Report – Takitimu North Link Stage 2 Specimen Design – Culverts Bridges and Streams

Review of Fish Passage Component by Ruth Goldsmith, Principal Ecologist, 4Sight – Part of SLR.

Comment: Table 3-3 of the Specimen Hydraulic Design Report provides a summary of proposed fish passage features at each culvert. Of the 13 culverts listed only three have been identified as requiring fish passage. There isn't sufficient information provided within the table (or the report body) as to why fish passage is not required at the other 10 culverts. The justification for not requiring fish passage at these culverts is also not included in any detail within the Ecology Report.

Response: Table 3-3 has been updated to clarify the three different types of approaches used, full fish passage provided, Limited fish passage provided and no fish passage required. A new section has been added to the text to explain the justification used for the culverts in each of the categories.

Comment: The modelling approach used in the Specimen Hydraulic Design Report to confirm that fish passage requirements will be met deviates from that presented in the New Zealand Fish Passage Guidelines (Franklin et al. 2023). The approach used may be appropriate, however it is not possible to determine this from the information presented, and more explanation is required as to why a different approach was used.

Response: In the original text, the text refers to Franklin et al. 2023, which are the updated New Zealand Fish Passage Guidelines. These guidelines are expected to be released to the public in March 2024. Hence, they are not currently available to the public but will be available and therefore be current at the time of the consent hearings, which is why they have been used for the design. However, this has understandably caused confusion when comparing the text to the 2018 version which is significantly different. The design for TNL 2 follows the design methodology for culverts with fish passage (Kikkert et al., 2023) that has been incorporated in the updated New Zealand Fish Passage. To clarify the approach, this reference has been added to the text. In addition details of the updated fish passage requirements for culvert have also been added to the text in section 3.1.3 and a presentation that was given to the NZ Regional Councils, DOC, MFE and NZTA has been attached in Appendix I.

Comment: TNL-11560 is the longest of the proposed culverts that require fish passage, however baffles should also be considered for other wide and long culverts, including TNL-5160, which is 46 m long.

Response: The length is taken into account as part of the velocity requirement of the culvert, i.e. the velocity has to be sufficiently low that the target species of fish at the 75% quantile is able to use its prolonged swimming speed and duration to swim from the resting places in the stilling basin downstream of the culvert to the resting places in the stilling basin upstream of the culvert. If the target species of fish cannot make it from the downstream to the upstream stilling basin, because of the length of the culvert, baffles are considered to create intermediate resting places, hence their use in culvert TNL-11560. Baffles are used as a last resort. In the case, the culvert is simply too long and the extreme skew of the stream to the new highway prevents the use of a bridge. For culvert TNL-5160, the minimum distances that the target species of fish can swim during the fish passage design flow rates are 74m and 64m (for the $1/10^{th}$ of the 2yr and 0.5 of the 2yr respectively). As this distance is larger than the length of the culvert at 46m, no intermediate resting places are necessary, hence no baffles are proposed.

Comment: It is not clear how the presence of perennial flow (i.e., year round flow) provides justification for not providing fish passage.

Response: It is not. The wrong word was used, it should have said 'ephemeral flow'. In addition, the wording 'not providing fish passage' is misleading. Just as for the culverts, stream realignments will either have full fish passage or limited fish passage. However, unlike the culverts there are no specific guidelines for the design of stream realignments that result in (full) fish passage. Instead, the stream realignment will be designed to mimic an unmodified existing stream that might have existed in that location. For stream realignments with small grades this will result in full fish passage for species of fish that live within the local fish habitat. For stream realignments with steep grades, the stream realignment will consist of drop structures with relatively flat grades in between the drop structures. This will enable the stream realignments to make the elevation difference while also protecting the constructed stream from erosion during large storm events. Because of the drop structures, the stream realignment will provide limited fish passage, predominantly for climbing species. However, it is likely that because of the steep grades in the existing condition, these were the only species in the existing condition as well. Section 5.2 of the report has been updated to reflect the above.

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Review of Hydrology and Hydraulic Components by Graham Macky, Macky Fluvial Consulting Ltd

Comment Reviewer: p12-13 - There seem to be minor inconsistencies between the rainfall depth tables and directly accessed HIRDS data. Not significant, but Zone C depths are overestimates for the Waipapa headwaters.

