BEFORE THE HEARING PANEL

IN THE MATTER	of the Resource Management Act 1991
A N D	
IN THE MATTER	of the Proposed Plan Change 29 to the Nelson Resource Management Plan

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REPLY (FLOODING)

DAMIAN NATHAN VELLUPPILLAI

17 October 2024

INTRODUCTION

QUALIFICATIONS AND EXPERIENCE

1 My full name is Damian Nathan Velluppillai. I have prepared a Statement of Evidence dated 21 June 2024, a Statement of Rebuttal Evidence dated 15 August 2024 and a Summary Statement of Evidence dated 23 August 2024.

2 I am a Chartered Professional Engineer with 22 years of experience in flooding and stormwater assessment in New Zealand. My qualifications and experience are outlined in my primary evidence.

CODE OF CONDUCT

3 I reconfirm that I have read the Code of Conduct for expert witnesses contained in the 2023 Environment Court Practice Note and that I agree to comply with it.

BACKGROUND

4 NCC received a number of submissions questioning the accuracy of flood mapping in the lower Brook/Waimarama Stream floodplain. The most comprehensive submission on this was S20.011 by submitter Mr. Tim Bayley.

5 A response to these submissions was provided in my evidence dated 21 June 2024 (refer paragraphs 21-28).

6 Further material and explanation was provided by Mr. Tim Bayley (individual submission S20.011) and Mr. David Gibson (block submission S741) in oral submissions on 4 September 2024 as part of the hearing process.

7 The matters raised are summarised as follows:

a Capacity of the Nile/Tasman culvert, including difference between PC29 layers and flood mapping presented in a T+T flood report for Kāinga Ora's proposed 107 Nile Street development;

b Capacity of the lower Brook/Waimarama channel between Nile Street and the Maitahi/Mahitahi River (also often referred to as the Maitai River);

8 Other matters, e.g. effect of king tides, Maitai Dam drawdown, residential evacuations within the Hardy/Tasman/Domett Street block during August 2022.

EVIDENCE STRUCTURE AND SCOPE

9 I will set out some general comments relevant to the submissions by Messrs Bayley and Gibson, before addressing each of the three matters above. I then present a summary of my main opinions and conclusions.

GENERAL COMMENTS

10 Figure 1 below presents the lower Brook/Waimarama floodplain with the two main drainage elements referred to in submissions – the Nile Street culvert intake and the lowest reach of the Brook/Waimarama Stream between Nile Street and the Maitahi/Mahitahi River. The three proposed PC29 flood layers that were based on the river flood mapping area shown.

