Jacobs

Memorandum

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Subject	Response to CRU comments on Volume 1 Methodology Report	Project Name	Kāpiti Coast Coastal Hazards Assessment
Attention	Lyndsey Craig	Project No.	IS355300
From	Derek Todd		
Date	October 5, 2021		
Copies to	Miriam Randall		

Jacobs have been asked by KCDC to provide a technical response to the comments raised by CRU[1] in their document titled "*Comments on Jacobs's Methodology Report (Volume 1)*". This document provides response comments to each of the 10 'Key Issues' raised in CRU's document. An addendum to this document has also been received from CRU, consequent to the publication of the IPCC 2021 Sixth Assessment Report. The response provided in this memo also addresses the comments in the addendum.

As a general statement, it is noted that a number of the 'Key Issues' raised by CRU are related to the use of the results of the Jacobs coastal hazard assessment in a council planning context. However, these results are not part of the Volume 1 Methodology Report, and will be presented in the Volume 2 Results Report. It is further noted that the primary purpose of the Jacobs work is to assess the nature and extent of coastal hazards facing the Kāpiti Coast District currently and in the future with sea level rise for use in guiding community adaptation planning. Any use of the assessment results in a District planning context is the responsibility of Council to consider, once they have received the results in Volume 2.

It is also noted that a number of the Key Issues raised by CRU are based around limitations of the methods adopted, which were also acknowledged in Section 6.9 of the Volume 1 Methodology Report.

In providing the following responses, we have followed the heading provided by CRU in their document and addendum.

1. Conservative Approach

CRU make as a general statement, that they *"have been struck by the pervasiveness of "conservative" approaches presented in the report",* and list the Bruun rule, coastal inlet migration, the bathtub model, extreme sea levels, and groundwater levels as being methods of particular concern. We note that in each of these sections of our Volume 1 Methodology Report we have stated in the report that there is a degree of conservativeness in the method. However, we reject the notation that there is a strong conservative bias to the assessment approach as these methods are only a small subset of the total assessment and in most

[1] CRU : Coastal Ratepayers United Inc.

cases there are no alternative methods for the data that is available. The following addresses each of the above-mentioned methods in detail.

The Bruun Rule (Section 6.4.3)

As noted in the hazard assessment (Section 6.4.3 and 6.9.4), there are a number of well recognised limitations to the Bruun Rule, including conservatism in dealing with progressive increases in backshore elevation and the time lags for equilibrium profile response to sea level rise increments. In relation to each of these points we can make the following responses:

- General limitations of the Bruun Rule: While the limitations are recognised, the Bruun Rule is an internationally well used method for assessing the erosional effect of sea level rise (SLR) on sandy beach environments; has been used in the majority of coastal hazard assessments in New Zealand; and has been accepted as an appropriate method by the Environment Court. The literature includes a number of alternative process-based models (e.g. Cowell et al 1992[2], Patterson 2009[3], Huxley 2010[4], Ranasinghe et al 2012[5]) however as pointed out by Shand et al (2013)[6] in their review of different response models to sea level rise, *"these models require high-quality, long-tern site specific field data*" which is not available for the Kāpiti Coast, and "*none have proved to be categorically correct and adopted universally*". As concluded by Shand et al (2013) in their review, "*the geometric equilibrium models such as the Bruun model, while subject to limitations, appear to provide reasonable results if used sensibly*", and "*the probabilistic analysis of input terms* (such as used in this assessment) *provides a method for managing uncertainty*".

- For Raumati, Queen Elizabeth Park and Paekākāriki beaches, the increasing backshore elevations were used in the Bruun Rule calculations for higher RSLR scenarios over longer timeframes. For the northern beach sections, this was not required due to single dune ridge-swale morphology, with the maximum dune elevation used in all Bruun rule calculations.