Response Designer: The rainfall depth tables presented in the text were obtained from HIRDS, but likely not at the exact same locations as the HIRDS data obtained by the reviewer. As the terrain is steep, there are significant elevation differences with higher rainfall intensities expected closer to the top of the hills. The slightly higher rainfall depths presented in the text may perhaps indicate that the rainfall data was obtained slightly further up the catchments.

Response Reviewer: No action needed.

Comment Reviewer: p13 - I agree that hydrological routing is unlikely to be significantly affected by whether the stream main channels are identified by LiDAR. Perhaps more uncertainty arises from the underlying assumptions of overland flow.

Response Designer: Within SWMM the overland flow is included in the subcatchment calculations that turn rainfall into run-off. The parameters available that affect the overland flow are the Manning's n, the percentage imperviousness, the slope and the longest flow path via the area and width of the subcatchment. The runoff hydrograph is sensitive to these input parameters, especially the width which yields the longest path. However, without calibration data it is not possible to estimate the accuracy of the overland flow from the subcatchments and this data would be very difficult to obtain. Hence the input parameters were based on the best knowledge available for each subcatchment.

Response Reviewer: No action needed.

Comment Reviewer: p14-15 – The assumed Manning's values are reasonable, but the two paragraphs don't agree. .0.13 for culvert pipes is perhaps low (being an accepted value for a concrete pipe but not allowing for ad hoc flow resistance such as joints) but frictional head loss within culverts is significant only if they are particularly long.

Response Designer: Manning's n for culverts with embedment was set to 0.028. Text has been updated so that the two paragraphs agree. For concrete, the standard n value was used. It is agreed that frictional head losses are small for most culverts in comparison with the inlet and outlet losses which were given coefficients of 0.5 and 1 respectively in the model.

Response Reviewer: No action needed.

Comment Reviewer: p15, para 3 - Does this describe an iterative culvert design or just finding complying input conditions (flows and water levels)?

Response Designer: It was finding the right set of culvert design parameters (such as size, invert levels, invert offsets (for multi-cell culverts) and grades) so that all the requirements were met. In general, this meant starting with finding a suitable design that met the fish passage requirements, as these generally result in a larger size culvert than the other requirements. The culvert hydraulics were then checked for the other requirements. If the culvert did not meet the other requirements, for example, the proposed culvert size did not yield sufficient cover to the road surface, the affected design parameters were changed. It was then checked whether fish passage requirements were still met, followed by the other requirements. The procedure was repeated until all requirements were met by the proposed culvert design.

Response Reviewer: That's good. You could perhaps change the wording slightly, e.g.: "using the culvert and site input data adjusting he culvert design".

Response Designer (2): Text has been updated accordingly.

Response Reviewer (2): Comment Resolved.

Comment Reviewer: p15, para 4 - Could there have been any undesirable outcomes with the PMF that the 100-year simulation didn't warn of?

Response Designer: It is very likely that with the PMF there will be undesirable outcomes that do not occur during the 100yr simulation. However, the culvert design requirements have to be met up to the 100yr ARI design storm, including climate change, hence checking for these outcomes is outside the scope of the design.

Response Reviewer: No action needed. I suppose overflow across the motorway is the only effect of the PMF that is worth avoiding.

Comment Reviewer: p15, para 5 - I presume the threshold depth is a lower limit set by the Guidelines. How is it ensured in practice? I also presume that the 10% and 50% of 2yr ARI flow are specified by the Guidelines. Were there cases where the culvert was too long for the fish, and what was done about it? What was the target fish species?

Response Designer: The threshold depth is indeed a lower limit set by the Guidelines. This limit has been set to 150mm. This has been added to the text and a more detailed explanation has been included in section 3.1.3. Stilling basins are proposed immediately upstream and downstream of the culvert and these will help reaching this limit in practice. Yes the 10% and 50% of 2yr ARI flow are specified by the guidelines, in absence of available flow-gauge for any of streams that Takitimu North Link Stage 2 crosses. There is one culvert that is too long for the fish, culvert TNL-11560. It includes suitable zones of low velocities along the walls of the culvert, however the length of the culvert means that fish cannot swim, using their prolonged swimming speed, from the downstream stilling basin to the upstream stilling basin, without needing to rest. To provide the resting places that the fish need, small (approximately 300mm x 300mm) concrete baffles are proposed to be placed along one side of the culvert. Details have been added to section 3.2.2. The target fish species was Inanga, and in particular the 75% quantile of Inanga. Details have been added to section 3.1.3.