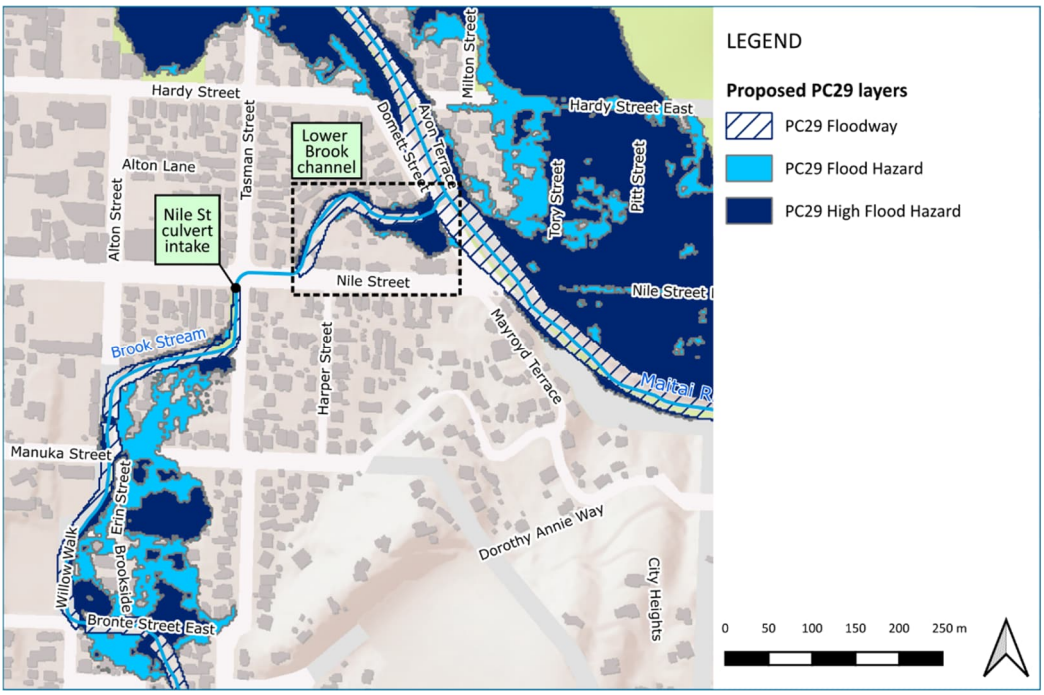


Figure 1 – Lower Brook/Waimarama floodplain at Maitahi/Mahitahi confluence showing areas of interest

11 The three proposed PC29 flood layers shown above are based on NCC's current river flood modelling for the Maitai/Mahitahi River and Brook/Waimarama Stream. As set out in my primary evidence, NCC periodically updates these flood maps to take account of latest information (e.g. climate change projections, ground survey information and flow gauge data). The updated modelling results are then peer-reviewed before being released to the public and used to inform new development and land use planning. The river flood mapping used for PC29 in this area is from modelling undertaken in 2020/2021.

12 The PC29 flood mapping significantly increases the extent of mapped flood hazard in the lower Brook/Waimarama and Maitahi/Mahitahi floodplains

compared with the existing NRMP layers. This is due to the 2020-2021 river flood modelling including projected climate change effects on rainfall intensities.

13 Given the magnitude of the August 2022 event and the significant amount of data that NCC was able to collect from this event (including surveyed peak flood levels along the main watercourses, rainfall and flow data, photographs and videos), NCC is currently using this data to refine the model calibration. This refinement is still in progress. As described in later sections of this written reply, early indications are that mapped flooding may increase in some areas, for example at the Nile Street culvert intake.

14 Observations, photos and videos from the August 2022 event provided by submitters are valuable additions to the information held by NCC and is also being used to support further model calibration.

15 It is also important to note that river flooding is not the only source of flooding for Nelson City. NCC acknowledges that there are significant flooding issues around the city associated with stormwater (pluvial) flooding not captured in the river flood mapping. NCC is currently developing coastal and stormwater flood models to complete the mapping of flood hazard across the city. I anticipate that the overall extents of flooding will increase beyond the current mapping once stormwater and coastal hazard mapping are included. Some of the stormwater and coastal inundation areas are already captured in the NRMP flood layers that are proposed to be retained in PC29. These areas are based on historic flood observations. As the stormwater models will also be able to represent flooding from the river systems (i.e. will include both fluvial and pluvial flooding), I understand NCC plans for these maps to supplement or supersede the river flood mapping and older NRMP flood overlays once they are completed and peer-reviewed. In the meantime, it is my opinion that the currently proposed PC29 layers represent the best peer-reviewed fluvial/pluvial flooding information available for land use and activity planning.

NILE STREET CULVERT CAPACITY / 107 NILE STREET FLOOD ASSESSMENT

16 Messrs Bayley and Gibson submit that the capacity of the Nile Street culvert intake appears to be overestimated in the existing (2020/2021) river model, and that the model therefore under-represents flooding at that location. Mr. Bayley bases his assertion on his observations of flood velocity, depth and flow rate during the August 2022 flood event, and his measurements of the intake

dimensions. He also references a Tonkin & Taylor Ltd (T+T) report for Kāinga Ora's development at 107 Nile Street that considers the possibility of more extensive flooding in this area.

