	23	44	44	39	62
44.50	22	42	42	38	60
44.75	21	40	40	36	57
45.00	20	38	38	34	55
45.25	19	36	36	33	52
45.50	17	34	34	31	50
45.75	16	32	32	29	47
46.00	15	30	30	27	44

Hours	Stop bank Breach Discharge (m³/s)				
	Breach 1	Breach 2	Breach 3	Breach 4	Breach 5
46.25	14	28	28	26	42
46.50	12	26	26	24	39
46.75	11	23	23	22	36
47.00	9	21	21	20	33
47.25	8	19	19	18	30
47.50	6	16	16	16	27
47.75	4	13	13	14	24
48.00	2.6	10	10	11	21
48.25	0.8	8	8	9	17
48.50	0.1	4.4	4.4	7	14
48.75	0.1	1.4	1.4	3.8	10
49.00	0.1	0.2	0.2	1.2	5.8
49.25	0	0.1	0.1	0.2	1.8
49.50	0	0.1	0.1	0.1	0.2
49.75	0	0.1	0.1	0.1	0.2
50.00	0	0	0	0.1	0.1
50.25	0	0	0	0	0.1
50.50	0	0	0	0	0
50.75	0	0	0	0	0
51.00	0	0	0	0	0
51.25	0	0	0	0	0
51.50	0	0	0	0	0
51.75	0	0	0	0	0
52.00	0	0	0	0	0
52.25	0	0	0	0	0
52.50	0	0	0	0	0
52.75	0	0	0	0	0
53.00	0	0	0	0	0

Table B-3 Model 1 & 2 - Downstream Breach Location Hydrographs

Hours	Discharge (m³/s)
0.0	0
0.5	16
1.0	47
1.5	102
2.0	185
2.5	184
3.0	183
3.5	180
4.0	171
4.5	169
5.0	167
5.5	160
6.0	153
6.5	150
7.0	148
7.5	140
8.0	135
8.5	131
9.0	126
9.5	124

Hours	Discharge (m^3/s)
10.0	122
10.5	116
11.0	109
11.5	103
12.0	97
12.5	91
13.0	83
13.5	75
14.0	68
14.5	59
15.0	54
15.5	47
16.0	40
16.5	34
17.0	28
17.5	21
18.0	15
18.5	10
19.0	8
19.5	7
20.0	0

Table B-4 Model 1 & 2 – Downstream Boundary Q-H Relationship

Water Level (m)	Discharge (m^3/s)
0	0
6.7	0
10	185
11	332
13.5	1019
14.2	1487
14.7	2132
15.6	3507
16	3994
16.3	4563

Table B-5 Breach Hydrographs for Models 3 to 7

Hours	Stop bank Breach Discharge (m3/s)				
	Model 3	Model 4	Model 5	Model 6	Model 7
0	0	0	0	0	0
0.5	50	7	20	10	20
1	130	13	30	40	70
1.5	230	22	36	85	150
2	340	30	35	93	168
2.5	450	45	35	92	167
3	512	60	34	91	166
3.5	510	75	34	90	164
4	507	90	33	88	162
4.5	503	105	32	85	159
5	499	120	31	81	154

