Christchurch City Council
AGENDA

Notice of Meeting:

An ordinary meeting of the Christchurch City Council will be held on:

Date:	**Thursday 25 August 2016**
Time:	**9.30am**
Venue:	**Council Chambers, Civic Offices, 53 Hereford Street, Christchurch**

Membership

Chairperson	Mayor Lianne Dalziel
Deputy Chairperson	Deputy Mayor Vicki Buck
Members	Councillor Jimmy Chen
	Councillor Phil Clearwater
	Councillor Pauline Cotter
	Councillor David East
	Councillor Jamie Gough
	Councillor Yani Johanson
	Councillor Ali Jones
	Councillor Paul Lonsdale
	Councillor Glenn Livingstone
	Councillor Raf Manji
	Councillor Tim Scandrett
	Councillor Andrew Turner

18 August 2016

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Council - Terms of Reference

Chair	The Mayor
Membership	The Mayor and all Councillors are members of Council
Quorum	Half of the members if the number of members (including vacancies) is even, or a majority of members if the number of members (including vacancies) is odd.
Meeting Cycle	To be separately considered

The Council has the power to: (these powers cannot legally be delegated)

- Make a rate
- Make a bylaw
- Borrow money, or purchase or dispose of assets, other than in accordance with the long-term plan
- Adopt a long-term plan, annual plan or annual report
- Appoint a Chief Executive
- Adopt policies required to be adopted and consulted on under the Local Government Act 2002 in association with the long term plan or the preparation of the local governance statement
- Adopt a remuneration and employment policy

The Council is also responsible for:

- Reviewing and making decisions, when required, on the District Plan
- Approving all Council strategy and policy, except that specifically delegated to a committee or subcommittee
- Adoption of, and amendment to, Committee Terms of Reference, Standing Orders and Code of Conduct
- Approving or amending the Triennial Agreement and Local Governance Statement
- Reviewing and making decisions on representation reviews
- Appointing and discharging trustees, directors or office holders to Council's Council-Controlled Organisations and Council Organisations, except where specifically delegated to a committee or officer, and determining the remuneration for trustees, directors or office holders
- Dealing with issues of significant community importance
- Monitoring progress on earthquake recovery
  Considering recommendations from Council committees, subcommittees, Community Boards, the public, stakeholders and others, and making Council decisions with regard for the requirements of Sections 76 – 81 of the Local Government Act 2002

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1. Apologies

At the close of the agenda no apologies had been received.

2. Declarations of Interest

Members are reminded of the need to be vigilant to stand aside from decision making when a conflict arises between their role as an elected representative and any private or other external interest they might have.

3. Confirmation of Previous Minutes

That the minutes of the Council meeting held on Thursday, 11 August 2016 be confirmed (refer page 5).

4. Public Participation

4.1 Public Forum

A period of up to 30 minutes is available for people to speak for up five minutes on any issue that is not the subject of a separate hearings process.

4.2 Deputations by Appointment

A period of up to 30 minutes for deputations that have made application and been approved by the Chairperson.

There were no deputations by appointment at the time the agenda was prepared

5. Presentation of Petitions

There were no Presentation of Petitions at the time the agenda was prepared.

3.6 If the Council agrees to receive the report from the Independent Expert Panel then staff will urgently report back with a comprehensive programme of work to address the recommendations. This will include a timeframe for completing the additional scientific work necessary to appropriately update the original Tonkin & Taylor Ltd 2015 Coastal Hazard Assessment Stage Two Report; a process for making decisions on LIM information; closer engagement and work planning with ECan; the ongoing engagement with all residents on the implications arising from coastal hazard science; and any update from central Government on their programme of work in this space.

Attachments

No.	Title	Page
A ⇩	Coastal Hazards Peer Review Final Report 18 August 2016	161
B ⇩	Appendix A Original Terms of Reference	236
C ⇩	Appendix B Relevant Provisions from NZCPS (2010) 21 July	249

Signatories

Authors	Clive Appleton - Team Leader Natural Environment Brendan Anstiss - General Manager Strategy and Transformation
Approved By	Brendan Anstiss - General Manager Strategy and Transformation

Peer Review Peer Review of the Christchurch Coastal Hazard Assessment Report

18 August 2016

Authors/Contributors:

Shonagh E. Kenderdine, Deirdre E. Hart, Ron J. Cox; Willem P. de Lange; Murray H Smith.

For any information regarding this report please contact the Christchurch City Council.

Recommended reference:

Kenderdine, SE; Hart, DE; Cox, RJ; de Lange; WP; Smith, MH. (2016) *Peer review of the Christchurch Coastal Hazards Assessment Report.* Review report produced for the Christchurch City Council, 18 August 2016, 74pp.

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Executive Summary

This review reports findings from the peer review panel ('the Panel') assessment of the Tonkin & Taylor Ltd (2015) report: Coastal Hazard Assessment – Stage Two ('the Report'). The Panel were asked to address four overarching questions in this review ('the Review'), covering both the science and legal context of the report. These were (i) Does the report represent good science?; (ii) Are the findings still relevant in terms of new research?; (iii) Has the report taken account of relevant statutory policy documents in providing technical or expert advice (refer to Appendix E GHD TOR as a guide)?; and (iv) Is the report and its findings appropriate for its intended purpose - to inform planning for future land use decisions (all referred to as Appendix E GHD Bundle of Documents for full purpose statements)?

The Panel found that the Report's purpose went beyond the technical assessment of areas subject to coastal hazards as required under Policy 24 of the New Zealand Coastal Policy Statement (2010) ('NZCPS'). Requiring mapping suitable to be included in the district plan should have required draft mapping. Such a technical exercise constitutes the first scientific stage in the process of eventually producing maps which are suitable for inclusion in the Proposed Christchurch Replacement District Plan (CRDP). This technical stage should be followed by adaptive planning and application of a precautionary approach identified in Policies 3, 25 and 26 NZCPS before such maps are finalised.

Notwithstanding, the Panel finds that the Report could, and should, constitute a suitable and robust technical basis on which to proceed towards the next stage of development of coastal hazard maps for the district of Christchurch after recommended modifications are made. This Review outlines *recommendations* for work that should be completed before the results of the Report are used to inform the next stages in establishing coastal hazard provisions for the CRDP. We also make *suggestions* for future work that could be incorporated into the first reassessment of the coastal hazard zones (planned to occur in around 10 years' time). To be clear, the *recommendations* are the only work that the Panel indicates needs to be done now.

Positive aspects of the Report included spatial data as requested by CCC on areas susceptible to coastal hazards, including the future timeframes of 2065 and 2115. It included the coastal settlements located on unconsolidated shorelines within CCC's jurisdictional boundaries. The Report also gave close attention to the documents that are directly relevant to an exercise of this technical kind, namely MfE (2008b) (shortly to be updated), and Ramsay et al (2012). The Report met with what might be considered truncated time frames for a technical exercise encompassing coastal erosion and inundation over many open coast and harbour sites.

The Report did not consult the community, nor was this within its Terms of Reference. Community consultation is not a requirement in Table I of the Ramsay et al (2012) good practice guide for this technical stage but rather is a requirement for the subsequent adaptive planning stage.

The Report was based on a single IPCC scenario RCP8.5, which is commonly used in hazard assessments. However, the subsequent adaptive stage of coastal hazard zone mapping will benefit from considering a range of scenarios. Thus, the Panel recommends that additional work is conducted to produce coastal hazard assessments for more than one IPCC scenario.

Regarding the open coast Coastal Erosion Hazard Zones (CEHZ), the Panel endorses a probabilistic approach, but recommends that the analysis use more appropriate probability distributions than the triangular distributions used in the Report. The open coast CEHZ is also dependent on the Waimakariri River sediment supply. The Panel recommends that the open coast CEHZ is reassessed for a range of sediment budget scenarios - with the current 'no change' scenario forming the middle scenario. This can readily be done with the probabilistic modelling approach.

In assessing the Coastal Inundation Hazard Zone (CIHZ) for the Open Coast (New Brighton, Sumner, Taylors Mistake) and for the harbour environments of Lyttelton and Akaroa, overall the Panel conclude that the simple 'building block bathtub' approach used is acceptable.

In assessing the harbour CIHZ, however, the Panel acknowledges that the assumption that all components concurrently reach extreme values is conservative. The Panel suggests that the likelihood of concurrence of extreme waves and coincidence of peak wave setup and wind setup be investigated for inclusion in the next (i.e. '10 years' into the future) reassessment. For the Avon-Heathcote Estuary and Brooklands Lagoon CIHZ, TUFLOW hydrodynamic modelling is used in the Report, but does not consider the effects of river baseflows and concurrent rainfall. The Panel suggests that river baseflows and rainfall, and the influence of climate change on them, be incorporated in the next reassessment.

The indicated coastal erosion hazard zone CEHZ for all harbour sites is not a robust indication of the likely erosion hazard for these specific areas. The Panel recommends that they are re-assessed with more attention to detail and on-ground inspections. The 'high tide translation' method approach should not be used and only the 'equilibrium profile' values considered.

The Report acknowledged the occurrence of ground elevation changes with the earthquakes and appropriately uses the 2011 LiDAR survey for baseline ground elevations. The Report did not assess earthquake-induced changes in groundwater depths and should not do so as this separate exercise is in the area of responsibility of EQC.