17 My response, set out in the following paragraphs, refers to a number of different flow values associated with this culvert intake. I present these values in the following table.

Table 1 Nile Street culvert flow values

Description	Flow value (m^3/s)
Modelled present-day 1% AEP flow	68
Modelled 2130 RCP8.5M 1% AEP flow	99
Original design flow capacity used in the 1970s and 1980s Lower Brook flood protection works (including the Nile Street culvert, and channel between the culvert and the Maitahi/Mahitahi River)	100
Culvert intake capacity used in the 2021 flood modelling / PC29 flood mapping	>99
Culvert capacity used in the 107 Nile Street assessment	Approx. 79 (i.e. assumed ~20 cumecs of overflow at the intake in a 2130 1% AEP event, due to either insufficient capacity and/or blockage)
Recalibrated culvert capacity following August 2022 data capture	~80 m^3/s to top of culvert ~90 m^3/s before overtopping onto road

18 I agree that the representation of the culvert requires refinement in the river flood model, and that outbreak flooding is likely at this location in the 2130 RCP8.5M 1% AEP event (currently estimated to result in a peak flow of 99 m^3/s at the culvert) that is not shown in current modelling. I note that:

a there have been no observed events that have surcharged the culvert soffit and made use of the available heading area at the intake since it was constructed almost forty years ago in the 1980s. However, this is a relatively short timeframe hydrologically and statistically speaking, and also doesn't provide a good indication of the potential effects of climate change;

b as described further below the original lower Brook/Waimarama flood scheme design (which included the use of a physical scale model) was based on a scheme capacity of 100 m³/s according to available design documents from the 1970s and 1980s. At the time of design, this was believed to be the 1 in 100 year (1% AEP) flood event in the Brook/Waimarama. It is therefore reasonable to assume that the original designers sized the intake to accommodate a 100 m³/s flow. The latest hydrological analysis suggests that this flow is likely to approximately represent a future (2130 RCP8.5M) 1% AEP catchment flow rather than a present-day one. This analysis is based on current rainfall depths and storm profiles (NIWA HIRDS v4) and MfE climate projections, and is subject to change when these datasets/guidance are updated;

c as described below, August 2022 flood observations indicate that the intake capacity of the culvert is about 90 m³/s, i.e. less than the 2130 RCP8.5M 1% AEP flow of 99 m³/s, and therefore some overtopping can be expected in this future design event.

19 Notwithstanding the above, T+T undertook further analysis of the Nile Street culvert intake for the purposes of providing flood advice to Kāinga Ora for their resource consent application to develop at 107 Nile Street. The 107 Nile Street assessment used a different flood model, which is described in more detail in a later section, however it is worth noting here that the two main reasons for not basing the 107 Nile Street assessment on NCC's current river flood mapping were that:

a The site is potentially affected by flooding from local stormwater catchments as well as potential outbreaks from the river in extreme events. The river flood model does not account for the local piped stormwater network whereas the stormwater model used for the assessment accounts for both stormwater and river flows.

b For the purposes of a site-specific flood assessment, a precautionary approach was taken to setting minimum development levels and assessing potential effects on neighbours. It is appropriate to take a different approach for a site-specific flood assessment than for a catchment-wide assessment. This site-specific assessment included consideration of over-design events where local overland flowpaths may

be more extreme than shown in catchment-wide 1% flood mapping, for example if local culverts or channels had reduced capacity. Particularly given that the site is located in a local low point in terms of ground contours and that elevated floor levels could be achieved without unduly constraining the development design, it was considered prudent for the purpose of the development to adopt a more conservative set of flooding assumptions than was used as a basis for the PC29 flood layers.

20 T+T's original flood assessment for 107 Nile Street dated June 2023 was based on a conservative (low) assessment of 60-70 m^3/s for the culvert intake capacity, on the basis that it was important to understand how any overflows from that location may impact the development site, e.g. under a blockage scenario.