- There is little that can be done about the time lags for equilibrium profile formation in the Bruun Rule. However, there is reasonable certainty that even with time lags in beach response, all of the predicted beach responses in the short to medium timeframes (i.e. 2050, 2070) will most likely occur at some time within a 100 year timeframe. Less certainty about the longer term RSLR scenarios, and therefore also about the timing of predicted beach responses, is the reason for applying an adaptative planning approach to the future management of the district coastline.

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[2] Cowell P.J., Roy P.S. and Jones R.A. (1992). Shoreface Translation Model: Computer Simulation of Coastal Sand Body Response to Sea Level Rise. Math. and Comp. in Sim. 33 (1992) 603-608.
[3] Patterson D. (2009) Modelling the Shoreline Impacts of Richmond River Training Walls, Proceedings of the 18th NSW Coastal Conference, 3 – 6 November 2009, Ballina.
[4] Huxley C. (2010). Quantification of the Physical Impacts of Climate Change on Beach Shoreline Response, Master of Philosophy, School of Engineering, Civil Engineering University of Queensland.
[5] Ranasinghe R., Callaghan D., Stive M.J F. (2012) Estimating coastal recession due to sea level rise: beyond the Bruun rule. Climate Change (2012) 110:561-574. DOI 10. 1007/s10584-011-0107-8
[6] Shand T., Shand R., Reinen-Hamill R., Carley J., and Cox R. (2013) A review of shoreline response models to changes in sea level. 2103 Coasts & Ports Australasian Conference, Sydney.

Coastal Inlet Migration (Section 6.7.3)

How to address inlet migration with RSLR is a topic that is not well represented in the coastal research literature, with no standardized method we can use to identify what these changes might look like. As stated in the Volume 1 report, "*there is currently limited understanding of how these coastal hydrosystems will respond in the future due to the complex influences which determine their morphology*". As a result, we have taken a subjective approach to predict potential future inlet shapes which has looked at each inlet individually and drawn upon patterns of how it migrated with adjacent shoreline erosion/accretion in the past. We assume that the conservative method referred to be CRU is most likely to be the method used to assess inlet migration where the adjacent shoreline is accreting. In these circumstances the area assessed to be susceptible to future erosion is the historical maximum landward extent of the inlet over the last 70 years of the aerial photograph record, which could be argued as being conservative for a shoreline that continues to accrete.

In the Volume 2 Results Report, we clearly describe which inlets this method has been applied to, show the historical shoreline positions, and note that it is recognised that it is a conservative approach. For example, the wording from the Draft Volume 2 report for the Waitohu Stream is as follows:
"Due to the accretional nature of the adjacent shoreline, and the net positive movement of the inlet itself, method 3 from the coastal hydrosystem decision tree, being the maximum historical hydrosystem shoreline position (see Section 2.2.7) was used to indicate the possible future migration of the hydrosystem. This is recognised to be a conservative approach, because the accretional nature of the adjacent shoreline means there is no coastal process reason to expect that the hydrosystem shoreline would erode back to this 1948 position in the future whilst the open coast continues to accrete. However, to give an indication of the spatial limits of where the hydrosystem has been in the past, this historical maximum envelope of the river mouth environment has been used".

We would also point-out that the inclusion of this position on the hazard maps does not imply that these areas will be managed in any particular way. They are included for information as we believe that knowing the historical extent of the inlet is useful for the council and community as a part of the adaptative planning process.

The Bathtub Model (Section 7.2.2)

Bathtub modelling is a commonly used high level (e.g. first cut) approach to determining areas potentially susceptible to coastal inundation, the results of which are frequently used to define areas which require a more detailed hydrodynamic modelling approach to better determine coastal flood extent and frequency. As such the limitations of the method, including being conservative due to not taking into account the capacity of inundation pathways, or the volume of water available for inundation over the period of a storm tide event, both of which can limit the extent and depths of inundation, are clearly stated in the Volume 1 Methodology Report, Section 7.6.

