BEFORE THE UPPER HUTT CITY COUNCIL

IN THE MATTER OF	**the Resource Management Act 1991**
AND IN THE MATTER OF	**Proposed Plan Change 42 to the Upper Hutt City Council District Plan (2004) – Mangaroa and Pinehaven Flood Hazard Extents**

SUPPLEMENTARY STATEMENT OF EVIDENCE OF KYLE JOHN CHRISTENSEN

19 October 2017

Introduction

1. My name is Kyle Christensen, my qualifications and experience are provided in my Evidence-in-Chief dated 25 August 2017.

2. I have read and agree to comply with the Code of conduct for expert witnesses outlined in the Environment Court Practice Note 2014. I understand that, according to the current Code of conduct:

   (a) an expert witness has an overriding duty to assist the Consenting Authority impartially on relevant matters within the expert's area of expertise;

   (b) an expert witness is not an advocate for the party who engages the witness.

3. I confirm that the statements made in this supplementary evidence are within my area of expertise (unless I state otherwise) and I also confirm that I have not omitted to consider material facts which might alter the opinions stated in this evidence.

Scope of Supplementary Evidence

4. My supplementary evidence provides further information to clarify technical points raised during the hearing. The technical points covered by this supplementary evidence include the following -

   i. Differences between Plan Change 15 and Plan Change 42 flood extents in Mangaroa Valley;
   ii. Accuracy of Flood Modelling;
   iii. Freeboard;
   iv. 100 mm reduction in design flood levels;
   v. Definition of terms;
   vi. 1976 flood event.

Differences between Plan Change 15 and Plan Change 42 Flood Extents in Mangaroa Valley

5. Mr Jefferies submission suggested that the differences between the Plan Change 15 Maps and the Plan Change 42 Maps for the Mangaroa Valley were due to "smoothing". This is incorrect. The changes to the maps between the two plan changes are the combined result of the items described at paragraph 21 in my Evidence-in-Chief and were the outcome of my initial peer review in 2014. Reference is also given to Table 13

of the Jacobs 2015 report - Ma*ngaroa River Flood Hazard Assessment Revision F,* which shows modelled flood level increases of up to + 1.27 m and flood level decreases of – 0.61 m between the 2007 model used for Plan Change 15 and the 2015 model used for Plan Change 42.

6. The key outcome of my initial peer review was that a model calibration difference of up to 38% was unacceptable and that further work was required to calibrate the model to more accurately replicate past measured flood events. The specific reasons for the unacceptable calibration were largely to do with the channel routing approximation in the hydrological model not being equivalent to the actual channel routing determined by the hydraulic model. Further discussion of this is provided in Annex 1 of my Evidence-in-Chief.

7. The model was recalibrated and replicated the February 2004 flood to within 12% of the measured flows and the May 1981 flood to within 14% of the measured flows. Along with a more robust application of freeboard, improved topographic information and the inclusion of climate change the model was accepted as being fit for the purpose of generating catchment scale flood hazard extent maps for the district plan.

Accuracy of Flood Modelling

8. A number of submitters have questioned the accuracy of the flood modelling. I refer to paragraphs 18 to 24 in my Evidence-in-Chief in response to this and add the following by way of further clarification.

(a) Individual Perceptions Based on Past Observations

9. A common theme amongst submitters was their understanding of the flood hazard evident on their property, based on past observations, is different from what is presented on the flood maps.

10. The first point with regard to this is the length of time an individual has been making observations of the river and the likelihood of observing a large flood during this period. It is useful to reference the statistical likelihood of a 100-year return period flood occurring over a defined period to better understand what an individual's observations might relate to. If observations have been made over a long period, such as 50 years there is still only a 40% chance that a 100-year flood event has occurred during this period. This reduces to 18% when considering a 20 year period and 10%

when considering a 10 year period. It is therefore more likely (i.e. greater than 50% chance) that an individual hasn't in fact observed a 100-year flood event.

11. Further to the above, the addition of climate change means that future floods are expected to be larger than we have experience before. In the Mangaroa catchment the current 100-year flood event is estimated to be 365 m^3/s. With climate change this is estimated to increase by approximately 30% to 475 m^3/s. It is highlighted that climate change predictions are based on increases in rainfall of 16-18 % but this typically results in a 20-35% increase in flood flows due to the non-linear catchment response. In simple terms, the additional rainfall is falling on ground that is already wet so there is proportionally a greater amount of run-off and subsequently larger flood flows.