21 During the resource consent application process, NCC requested further analysis and commentary on the difference between the flooding shown in the 107 Nile Street assessment and their river flood modelling on which the PC29 layers are based (Request for Further Information letter dated 24 August 2023).

22 T+T undertook further analysis to inform their response and issued an updated flood assessment dated December 2023 that included additional assessment of the culvert intake. This assessment found that the culvert intake capacity is likely higher than assumed in the original assessment for 107 Nile Street, though less than assumed in NCC's river flood modelling. As part of their regulatory/compliance review, NCC had the 107 Nile Street modelling and reporting (including the updated culvert intake capacity assessment) peer reviewed.

23 Based on the findings of the 107 Nile Street assessment during 2023, a task was added to NCC's river flood model improvement opportunity log to review the representation of the Nile Street culvert intake in the river flood model. NCC is currently undertaking this refinement as part of the model recalibration, using:

a information collected from the August 2022 flood event, and

b analysis of the culvert undertaken as part of the 107 Nile Street development.

24 The model refinement is currently underway and will need to be peer reviewed before being released to the public. Current indications are that:

a the capacity of the culvert up to top of culvert is about 80 m³/s, and about 90 m³/s before flow heads up enough to spill onto Nile Street. The refined rating curve for this culvert intake shows a good match between the August 2022 event observation, and the 107 Nile Street assessment. It shows that the August 2022 flow level is underestimated in the existing river flood model.

b there is therefore likely to be an additional overland flowpath from the culvert intake in events exceeding about 90 m³/s, compared with what is shown in PC29 flooding layers. However, this flooding will be significantly less than was assumed for the 107 Nile Street assessment, and significantly less than indicated in Mr. Bayley's submission.

25 As the model update is still in progress at this time and has not yet been peer-reviewed, I can only provide preliminary and provisional flood mapping for this outbreak (approximately 9 m³/s of outbreak flows at the peak of the 2130 RCP8.5M 1% AEP flood event). The figure below presents existing PC29 flood hazard extents in blue, with the additional flooding outbreak due to the model refinement in yellow and orange. As shown, I anticipate that in the residential block that is the subject of Messrs Bayley and Gibson's submissions, the additional flood extents would largely be confined to the Tasman Street carriageway with potential residential flooding along the frontages of Tasman Street properties and on the margins of the Brook/Waimarama Stream, rather than more widely through that block. This is significantly less than the extent estimated by Mr. Bayley in his submission.