As stated in the Volume 1 Methodology Report (Section 7.1), the purpose of the inundation assessment was to "*use the current available data and a simpler "bathtub" approach to provide an <u>interim</u> assessment ahead of more detailed models and outputs becoming available*". We accept that bathtub modelling can be conservative, however we believe that within the context of this project and for beginning a conversation with communities on these hazards, this is an appropriate approach until more complex hydrodynamic modelling, being undertaken by a different consultant, becomes available.

Again, we would note that the inclusion of the inundation areas from the bathtub modelling on the hazard maps does not imply that these areas will be managed in any particular way.

Extreme Sea Levels (7.3.1)

Given the reference to Section 7.3.1, it is assumed that CRU's comment around conservativeness is in regards the following statement in that section:

"The wave setup included in these estimates was derived for the open coast, whereas the primary inundation pathways along the Kāpiti coast are through river mouths where wave setup tends to be less, therefore these estimates are likely to be somewhat conservative."

The conservativeness referred to in this statement relates solely to the wave set-up component of the water level at the river mouths. This is due to wave set-up being dependent on the nearshore slope in the wave break zone, which tends to be steeper on the open coast than at river mouths (due to the presence of ebb tide deltas), therefore resulting in greater set-up on the open coast. Due to a lack of research and literature on wave set-up in river mouths, it is difficult to provide a quantitative estimate of the difference in set-up at these positions, but in principle the greater the size of the river mouth or inlet, the greater the reduction on wave set-up due to greater flatting of nearshore slope by the ebb tide delta. Therefore, for the Kāpiti Coast the greatest degree of conservativeness in the resulting extreme water levels at shore (i.e. including set-up) would be at the Ōtaki and Waikanae Rivers. As referenced in Section 7.3.1, one of the few articles on wave set-up in river mouths (Tanaka & Tinh , 2008)[7] established a relationship between set-up and wave height (i.e. set-up in a river mouth equals 14% of wave height). As shown in Table 7.4, applying this relationship to the range of wave heights possible in a 1% AEP event, results in wave set-ups which are within the range of open coast values from Lane et al (2012)[8] that are presented in Table 2.4 of the Volume 1 Methodology Report. From this, we consider that the degree of conservatism of the wave set-up and therefore the extreme water levels at river mouths along the Kāpiti Coast is most likely to be minimal and will have little impact on the bathtub inundation modelling in these areas.

Groundwater levels (7.3.3).

It is assumed that CRU's concerns with this point is in regard to using the "*conservative 'extreme' rainfall estimates*" for increase in winter rainfall from MfE (2008)[9] guidance as used in the SKM (2012)[10] effects of climate change on groundwater assessment. We note that this reference to conservative is a direct quote from the SKM (2012) report, and our apologies that this was not indicated in our report. However, we note that the estimates of extreme rainfall with climate change have been updated (MfE, 2018)[11] to be higher

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[7] Tanaka H. and Tinh N.X. (2008). Wave set-up at river mouths in Japan. Journal of water Resources and Environmental Engineering, no.23; p5-12.
[8] Lane E., Gorman R., Pew D, Stephens S. (2012). Assessing the storm inundation hazard for coastal margins around the Wellington region. NIWA report prepared for GWRC, KCDC and WCC.
[9] MfE (2008) Climate change effects and impacts assessment. A guidance manual for local government in New Zealand – 2nd edition.
[10] SKM (2012). High level assessment of climate change impacts on Kāpiti's groundwater. Report for KCDC.
[11] MfE (2018) Climate Change Projections for New Zealand: Atmosphere Projections Based on Simulations from IPCC Fifth Assessment, 2nd Edition.

than the 2008 estimates, implying that the given estimates of rainfall increases are not as conservative now as they were considered at the time of the SKM (2012) report.

Importantly, it should also be noted that the groundwater levels were not incorporated into the bathtub modelling so do not influence the resulting inundation areas mapped in the Volume 2 Results Report.