NZCPS Policy 24(1)(a)-(h) is the only NZCPS provision relevant to a technical exercise at the first stage in identifying the coastal environment potentially affected by coastal hazard risk and the likely effects of climate change including sea level rise. It was not identified in the Tonkin & Taylor Terms of Reference for the Report, and should have been.

NZCPS Objective 5 and other relevant policies – Policy 3 Precautionary approach, Policy 25 Subdivision, use and development in areas of coastal hazard risk, and Policy 27 Strategies for protecting significant existing development from coastal hazard risk, and its consequences, are all relevant to the next stages of providing mapping of such areas to a sufficient standard to be included in the CRDP – stages and mapping to be defined with the involvement of the community and stakeholders.

An evaluation required under s 32 RMA is only undertaken after information provided by CCC and other experts are brought together to further inform the community, stakeholders and CCC officials on such matters as cost, benefit and the other issues identified in Appendix B. This is to inform through a process of adaptive management the evaluation report for CCC to approve under s 32 sometime in the future.

The hazard maps generated from the results of the Report should be withdrawn for now until the final mapping is concluded. The hazard lines may end up being reinforced after this stage but in the meantime the Coastal Hazard Zones (CHZ) formerly established by ECan may suffice as an interim measure for the open coast, but these do not apply to most of the harbour coasts.

Overall, it is recommended that CCC and ECan work more closely together to develop such information resources as are needed for the coastal hazard assessment and community considerations of adaptive management pathways as part of an integrated approach to coastal management.

Background

[1] This review has been prepared in accordance with the Terms of Reference as prepared by GHD in the commissioning of the Peer Review Panel comprising: retired Environment Court Judge Shonagh Kenderdine (Wellington) (Chair); Associate Professor Ron Cox (UNSW Australia); Dr Willem de Lange (University of Waikato); Dr Deirdre Hart (University of Canterbury); and Dr Murray Smith (private consultant) ('the Panel').

[2] In June 2015 Tonkin & Taylor Ltd (Tonkin & Taylor) prepared the Report, *Coastal Hazard Assessment – Stage Two* (the Report), for the Christchurch City Council (CCC). The Report (Tonkin & Taylor 2015) was peer reviewed by Dr Terry Hume (Hu*me Consulting Ltd) in May 2015.* The Report provides information on those locations that ar*e considered susceptible to coas*tal hazards over both a 50 year and 100 year planning timeframe for Christchurch and Banks Peninsula, taking into account the potential impact of sea level rise (SLR). The Report was used to inform the development of policy and planning rules within the Proposed CRDP.

[3] Whilst the purpose of the Report was to inform policy decisions for future land use within the CRDP, the Local Government Official Information and Meetings Act 2004 has required the report to be notified on Land Information Memoranda for those properties that fall within the areas identified at risk within the report.

[4] In December 2015, following feedback from members of the community on The Report and the recent Parliamentary Commissioner for the Environment's report on sea level rise, the Council passed the following resolution: '*Direct staff to seek a further peer review of the Coastal Hazards Assessment (Tonkin & Taylor, 2015). The peer review be conducted as soon as practicable by a panel of scientific (or other relevant) experts, the details of which will be determined after consultation with affected communities*'.

[5] GHD was commissioned by CCC to independently manage this peer review in collaboration with the community potentially impacted. Questions on the Report have been received from the community by email, phone, letters and meetings throughout April 2016.

[6] A Community Reference Group was established to develop the questions and finalise the terms of reference with support from GHD. The group has also advised on the makeup of the Expert Peer Review Panel, selecting a long list of potential panel members for GHD to approach. The Community Reference Group was nominated by the community and consists of members from the different geographic locations identified within the report. This group worked together to develop the terms of reference that was tabled at the council meeting on May 26 2016 (GHD, 2016).

[7] The GHD 2016 Terms of Reference document (GHD Bundle of Documents, 2016) contains the Tonkin & Taylor (2015) report in Appendix A, the original terms of reference for this work (and

the variation) in Appendix B, the terms of reference for the review by Dr Terry Hume in Appendix C, the Peer Review by Dr Terry Hume in Appendix D, a legal reference document to guide the expert panel on the relevant national legislative and policy framework in Appendix E, a full list of questions and material submitted by the local community agreed to be within the scope of the terms of reference in Appendix F, a summary of questions raised by the community that were agreed to be outside the scope of the terms of reference in Appendix G, and a list of potential peer review members in Appendix H.

Scope of the peer review

[8] As outlined by GHD (2016) the purpose of the peer review is to provide the community and the Council with an impartial and expert view on the data, methods and assumptions used within the Report when responding to the brief set by the Council. In doing so, the peer review panel might want to review and critique the terms of reference provided by Council and the peer review brief and report by Hume Consulting Ltd. The Panel is asked to review the following key questions:

i. Does the report represent good science? The expert peer review panel is asked to assess the methodology and data used and critique any assumptions made.

ii. Are the findings still relevant in terms of new research?

iii. Has the report taken account of relevant statutory policy documents in providing technical or expert advice (refer to Appendix E GHD TOR as a guide)?

iv. Is the report and its findings appropriate for its intended purpose - to inform planning for future land use decisions (refer to Appendix E GHD TOR for full purpose statements)?

[9] The following review by the Panel concentrates on the four key questions above. These sections are further supported by conclusions and recommendations, a bibliography and a glossary. In preparing the responses to the four key questions the Panel noted and have addressed in principle the individual questions raised by members of the community.

Site

[10] The Panel visited some of the sites of the proposed hazard zones on 17 June 2016. The day was clear and bright with a chilly easterly wind. Some of the visit to the southern coastline was to Brighton Beach itself and drive by to some other relevant areas around the estuary and the small communities.

[11] Most of the existing development, residential and commercial within the Christchurch dunes area is set back from the current dune toe by a distance of between 50 to 130 metres. The main CCC asset at risk from shoreline retreat due to sea level rise is the northern section of Marine

Parade located between Shackelton Road and Beach Road. This section of Marine Parade is approximately 3.2 kilometres long and is located within 60 metres of the current dune toe. The additional existing CCC assets located seaward of this section of Marine Parade are the New Brighton Community Library (Te Kete Wānanga o Karoro) and the North New Brighton Memorial and Community Centre including the associated car parking areas. The dune crest elevation is also lower in these areas which will most likely result in a greater distance of shoreline retreat than adjacent areas.[1]

[12] The three open coast beaches of Clifton, Scarborough and Taylors Mistake are located south of the Avon Heathcote Estuary mouth. Clifton Beach is both a relatively flat estuary harbour and open coast beach which is approximately 900 metres long and has developed an incipient foredune at the eastern end. The western 400 metre long section of Clifton Beach is backed by a rock revetment protecting Main Road and has no high tide beach. The eastern 500 metres of Clifton Beach is a sandy beach which includes a vegetated dune system. Scarborough is the main sandy beach at Sumner which is approximately 1.2 kilometres long and has no high tide beach or dune system. Scarborough Beach is backed by a rock revetment structure along the entire length. Taylors Mistake is a sandy beach with a dune system that is approximately 500 metres long.

[1] Report Vol 1 Effects of Sea Level Rise For Christchurch City, Site Description 4.3.1, p 43.

Good science?

Assessment and critique of methodology and data used

[13] In responding, the Panel makes the necessary comment that the hazard assessment as undertaken by Tonkin & Taylor (2015) in the Report covered many coastal sites with varying exposures, varying coastal processes and was undertaken in a very tight timeframe with limited budget. In these circumstances, to meet time and budget constraints, simplifying assumptions can be expected. In this case the limiting assumptions that, where made, are clearly stated. Tonkin & Taylor have generally adopted commonly accepted New Zealand methods as outlined in the Ramsay et al (2012) best practice guide[2] for most of the assessment.

[14] All assumptions are clearly stated in the Report – they are in the main, conservative. This conservatism has limited impact on estimates for 2065 as sea level rise over this timeframe is smaller and more certain. The impact of conservatism in hazard estimates increases in time, being reliant on the less certain sea level rise projections – making the hazard lines for 2115 less certain than those for 2065. This is not unusual and is commonly accepted worldwide with continuance of regular monitoring and periodic reassessment incorporated in best practice effective climate change adaptation practice. Notwithstanding, the Panel recommends additional work is required in order to provide multiple scenarios for the next, adaptive management stage of the process of producing coastal hazard information suitable for incorporation into the CRDP.

[15] The Panel endorses the recommendations of the Report - that the baselines and both the CEHZ and CIHZ values be reassessed at least every 10 years or following significant changes in either legislation or best practice and technical guidance.

Conclusion

[16] Overall, the Panel finds that the Report could, and should, constitute a suitable and robust technical basis on which to proceed towards the next stage of development of coastal hazard maps for the district of Christchurch after the recommended additional work and modifications are made as detailed throughout the rest of this Review and as summarised in the recommendations section.

[2] Ramsay et al (2012). Defining coastal hazard zones for setback lines. A guide to good practice.

Open Coast Science

Open Coast Beach Coastal Erosion Hazard Zone (CEHZ)

[17] This analysis is the most thoroughly undertaken in the Report using the recommended best practice probabilistic approach – in contrast to the simpler 'building block' approach used for other hazard zones in the Report, which is considered adequate (for example, in the Ramsay et al 2012 government guidance document). Shoreline erosion at the dune toe was investigated with Monte-Carlo simulations including the probability distributions of 4 contributing components - short term/horizontal coastline fluctuations including short-term fluctuations (ST), dune stability (DS), long term change (LT) (in this case accretion) and sea level rise induced shoreline change (SL). The outcome is affected by the distributions assigned to each component.