12. Specific reference is given to the submission presented by Mr Williams who referred to the "large floods" that occurred last November in the Mangaroa River. Inspection of the flow record from the Mangaroa at Te Marua gauging station shows that this flood of around 160 m^3/s is only a 3-year return period flood and that later in November 2017 there was another small flood of 140 m^3/s being approximately a 2-year return period flood. Observations of these floods provide little value in terms of validation of the flood model outputs of the 100-year flood event (including climate change and freeboard).

13. A further issue can arise from individual observations within a large catchment where different parts of the catchment experience different rainfall and subsequent flood sizes in any given event. By way of example the 1976 flood significantly affected the Pinehaven catchment with over 300 mm measured in the upper catchment. Similar depths of rainfall fell in isolated, upper sections of the Mangaroa Valley but the measured rainfall for most of the remaining catchment area was less than 150 mm. Mrs Berkett measured 95 mm at her property in the mid-valley zone and the overall flood that occurred, as measured at the Mangaroa River gauging station at Te Marua was around a 20 year flood event. This is discussed further in this supplementary evidence with regard to why the 1976 flood wasn't used for calibration of the flood model.

(b) Catchment Scale Flood Modelling

14. The flood model of the Mangaroa valley is a catchment scale numerical representation of a complex natural system. A number of simplifications are required to allow the model to be constructed and run in a cost effective and timely manner.

15. With specific regard to the Mangaroa catchment, the main river channel has had 130 cross sections surveyed at approximately 150 m centres in the lower reaches and 300 m centres in the upper reaches. These surveyed cross sections form the basis for the 1-dimensional component of the model. This is considered an acceptable level of detail for a catchment of this scale and further, more tightly spaced cross sections would add little value. The 2-D element of the model has been derived from a 1 m^2 LiDAR grid to create a 5 m^2 grid in the model. This again is considered appropriate for a catchment scale model. A schematic representation of a 1-D/2-D hydraulic model is provided in Annex 1.

16. If very detailed site specific topography was surveyed and an alternative method used for the hydraulic analysis at a particular site, then it is quite possible that a different flood depth and extent would be obtained.

17. It must be highlighted that the accepted practice around New Zealand is to use LiDAR for the 2-D component and a grid size of 5 m would be considered normal for a relatively flat, largely rural catchment. The spacing of the cross sections within the 1-D component of the model is also considered acceptable and consistent with what is used in other parts of the country. Further details on the assessment of the model are provided in Annex 1 of my Evidence-in-Chief.

18. It is reiterated that in my opinion the Mangaroa model is in line with industry best practice and fit for the purpose of generating flood hazard maps to form the basis of Plan Change 42.

Freeboard in Mapping

19. Freeboard has been questioned by a number of submitters and there appears to be some misunderstanding of the purpose of freeboard. I again refer to paragraphs 25 to 30 of my Evidence-in-Chief and provide the following for clarification.

20. Freeboard is not an optional extra added to the outputs of flood models. It is an estimate of the upper range of inundation for a given return period flood event. If the modelled flood depth is 100 mm and 300 mm freeboard is considered appropriate then the design flood depth is 400 mm not 100 mm.

21. If appropriate freeboard is not included in the flood extent provided in the district plan then it is possible that future development of areas affected by flooding would proceed without the appropriate controls, such as minimum floor levels, being provided. This is considered unacceptable. Further discussion is provided below regarding removing areas from the flood extent where the depth (including freeboard) is less than 100 mm.

22. The method for application of freeboard for both Mangaroa and Pinehaven catchments is based on the "dynamic" method which is depicted in Annex 1. The "dynamic" method involves adding the designated freeboard to the peak water level in the model and then re-starting the model and allowing the added freeboard to spill out to determine the flood extent. The other method commonly used is referred to as the "static" method which adds the designated freeboard to the peak water level in the model and then extends that out to where that level intersects the land surface. The "dynamic" method is generally preferred as this lessens the potential for exaggerated extents due to the additional volume required to actually fill the floodplain up to the "statically" determined extents.