2. Relationship between Global MSL and Local MSL

As well as being raised in the initial CRU review comments, this point is elaborated on in the Addendum added consequent to the publication of the IPCC (2021)[12] Sixth Assessment Report in August 2021. The basis of this alleged issue is that "*Jacobs therefore overstates projected RSLR by using the worst case possible*", by applying a Vertical Land Motion (VLM) adjustment of 1-3 mm/yr to projections of local SLR due to climate change.

Our comments on the points raised by CRU are as follows:

- What is required for the hazard assessment is the impact of future local relative SLR (RSLR) at Kāpiti, not the impact of Global MSL (GMSL) as suggested by CRU. While we have data on the past rates of RSLR from the Wellington tide gauge data, the estimates of future Kāpiti RSLR need to be based on projections of SLR for NZ as presented in MfE (2017)[13] plus local VLM.

- It is misleading to use a comparison between past Global MSL (GMSL) rise and regional relative SLR to estimate the future local VLM. Neither Bell et al (2018)[14] or our Jacobs report employs this method. As stated in IPCC (2021, chapter 9 -Ocean, cryosphere and sea level change), *"Regional differences in sea level arise from ocean dynamics; changes in Earth gravity, rotation and deformation due to land-ice and land-water changes; and vertical land motion*". Therefore, difference from GMSL to regional RSLR can be due to a number of factors in addition to VLM. The IPCC (2021) report further notes that these additional processes "*give rise to a spatial pattern that tends to increase sea level rise at low latitudes and reduce sea level rise at high latitudes*", and *"that sea levels rose fastest in the Western Pacific and slowest in the Eastern Pacific over the period 1993-2018"*, again implying that comparing regional to global sea level rise is driven by more than just regional VLM.

- When considering past rates of SLR, it is also misleading to only consider rates over the 100+ year timeframes as the rate of SLR has accelerated since the late 1960's. This is clearly shown in both the GMSL data presented by IPCC (2021) and the RSLR for Wellington presented by Bell et al (2018).

[12] IPCC (2021) Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.
[13] Ministry for the Environment (2017). Coastal Hazard and Climate Change Guidance to Local Government.
[14] Bell R.G., Denys P. Hannah J. (2018). Update on relative sea-level rise and vertical land motion: Wellington region. NIWA report prepared for Greater Wellington Regional Council, December 2018.

- The reference to Denys et al (2020) [15] more extensive analysis of VLM associated with long-term Tide gauge records at major NZ ports is noted, and this paper has subsequently been reviewed. In comparing the two papers, it is noted that the analysis in Bell et al (2018) includes nine GNSS[16] sites in the Wellington region including two in Kāpiti (and another one in Levin) compared to the analysis of three Wellington city sites in Denys et al (2020). It is also noted that Paul Denys was a co-author of the Bell paper and appears to responsible for the information on VLM presented in that report, so it is hard to imagine there would be a major difference in the interpretation of this data.

- In calculating future VLM, both papers recognise that the current knowledge on rates of VLM is limited to only 10 - 20 years of data, which given the periodic nature of some of the drivers of VLM (e.g. Slow Slip Events (SSE's) & large earthquakes) and the time required for post-seismic adjustments, is a major limitation in extrapolating this data both backward in time and forwards into the future. For example, as presented in Bell et al (2018) GNSS sites with 10 years of record (2008-2018) displayed a net positive vertical displacement (e.g. uplift) due to presence of the Kaikoura & Seddon earthquakes and two SSE, while the sites with 20 years of record (1998-2018) displayed a net negative vertical displacement (e.g. subsidence) due to the absence of significant earthquakes in the initial 10 years of record.