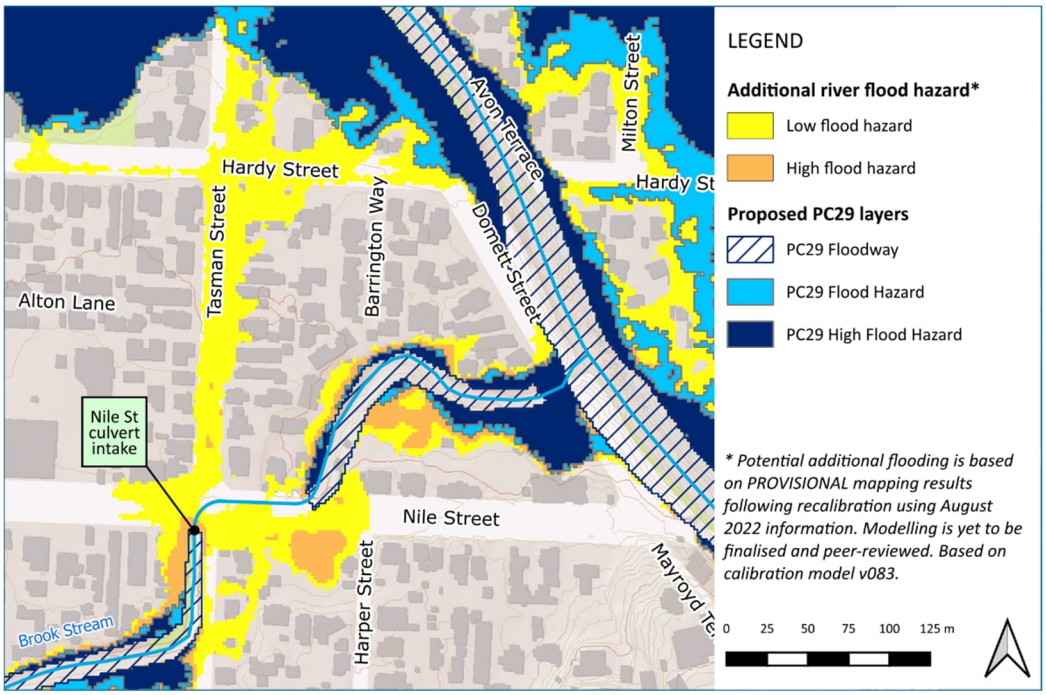


Figure 2 – Provisional results from the model refinement (yellow/orange) show additional flooding areas in the Lower Brook/Waimarama floodplain.

26 On the basis of this provisional flood mapping, I consider that flood hazard affecting any new development in this block can be managed in the same way as proposed in PC29 for other residential areas within the city also affected by river flooding and note that this opinion aligns with Mr. Toby Kay's opinion in Section 6.6 of his evidence.

LOWER BROOK/WAIMARAMA STREAM CHANNEL CAPACITY

27 Messrs Bayley and Gibson also submit that the capacity of the lower Brook/Waimarama Stream channel appears to be overestimated in the existing river model, and that the model therefore under-represents flooding in that reach. They refer to the high tailwater conditions provided by the Maitahi/Mahitahi River as being a governing factor at this site, they provide an alternative flood map showing extensive flooding up to RL 9 m and provide a range of observations from the August 2022 flood event in support of their submission. In particular, the observation is made that at the peak of the August 2022 event, flood flows were in the order of 30-40 m^3/s, with a cross-sectional flow area of about 30 m^2, and therefore with an average flow velocity in the lower channel of about 1 m/s. Given that this flow exceeded the banks of the concrete flood walls and based on the observed flow depth under the Domett Street bridge, Messrs Bayley and Gibson estimate that the flow capacity of this

channel cannot be much more than the August 2022 event peak flow when Maitahi/Mahitahi River levels are elevated.

28 I concur with much of their submitted analysis of flow behaviour during the August 2022 event and will show in the following paragraphs how these observations match reasonably closely with the modelling (notwithstanding the current work being done to refine the model further). However, I do not concur with the way they have extrapolated from the August 2022 event conditions to estimate the maximum channel capacity, or their mapped 2% annual exceedance probability (AEP)[1] flood extents.

29 In particular, the flood extents estimated in Mr. Bayley's submission appear to be significantly overestimated. His submission includes a figure of the area overlaid with blue lines labelled "Flood line 9m +" (where the 9m refers to a ground contour). It is not clear how these extents have been estimated, however I note that the flood line appear to climb up above the RL 10 m ground contour on the north side of the stream. In one section of the submission, it is referred to as the 100 year event, and in another the 50 year event. In my opinion, the flooding area indicated is significantly in excess of the expected flooding in a 2130 RCP8.5M 1% AEP event. As shown in Figure 2 above, while there is likely some additional expected flooding in this area, it is largely "low hazard" flooding, i.e. both less than 0.3 m in depth and less than 2 m/s in velocity (and mostly significantly lower than these thresholds).