23. The inclusion of freeboard in flood hazard mapping is consistent with what has been applied across the Wellington Region for the respective district plan maps covering the Otaki, Waikanae & Hutt floodplains as well as the mapping currently being developed for a number of floodplains in the Wairarapa.

24. There is currently no national standard specifying how freeboard is to be determined or applied within a planning context but recent approaches by the Auckland Council and Christchurch City Council to including freeboard within flood maps provides some guidance.

25. Auckland Council provide information covering areas defined as "floodplains" as being the area inundated in a 100 year flood and separately identify wider extents as "flood sensitive areas" as being those areas affected once 0.5 m freeboard has been added to the modelled levels. It is noted that within "flood sensitive areas" there is a

requirement for minimum floor levels to be set at 0.5 m above the 100 year flood level. This is effectively the same as the provisions of Plan Change 42 within the "ponding" areas which will in most cases include the freeboard margin around the outer extent of the flood hazard area and where minimum floor levels are required.

26. The Christchurch City Council (CCC) "flood level and fill management areas" are based on a 200 year flood event and include 250 mm freeboard applied using the "static" freeboard method described above. The "static" freeboard method is applied out to where it intersects the ground surface in areas determined to be within the tidal zone but is limited to a 60 m buffer in all directions for areas upstream of the tidal zone. It is noted that a larger flood event (200 year) is being used as the basis for the CCC maps but also that a lesser amount of freeboard has been applied compared to both the Mangaroa and Pinehaven maps, with the overall net difference likely to be relatively limited. I would also generally expect that the use of the "static" freeboard method, even with the 60 m buffer limit would provide a wider (more conservative) flood extent than the "dynamic" method used for the Mangaroa and Pinehaven models.

27. There are various other methods, terminology and standards used by other councils around the country but the generally accepted practice nationally, as well as the method adopted for the Wellington region, is to use the 100 year flood event and include freeboard in flood hazard mapping.

28. In my opinion freeboard must be added to modelled flood levels to determine the extent to which planning controls should be applied to. Further to this the manner in which freeboard has been determined and applied to the outputs from the Mangaroa model are consistent with the regionally adopted practice as well as the generally adopted national practice and are therefore fit for the purpose of generating flood hazard maps to form the basis of Plan Change 42.

100 mm Reduction in Design Levels

29. In response to submissions a proposed change to the flood extent has been recommended in the 42a report. The proposed change was to remove areas of the flood extent where the design flood depth was less than 100 mm. I, along with Mr Law agreed that this was acceptable and the flood maps were modified by Greater Wellington Regional Council under my direct supervision.

30. The 100 mm reduction was made to the design flood levels <u>including</u> freeboard not to the modelled flood levels without freeboard. This was done by deleting all areas that had a depth (including freeboard) of 100 mm or less.

31. This process did not involve re-running any of the hydraulic models and was solely a mapping exercise undertaken in GIS. This is considered an acceptable approach.

32. It is highlighted that taking 100 mm of the modelled results without freeboard would not be considered acceptable for the reasons explained in paragraphs 19 and 20 above.

33. It is further highlighted that this process has not changed the design flood levels (including freeboard and climate change) at any location in the Mangaroa or Pinehaven catchments, rather it has limited the extent over which the district plan controls apply to areas where the design flood depth is greater than 100 mm.

Definition of Terms

34. Questions have arisen over the terminology used to describe the different hazard zones with particular reference to the New South Wales Guidelines and the Hamilton City Council flood hazard maps. The definition of terms is covered in paragraph 33 in my Evidence-in-Chief and it is highlighted that the depth x velocity criteria relating to high, medium and low hazard areas is consistent with that provided in the New South Wales Guidelines.

35. The terminology used for these different hazard zones (river corridor, overflow path and ponding) is consistent with those applied across the Wellington region.

1976 Flood

36. The 1976 flood was not used to calibrate or verify the hydrological or hydraulic model of the Mangaroa catchment. The primary reason for this was that Mangaroa River gauging station at Te Marua was not yet operating at this point so there was no accurate record of the flood flows that occurred during the event.

37. However, I have undertaken some analysis on the 1976 flood in response to questions from Mrs Berkett. This analysis showed that although this was a large event in the Pinehaven catchment with approximately 300 mm of rainfall in a 24 hr period, the Mangaroa catchment was affected to a much lesser degree with Mrs Berkett measuring

95 mm of rainfall over the same period which was consistent with the other rain gauge measurements from the Mangaroa catchment.