- Both papers also note the spatial variation in the pattern of subduction around the Wellington region and top of the South Island. As stated by Bell et al (2018), "*It is difficult to provide a definitive long-term trend of VLM for any site in the Wellington region, largely due to the effects and ongoing influences on crustal movement of the recent earthquake events since 2013. What the GNSS position data does show, is that the deformation in this region is complex and is likely to remain so in the future*".

- However, the data presented in Table 4-2 of Bell et al (2018) indicates that the rates of subsidence are higher for the Kāpiti Coast than for the Wellington City sites, and increasing in a northward direction for the three sites from Paekākāriki through to Levin. It is therefore considered reasonable include a higher future VLM rate in the calculation of RSLR for the Kāpiti Coast than shown in the Denys et al (2020) analysis for Wellington city sites.

- Bearing in mind the above limitations in the VLM data and uncertainties for future predictions, we used the data presented in Bell et al (2018) Table 4-2 for the Paekākāriki, Kāpiti and Levin GNSS sites, being the most relevant to the Kāpiti Coast District, to arrive at the range of 1-3 mm/yr for future local VLM to be added to NZ SLR projections. For these calculations the long-term subsidence rate for the Kāpiti and Levin sites were multiplied out for 20 years to be constant with the Paekākāriki site and overcome the earthquake uplift basis of the 2008-2018 period. The

[15] Denys P.H., Beavan R.J., Hannah J., Pearson C.F., Palmer N., Denham M., and Hreinsdottir S. (2020) Sea Level Rise in New Zealand: The Effect of Vertical Land Motion On Century-Long Tide Gauge Records in a Tectonically Active Region. Journal of Geophysical Research: Solid Earth. https://doi.org/10.1029/2019JB018055.

[16] GNSS: Global Navigation Satellite System, of which GPS (referred to by Denys et al, 2020) is one type of. The three GPS sites in Wellington analysed by Denys are included in the nine GNSS sites reported in Bell et al (2018).

resulting VLM rates were -0.9mm/yr at Paekākāriki, -2.4 mm/yr at Kāpiti and -3.25 mm/yr at Levin. For the RSLR projections these rates were rounded to a district wide range of 1-3 mm/yr.

Based on all of the above points, we are confident that the range of estimates of future VLM rates used in our assessment are appropriate for the Kāpiti coast for the current state of knowledge. However, these estimates should continue to be updated at regular intervals as on-going data of VLM rates is collected.

3. Trigger Points

It is our interpretation that this issue in the CRU review is that we have focused our assessment on fixed scenarios of the timing and magnitude of RSLR and failed to account for some of the uncertainties associated with when these, and the associated impacts, will occur. It appears that CRU assess that this in turn could limit decisions on selection of adaptation pathways and actions if appropriate trigger points are not developed. Reference is made to Section 4.2 (Extreme tide levels with future sea level rise) and 6.1 (General approach for erosion methodology) as being areas of the report where fixed scenarios are used.

Our comments on the points raised by CRU are as follows:

- The coastal hazard susceptibility and vulnerability assessment does not define trigger points for adaptation actions to manage hazard risk. The purpose of the assessment is to define the level of exposure to erosion and inundation hazards as a starting point for council conversations with communities on how this can be managed via an adaptive process. The definition of trigger points for particular actions will be part of that process.

- Both inundation and erosion modelling in this hazard assessment do recognise the uncertainties in projections of future RSLR by applying the full range of RSLR scenarios from RCP2.6 to RCP8.5+ and a range of VLM rates. However, for assessment purposes, particularly for erosion impacts (due to be being dependent on changes in rate of RSLR), a fixed date is required, which were chosen as 30, 50, and 100-year intervals. The Draft Volume 2 Results Report presents the erosion distances and inundation extents for the lower and upper limits of RSLR range for these dates, and will include reference to the fact that these magnitudes of RSLR could occur sooner or later than these dates.