Response Reviewer: Am I correct in deducing that the culvert slope and size are adjusted to get velocities below and depth above their respective limits from the Guideline?

Response Designer (2): That is correct.

Response Reviewer (2): Comment Resolved.

Comment Reviewer: p15, para 6 - This paragraph is confusing. I presume that the starting point is an embedment layer made up of the stream bed material. Do the Guidelines specify a maximum permissible shear stress from the d50, or have you calculated that from the Shields equation?

Response Designer: For the culvert embedment layer, the main aim is to have a stable embedment layer that will stay within the culvert up to the maximum design storm, the 100yr ARI storm including climate change. During this storm, significant flow contraction will occur when the flow enters the culvert, resulting in larger velocities in the culvert than upstream of the culvert. Therefore, using stream bed material is unlikely to result in a stable embedment layer. Instead, a d50 is chosen for the embedment layer so that the permissible shear stress is larger than the applied shear stress. The applied shear stress was obtained from HY-8 and compared with the permissible shear stress for the d50. The guidelines do indeed give a maximum permissible shear stress. We have also used the methodology in HEC-26 for the calculation of the applied and permissible shear stresses.

Response Reviewer: What you are doing sounds fine, but I still find the paragraph confusing.

Response Designer (2): Text has been updated to eliminate confusion.

Response Reviewer (2): Comment Resolved.

Comment Reviewer: *p16 - Cowan's method reads as delightfully subjective, and the simple addition of components of n is probably theoretically unsound, but at least it's methodical.*

Response Designer: The main reason for including Cowan's method was to obtain suitable 1D and 2D Manning's n values, taking into account that certain sources of losses that are included in the 1D Manning's n are modelled explicitly in the 2D model and therefore should be removed from the 2D Manning's n. At all times, the 1D and 2D Manning's n values were evaluated for their suitability using reputable references.

Response Reviewer: No action needed.

Comment Reviewer: p16 - This appears to be a reasonable and pragmatic way of allowing for sudden contractions and expansions without resorting to a 2-d model.

Response Designer: Noted

Response Reviewer: No action needed.

Comment Reviewer: p16 - Can you please briefly explain the discharge coefficient of 0.8 and what it does.

Response Designer: When both the upstream and downstream sides of the bridge are submerged, the flow underneath the bridge deck is pressurized. In HEC-RAS this was modelled using the orifice equation. The coefficient of discharge in the orifice equation is typically in the range 0.7 to 0.9. We used the commonly used value of 0.8. Although, the results indicated that pressurized flow did not actually occur at any of the bridges. Text has been updated to clarify.

Response Reviewer: Thanks. No further action needed.

Comment Reviewer: *p17 - I presume "with climate change" refers to sea level rise. Using MHWS with the 2yr and 10yr ARI events is quite conservative, and using the 20-year ARI tide with the 100-year rainfall is extreme conservatism.*

Response Designer: In this case "with climate change" refers to the rainfall intensities, i.e. the 2yr, 10yr and 100yr ARI rainfall intensities in 2130. The combination of 20yr ARI tidal event and 100yr ARI rainfall event is as per BoPRC modelling guidelines.

Response Reviewer: On reading this again, yes, of course you meant the rainfall events. No action needed, but you could always add that these were BoPRC combinations of events. But I've always thought the BoPRC combinations conservative.

Response Designer (2): Reference to BoPRC has been included.

Response Reviewer (2): Comment Resolved.

Comment Reviewer: *p18 - So what was the design target in refining the cross-sections?*

Response Designer: The aim of refining the cross-sections was to end up with a stable unsteady flow model that appropriately reflected the change in grades. So additional cross-sections were often added immediately upstream and downstream of drop structures for example. Text has been updated to clarify.

Response Reviewer: Thanks. No further action needed.

Comment Reviewer: p19 - The 100-year ARI Manning's n values look credible. It's harder to assess the n values for the smallest flow considered for fish passage, but they will be somewhat higher in places where low flows have to flow around an obstruction rather than over it.

Response Designer: Agreed. We spend quite some time investigating values for Manning's n in stream that either have low flow, are steep or both. The conclusion we came to is that there is no universal accurate equation or approach for Manning's n under these circumstances. The approach described appeared to be the most appropriate for the flow expected in the stream realignments.

Response Reviewer: No action needed.