30 I believe this is largely because of the incorrect assumption used that the flow velocity observed in August 2022 (~1 m/s) is approximately what could be expected for much greater flow rates, and therefore that a much larger cross sectional flow area would be needed to pass much larger flood flows. However, this is not the case. For a given water level in the Maitahi/Mahitahi River, the cross sectional flow area needed to pass Brook/Waimarama Stream flows into the Maitahi/Mahitahi River does not increase linearly with flow. i.e. as Brook/Waimarama Stream flows increase, so too does flow velocity. Consider the hypothetical case where Maitai/Mahitahi River levels are elevated, but there is only 1 m^3/s of flow in the Brook/Waimarama Stream. Water levels (and therefore cross-sectional flow area) in the lower Brook/Waimarama channel

[1] Often referred to as a 1 in 50 year event (or a 50 year average recurrence interval event).

would be very high due to the tailwater conditions in the Maitahi/Mahitahi River, but the average flow velocity through the channel would be very low (1 m^3/s through about 30 m^2 flow area gives a cross-sectional average flow velocity of only approximately 0.03 m/s). If the Brook/Waimarama Stream flows were then increased by a factor of ten to 10 m^3/s, we would see very little change in cross sectional flow area (and water levels), but an almost ten-fold increase in flow velocity to about 0.3 m/s. Multiply this by a factor of three again, and you get approximately the conditions observed by Mr. Bayley in August 2022. This non-linear relationship between flow and water level continues beyond 30 m^3/s.

31 Illustrated another way, the figure below shows the modelled velocity-elevation (VH) curve at this location. i.e. it shows how flow velocity changes as the water level increases due to increased Brook/Waimarama Stream flow and Maitahi/Mahitahi River tailwater. Two storm plots are presented – the modelled August 2022 flows (peaking at 40.2 m^3/s at the Seymour Ave flow gauge on the Brook/Waimarama Stream), and the design 2130 RCP8.5M 1% AEP 24hr storm flows (peaking at 99 m^3/s at the Nile Street culvert intake). Both plots assume elevated river levels in the Maitahi/Mahitahi River.

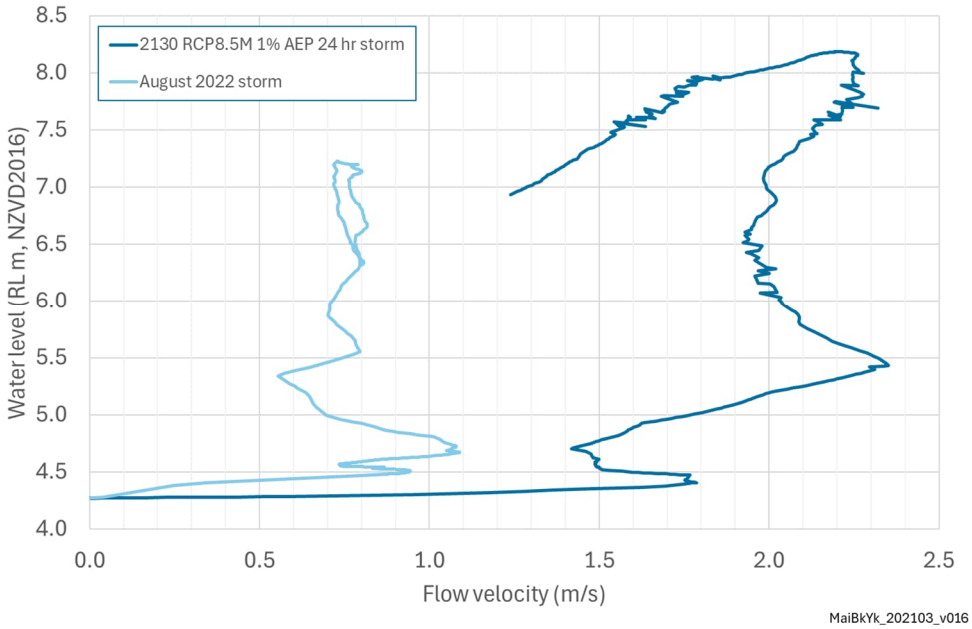


Figure 3 – Modelled velocity-head curves from PC29 river flood model for August 2022 and a design future event, assuming relevant tailwater levels in Maitahi/Mahitahi River.