- In undertaking the assessment, we also needed to define further changes from a fixed current shoreline position and condition, and with an assumption on future of existing coastal protection structures as set out in section 6.1.1 and shown in figure 6.5 of the Volume 1 Methodology Report. As part of the development of potential adaptive pathway options, it is likely that the council and the community will wish to explore different futures for these structures, for which we can reassess the hazard susceptibility and vulnerability (as well as indicative costs and other environmental/social impacts) for at that time. This is a recognised as being a part of the optioning requirements under an adaptation management approach.

4. Use of RCP8.5+ and de facto Adoption of RCP 8.0[17] for Sea-Level Rise (SLR)

As well as being raised in the initial CRU review comments, this point is elaborated on in the Addendum added consequent to the publication of the IPCC (2021) Sixth Assessment Report in August 2021. It is noted that there is no RCP 8.0 scenario, so is assumed that this should read RCP 8.5 scenario. From our interpretation the central points to this issue appear to be that RCP 8.5H+and RCP8.5 scenarios, and hence SSP-8.5 from IPCC (2021), are not likely scenarios, therefore should not be used to inform District Plan hazard zoning.

Our comments on the points raised by CRU are as follows:

- The national guidance to NZCPS Policy 24 is provided by MfE (2017), which recommends that a range of SLR projections should be applied as it is not possible to determine a "most likely" climate future due to different types of uncertainty, especially the future global emissions pathways and emergence of polar ice sheet instabilities. It is pleasing that the CRU addendum now accepts no likelihoods can be attached to the scenarios.

- CRU is correct that the function of the RCP 8.5H+ scenario is to "*stress test adaptation plans where the risk tolerance is low and/or future adaptation options are limited, and for setting an SLR for green-fields development where the foreseeable risk is to be avoided.*" In order to perform this function, the RCP 8.5H+ scenario is required to be included in the assessment, and is in line with the MfE (2017) guidance.

- For coastal erosion, the Draft Volume 2 Results Report presents the PFSP results for the lower and upper RSLR values across the total range of scenarios from RCP 2.6 to RCP 8.5H+ for 2050, 2070 and 2130. It is recognised that the RSLR and the resulting PFSP's may take any value within the range presented, and there is no discussion on which scenario, timeframe, or probability should be used for either determining future management under or District Plan zoning under an adaptative planning pathway. These tasks are for the Council and community to consider once they have received the results in Volume 2.

- For coastal inundation, the RSLR values chosen also cover the range of RCP scenarios from RCP 2.6 and RCP 8.5H+ for 2070 and 2130. An upper RSLR scenario for 2050 (+0.4 m) is also assessed, but the lower scenario (+0.2 m) is not included in the assessment. However, potential inundation extent from the current sea level (+0m) is included.

- The 1 m and 1.25 m RSLR scenarios for 2120 are presented in the erosion assessment as a 'intermediate' projection between the lowest increment (0.6 m) and highest (1.65 m) RSLR scenarios for this timeframe, not as representative of a particular RCP scenario. The difference between highest and lowest RSLR scenarios by 2050 is 0.2m, and by 2070 it was 0.4 m, therefore the presentation of intermediate projections was not considered to be necessary at this stage of the project. However, by 2120 the range of RSLR projections increases to 1.05 m, and therefore the difference between the PFSP from the lower to higher RSLR scenario is large, hence the

[17] There is no RCP 8.0 scenario, so is assumed that this should be RCP 8.5 scenario

inclusion of the two 'intermediate' projections was considered justified. It is noted that RCP 4.5 scenario with 1-3 mm/yr VLM would result in RSLR of 0.73-0.93 m from 2020 to 2120, and that RCP 6.0 produces similar SLR projects to RCP 4.5 by 2100, so is not considered as a separate scenario in MfE (2017).

- CRU's request to add addition scenarios into the assessment to be aligned with RCP4.5 and RCP6.0 scenarios (or SSP3-7.0 scenario from IPCC (2021) which appears to have replaced the RCP 6.0 scenario) may fall out of discussions with the CAP and the community consultation as to whether they need further information about these intermediate scenarios.