Comment Reviewer: p22 -Fish species and size Some notes I made about the choice of fish perhaps they are telling you what you already know! It seems likely that inanga would be the target species for these sites, but is that confirmed? Franklin et al. (2023) says to choose juvenile inanga if they are in the catchment; surely one would choose them if the catchment was suitable but there was a barrier to their migration. However, it is possible that you have some catchments that are too steep for inanga anyway. Juvenile inanga are typical of weaker-swimming species (Baker 2014) so this discussion can be ignored unless accommodating them is a problem. What size of inanga? The equation applies between 48 and 91 mm, but to be conservative, especially near the coast, perhaps we should assume smaller fish, say 50mm. Note that the equation is valid only up to 400s.

Response Designer: - The target fish species is indeed Inanga. Their ability to swim through the culverts has been based on their prolonged swimming speed (see section 3.1.3). The experimental results were obtained from a study supervised by Paul Franklin that used Inanga as the representative New Zealand native fish species. The Inanga in the study were juvenile fish, approximately 20mm long, that migrated during bank-full discharge. The results shown in the Figure will be published in February 2024. Design compliance is based on ensuring that 75% of target species are able to make it through the culvert. Note that the minimum depth within a culvert conveying the fish passage design flow was not based on the size of the Inanga. Instead it was set to 150mm. This is 36% larger than the largest mean size obtained for a range of native fish during their primary upstream migratory life-stage. The text has been updated to reflect the above.

There are catchments that have been identified as having very little or no suitable fish habitat. Part of the reason for the lack of suitable fish habitat is that streams are very steep, because they are close to the top of the catchment. In addition, the catchment areas contributing to the flows in the streams are small and therefore the flow paths in these streams are best described as ephemeral or intermittent drainageways. The effect on this on the design of the culverts and stream realignments has been added to sections 3.2.2 and 5.2.

Response Reviewer: No action needed other than to ensure that you state the fish species – I think people will ask.

Response Designer (2): It has been included on p22.

Response Reviewer (2): Comment Resolved.

Comment Reviewer: p35 - Manning's n for embedment layer. For d50 = 150mm, Strickler formula gives n~.034. This becomes gradually less accurate with decreasing depth < 5.d50. See for example Froelich (2012), whose Figure 3 is reproduced below: eq. 11 is the conventional Manning form, and eq. 9 is an adjusted formula. So the .028 looks a bit low. Perhaps we need to revisit this only if we have a borderline case for adequate fish passage. See p22: Could the catchment be made suitable for inanga, or is it too steep?

Response Designer: Note that we used two different Manning's n for the culvert with embedment with a d50 of 150mm. For the fish passage design flows, the Manning's n used was 0.04, while for the large storm, 2yr ARI to 100yr ARI, the Manning's n used was 0.028. These appear to be in reasonable agreement with Strickler's formula as the average Manning's n of these two values is 0.034 as well.

The discussion on fish passage compliance for the culvert is based on Inanga as the target species. As the culvert meets the fish passage requirements, the culvert is suitable for Inanga.

Response Reviewer: No action needed.

Comment Reviewer: p41 Fish Speeds - Could you perhaps repeat in the caption what you've said elsewhere, that Fig 3-24 applies to inanga? What size of fish is this figure for?

Response Designer: Target species have been added to the Figure and the text. Figure was obtained from study based on 20mm long juvenile Inanga.

Response Reviewer: Thanks. No further action needed.

Comment Reviewer: p41 The quoted permissible bed shear stress corresponds to a Shields Number of 0.04, slightly below the initiation of motion. Perfect!

Response Designer: Excellent.

Response Reviewer: No action needed.

Comment Reviewer: p44 - "There will be an increase in peak flow rate and hence in water level ..."

Response Designer: Text has been updated.

Response Reviewer: Thanks. No further action needed.

Comment Reviewer: p44 - No effect of increased water levels on buildings downstream. What about flood risk to roads downstream? If there is increased risk, is it minor?

Response Designer: Details in the Takitimu North Link Stage 2 – Downstream Effects Investigation report highlight that within the Oturu Creek catchment (that will include bridges AIN-1275 and SH2-5380), the roads downstream of the proposed bridges (Armstrong Rd and Borell Rd) overtop in the existing condition without climate change. Overtopping will get worse in the proposed condition with climate change, but this is largely due to climate change. Because the overtopping depth in the existing condition without climate change is already 0.74m, the risk is already very high. The increase in the risk due to the additional overtopping may therefore be classified as minor.