Short-term coastline fluctuations component

[18] The estimation of ST values incorporated in the Monte-Carlo simulation are primarily based on the analysis of the dune toe position over time from ECan beach profile surveys. For each profile the maximum negative residual, the maximum cumulative erosion and 3xSD (standard deviation) of the residuals of the dune toe position from the fitted linear trend are determined (Table 4.4). These are subsequently used in determining the centre and bounds of an erosion triangular distribution for ST. The focus is only on the erosion effects. Limited SBEACH modelling has been undertaken with the indicated maximum erosion of 10 m from two consecutive 1% AEP storms being adopted as the lower bound of a triangular ST erosion distribution. The Report adopts a single triangular distribution (Table 4.7) for only erosion for all open coast beach cells A to F (noting that cell G is separately analysed using the inlet migration method). The upper bound for the adopted ST erosion distribution then surprisingly uses the maximum 3xSD of the beach profile residuals from profile C0300, which is within cell G. The adoption of 3xSD as an upper bound to the ST short term fluctuation erosion is not accepted practice internationally and is stated in the Report as being based on the experience of Tonkin & Taylor (2004 and 2006).

[19] The single short-term erosion distribution from 10 to 20 m with a centre value of 15 m (Table 4.7) is applied to all cells on the open coast, and incorrectly does not include any of the positive short term fluctuations of the dune toe around the linear regression trend indicated in the beach profile data. A more appropriate distribution of the short term fluctuations within a cell, should be based on all the residuals from all the profiles within the cell – the resulting central value will be close to zero with the bounds defined by a histogram plot of the residuals – the distribution is unlikely to be triangular and may be skewed. The impact of seawalls, carparks or major dune modifications on beach profile behaviour needs to be recognised and not included in the ST analysis. Separate ST distributions should be applied to each cell as has been applied for the LT long term components.

[20] It is recommended that the ST values be re-assessed as indicated above and the Monte-Carlo simulations be re-run for each cell, with the CEHZ open coast mapping revised for use in the next planning stage. Better use of the ECan beach profile data for estimation of short-term storm erosion and longer term behaviour is suggested for inclusion in the first reassessment - refinement of the delineation of cells being included. It is also suggested that the first reassessment include a volume based approach as well as the shoreline excursion methodology used in the Report. Overall, both for the present and future assessments, it is recommended that CCC and ECan work more closely together to develop such information resources as are needed for the coastal hazard assessment and community considerations of adaptive management pathways as part of an integrated approach to coastal management.

Dune stability and long-term coastline fluctuation components

[21] The dune stability method is appropriate and follows accepted international practice. The longer term rates of coastline horizontal movement LT are based on analysis of 5 aerial photos from 1941 to 2011. The variation in shoreline movement rate was calculated at 10 m intervals along the open coast. The spatial variation is shown in Figure 4.7 and the adopted triangular distribution values for each cell given in Table 4.9. Whilst undertaking the recommended re-analysis for the ST component indicated above, it is also recommended that the LT distributions be re-assessed (considering normal rather than triangular distributions, with the mean being the fitted LT estimate and the SD being the standard error of the slope for each cell). Incorporation of new photography, LIDAR and the results of ongoing ECan beach profile measurements is suggested in the first reassessment.

Sea level rise component

[22] The SLR values adopted in Table 4.10 for 2065 and 2115 are based on the middle and 5-95% range of projections from process based models from IPCC AR5 in Figure 2.3 (this band of values is considered 'likely' by the IPCC panel of scientists). A minor error appears to have been made in listing a value of 1 m for 2115 in the Table when the Figure indicates 0.94 m.

[23] The Bruun rule is applied to estimate erosion due to SLR utilising appropriate estimates of the slope for central, upper and lower bounds based on different estimates of the closure depth. As stated by Ramsay et al (2012), the Bruun rule is applicable on open coast sandy beaches – this is consistent with common practice in the application of the probabilistic approach. Some researchers propose the use of a more sophisticated model for estimating response to SLR. However, such a more sophisticated modelling approach is reliant upon having extensive beach monitoring data with which to calibrate and verify the model to be used (Fitzgerald et al, 2008; Woodroffe et al, 2012; Shand et al, 2013; Mariani et al, 2013).

Sediment supply component

[24] The Christchurch coast is currently supplied with the sand size sediment needed to nourish its beaches predominantly by local rivers. The most substantial river sediment input comes from the Waimakariri River, which discharges to the coast north of the city, with sediments carried south to nourish the New Brighton coastline via longshore drift.

[25] This longshore drift is driven by remotely- and locally-generated wind waves as well as an eddy of the current that typically flows northward along the east coast of the South Island of New Zealand, but which is reversed in the lee of Banks Peninsula due to sheltering and wave refraction processes (Reynolds-Fleming & Fleming, 2005). The open coast beaches have historically been naturally replenished with sediment supplied from the Waimakariri River – notionally 360,000 m^3 per year being supplied to the coast, of which around half is estimated by Hicks (1998) to come south to the beaches considered in the Report (note that estimates vary between sources such as Hicks 1998; Duns 1995; and Kirk 1979).

[26] The Report relies on Hicks' (1998) research (cited by Tonkin & Taylor, 2015 as 'NIWA 1998') for information on the Pegasus Bay sediment budget. This is appropriate since the Hicks (1998) research represents the most recent quantitative assessment available, although comparisons with earlier work on this topic by Duns (1995) and Kirk (1979) indicate a level of uncertainty in the Pegasus Bay sediment budget. This uncertainty grows when considering that wind and wave climates could undergo directional shifts with future climate changes. Accordingly we recommend that the Report examine the outcomes for the open coast CEHZ based on a wider range of Waimakariri sediment budget scenarios - with the current 'no change' scenario forming the middle scenario. This can readily be done with the probabilistic modelling approach.

[27] Sediment budget analysis is an area where an up-to-date report on the data gathered from the ECan beach profile monitoring network, including comparison of the beach profile data with the results produced by Hicks (1998) would be very helpful. Accordingly, we suggest that a Pegasus Bay coastal monitoring analysis report, including careful analysis of beach volume indices, is produced before the first reassessment of the coastal hazards assessment.

[28] The Report uses the short to medium term climate change predictions from NIWA to assess the future potential sediment supply to Pegasus Bay from the Waimakariri River. Based on these forecasts, the assumption that climate change effects on river sediment supply to the coast are likely to be minor over the short to medium term are reasonable when considering natural processes of catchment sediment delivery alone. This takes account of the nature of the Waimakariri as a large braided river, fed by headwaters in the Southern Alps.

[29] Previous research indicates precipitation over the Canterbury Plains is affected by large atmospheric circulation patterns, such as ENSO and IPO, which are expected to respond to projected

climate change resulting in a change in the frequency, magnitude and seasonal distribution of rainfall, for example (Ummenhofer and England, 2007; Ummenhofer et al, 2009). NIWA also forecasts that the Canterbury Plains will likely experience less rainfall over the short to medium term[3]. The Canterbury plains represent a dryland and drought prone environment under current conditions and the plains agriculture is already heavily reliant on irrigation water, with the region's catchments having been under extreme water use pressures for over a decade (e.g. OECD 2007; Glubb et al, 2012).

[30] Further to the water resource pressures on the Waimakariri, there are currently significant pressures on the river's sediment resources, with implications for the coastal sediment budget. Gravel and its associated sand 'bycatch' is being extracted from the lower reaches of the river, near the State Highway bridge, in an area flanked by stopbanks to protect surrounding settlements from the hazard of Waimakariri River flooding. This sediment extraction pressure is likely to increase with future demand from the construction industry as well as with the desire to maintain the river channel depth and thus the design standard of the stopbanks.

[31] Given the range of future anthropogenic water resource management options under NIWA's regional climate change predictions, and alongside sediment resource and flood hazard considerations, significant future alterations to the Waimakariri River sediment supply to Pegasus Bay are possible. In this context, the sediment budget assumptions made in the Report could be described as optimistic. The Report assumes no change in longer term sediment supply from the Waimakariri River, and hence adopts the aerial photo analysis for historical long term (LT) accretion rates. However, with the probabilistic model established, the sensitivity of the CEHZ results to possible changes in sediment supply can be readily examined by changing the input LT accretion distribution in the modelling. The Panel recommends that the open coast CEHZ is reassessed for a range of sediment budget scenarios - with the current 'no change' scenario forming the middle scenario. This can readily be done with the probabilistic modelling approach.

[32] Despite the specific issues raised above with associated recommendations for re-analysis, the new CEHZ for the open coast results in the additional inclusion of less than 100 properties beyond those previously considered susceptible to coastal erosion hazard in the Canterbury Regional Coastal Environment Plan's (2005) Coastal Hazard Zones. The CEHZ 2065 and 2115 zones are qualitatively consistent with cursory extrapolations of the ECan beach profile responses to storm events monitoring and Panel experience for similar dissipative beach systems. It is noted that the mapping does not allow for the effects of seawalls and other structures. It is recommended that the location and condition status (poor/inadequate OR good/engineering design standard) of seawalls and other structures on the shoreline be indicated in the CEHZ mapping.