32 I note that in my primary evidence I referred to flow velocities in this channel reaching up to 3-4 m/s, even in high tailwater conditions. To clarify, I was

referring to peak velocity results from the draft 2d stormwater modelling used for the 107 Nile Street assessment that allows for variation in flow velocity across the channel. This is different to the cross-sectional average flow velocity as used in Mr. Bayley's calculations, or as results from 1d modelling. In reality, the flow velocity varies across a river cross section, with generally higher than average velocities in the more central and upper parts of the cross section, and lower than average velocities elsewhere. For comparative purposes, the cross-sectional average flow velocity from the 2d model (i.e. as corresponds to the peak velocities of 3-4 m/s I reported earlier) is in the order of 2-2.5 m/s, when Maitahi/Mahitahi River levels are elevated. As shown in the figure above, this equates to a significantly higher flow capacity than was observed during the August 2022 event.

33 The figure above clearly shows that the model agrees very well with Mr. Bayley's observation during the August 2022 flood event, that the peak flow velocity in this part of the channel was about 1 m/s. When the modelled August 2022 event is at peak water level, the average flow velocity is modelled as 0.7 to 0.8 m/s. It is likely that parts of the channel would be flowing both faster and slower than this.

34 However, the modelling disagrees significantly with Mr. Bayley's assertion that with elevated Maitahi/Mahitahi River levels, the Brook/Waimarama Stream flow velocities will not get significantly above 1 m/s at higher Brook/Waimarama Stream flows. The modelling shows that higher Brook/Waimarama Stream flows would drive significantly faster flow velocities (2-2.5 m/s cross sectional average) so that much greater flow rates are possible with only modest increases in flood levels. This is also corroborated by the original design information from the 1980s.

35 I concur with Mr Bayley that the Domett Street bridge capacity is another key factor at this location and confirm that this is taken into account in the modelling. NCC holds survey information provided by Jones and Associates Ltd from 2015 that the bottom of the bridge deck is at RL 8.0m (NZVD2016 datum). I confirm that this level is reflected in the flood modelling. Mr Bayley notes that gravel accumulation may reduce flow capacity below modelled values. While this is possible, observations of gravel movement down the Brook/Waimarama Stream indicate that as extreme/flood flows develop in the Brook/Waimarama

in response to catchment runoff, accumulated gravel tends to be flushed through the channel during the rising and peak limbs of the storm flow hydrograph, with deposition of gravel occurring in the falling limb as flow velocities slow. Therefore, under typical gravel transport conditions, channel flow capacity tends to be maintained when flows are highest, and then may lessen with gravel accumulation after the peak flows have passed.

36 A further point to note in relation to the capacity of this part of the channel is that NCC holds information from the 1980s when the channel was originally designed, following the 1986 flood event. While the original design report has not been able to be located, a letter from the Ministry of Works and Development to the Nelson Catchment Board dated 3 March 1986 reports that "the design flood is 100 cumecs". This design capacity is confirmed in a paper jointly written for the Water and Soil publication (Dec 1975/Feb 1976 issue) by an NCC staff member and a designer from Worseldine and Wells. A Worseldine and Wells design drawing Plan 26/359 Sheet 2 of 5 approved 18 February 1987 shows that the design for this section of channel used a Maitahi/Mahitahi River tailwater level of RL 19.81 m (NCC Datum), equivalent to RL 7.61 m NZVD2016 datum. This level is very similar to what was observed in the August 2022 event, further supporting NCC's modelling that indicates a significantly higher capacity than the 45 m^3/s or so as posited by Mr. Bayley.

37 Thus, given the information above, while there is certainly an opportunity to refine the flood model in this reach between Nile Street and Domett Street using August 2022 information (including with respect to Maitai/Mahitahi River levels), I do not agree with Mr Bayley that there is "a serious anomaly" in the modelling. Both the model and verification hand calculations show that much higher flows can be passed through this channel than estimated by Mr. Bayley, even while Maitai/Mahitahi River levels are elevated.