Response Reviewer: I agree that a depth of 0.74m already means a closed road, but the changed regime also means more frequent road flooding. Is this effect minor? Perhaps it is tolerable because it's a return to pre-SH2 conditions.

Response Designer (2): The model results indicate that for the 2yr ARI storms, the road overtops in the existing and proposed condition. In addition, there will be a storm event for which no temporary storage of flood volume occurs upstream of the culverts in the existing condition, hence the proposed upsizing of the culverts will not have any effect on the downstream flow rates. The question is then, is the storm that does not overtop in the existing condition, but will overtop in the proposed condition, larger than the storm for which there is no temporary storage of flood volume upstream of the culvert? If yes, then there is a potential increase in the frequency of road flooding. However, for a local road the frequency of overtopping is already very high in the existing condition, therefore the effect of a potential increase in the frequency may again be classified as minor.

Response Reviewer (2): Comment Resolved.

Comment Reviewer: p46 - To your knowledge, how sensitive are your scour results to the choice of d50? Also, is the 0.13mm from sieved samples?

Response Designer: The d_{50} was not obtained from a sieve analysis. Instead, it was obtained from the available soil information, i.e. geotechnical information, NZ Landcare Research S-Map Online and site observations. The scour results were not dependent on d_{50} as the equations used for the contraction scour, pier scour and abutment scour ended up not including the parameter d_{50}. For the contraction scour, HEC-RAS selects either the live-bed or clear-water contraction scour equation based on computed critical velocity that will transport bed material finer than d_{50}. As the average velocity at the approach channel was found to be greater than the critical velocity, HEC-RAS uses the live-bed contraction equation, which is a modified version of Laursen's (1960) live-bed scour equation:

$$y_2 = y_1 \left[\frac{Q_2}{Q_1}\right]^{6/7} \left[\frac{W_1}{W_2}\right]^{K_1}$$

For the calculation of pier scour, the default equation within HEC-RAS is the pier scour equation based on the Colorado State University (CSU) equation:

$$y_s = 2.0 K_1 K_2 K_3 K_4 a^{0.65} y_1^{0.35} Fr_1^{0.43}$$

The ratios of the wetted embankment length to the approach flow depth were found to be less than 25. Hence, the Froehlich equation was used to calculate abutment scour.

$$y_s = 2.27 K_1 K_2 (L')^{0.43} y_a^{0.57} Fr^{0.61} + y_a$$

Text in the report has been expanded to clarify the above.

Response Reviewer: No further action required, though I'd be interested to read your revised text.

Comment Reviewer: p47 – What are the criteria applied to calculated scour to decide whether scour protection is needed? Whilst the design of scour countermeasures is beyond scope, can this report state how those countermeasures would be designed?

Response Designer: The scour calculations as part of the Specimen Design will inform consenting of the project. The consent will likely include a clause that refers to not causing erosion in stream and floodplain area that currently do not erode or not causing an increase in erosion in areas that do currently erode. The scour calculations have identified the areas where the proposed bridge structures cause erosion to the existing stream and/or floodplain. Scour countermeasure will therefore have to be included at all areas where scour has been identified. The methodology used for design of the scour countermeasures will be decided by the designer during Detailed Design. Suitability of the approach will be evaluated during Peer Review of the Detailed Design.

Response Reviewer: Can you say here that consent conditions and bridge structural design will determine from the calculated scour depths any need for scour protection? That would make clear why you go no further at this stage.

Response Reviewer (2): It will be the consent conditions and structural, geotechnical and ecological considerations that will determine the need for scour countermeasures.

Response Reviewer (2): Comment Resolved.

Comment Reviewer: p48 – Table 4-5 caption: add "peak scour in 100-year ARI event"

Response Designer: Caption has been updated.

Response Reviewer: Comment Resolved.

Comment Reviewer: p51 - This says that bankfull discharge will preferably be determined in the field, yet it seems that the alternative of half of the 2-year ARI flow has been used pretty much throughout. Is that just for the meantime or are you pretty happy with just using the designated flow? I questioned earlier the particular choice of 50% of the 2-year ARI flow, when some studies show 100% or higher. Given the NZ studies you've found, I'm comfortable enough with that now, the design choice, but I do think you need to keep in mind "what if the real channel-forming discharge *is double our assumption?" Where there is a wide floodplain, it may be a matter of little concern, as the extra flow would be widely spread and the extra depth minimal. But there may be other more confined channel reaches where you might consider erring on the high side.*

Response Designer: To confirm the flow rate of the bank-full discharge, it would always be preferable to obtain input parameters from the field to carry out a detailed analysis. However, it is unlikely that this will happen as part of engineering projects, hence why alternative have been investigated, as part of the updated fish passage guidelines, that allow reasonable estimates to be obtained for the bank-full discharge from readily available information.