[3] See: https://www.niwa.co.nz/our-science/climate/information-and-resources/clivar/scenarios

Conclusion

[33] Overall, both for the present and future assessments, it is recommended that CCC and ECan work more closely together to develop such information resources as are needed for the coastal hazard assessment and community considerations of adaptive management pathways as part of an integrated approach to coastal management.

[34] We recommended that the open coast CEHZ maps are revised before they are used for planning purposes as follows:

a. The short-term (ST) and long-term (LT) component values are recommended to be re-examined as indicated in this report. Specifically, ST and LT component estimates should be evaluated based on the measured probability distribution (ST) and a normal distribution (LT). Normal, rather than triangular, distributions should be considered for the other components in the probability analysis. The Monte-Carlo simulations should be re-run taking into account the new ST and LT component estimates. The CEHZ should be based on individual coastal cell distributions and not an overall aggregated distribution.

b. It is also suggested that any subsequent future reassessment might include refinement of the delineation of coastal cells - smaller cells perhaps being able to better capture longshore variability.

c. Using the probabilistic modelling approach, we recommend that the Report should examine outcomes for the open coast CEHZ for a wider range of Waimakariri sediment budget scenarios, with the current 'no change' scenario forming the middle scenario.

Open coast beach Coastal Inundation Hazard Zone (CIHZ)

[35] A 'building block' approach as discussed in section 3.2.1 of the Ramsay et al (2012) best practice guide is carried out incorporating the components of storm tide (with its various components), wave setup and SLR.

Extreme water level component

[36] The storm tide values for 1% and 2% AEP were based on water level gauge analyses for Lyttelton and Sumner Head by Goring et al (2009, 2011). These two water level monitoring sites appropriately have record lengths (exceeding 20 years) to allow reasonable analysis for predicting 2% and 1% extreme water levels for 2065 and 2115 respectively – the prediction of the 1% 2115 extreme storm tide levels being less reliable than those for the 2% 2065 value. Extreme water levels within the harbour embayments are complex with varying contributions at varying timescales including tides, storm surges, waves, winds, seasonal effects, El Niño Southern Oscillation/ Inter-decadal Pacific Oscillation, long period edge waves and resonance, (Goring & Henry, 1998; Borrero

et al, 2013; Goring 2014, 2015; Borrero & Goring, 2015). It is suggested that an updated thorough analysis for extreme water levels of all water level monitoring stations in the Canterbury area be undertaken prior to the first reassessment. The surge components of the extreme 1% and 2% extreme storm tides are not expected to change significantly in the reassessment.

Wave set-up component

[37] The wave set-up estimated for New Brighton, Sumner, and Taylors Mistake was derived from deep-water wave height and period data AEP distributions and the beach slope, using the methodology in section II-4-3 of the Coastal Engineering Manual. The deep water wave climate 1% and 2% values given in Table 4.1 are noted as being from Tonkin & Taylor (1998). The values of wave setup given in Table 4.2 are a significant component of the total CIHZ. It is recommended that the deep water wave climate be updated (from Tonkin & Taylor, 1998) and wave setup with transformation across the surf zone be re-evaluated using both the CEM and alternative methodologies (for example, consider use of the Dally et al (1985) surf zone wave transformation model that is incorporated in SBEACH). It is recommended that this be undertaken, the effect on total CIHZ level assessed, and where necessary the CIHZ mapping amended.

Run-up component

[38] Although wave run-up is discussed no calculations of likely levels and/or overwash with assessment of safety for people or vehicles and damage to property is presented – such analysis and considerations are common internationally, (and recommended by Ramsay et al, 2012) especially in areas where overwash is likely such as the pier and library area at New Brighton. This aspect is suggested for inclusion in the first reassessment.

Sea level rise component

[39] SLR values used in Table 4.2 are 0.4 m for 2065 and 1 m for 2115 – the stated basis being recommendations from Bell (2013) and Tonkin & Taylor (2013a) – the values are reasonable for inclusion of regional/local effects in consideration of the IPCC AR5 values shown in Figure 2.3.

Overall

[40] The simple 'building block' approach and outcomes are summarised in Table 4.2. The result assumes extreme storm tide is co-incident with the peak of the wave setup and as such is conservative. It is suggested that prior to the first reassessment and in conjunction with the recommended update of extreme water levels from monitoring stations the likelihood of concurrence of extreme waves and coincidence of peak wave setup with extreme storm tide be investigated.

[41] The impact of the projected inundation was assessed in the Report by the derivation of CIHZ lines corresponding to the 2065 and 2115 inundation elevations. The CIHZ appropriately enclose areas that are connected to the open coast by a pathway that would allow the ingress of seawater as sea level rises.

[42] Overall, the various approaches used for determination of the CIHZ lines for the open coast have been consistent with the 'building block' approach of Ramsay et al (2012). As such they are acknowledged as being conservative.

Conclusion

[43] In assessing the Coastal Inundation Hazard Zone (CIHZ) for the Open Coast (New Brighton, Sumner, Taylors Mistake), overall we conclude that the simple 'building block bathtub' approach used is acceptable. This conclusion should be understood together with the recommendation in latter legal sections of this report that additional work be conducted using multiple IPCC scenarios to feed into the adaptive management exercise.

Harbour Coast Science

Harbour Coast CEHZ

[44] The approach is different to that used for the open coast beaches – this is appropriate considering the different geomorphology, soils and wave exposure. Two different approaches are applied: the 'equilibrium profile' method and the 'high tide translation' method.

Equilibrium profile method

[45] In the 'equilibrium profile' method (based on the Bruun rule) a simple 'building block' approach is applied with the summation of the same 4 components considered for the open coast – ST, DS, LT and SL.

[46] DS and LT are taken as zero based on published research and local knowledge. ST is taken as -5 m for all sites – this appears an oversimplification as the sites have varying exposure to waves and varying soils. Better estimates of likely short term ST erosion in extreme storms can be made. For example, the Stevens and Giles (2010) paper cited in the Report gives a simple method based on wave climate and water depth/underwater slope. It is suggested that the DS, LT and ST values be re-evaluated in the first reassessment.

[47] The simple equation 8 is used to estimate shoreline adjustment with SLR – the slope to be used being determined from analysis of aerial photos or LIDAR between the HAT contour and the beach toe (noticeable break of slope). The adopted SLR values used in Tables 4.18 and 4.19 are the mean 50% RCP8.5 values from Table 4.10 adjusted for the historic rate of SLR.

[48] The 'equilibrium shoreline' erosion values given in Tables 4.18 and 4.19 are considered adequate indicators of likely erosion for the harbour coast sites, even though conservative. The high values for Teddington arise from the very flat slope adopted – it is recommended that this be re-assessed in the field and, if necessary, the CEHZ mapping amended.

High-tide translation method

[49] The second 'high tide translation' method results in CEHZ mapping for many harbour sites (including the Avon-Heathcote and Brooklands areas) that is misleading and clearly of concern to the affected communities. The 'high tide translation' method results in CEHZ lines that look more like CIHZ lines. The analysis claims to be based on the eShoreance method of Stevens and Giles (2010), yet it does not follow Stevens and Giles (2010) exactly. Specifically, the Report uses HAT as the baseline, whereas eShoreance is based on changes from MSL, and the eShoreance method is not applicable if the future mean high water exceeds the estuary bank crest height.

Overall

[50] The mapping of the CEHZ for the harbour sites, including the Avon-Heathcote Estuary and Brooklands Lagoon, is taken as the upper envelope of erosion by either the 'equilibrium profile' or 'high tide translation' methods: the mapping and report do not indicate for the different shorelines which method controls the indicated CEHZ zones. The areas incorrectly mapped using the 'high tide translation' method can be generally discriminated by the considerable change in mapped hazard: for example, at the northern end of the Akaroa site in Figure Appendix D.12

[51] The mapped CEHZ lines for all harbour sites including the Avon-Heathcote Estuary and Brooklands Lagoon are misleading and should not be considered as indicative of likely erosion hazard. It is recommended that they be re-assessed with more attention to detail and on-ground inspections. The 'high tide translation' method values must be discarded and only the 'equilibrium profile' values considered. The zones should not extend up small inlets. It is noted that the extent of the indicated CEHZ erosion hazard are contained within the wider extent of the CIHZ coastal inundation hazard zones discussed below.

Conclusion

[52] We recommended that for all harbour coast sites that the CEHZ mapping is reworked, including the following:

a. The harbour CEHZ as currently mapped in the Report should be discarded.

b. More attention should be paid to detail and on-ground inspections, and profile slopes should be reviewed.

c. The 'high tide translation' method values should be discarded and only the 'equilibrium profile' values considered.

d. The zones should not extend up small inlets.

Harbour Coast CIHZ

[53] Two approaches were used for assessing the CIHZ for harbour coasts depending on the availability of high-resolution topographic data and pre-existing flood models. The simplest being the 'bath-tub' approach using the 'building block' approach for determining inundation levels: this projects the extent of inundation based on the elevation of land connected by a pathway. This approach does not account for estuarine hydrodynamics and frictional losses when water flows across wide areas of relatively flat land. The Report applied the bath-tub approach to most sites around Banks Peninsula, and a different approach for the Avon-Heathcote Estuary, Sumner[4], and Brooklands Lagoon (Waimakariri River Entrance – Styx Catchment).