OTHER MATTERS RAISED

38 Mr Gibson submitted that there is "even a greater risk [of flooding in the lower Brook/Waimarama] should there be a King Tide or if there is a need to release water from the Maitai Dam during a flooding event as there was in the August 2022 floods". In response:

39 The flood modelling used for PC29 is based on a mean highest high water (MHHW) tide (present-day tide peak level of RL 1.21 m) and includes allowance

for 1.11 m of sea level rise between the 2008-2017 baseline sea level and 2130. I agree that more extreme tides (e.g. a 'king tide' with a present-day peak level over RL 1.7 m) will result in worse flooding in the lower parts of the city. However, the river bed level at the confluence of the Maitahi/Mahitahi and Brook/Waimarama is well above even a 2130 'king tide' level, and the influence on flood behaviour at the confluence is expected to be minimal, even by 2130. Furthermore, the PC29 modelling is based on advice from NIWA on the combined probabilities of extreme river flows and extreme sea levels. NIWA reports that more extreme combinations than has been modelled are indeed possible, but would have a combined probability significantly less than the 1% AEP event selected for the purposes of flood mapping.

40 During the August 2022 event, NCC did not release water from the Maitai Dam beyond the normal operating regime. All outflows from the dam were via the service spillway that remains operative at all times (except for a minor amount of scour valve and stream augmentation flows). In an emergency event where NCC may need to dewater the dam (e.g. following earthquake damage to the dam), the maximum dewatering rate is at least an order of magnitude less than the modelled 1% AEP river flows, with a rate and timing that is controllable by the dam operators.. Any emergency measures associated with extreme water levels in the Maitai Dam are therefore not expected to pose flood risk to the lower Brook/Waimarama floodplain above the design 2130 RCP8.5M 1% AEP flood event.

41 Mr Gibson also referred to evacuations of residential property in the lower Brook/Waimarama floodplain during August 2022. He submitted that the fact that evacuations were being carried out or at least considered for residents in this block, may be an indication of flood hazard, exposure to which should not be increased through housing intensification., I note that in the early part of a major rainfall event, it is usually very uncertain as to who may be affected by any flooding, or by how much. Organisations involved in civil defence work may arrange evacuations as a precautionary measure in areas either known to flood in design events, or in case the event exceeds the level of service and/or design standards used for development in a particular area.

CONCLUSIONS

42 I agree with submitters that there is a flood outbreak missing from the PC29 flood hazard layers at the Nile Street culvert intake on the Brook/Waimarama Stream. While the existing PC29 flood mapping aligns with the original design intake capacity of 100 m³/s, recent work by T+T on the Kāinga Ora site at 107 Nile Street indicates that overflows are likely for flows exceeding 90 m³/s. The PC29 flood mapping is based on a 2130 RCP8.5M flow event which peaks at 99 m³/s, so I would expect overflows at this point to peak at 9 m³/s, based on current hydrological information and climate projections. Finalised mapping of this outbreak flowpath is not yet available, however preliminary mapping has been presented above. Enough work has been done (and peer-reviewed) for the Kāinga Ora site to be confident that outbreak flooding in the design event will be significantly less than was assumed for the 107 Nile Street site development.

43 As NCC's stormwater models throughout the city are developed, peer-reviewed and released, I expect further flood hazard areas outside existing river flood mapping used for PC29 to be identified. i.e. the Nile/Tasman/Domett residential block will not be unique.

44 I disagree with submitters that there are major issues with the modelling of the lower Brook/Waimarama Stream. Observations made during August 2022 are being used to refine the model, but refinements will be relatively modest, and nothing like the scale of change suggested by submitters. As described in my evidence, this is largely due to the ability of channel flow velocities to increase as Brook/Waimarama flows increase, even with high tailwater conditions. Original design information available for this section of the channel, constructed in the 1980s, also indicates a much larger capacity than posited by Mr. Bayley.

45 I do not expect other factors raised (king tides and Maitai Dam emergency operations) to present higher river flood risk for this block than estimated using the river flood model.



Damian Nathan Velluppillai
17 October 2024

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