Hours	Stop bank Breach Discharge (m3/s)				
	Model 3	Model 4	Model 5	Model 6	Model 7
5.5	494	135	29	75	147
6	489	150	27	66	137
6.5	484	170	26	54	124
7	480	190	24	47	116
7.5	475	210	23	42	107
8	471	230	21	34	99
8.5	466	265	20	33	90
9	461	300	19	31	82
9.5	456	355	17	28	76
10	451	410	15	25	71
10.5	446	426	13	23	65
11	440	442	11	21	57
11.5	433	446	9	18	49
12	426	450	7	16	48
12.5	419	448	5.4	13	46
13	411	445	3.9	11	37
13.5	402	443	2.8	9.2	34
14	394	440	2	7.5	31
14.5	384	438	1.2	6.1	29
15	375	435	0.8	4.7	26
15.5	365	430	0.5	3.3	23
16	354	425	0.4	1.9	21
16.5	343	420	0.3	0	18
17	332	415	0.1	0	16
17.5	321	408	0	0	13
18	309	400	0	0	10
18.5	296	390	0	0	8
19	282	380	0	0	6
19.5	267	368	0	0	3.7
20	253	355	0	0	1.9
20.5	238	338	0	0	1.3
21	224	320	0	0	1.2
21.5	210	303	0	0	1
22	196	285	0	0	0.8
22.5	183	260	0	0	0.6
23	171	235	0	0	0.4
23.5	159	209	0	0	0.1
24	148	182	0	0	0
24.5	139	141	0	0	0
25	130	100	0	0	0
25.5	122	69	0	0	0
26	115	37	0	0	0
26.5	108	19	0	0	0
27	103	0	0	0	0
27.5	98	0	0	0	0
28	94	0	0	0	0
28.5	90	0	0	0	0
29	86	0	0	0	0
29.5	83	0	0	0	0
30	79	0	0	0	0
30.5	76	0	0	0	0
31	73	0	0	0	0
31.5	70	0	0	0	0
32	67	0	0	0	0
32.5	64	0	0	0	0

Hours	**Stop bank Breach Discharge (m3/s)**				
	Model 3	Model 4	Model 5	Model 6	Model 7
33	60	0	0	0	0
33.5	57	0	0	0	0
34	53	0	0	0	0
34.5	50	0	0	0	0
35	47	0	0	0	0
35.5	43	0	0	0	0
36	40	0	0	0	0
36.5	37	0	0	0	0
37	34	0	0	0	0
37.5	32	0	0	0	0
38	29	0	0	0	0
38.5	26	0	0	0	0
39	24	0	0	0	0
39.5	22	0	0	0	0
40	19	0	0	0	0
40.5	17	0	0	0	0
41	16	0	0	0	0
41.5	14	0	0	0	0
42	12.6	0	0	0	0
42.5	11.3	0	0	0	0
43	10.3	0	0	0	0
43.5	8.5	0	0	0	0
44	7	0	0	0	0
44.5	5.5	0	0	0	0
45	4	0	0	0	0
45.5	3	0	0	0	0
46	2	0	0	0	0
46.5	1	0	0	0	0
47	0.5	0	0	0	0
47.5	0	0	0	0	0
48	0	0	0	0	0

APPENDIX C: LIST OF ELECTRONIC DATA SUPPLIED

The following Information has been supplied to HRC in electronic format.