Building block bathtub approach

[54] For the Banks Peninsula sites, a 'building block' approach as recommended by Ramsay et al (2012) incorporating the components of storm tide (with its various components), wave setup, wind setup and SLR is used to conservatively estimate extreme total inundation levels. It is slightly different to that for the open coast with the inclusion of wind setup.

[55] The storm tide values for 1% and 2% AEP were appropriately based on water level gauge analyses for Lyttelton and Sumner Head by Goring et al (2009, 2011). As noted in the discussion on CIHZ for the open coasts, these two water level monitoring sites appropriately have sufficient record lengths to allow reasonable analysis for predicting 2% and 1% extreme water levels for 2065 and 2115 respectively – the prediction of the 1% 2115 extreme storm tide levels being less reliable than those for 2% 2065 value. Extreme water levels within the harbour embayments are complex with varying contributions at varying timescales. It is noted that there are other monitoring stations within the harbour and surrounding areas (Kaikoura, Timaru, Sumner, Port Lyttelton, Akaroa, Canterbury Bight) that may provide useful extreme water level information. It is suggested that an updated thorough analysis for extreme water levels of all water level monitoring stations in the Canterbury area be undertaken prior to the first reassessment.

[56] Wave and wind setup at each of the harbour sites was calculated using standard estimation methods based on 1 h duration winds determined from extreme 3 s wind gust data. Both the wind and wave setup values (Table 4.15 for 2115 and Table 4.16 for 2065) are upper limit values since they were calculated assuming the wind blows along the longest fetch to the site. The contributions of wave and wind setup to the total inundation levels are significant. Numerical

[4] Appendix F does not provide any information about the modeling undertaken for Sumner. It only discusses the model coverage for the Styx, Avon and Heathcote urban catchments. Further, the legend for the CIHZ plotted in Appendix E, Figure 1A indicates that the results are not based on TUFLOW (no mention of Freeboard unlike the legends for the Avon-Heathcote Estuary and Broadlands Lagoon). Tables 4-1 and 4-2 suggest that, consistent with the figure caption, Sumner was treated as an open coast site, not a harbour site as implied by section 4.2.1.6.

modelling of waves within Lyttelton Harbour has been undertaken by the Lyttelton Port of Christchurch as part of its recovery plan (e.g., Goring 2014, 2015). These results could be used to assess the wind and wave set-up around the harbour, including the potential effects of future dredging scenarios. It is suggested that in the first reassessment the wave and wind setup values be re-evaluated for each site – specifically the assumption that the extreme 1% and 2% winds will blow along the longest fetch needs to be tested.

[57] As for the open coast, SLR values used in Tables 4.16 and 4.15 are 0.4 m for 2065 and 1 m for 2115 – the stated basis being recommendations from Bell (2013) and Tonkin & Taylor (2013) – the values are reasonable for inclusion of regional/ local effects in consideration of the IPCC AR5 global values shown in Figure 2.3

[58] The resulting total inundation levels based on the building block approach used in mapping of the CIHZ for harbour coasts assumes sea level rise is added to extreme storm tide which is co-incident with the peak wind and wave setup arising from winds blowing from the worst direction along the longest fetch and as such is conservative. Ramsay et al (2012) note that '*Whilst the various components combining to result in an extreme storm tide level are typically correlated in some way, very rarely does an extreme high-tide level coincide with both a high storm surge and high wave conditions*'. Therefore, the 'building block' approach used in the Report to assess current inundation hazard '*will tend to overestimate inundation risk*'. As for the CIHZ open coast, it is suggested that prior to the first reassessment and in conjunction with the suggested update of extreme water levels from monitoring stations the likelihood of concurrence of extreme winds and waves with coincidence of peak wind and wave setup with extreme storm tide be investigated.

[59] Mapping takes an appropriate bathtub approach as outlined above for the majority of the harbour sites. For the Avon-Heathcote estuary and Brooklands areas where tidal propagation will encounter overland flows and friction effects can be expected to significantly affect water levels, Tonkin & Taylor have undertaken TUFLOW modelling. This has only been possible because Tonkin & Taylor had a TUFLOW model previously developed for another study.

TUFLOW

[60] For the estuaries modelled using TUFLOW the effort is considerable as outlined in Appendix F of the Report. Digitisation of the Avon, Heathcote and Styx catchments, incorporation of available bathymetry (underwater survey), stormwater drainage and overland flow paths are all required and necessary model inputs. The modelling effort is rigorous but without thorough calibration and verification the accuracy is uncertain. As expected, TUFLOW indicates lower inundation levels than the bathtub approach as the distance upstream of the estuary entrance increases.

[61] The TUFLOW model was run for only two future downstream tidal boundary conditions as defined in Table 4.17 and outlined in more detail in Appendix F section 4.2. The tidal boundary conditions were chosen to have peak water levels being the sum of storm tide (2% AEP=1.8 m and 1% AEP = 1.85 m), sea level rise (2065 = 0.4 m and 2115 = 1.0 m) and a 'freeboard' of 0.4 m. The storm tide and SLR values are consistent with those adopted for the harbor coasts mapped using the bathtub approach. The tidal boundary condition included an allowance of 0.4 m on top of extreme tide and SLR, which is stated as a 'freeboard' to compensate for wave and wind setup. The calculations to justify the value of 0.4 m allowance for wave and wind setup should be included in the Report. CAUTION is needed as this is not a freeboard in the sense of 'freeboard' that is normally added to CIHZ by CCC in planning to set floor levels in areas vulnerable to flooding.

[62] The TUFLOW modelling did not include river baseflows, or the effects of coincident rainfall, which could increase the extent of flooding. These factors were not included in the bathtub modelling undertaken for other sites. A partial analysis based on a short duration rainfall record was undertaken by Tonkin & Taylor as part of an assessment of increased flooding vulnerability arising from the Canterbury Earthquake Sequence (Tonkin & Taylor, 2014a, b,c). It is suggested that these factors, and the influence of climate change on them, be incorporated in the first reassessment of the coastal hazard zones.

Conclusion

[63] In assessing the CIHZ for harbour environments, overall we conclude that the simple 'building block bathtub' approach used is acceptable for Lyttelton and Akaroa Harbours.

[64] However, with respect to the Avon-Heathcote Estuary TUFLOW model, the calculations to justify the value of 0.4 m allowance for wave and wind setup should be included in the Report and the wording of the Report should be clarified to distinguish between flood freeboard and the effect of wave and wind setup.

LiDAR and earthquake effects

LiDAR

[65] The Report used a digital elevation model (DEM) of the Christchurch city ground surface elevations produced using the 2011 LiDAR data supplied by the 'Council' (Tonkin & Taylor, 2015, p 10). LiDAR is a remote sensing technique that uses a pulsed laser to measure distances to the ground from, in this case, a sensor mounted on an aircraft. For the inundation modelling, additional data were incorporated into the DEM from an earlier 2010 LiDAR survey, and hydrographic surveys of the Avon-Heathcote Estuary by NIWA in March/April 2010 and January 2013 (Tonkin & Taylor, 2015, Appendix F). The methodology used to derive the DEM is described in Tonkin & Taylor (2014)

[66] The May 2011 Christchurch LiDAR dataset was collected after the first two significant earthquakes of the Canterbury Earthquake Sequence (CES, that is, September 2010 and February 2011) to measure the significant ground elevations changes and displacements that had occurred. As such, any uplift or subsidence experienced in the Southshore and other areas during the September 2010 and February 2011 earthquakes has been incorporated into the baseline ground elevations that the Report has used for their hazard assessments, although changes since 2011 have not been incorporated.

[67] Another significant land elevation process accounted for in the 2011 LiDAR DEM is the growth of the open coast dunes that occurred between the 2011 LiDAR survey and the previous survey, which was conducted in 2003.

[68] More recent aerial LiDAR surveys have been flown for parts of Christchurch city after each major earthquake since 2011, but the spatial extent of these surveys is more limited than the 2011 survey. Given that the 2011 LiDAR survey accounts for a large proportion of the ground elevation change that has so far occurred in the CES, and given the spatial limitations of post-2011 LiDAR surveys, it is appropriate that Tonkin & Taylor relied on the 2011 survey for its baseline DEM in their 2015 report.

[69] However, since the GNS (Geological and Nuclear Sciences) forecasts indicate that the Canterbury aftershock decay sequence will continue for years to decades, it would be appropriate that any subsequent reassessment of this coastal hazards assessment include an examination of new data on ground elevation changes. This would be particularly relevant to the estimation of the inundation extent and erosion hazard lines associated with the waterways and low-lying flood plains upstream from the mouth of the Avon-Heathcote Estuary Ihutai.

[70] Further, we suggest that future LiDAR surveys of Canterbury cover the areas predicted to be affected by coastal hazards over the next 100 years in the Report, plus adjacent low-lying land.

Groundwater

[71] In areas of Christchurch that have undergone earthquake-induced changes in ground elevations, the relationship between the land surface and the groundwater table has been altered: that is, depths to groundwater have decreased where subsidence occurred and increased where uplift occurred (Hart et al, 2015). The depth to groundwater is important for at least two reasons related to hazard assessments. Firstly, when ground water levels are high, there is little capacity for water falling on, or running across, the ground surface to infiltrate into and/or be stored in the soil. As such, a decrease in depth to groundwater can enhance the flood hazard. Secondly, significant decreases in the depth to groundwater has increased liquefaction hazard in low-lying areas of Christchurch where the dry layer of the surface crust has been substantially reduced (Russell and van Ballegooy, 2015; Quilter et al, 2015).