38. The best approximation of the size of the 1976 flood event is based on the measured flows from the Birchville gauging station on the Hutt River. Using this as a proxy suggests that the 1976 flood event was approximately a 20-year flood event of around 250 m^3/s being similar to the 1981 and 2004 flood events that were used to calibrate the model.

39. A summary figure of the rainfall and estimated river flows in the Mangaroa catchment is provided in Annex 3.

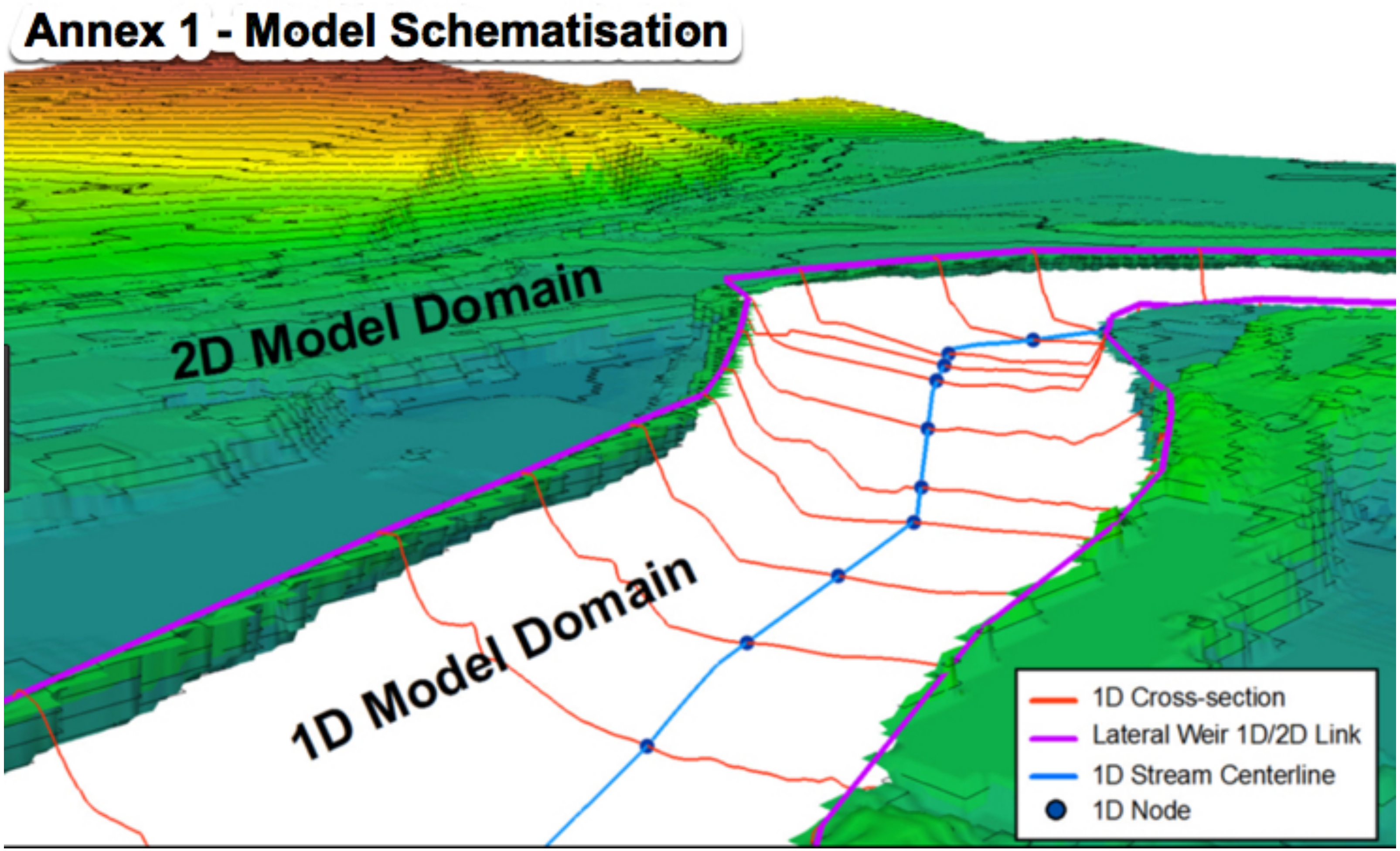
Conclusion

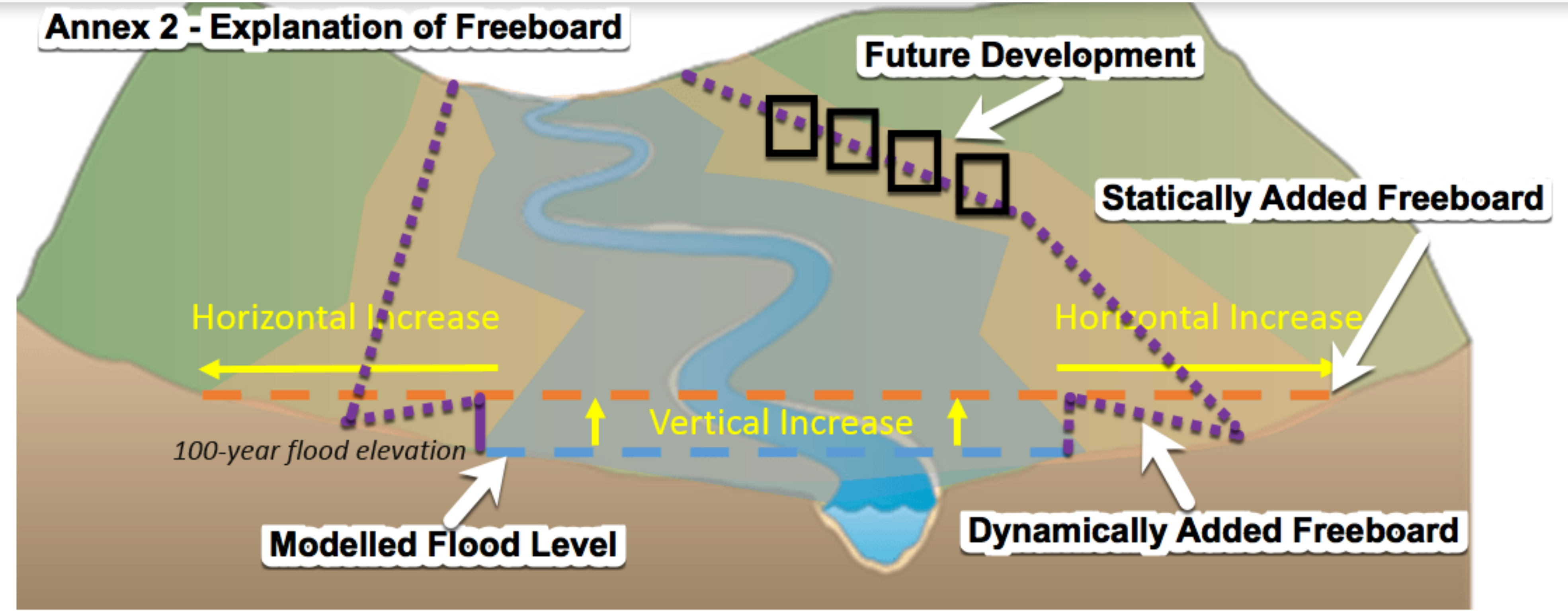
40. The supplementary evidence presented above is largely clarifications and further details as requested during the course of the hearing. The conclusions of my Evidence-in-Chief still stand and I re-iterate the primary conclusion that the flood modelling and mapping for the Mangaroa Catchment that form the basis for Plan Change 42 are in-line with industry practice and fit for purpose.