Area	Description	Filename	File type
Area 1 & 2			
	Area 1 & 2 - base maps		
	Area 1 & 2 - map showing Flood Depths	Area 1 & 2 - Depths.mxd	ArcGIS mxd
	Area 1 & 2 - map showing flood depths (corrected data)	Area 1 & 2 - Depths_v2.mxd	ArcGIS mxd
	Area 1 & 2 - map showing Hazard results	Area 1 & 2 - Hazard.mxd	ArcGIS mxd
	Area 1 & 2 - map showing Peak Flood Levels	Area 1 & 2 - Peak Flood Levels.mxd	ArcGIS mxd
	Area 1 & 2 - map showing Peak Flood Levels (Corrected data)	Area 1 & 2 - Peak Flood Levels_v2.mxd	ArcGIS mxd
	Area 1 & 2 - map showing Speed results	Area 1 & 2 - Speed.mxd	ArcGIS mxd
	Area 1 & 2 - data		
	Flood Depths	depths_rot	ArcGIS grid
	Flood Depths (Corrected data)	a12_depths_v2	ArcGIS grid
	Hazard	hazard_rot	ArcGIS grid
	Hazard for River	river_hazard	ArcGIS grid
	Peak Flood Levels	levels_rot	ArcGIS grid
	Peak Flood Levels (Corrected data)	levels_v2	ArcGIS grid
	Peak Flood Levels for River	river_levels2	ArcGIS grid
	Speed	speed_rot	ArcGIS grid
	Horizons data includes roads, stopbanks & stream network		
	Area 1 & 2 - PDF's		
	Pdf's of all maps above		
	Area 1 & 2 - Layer Files		
	Layer files to set symbology for data and grids		
	Area 1 & 2 - Hazard Animation		
	Animation of hazard results (15 min intervals)	Model 1 and 2 - Hazard.avi	
Area 3			
	Area 3 - base maps		
	Area 3 - map showing Flood Depths	Area 3 - Depths.mxd	ArcGIS mxd
	Area 3 - map showing Hazard results	Area 3 - Hazard.mxd	ArcGIS mxd
	Area 3 - map showing Peak Flood Levels	Area 3 - Peak Flood Levels.mxd	ArcGIS mxd
	Area 3 - map showing Speed results	Area 3 - Speed.mxd	ArcGIS mxd
	Area 3 - data		
	Flood Depths	area3_depths	ArcGIS grid
	Hazard	area3_hazard	ArcGIS grid
	Peak Flood Levels	area3_levels	ArcGIS grid
	Speed	area3_speed	ArcGIS grid
	Horizons data includes roads, stopbanks & stream network		
	Area 3 - PDF's		
	Pdf's of all maps above		
	Area 3 - Layer Files		
	Layer files to set symbology for data and grids		
	Area 3 - Hazard Animation		
	Animation of hazard results (15 min intervals)	Model 3 - Hazard.avi	
Area 4			
	Area 4 - base maps		
	Area 4 - map showing Flood Depths	Area 4 - Depths.mxd	ArcGIS mxd
	Area 4 - map showing Hazard results	Area 4 - Hazard.mxd	ArcGIS mxd

Area	Description	Filename	File type
	Area 4 - map showing Peak Flood Levels	Area 4 - Peak Flood Levels.mxd	ArcGIS mxd
	Area 4 - map showing Speed results	Area 4 - Speed.mxd	ArcGIS mxd
	Area 4 - data		
	Flood Depths	area4_depths	ArcGIS grid
	Hazard	area4_hazard	ArcGIS grid
	Peak Flood Levels	area4_levels	ArcGIS grid
	Speed	area4_speed	ArcGIS grid
	Horizons data includes roads, stopbanks & stream network		
	Area 4 - PDF's		
	Pdf's of all maps above		
	Area 4 - Layer Files		
	Layer files to set symbology for data and grids		
	Area 4 - Hazard Animation		
	Animation of hazard results (15 min intervals)	Model 4 - Hazard.avi	
Area 5			
	Area 5 - base maps		
	Area 5 - map showing Flood Depths	Area 5 - Depths.mxd	ArcGIS mxd
	Area 5 - map showing Hazard results	Area 5 - Hazard.mxd	ArcGIS mxd
	Area 5 - map showing Peak Flood Levels	Area 5 - Peak Flood Levels.mxd	ArcGIS mxd
	Area 5 - map showing Speed results	Area 5 - Speed.mxd	ArcGIS mxd
	Area 5 - data		
	Flood Depths	area5_depths	ArcGIS grid
	Hazard	area5_hazard	ArcGIS grid
	Peak Flood Levels	area5_levels	ArcGIS grid
	Speed	area5_speed	ArcGIS grid
	Horizons data includes roads, stopbanks & stream network		
	Area 5 - PDF's		
	Pdf's of all maps above		
	Area 5 - Layer Files		
	Layer files to set symbology for data and grids		
	Area 5 - Hazard Animation		
	Animation of hazard results (15 min intervals)	Model 5 - Hazard.avi	
Area 6			
	Area 6 - base maps		
	Area 6 - map showing Flood Depths	Area 6 - Depths.mxd	ArcGIS mxd
	Area 6 - map showing Hazard results	Area 6 - Hazard.mxd	ArcGIS mxd
	Area 6 - map showing Peak Flood Levels	Area 6 - Peak Flood Levels.mxd	ArcGIS mxd
	Area 6 - map showing Speed results	Area 6 - Speed.mxd	ArcGIS mxd
	Area 6 - data		
	Flood Depths	area6_depths	ArcGIS grid
	Hazard	area6_hazard	ArcGIS grid
	Peak Flood Levels	area6_levels	ArcGIS grid
	Speed	area6_speed	ArcGIS grid
	Horizons data includes roads, stopbanks & stream network		
	Area 6 - PDF's		
	Pdf's of all maps above		
	Area 6 - Layer Files		
	Layer files to set symbology for data and grids		
	Area 6 - Hazard Animation		
	Animation of hazard results (15 min intervals)	Model 6 - Hazard.avi	