[72] The Mayoral Taskforce made an initial summary of the post-quake increases in flood hazard that have affected several different inland and coastal areas of Christchurch city (CCC 2014). Their examination of this phenomenon was prompted, in part, by the March 2014 extreme rainfall event (see Allen et al, 2014 for details). Increased Flooding Vulnerability (IFV) and Increased Liquefaction Vulnerability (ILV) are now both recognised as an earthquake 'land damage' categories by the Earthquake Commission (EQC).

[73] In terms areas covered by the Report, post-quake flood hazard changes are of particular concern in the lower reaches of the Avon River and northern Avon-Heathcote Estuary Ihutai. The southerly storm conditions that produce elevated estuary water levels and conditions conducive to inundation in this the Ōtākaro Avon River mouth area also tend to be correlated with rainfall over the city resulting in a combined fluvial and coastal flood hazard (Lamb, 1997).

[74] CES-induced increases in the flood hazard were not examined in detail in the Report but were previously examined as a series of reports produced for EQC (Tonkin & Taylor, 2014 a,b,c). It is appropriate that the CES-increased flood hazard was not studied as part of the Report's assessment of 2065 and 2015 likely and potential coastal erosion and inundation zones, and that the latter assessment used post-earthquake land elevations. This is because the detailed assessment of the CES-induced increases in flood and other hazards should instead form part of the earthquake effects assessment, and be dealt with under EQC provisions.

[75] It is worth noting that the full picture of changes in the Christchurch flood hazard after the CES is yet to be known, and continues to change as lifelines systems repairs proceed, including those to the stormwater and wastewater networks. Of note for areas of overlap with the coastal hazards assessment, it would be advisable to undertake a further analysis of the extent of the IFV (increased flood vulnerability) for the estuary margins of New Brighton Spit, since changes in this area are complex and relate no only to CES-induced subsidence but also to the subsequent red zoning of

residences and the eventual removal of some infrastructure in this area. However, this should be undertaken as a separate exercise from the Report's coastal hazard assessment.

Conclusion

[76] The Report acknowledged the occurrence of ground elevation changes with the earthquakes and appropriately uses the 2011 LiDAR survey for baseline ground elevations. The Report did not assess earthquake-induced changes in groundwater depths and should not do so as this separate exercise is in the area of responsibility of EQC.

Distributions and the probabilistic approach

[77] Use of the probabilistic approach in determining hazard zones is highly desirable and is recommended in Ramsay et al (2012). The approach requires a suitable probability distribution as a way of quantifying uncertainty for each component of Equation 2 in the Report. These probability distributions should reflect uncertainty from many different sources including coastal processes, lack of data, in estimates obtained from available data, and uncertainties from future changes.

[78] Assessments of parameters for and selection of the form of the component probability distributions can have substantial consequences for the position of hazard zone lines drawn using the distribution of the sum of components. Assessments are difficult, have to be made carefully, use all available information, and not add biases to the resultant hazard zones.

[79] The use of triangular probability distributions for the probabilistic approaches is recommended for coastal modelling by Ramsay et al (2012) and used in Cowell et al (2006). Triangular distribution forms, while being easy to sample, have some undesirable properties. There are many situations where other forms of probability distribution should be used. For example, where thick-tailed or highly skewed distributions appear to apply. Normal distributions can also better represent the uncertainty in many cases, especially where it is possible to exceed the absolute bounds assessed for triangular distributions.

[80] It is very difficult, if not impossible, to introduce correlations between components when the (marginal) distribution shapes are triangular. Not having correlations between components where it is obvious that it should be so can strongly affect the hazard lines, especially where the lines have small tail probabilities beyond their determined locations. It is relatively easy to introduce correlations where the components have normal uncertainty distributions, but it can also be done in skewed cases.

[81] An issue has been raised by the community in a statement that "*the best international guidance is that 1 m sea level rise in 100 years is very unlikely*". This statement follows from a probability calculation that gives a probability of approximately 4% that the sea level rise in the 100 years to 2100 exceeds 1 m (4% is approximately = 17% × 25%).

[82] This statement is not applicable to sea level rise to 2115, which is the time period required for the Report. There is every reason to believe that the sea level rise between 2015 and 2115 will be greater than between 2000 and 2100.

[83] The calculation is also in error and makes a number of unjustified assumptions. What has been calculated is the 'probability' that the two events, 'sea level rise to 2100 exceeds 1 m' *and* 'emission levels to 2100 have followed pathway RCP8.5', have both occurred together. This is

because it is the product of the conditional 'probability' that sea level rise to 2100 exceeds 1 m given that emission levels to 2100 have followed pathway RCP8.5.

[84] Further, the 'probability' that emission levels to 2100 have followed pathway RCP8.5 being 25% cannot be taken seriously. Is the RCP8.5 pathway the only pathway among the myriad possible pathways for which a sea level rise of greater than 1 m is possible? Clearly it is not. The only way to use pathways to calculate the marginal 'probability' that sea level rise to 2100 exceeds 1 m is to calculate the conditional 'probability' for each pathway, and this will vary over all possible pathways, and then to average all these conditional 'probabilities' over some 'probability' distribution on all the pathways.

[85] The IPPC does not attach any probability to the sea level rise projections under each of the four RCP scenarios identified in its latest reports for very good reasons. In the IPCC AR5 Chapter 13 publication it is stated that for the RCP8.5 scenario it is likely (66%-100%) that the global mean sea level rise will be in the 5% to 95% range of projections from processed based models of 0.52 m to 0.98 m by 2100. The 90% bounds are calculated from an ensemble of process based model results and therefore the interval defined by the range cannot even be interpreted as a 90% confidence interval as it not based on data which has a random nature let alone a probability. Furthermore, the IPCC then attaches a likely weighting of 66%-100% to the interval because of uncertainties not considered in the process based model results.

[86] The 25% used as a probability that *"emission levels to 2100 have followed pathway RCP8.5"* is at best subjective and seems to be related to the fact that for reporting purposes the IPPC chose four different emission scenarios of which RCP8.5 projects the highest sea level rise. Again, the IPPC does not attach any probability to the representativeness of the four emission scenarios, which is why it has used a scenario approach. There is an infinite number of possible emission pathways to the 2100 endpoint and it is impossible to enumerate all pathways or assign a 'probability' to the event that a particular group of pathways contains the actual pathway that will happen.[5]

[87] There are some very large assumptions made in this calculation with little justification. In addition, the calculation treats the weighting numbers from the IPCC AR5 report as probabilities when the IPCC does not. The calculation has no validity even as rough approximation.

[5] This assertion applies to pathways to sea level rise projections and does not apply to probability distributions used to model uncertainty in the components when the probabilistic approach is used. It is also why Ramsay et al (2012) suggest the use of sea level rise scenarios rather than the use of one single scenario.

Conclusion

[88] Regarding the open coast Coastal Erosion Hazard Zones (CEHZ), the Panel endorses a probabilistic approach, but recommends that the analysis use more appropriate probability distributions than the triangular distributions used in the Report.

Does the Report focus on upper end scenarios at the expense of more likely scenarios?

[89] As illustrated in the figure below, the IPCC AR5 used four Representative Concentration Pathways (RCP) possibilities – RCP2.6, RCP4.5, RCP6.0 and RCP8.5 – to represent possible future outcomes (refer to the earlier science section comment regarding RCP2.6). The 'likelihood' range for sea level rise presented for each pathway is based on a particular emission occurring. It is not a trend projection set in stone and is based on the collective judgement of the scientists. Note that the likely projections for global mean sea level rise vary little between the different scenarios until after the middle of the 21st century, with variation significantly increasing after that again.

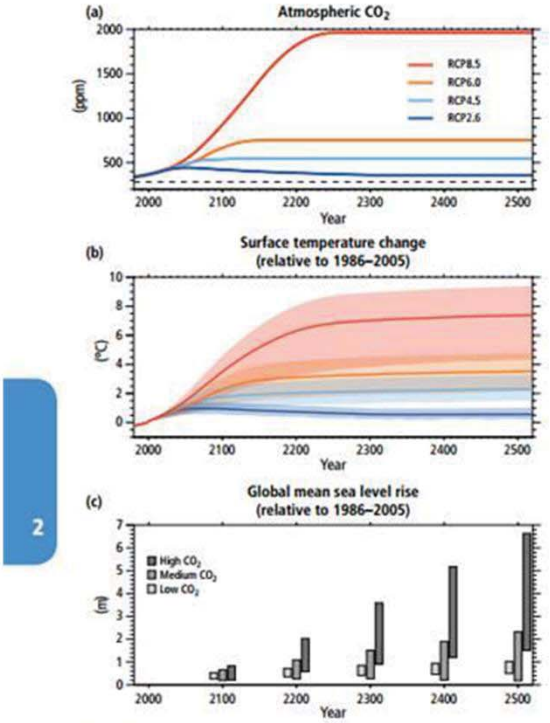

Figure 2.8 | **(a)** Atmospheric carbon dioxide (CO_2) and **(b)** projected global mean surface temperature change as simulated by Earth System Models of Intermediate Complexity (EMICs) for the four Representative Concentration Pathways (RCPs) up to 2300 (relative to 1986–2005) followed by a constant (year 2300 level) radiative forcing. A 10-year smoothing was applied. The dashed line on (a) indicates the pre-industrial CO_2 concentration. **(c)** Sea level change projections grouped into three categories according to the concentration of greenhouse gas (in CO_2-eq) in 2100 (low: concentrations that peak and decline and remain below 500 ppm, as in scenario RCP2.6; medium: 500 to 700 ppm, including RCP4.5; high: concentrations that are above 700 ppm but below 1500 ppm, as in scenario RCP6.0 and RCP8.5). The bars in (c) show the maximum possible spread that can be obtained with the few available model results (and should not be interpreted as uncertainty ranges). These models *likely* underestimate the Antarctica ice sheet contribution, resulting in an underestimation of projected sea level rise beyond 2100. *[WGI Figure 12.43, Figure 13.13, Table 13.8, WGII SPM B-2]*

[90] In answering the question that titles this section, IPCC's AR5 RCP8.5 is based on a high emission scenario, with no new additional efforts to constrain emissions, and is broadly comparable to previous IPCC assessments. It is not, however, a *maximum* sea level rise scenario, as it excludes certain non-linear effects and the possibility of early (21st century) ice sheet collapse occurring.