Signed:

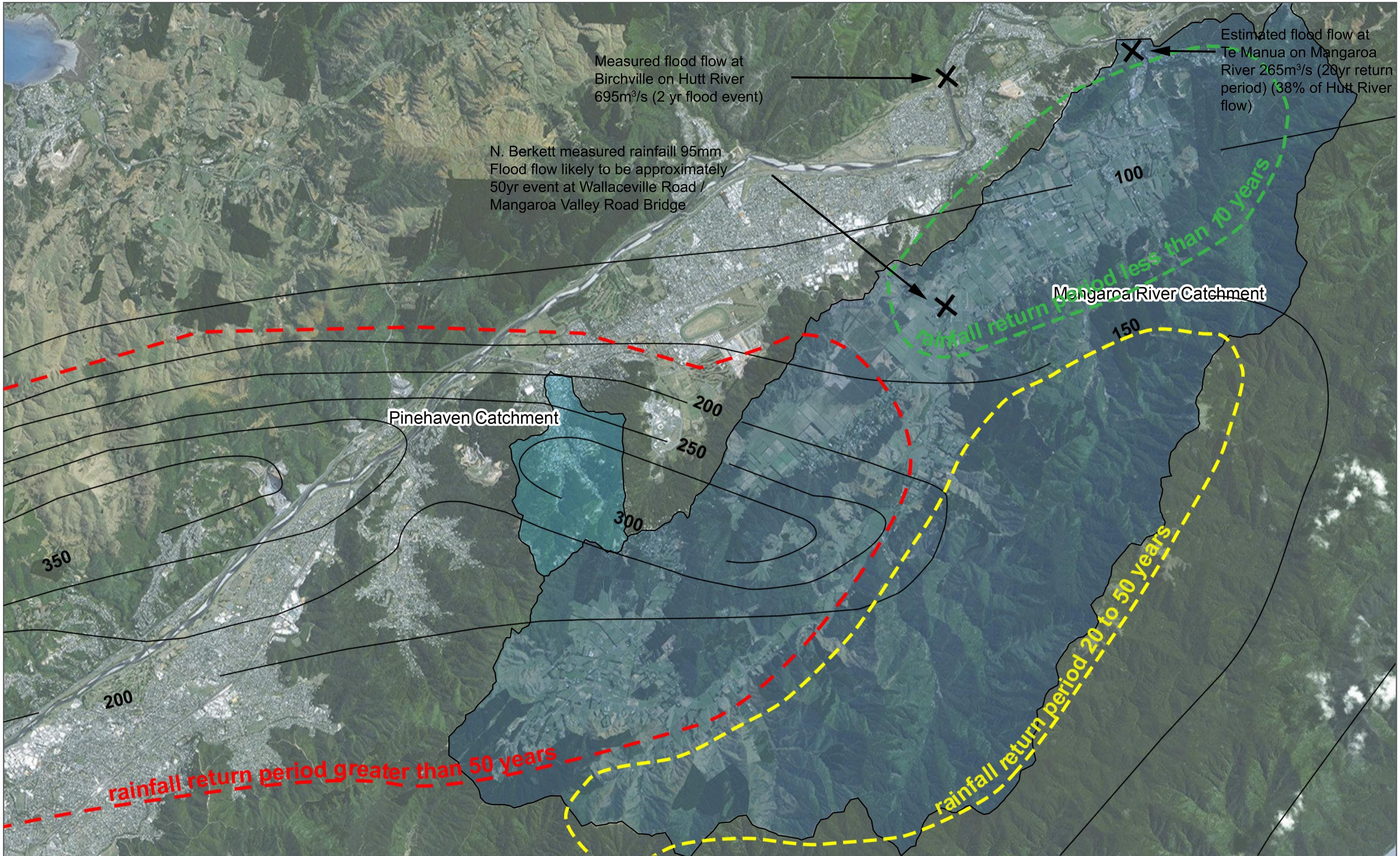
Kyle Christensen

Date: 19 October 2017


Annex 1 - Model Schematisation
2D Model Domain
1D Model Domain
1D Cross-section
Lateral Weir 1D/2D Link
1D Stream Centerline
1D Node


Annex 2 - Explanation of Freeboard
Future Development
Statically Added Freeboard
Horizontal Increase
Horizontal Increase
Vertical Increase
100-year flood elevation
Modelled Flood Level
Dynamically Added Freeboard

Annex 3 – Summary of Hydrology of 1976 Flood Event



Mangaroa Flood Hazard

24hrs - Rainfall 20 December 1976

1:60,000Scale at A3

Metres

0 1,000 2,000 3,000

Cardno

Map Produced by Cardno (NZ) Ltd
Date: 2015-12-16
Coordinate System: NZGD 2000 New Zealand Transverse Mercator
Project: NZ0113259
Map: NZ0115064 - Mangaroa Flood Hazard Rainfall_mapC.mxd 02