- The CRU addendum correctly notes the extracts from IPCC (2021) Sections 1.6.1.4 and 4.2.2 regarding the lower likelihood and plausibility of the RCP 8.5 or SSP5-8.5 scenarios due to not including allowance for emission reduction policies in their storylines. However, as noted by CRU, no likelihood is attached to the scenarios assessed in the IPCC (2021) report. It is also noted that the IPCC report does include the SSP5-8.5 scenario as one of its five base scenarios, and note that "*the default concentrations aligned with RCP 8.5 or SSP5-8.5 and resulting climate futures derived by ESMs could be reached by lower emission trajectories than RCP 8.5 or SSP5-8.5*". It is further noted that the sea level chapter of IPCC (2021, Chapter 13) states there is medium confidence in the processes producing SLR under all SSP scenarios, including SSP5-8.5, the projections for SSP3-7.0 and SSP5-8.5 are consistent with a continuation of the GMSL satellite-observed rate and acceleration over the 1993-2018 period, and that all scenarios produce similar SLR projections up to 2050.

- To date there has been no update in the New Zealand SLR projections or national guidance in response to the latest IPCC report, so until that time, it is considered appropriate to continue to assess coastal hazard impacts with the full range of scenarios as recommended by MfE (2017). It is noted that with the addition of an upper VLM value of 3 mm/yr, the range of RSLR values applied in the assessment covers the slightly higher SLR scenarios under the SSP scenarios than under the RCP scenarios.

5. Treatment of Vertical Ground-Level Movement

CRU are correct in stating that plate tectonics and climate change are not correlated, with local VLM being independent of SLR from climate change. However, since both net subsidence and climate change induced SLR are both continuously occurring over future timeframes, they will both influence the magnitude of future RSLR occurring along the Kāpiti Coast.

In the most recent IPCC (2021) report, it was described as high confidence that vertical land movement will remain a major driver of relative sea level change, and therefore it is important that we have included this in the coastal hazard assessment for Kāpiti. As noted in CRUs Key Issue 2, tectonics play a significant and uncertain role in RSLR, and therefore we have chosen the range of 1-3 mm/yr to reflect this.

6. Treatment of Accretion when it Outpaces SLR

The 'present day' hazard mapped is exactly that – the magnitude of dune erosion that may occur in a significant storm with current beach conditions and dune or seawall positions. It does not represent the short term storm and dune stability erosion from some future dune or seawall position. While these components are included in the calculation of the Projected Future Shoreline Position (PFSP) for the various timeframes, the resulting erosion from these components is not separated out in the mapping from the net shoreline movements (either erosion or accretion) mapped for these timeframes.

So, if these short-term storm erosion components are less than the projected longer-term accretion over a specified timeframe, the shoreline would still be assessed as being in a state of long-term accretion, as the short-term storm erosion could all be accommodated within the accreted area, and therefore would not be mapped as being erosional.

7. Use of Bruun Rule and Lack of Validation

It is our interpretation that this issue in the CRU review is regarding the validity of applying the Bruun Rule to the Kāpiti Coast due to the sediment movement present along this coast. The review goes on to suggest that hindcasting of the SLR impacts as calculated by the Bruun Rule is required to validate these results.

Our comments on the points raised by CRU are as follows:

- The criticism that the Bruun Rule does not apply to accreting or eroding shorelines is valid if using only the Bruun Rule results to predict future shoreline positions. However, in our coastal hazard assessment this criticism is largely overcome by also extrapolating past rates of shoreline movements (both erosion and accretion) into the future, which inherently include the influences of sediment supply and transport, as well as considering future RSLR effects on shoreline position. Under this approach, as set out in section 6.4 of the Volume 1 Methodology Report, to avoid 'double accounting' of effects of past RSLR that are already present in the past history of shoreline movement, the consideration of future RSLR impacts is limited to rates of rise above contemporary rates. The approach also assumes that the past patterns and magnitudes of sediment supply and transport will continue in the future.