[91] It is important to note that under many modelled scenarios, sea level rise continues well after the 21st century such that 2100 or 2115 estimates of sea level rise are not a final result in terms of Earth System responses. It is also worth noting that several sea level rise experts argue in peer reviewed published studies that 21st century sea level rise may exceed the IPCC RCP8.5 scenario in the 21st century. Further, atmospheric concentrations of carbon dioxide have recently reached a record high[6], leading many NASA scientists to conclude that we are now passing the point where the lower IPCC scenarios are likely or possible, such that RCP2.6 could reasonably be excluded from any future scenario sensitivity assessments. Considerable scientific effort is presently focusing on refining understanding of ice sheet behavior so that it might be realistically included in future IPCC assessments. In short, experts are generally in agreement that sea level is rising, and will keep rising for many decades to centuries, but there is debate around which sea level rise rates best represent late 21st century rises.

[92] The debate in refining late 21st century and beyond sea level rise estimates is perhaps why the IPCC's RCP8.5 is commonly used in hazard assessments, as a cautious ground between possible approaches. The Panel notes that the proposed 10 year reassessment of the coastal hazard information for Christchurch proposed in the Report is a mechanism that will allow alterations in sea level rise scenarios to be taken into account as a part of an adaptive management process. We also note that the adaptive management process that should follow the technical exercise that the Report represents can take account of the implications of the less certain late 21st century sea level rise estimates in a planning process. It is important to note that that the above debate relates largely to sea level rise estimates towards the end of the 21st century, not to estimates up until the 2065 timeframe used in the Report.

[93] Ramsay et al (2012) recommends that a range of sea-level rise scenarios be assessed for the future timeframe(s) under consideration and the sensitivity of the resulting coastal change/ inundation ascertained (Box 3 - Key checklist for coastal hazard assessments). Such scenarios can incorporate possible regional variations from global sea level projections.

[94] The Parliamentary Commissioner for the Environment identifies that sea level is projected to rise by about 30 cm between 2015 and 2065, calculated by a base level of 27 cm with 10% added

[6] In 2016 atmospheric carbon dioxide concentrations have exceeded 400 ppm as measured at the Mauna Loa Observatory in Hawaii. See: http://www.esrl.noaa.gov/gmd/ccgg/trends/global.html

on,[5] because IPCC considers New Zealand regional sea rise may project up to 10% more than global SLR. The Commissioner's assessment takes the average of the midpoints in IPCC (2015) as about 26 cm. The additional 10% rise proposed by the IPCC gives a figure of 28.6 cm, rounded out to a value of 30 cm. We note too that the Parliamentary Commissioner expresses the results in her document in terms of exceedances of high water levels that are currently expected to occur only once every hundred years – or a 1% chance in any one year at present (with the predicted rate of exceedances changing over time).

[95] It is also important to note that climate change scenarios include changes in other processes, in addition to those in sea levels. In the relevant IPCC documents, it is stated that 'It is *likely* (with *medium confidence*) that the annual mean significant wave heights will increase in the Southern Ocean as a result of wind speeds. While Southern Ocean-generated swells are *likely* (with *medium confidence*) to affect heights, periods, and directions of waves in adjacent basins'.[6] El Nino Southern Oscillation effects can raise or lower the level of the sea around New Zealand by as much as 12 cm. Interdecadal Pacific Oscillation effects can raise or lower sea level by about 5 cm.[7] These are temporal uncertainties, the practical effects of which may be factored into more detailed possible scenarios for sea level rise.

Conclusion

[96] We recommend that, in order to inform the next adaptive management stage of the process of producing coastal hazard information ready to be incorporated in the CRDP, projections from a range of RCP scenarios (with the exception of RCP2.6) need to be included in the assessments for the CEHZ and CIHZ, at least for the 2115 assessments. This may have little effect on the hazard assessments for 2065, but will likely produce a greater range of scenarios for 2115 for planning consideration.

[5] Parliamentary Commissioner for the Environment (2015) *Preparing New Zealand for Rising Seas: Certainty and Uncertainty*. Notes, 7, p 82, citing IPCC 2014 Working Group 2, Chapter 25, p 1381. Hannah and Bell 2012, para 32.
[6] Ibid Chapter 13 Sea level Change, pp 1179-1181.
[7] NIWA 2015 b, p 31.

Appropriate use of 100 year and 50 year time frames?

[97] In short, the answer is yes. 'Over' 100 years (i.e. 100 years plus) is the timeframe identified in the NZCPS (2010). Scientists note that sea level rise is anticipated to continue well over the next century - this is why the qualification 'over' 100 years in the NZCPS Policy 24 was ruled more appropriate than a 'fixed' horizon. Meanwhile, action taken to reduce greenhouse emissions will make little difference to the rate of sea level rise for several decades as a result of the past effects of greenhouse gas emissions moving slowly through the Earth's system,[8] such that that 50 year assessments can have a high degree of confidence attached to them. The Panel endorses that these timeframes were used in the Report in tandem with the recommended '10 year reassessment' mechanism.

[8] Parliamentary Commissioner for the Environment, Preparing New Zealand for rising seas: Certainty and Uncertainty, Note 6, p 82.

Are the Report's findings relevant in terms of new research?

[98] The assessment by this Review has been restricted to the TOR and conditions agreed between Tonkin & Taylor and CCC. In this respect the Report has met most reasonable expectations. As noted above, there are some omissions and errors that should and can readily be recalculated and mapping amended. There is no new research that brings into dispute the work presented.

[99] The methodology used to assess coastal hazards is likely to continue to evolve over time, as are the legislative frameworks within which the results are applied, and the scientific evidence and observational data on which the assessments are based.

[100] The discussion of Key Question 1 has identified aspects that should be amended within the Report, addressed by specific research to address knowledge gaps, or incorporated into the first reassessment. The suggested research and first reassessment should also consider new research available when that work is undertaken.

[101] Therefore, while there is no specific new research that necessitates a modification of the Report, it is suggested that a review of published research be incorporated into each reassessment of coastal hazards.

Conclusion

[102] The Panel considers that the Report represents a technical assessment of the coastal hazards at the time it was undertaken, and no specific new research has been identified as requiring consideration in the revision of the Report. It is expected, however, that additional information will become available after the completion of any technical assessment that can alter the conclusions drawn. Therefore, the Panel would stress that an essential part of the process is a requirement for periodic reassessment to incorporate any new research. This approach is also necessary for a successful adaptive management strategy.

Has the Report taken account of relevant statutory documents in providing technical or expert advice (refer Appendix E of the GHD Bundle of Documents supplied to the Panel for full purpose statements)?

[103] In identifying the scope of this peer review, GHD set out what is expected of the Panel. In addition to reviewing the science that underpins the Report, the Panel is to review whether Tonkin & Taylor correctly accounted for the legislative and policy framework outlined in the document.

[104] The Panel was also asked to provide observations or recommendations on the steps or actions CCC should undertake to meet its legislative requirements.[82]

[105] Under the heading 'The expert and the law' GHD set out the relevant provisions of the statutory framework and the law that [could] apply to the Report.[83]

[106] The Panel was therefore startled to find in the submissions on the draft report from the Joint Community/Councils meeting[84] the following directive under Science and Communication: 'It was agreed that the Panel should focus on the science'. We do not accept that.

[107] The GHD Bundle of Documents included a list of legal issues raised by the community, précised them along with those with the science indicators, and then formulated two series of questions around the statutory documents and whether the findings in the Report are appropriate.

[108] Inevitably, the scientific language of a technical report for a legal document requires references back to any scientific findings within the appropriate legal directives.

Statutory provisions

- **Resource Management Act 1991 (RMA)**

  The relevant provisions in the GHD document are listed as the Resource Management Act 1991 (1-11) which encompass:

  district plans and the process for preparing them (s 31);

  the matters to be considered in preparing or changing plans (s 74);

  the fact that the Act identifies a plan must give effect to any New Zealand coastal policy statement and any regional policy statement (s 75(3));

[82] GHD Bundle of Documents 3 Scope of the Peer Review, p 3.
[83] Ibid Appendix E Legal Reference Document, pp 1-3.
[84] GHD Peer Review of Coastal Hazard Assessment Report. Submissions on Draft Report August 2016, para 2.4 *Reviewing Science vs Communication,* p 4 (fourth bullet point).

an evaluation report under s 32;

the fact that preparation, change and review of plans is prescribed in Schedule 1 RMA.