Area	Description	Filename	File type
Area 7			
	Area 7 - base maps		
	Area 7 - map showing Flood Depths	Area 7 - Depths.mxd	ArcGIS mxd
	Area 7 - map showing Hazard results	Area 7 - Hazard.mxd	ArcGIS mxd
	Area 7 - map showing Peak Flood Levels	Area 7 - Peak Flood Levels.mxd	ArcGIS mxd
	Area 7 - map showing Speed results	Area 7 - Speed.mxd	ArcGIS mxd
	Area 7 - data		
	Flood Depths	area7_depths2	ArcGIS grid
	Hazard	area7_hazard2	ArcGIS grid
	Peak Flood Levels	area7_levels2	ArcGIS grid
	Speed	area7_speed2	ArcGIS grid
	Horizons data includes roads, stopbanks & stream network		
	Area 7 - PDF's		
	Pdf's of all maps above		
	Area 7 - Layer Files		
	Layer files to set symbology for data and grids		
	Area 7 - Hazard Animation		
	Animation of hazard results (15 min intervals)	Model 7 - Hazard.avi	
MIKE Flood Files			
	Models 1 and 2	Models 1 and 2.zip	
		2004-05 revised.xns11	
		4500-revisedDesign-less0025.HD11	
		Mnw2-Q4500-breach_US.BND11	
		Models 1 and 2 Bathymetry.dfs2	
		Models 1 and 2 M11.sim11	
		Models 1 and 2 Roughness.dfs2	
		Models 1 and 2 Water Surface.dfs2	
		Models 1 and 2.couple	
		Models 1 and 2.M21	
		Models 1 and 2.nwk	
		Multiple Breach.dfs0	
		Q-at-BM898_4500cmc-breach.dfs0	
		SC and Asns Inflow Hydrographs.dfs0	
	Model 3	Model 3.zip	
		Model 3 Bathymetry.dfs2	
		Model 3 Breach Outflow.dfs0	
		Model 3 Roughness.dfs2	
		Model 3 Water Surface.dfs2	
		Model 3.m21	
	Model 4	Model 4.zip	
		Model 4 Bathymetry.dfs2	
		Model 4 Bridge.bnd11	
		Model 4 Bridge.hd11	
		Model 4 Bridge.nwk11	
		Model 4 Bridge.sim11	
		Model 4 Bridge.xns11	
		Model 4 Initial Water Surface.dfs2	
		Model 4 Roughness.dfs2	
		Model 4.couple	

Area	Description	Filename	File type
MIKE Flood Files			
Model 4 cont.		Model 4.m21 Moutoa Floodway Breach Hydrograph.dfs0	
Model 5		Model 5.zip Model 5 Bathymetry.dfs2 Model 5 Roughness.dfs2 Model 5 Water Surface.dfs2 Model 5.m21 Nagels Breach.dfs0	
Model 6		Model 6.zip Flock House Breach.dfs0 Model 6.zip Model 5 Bathymetry.dfs2 Model 5 Water Surface.dfs2 Model 6 Roughness.dfs2 Model 6.m21	
Model 7		Model 7.zip Model 7 Bathymetry.dfs2 Model 7 Roughness.dfs2 Model 7 Water Surface.dfs2 Model 7.m21 Tangimoana Breach.dfs0	