It is agreed that the bank-full discharge depends on the channel and floodplain geometry. However, the fish passage guidelines have focused on a relatively small sub-set of streams where providing full fish passage (i.e. for swimming species) by means of a culvert is the chosen option. For larger streams, small rivers etc, ecological, financial and buildability considerations quickly result in the chosen option for the crossing to be a bridge. Smaller stream crossings generally occur in locations with very small upstream catchments and hence the flows are either ephemeral or intermittent drainageway that are also likely to be steep because they are near the top of the catchments. For these streams the chosen option for the crossing may well be a culvert, but full fish passage is not required as there is very little or no suitable fish habitat upstream of the crossing. For the streams that fall within the range where full fish passage is required, the references indicate that, using the 50% of the 2yr ARI as an approximation for the bank-full discharge, is a reasonable approximation.

Response Reviewer: No action needed.

Comment Reviewer: p52 - I'm not sure how helpful this text (on stable vs unstable channels) will be. Whether one could get misled in the field depends on whether the changes that create the channel act quicker than aggradational or degradational changes the define an unstable channel. There will be places in NZ where aggradation in particular is rapid enough to dominate the morphology, but I doubt that these streams are aggrading or degrading that much. What do we look for on site to tell us? Is this field work proposed?

Response Designer: Field work to obtain estimates for the channel forming discharge is not proposed and is also not expected to be carried out by whomever ends up carrying out the detailed design. It is expected that the designer will use 50% of the 2yr ARI flow rate instead. The text is included only as background information and is only relevant for streams where full fish passage is required (see previous comment's reply for details). Details on the channel-forming discharge will be included in the updated fish passage guidelines, but as these are not yet available, some of the details from the updated guidelines have been included in the text as well.

Response Reviewer: Using the chosen design flow is just fine, I think. However, this text led me to expect the geomorphic approach it describes. Can you make it clear in the report that you don't expect this?

Response Designer (2): The text has been updated stating that all the streams impacted by the construction of Takitimu North Link Stage 2 are highly modified, hence the estimate for the channel forming discharge will be calculated as 50% of the 2-year ARI flow.

Response Reviewer (2): Comment Resolved.

Comment Reviewer: p55 5.1.8 - 2nd paragraph: it's not clear to me whether this refers to different construction details or just different calculation approaches. Regardless, the 1D model with weirs seems just fine for the purpose.

Response Designer: The paragraph refers to two different design (and therefore by association, different construction) approaches. The first one is to design the channel with a single slope that yields an acceptable hydraulic grade. The second one includes steep sections at the drop structures and flatter sections in between the drop structures. The average slope of the second is likely to be higher than for the first approach while still yielding an acceptable hydraulic grade, hence why this method is preferred.

Response Reviewer: I'm still confused by this paragraph, but your explanation is clear enough: you've chosen to build a series of riffles and pools (that's good) and have used a 1-D model to design (also fine).

Comment Reviewer: p55 5.1.8 - 3rd paragraph: This makes me wonder about the velocities and shear stresses down the ramp in flood flows. Will the bed material be shifted by the 5-year ARI event, say? (One might accept having to rebuild after the 100year ARI event.)

Response Designer: Example results for the rock ramp during the 100yr ARI storm are given in Figures 5-26, 5-28 and 5-29. In this example, the flow accelerates when going down the rock ramp and flow depth reduces, but it remains sub-critical. A maximum velocity of 1.67m/s is obtained in the channel. Hence the large boulders and riprap should protect the channel from erosion. The maximum velocity in the floodplains is 0.66m/s. These floodplains will be densely planted, thereby mitigating erosion of the floodplains.

Response Reviewer: What material paves the pools? The answer may make it obvious that the bed is stable (or not) for those velocities. Are you aiming for no bed movement in moderate events or is there an upstream supply of bedload?