- As agreed by CRU, sediment budgets, which involve sediment supply and transport, are hard to measure. In applying the above approach of extrapolating past trends of shoreline movement under the assumption that these will continue and only considering future changes in rate of RSLR, we do not see the need to separate out these difficult to calculate factors for the calculation of future impacts of RSLR. The alternative approach would be, as suggested by CRU, to subtract the theoretical effects of past RSLR from the record of shoreline movements, and then extrapolate this adjusted rate forward into the future along with the calculated effects of the total projected RSLR over specified timeframes, rather than the rate of increase in projections over contemporary rates of rise. The resulting erosion is the same as for the discounted future RSLR method we have used.

- While it is a relatively easy task to calculate the theoretical influence of RSLR on shoreline movements over the period of aerial photographs (i.e. approximately last 70 years), without information on the actual influence of sediment supply and transport on shoreline movements (rather than assumed information), we do not see how these calculations can be used to validate the further retreat due to RSLR.

- In presenting the results in the Draft Volume 2 report, future shoreline movements are separated out into those due to the extrapolation of past trends of movement, those due to accelerated RSLR, and those due to short-term storms & dune stability. In this way, it is possible to identify the relative impacts of these different influences on the future shoreline position, and for accreting coasts when the tipping point from accretion to erosion may occur under the various RSLR scenarios. Note that this separation is presented in the report, with the mapping showing the net change from the combination of all four factors.

8. Linear Model in Time for Historic Trends

As indicated above, the approach suggested by CRU is a relatively easy task. However, as also stated above:

- We do not see how this separation of past drivers of shoreline movements will aid the certainty/uncertainty of the PFSP; and

- The PFSP results presented in Volume 2 do include the separation of projected shoreline movements due to the extrapolation of past trends, those due to accelerated RSLR, and those due to short-term storms & dune stability.

In reference to footnote 17 of the CRU review, we would also note that the vegetation line is the most reliable reference position to track on historical imagery and is considered to be best practice internationally. It is responsive to changes in the environment in both directions, and it is not tidally driven (such as the wet water line), so therefore does not require assumptions around the time of day it is taken, of which such information would be extremely difficult to determine for early historical imagery.

9. Treatment of Options for Sea Walls

It is CRU's opinion that the assumption in the coastal hazard assessment that current seawalls would be abandoned following the end of their useful life is not appropriate.

Our comments on the points raised by CRU are as follows:

- To undertake the assessment, we had to make an assumption around what the future of the seawalls along the Paekākāriki and Raumati area would be in order to model a scenario of a potential future shoreline position. The scenario chosen acknowledged the presence of existing seawalls and a future potentially without them as a starting point for discussions on possible future pathways.

- As set out in Section 6.1.1 and shown in Figure 6.5 of the Volume 1 Methodology Report, there are possible other alternative assumptions that could have been made. However, if we choose the alternative scenario where all seawalls were maintained and rebuilt over the 100 year period, then the shoreline will be a stable position, which in mapping would not provide any useful information to the community on potential consequences of this approach. Alternatively, if we assumed there were no walls there currently, it would simulate a scenario which is not realistic to the community, given the existing structures will provide some form of protection for at least the next 10-50 years in areas.

- As set out above in response to CRU item 3, as part of the development of potential adaptive pathway options, it is likely that the council and the community will wish to explore different futures for these structures, for which we can reassess the hazard susceptibility and vulnerability (as well as indicative costs and other environmental/social impacts) for at that time. This is a recognised as being a part of the optioning requirements under an adaptation management approach.

10. Uncertainty Distributions and Materiality

CRU's review raised that mean, min and max values of the distribution were not presented in the Volume 1 report. As these form part of the results of the assessment, they will be presented in the Volume 2 report.