Response Designer (2): We would expect the pools to be paved with voids filled riprap and the size of the riprap to be determined based on calculations using the velocities obtained from a model for the 100yr ARI storm. Equations for calculating riprap for these relatively steep sections do assume that the channel bed is uniform. The large boulders and pools result in a channel that is not very uniform. However, during the 100yr ARI storm, the effect of this non-uniformity will be substantially smaller because of the large flow depth within the channel at that time. Based on initial calculations, the flow depth in the channel was 3 to 4 times the vertical elevation difference between the top of the boulder and the bottom of the pool. Hence under these circumstances, it is assumed that the riprap calculation equations yield reasonable results.

Response Reviewer (2): Comment Resolved.

Comment Reviewer: p59 - Re the 2D modelling, validation against in situ measurements and (particularly) observations of fish behaviour would be needed to make any conclusions rigorous. Nevertheless, I think this provides the best practicable indication of flow conditions.

Response Designer: Agreed.

Response Reviewer: No action needed.

Comment Reviewer: Bottom of p59 - Just a thought about flood flows through the ramps: if there are flows that fully cover everything by 0.5m, say, Manning's n will owe its value more to conventional bed "friction". So I'd expect the Huka Huka n values to continue their downward trend with increasing flow; Hicks & Mason didn't have genuine high flows for this site, by the looks of it. Perhaps the only relevance of this point might be in designing the downstream stilling basin.

Response Designer: The use of Hicks & Mason was only used to confirm the Manning's n across the rock ramp in the 2D model. This has been clarified in the text. As Figure 5-26 to 5-29 show, the average flow depth is about 1.5m, therefore significantly above the largest boulders of the rock ramp. The Manning's n for the 100yr ARI flow for the steep rock ramps were therefore obtained using the Jarrett (1984) equation.

Response Reviewer: No action needed.

Comment Reviewer: p61 and 63 - SR3A, SR4C, SR5B, SR8B are described as perennial. Did you mean ephemeral? (If not, climbing fish species should probably be accommodated in SR8B.)

Response Designer: Correct, it should have said perennial. Text has been updated. It also includes a description of the approach for these stream sections that will results in limited fish passage that is not worse than the existing condition.

Response Reviewer: No further action needed.

Comment Reviewer: p63 - What form will the drop structures take with 25% and 33% slope? Passage for climbing fish? The downstream stilling basin will be important.

Response Designer: It will be up to the designer during Detailed Design to work out the details. However, on previous projects we have successfully installed drop structures with up to a 33% slope. These consist of steps approximately 1m long and up to 300mm high for each step. An example is shown in the photo below. Downstream stilling basin will be installed to provide resting places for climbing species.

Response Reviewer: No action needed. Your photo looks very natural and (to my limited knowledge) fish friendly

Comment Reviewer: p63 - I find the paragraph on SR3A confusing and parts seem ungrammatical.

Response Designer: It appears part of the paragraph were rewritten, but not all of the original text was deleted. Text in the paragraph has been updated.

Response Reviewer: No further action needed.

Comment Reviewer: p66 - Figure numbers in the text need "Update field". In Fig 5-18, the stream diversion is hard to see in such a pale turquoise.

Response Designer: Figure numbers have been updated. Updated Figure 5-18 has been inserted in the text that more clearly shows the location and alignment of SR5A.

Response Reviewer: Thanks. No further action needed.

Comment Reviewer: p67-68 - Judging from Figs 2022, this constructed stream, so visible from the motorway, will be a great showpiece for the ecological enhancement. I wonder whether it'll need quite a lot of the heavy rock bank on its true right, given the adjacent steep cutting.

Response Designer: It will need quite a bit of rock, but mainly along the bottom and the immediate sides next to the rock ramps. By the time the plants are fully grown, the rocks should be well covered. From the motorway, the drivers will mainly see the top part of the proposed cut. This will be fully planted.

Response Reviewer: No action needed.

Comment Reviewer: p 68, also p73 - Will the downstream weir accommodate upstream fish migration, or perhaps is it drowned at high tide anyway? From Fig 525 crest level looks like 0.4m, which I suspect is low enough to be drowned.

I agree that the details are best finalised at detailed design and on-site if necessary. I presume the weir will be quite long so that flow over it at low tide levels doesn't cause scour.

Response Designer: Yes, the downstream weir will have to accommodate upstream fish migration. The weir will likely be submerged at low tide and relatively wide, which will reduce the velocity of the flow across the weir so that it does not cause erosion within the Te Puna Stream. At high tide, the tidal waters will inundate the bottom end of the stream realignment, thereby removing most of the momentum of the flow from the stream realignment before it reaches the weir and hence erosion will not be a concern.

Response Reviewer: No action needed.