- **Canterbury Earthquake (Christchurch Replacement District Plan) Order 2014**

  The regulatory process outlined here, we are advised, is not the context within which the report(s) commissioned by CCC and prepared by Tonkin & Taylor were undertaken.[85]

- **New Zealand Coastal Policy Statement (NZCPS 2010)**

  Objective 5, 'relevant' policies including 3, 24, 25, 26, 27 (but see below).

- **Canterbury Regional Policy Statement (CRPS) 2013**

  This provides an overview of the resource management issues of the region. Chapters 8 and 11 set out objectives and policies in respect of the coastal environment and natural hazards.

  Issue 8.1.7 – Natural hazards in the coastal environment

  There is a need to assess the effects of climate change, and coastal hazards such as coastal erosion, on the coastal environment, and develop responses where human assets and natural values are threatened by such coastal hazards.

  Objective 8.2.1 – Increasing knowledge of the coastal environment and its resources

  A programme of information gathering is undertaken on the natural processes, ecosystems and resources in the coastal environment; with the purpose of providing the basis for:

  (1) Development of a coastal strategy (ies) within five years to address the management of the coastal environment in Canterbury.

  (2) Consequential changes to the Canterbury Regional Policy Statement, any relevant regional coastal plan(s) and district plans.

  Objective 11.2.1 – Avoid new subdivision, use and development of land that increases risks associated with natural hazards.

  New subdivision, use and development of land which increases the risk of natural hazards to people, property and infrastructure is avoided or, where avoidance is not possible, mitigation measures minimise such risks.

[85] GHD Bundle of Documents Appendix E, pp 3-4.

Objective 11.2.2 – Adverse effects from hazard mitigation are avoided or mitigated

Adverse effects on people, property, infrastructure and the environment resulting from methods used to manage natural hazards are avoided or, where avoidance is not possible, mitigated.

Objective 11.2.3 – Climate change and natural hazards

The effects of climate change, and its influence on sea levels and the frequency and severity of natural hazards, are recognised and provided for.

Objective 11.2.4 – Effective integration of the management of, and preparedness for, natural hazards

The level of cooperation between agencies and organisations necessary to achieve integrated management of Canterbury's natural hazards, and preparedness for natural hazards is maintained or enhanced.

Policy 11.3.5 – General risk management approach

Subdivision, use or development of land shall be avoided if the risk from natural hazards is unacceptable. When determining whether risk is unacceptable, the following matters will be considered:

(1) the likelihood of the natural hazard event; and

(2) the potential consequence of the natural hazard event for: people and communities, property, infrastructure and the environment, and the emergency response organisations. Where there is uncertainty in the likelihood or consequences of a natural hazard event, the local authority shall adopt a precautionary approach.

Policy 11.3.8 – Climate change

When considering natural hazards, and in determining if new subdivision, use or development is appropriate and sustainable in relation to the potential risks from natural hazard events, local authorities shall have particular regard to the effects of climate change.

This statement was developed under the NZCPS.[86]

- **Local Government Official Information and Meetings Act 1987**

[86] Canterbury Regional Policy Statement 2013, p 88.

This requires councils to put certain material relating to individual properties into a land information memorandum. Section 44A(2) states:

The matters which shall be included … are –

information identifying each (if any) special feature or characteristic of the land concerned, including but not limited to potential erosion … being a feature or characteristic that –

is known to the territorial authority; but

(ii) is not apparent from … a district plan …'

- **Building Act 2004**

  This provides for hazard notices on titles of land if certain building work is carried out and if the land 'is subject or is likely to be subject' to one or more natural hazards which is not mitigated (ss 71-74).

Tonkin & Taylor's reference to statutory documents

[109] In its letter referring to the Terms of Reference Tonkin & Taylor suggests hazard mapping from previous 'high level mapping' studies needs to be revised for CIH and CEH in the Harbour Coast, and the second stage mapping be suitable to be included in the district plan.

[110] The phrase 'mapped to be suitable in the district plan' is repeated in the Project Purpose in the Terms of Reference. Mention is also made of the existing reassessment of the CHZs and the need for reassessment because they do not adequately incorporate the potential effects of sea level rise as requested under the NZCPS. [87]

[111] Tonkin & Taylor identify that a risk-based approach to managing coastal hazard is advocated by the NZCPS (2010). For example, the policy statement suggests consideration of areas both 'likely' to be affected by hazard (Policy 27) and areas 'potentially' affected by hazard (Policy 24). … While the term likely may be related to a likelihood over a defined timeframe based on guidance provided by MfE (2008b), (i.e. probability greater than 66% as shown in Table 1), the term potential is less well defined. This assessment therefore aims to derive a range of hazard zones corresponding to differing likelihoods which can be selected based on planning methods. [88]

[112] In the Terms of Reference there is mention only to a 'district plan' and NZCPS Policy 24 and the risk-based approach to managing coastal hazard advocated by the NZCPS - Policy 27.

[87] GHD Bundle of Documents Appendix B – Original Terms of Reference for Tonkin & Taylor and Variation, p 13.
[88] Letter from Tonkin & Taylor to Christchurch City Council. Coastal Hazard Assessment for Christchurch City – Stage Two dated 5 February 2015 (marked V 2). Appendix B attached to this review marked Appendix A, pp 3, 5.

[113] In the Executive Summary of the Report, Tonkin & Taylor identifies the New Zealand Coastal Policy Statement (NZCPS) is a national policy statement under the Resource Management Act 1991. The NZCPS states policies in order to achieve the purpose of the Act in relation to the coastal environments of New Zealand. Both the Environment Canterbury Regional Policy Statement (RPS) and the proposed Replacement District Plan will give effect to the NZCPS. **The CEHZ methodology used for this project has been developed in accordance with the Objectives and Policies of the NZCPS directly relevant to the assessment of coastal erosion hazard**.[89] [Emphasis]

[114] And in its Introduction to the Report, Tonkin & Taylor variously identify that 'the hazard mapping produced in the 2013 report, needs to be refined for inclusion in the District Plan'; and 'Tonkin & Taylor recently reviewed the coastal hazard zones (CHZ) as presented in the Canterbury Regional Coastal Environment Plan … [That] review recommended reassessing the existing CHZ because they did not adequately incorporate the potential effects of sea level rise as required under the New Zealand Coastal Policy Statement (NZCPS, 2010).'[90]

[115] But as the Panel was to find, there appears to be no instruction from CCC to Tonkin & Taylor of what objectives (if any) and policies (all or one) in the NZCPS the consultant was to meet in its identification of coastal hazard areas. The result has been confusion for all parties associated with this review, including the Panel – confusion exacerbated by GHD's latest instruction to the Panel that it should focus on the science.[91] The NZCPS is the only mandatory statement under the RMA that directs what decision-makers are required to take into account for planning issues around the coastal environment (s 57 RMA). The district plan must give effect to NZCPS.

[116] Paragraph 2.4 of GHD's Submissions on Draft Report August 2016 opens with the recognition that this is a review of science, **including science as it relates to national statutes and policy.** This is therefore a focus of the Panel's review.

Resource Management Act processes

[117] The proposal for which the Report was commissioned was to provide a technical scientific basis from which the identification of Coastal Erosion and Inundation Areas could be considered for Stage 3 of the CRDP under a Plan Change.

[118] The focus of the Terms of Reference between CCC and Tonkin & Taylor circumscribe what the Report is to provide – identification of areas around the main coastal settlements of Christchurch City susceptible to coastal hazards, namely those particularly affected by inundation and erosion and sea level rise. The areas are termed coastal erosion zones (CEHZ) and coastal inundation zones

[89] Tonkin & Taylor Report (2015) Executive Summary, p 2.
[90] Ibid. Introduction, p 3.
[91] GHD Peer Review of Coastal Hazard Assessment Report Submissions on Draft Report, August 2010, para 2.4, Reviewing Science and Communication, p 4.

(CIHZ). The zones are to be mapped over a suitable 50 year (2065) projection for sea level rise for CIHZ (to be agreed with CCC and ECan), and for the Open Coast, assessment is to be made of CHZ2 distance for both 2065 and 2115 time frames. The mapping for those areas is to be to a standard suitable for including in the District Plan.[92]

[119] The contents of the Report subsequently agreed upon by CCC and Tonkin & Taylor as set out in the Terms of Reference appear essentially technical. The proposed purpose, scope of services etc of the works is attached to this review as Appendix 1. But because the mapping of these areas is to be a standard suitable for including in the CRDP, as a matter of law the process and the mapping 'standard' is required to meet the relevant provisions of the RMA that are administered by CCC, and that includes any relevant provisions of the NZCPS attached to this review

The role of CCC in administering the RMA

[120] Section 5(1) RMA requires the *active promotion* of the sustainable attributes of the RMA by the CCC.

[121] In the normal course of events, what is to be achieved here is an initial technical assessment to assist the CCC's purpose in providing for the sustainable management of the city's natural and physical resources, and its communities, as defined in s 5(2) RMA. This provision requires the CCC to:

- manage the use, development and protection of natural and physical resources;
- in a way or at a rate that enables the communities of those coastal settlements to provide for their social, economic and economic wellbeing and for their health and safety;
- sustain those resources to meet the reasonable needs of future generations of the Christchurch coastal communities; and
- safeguard the life supporting capacity of the water, soil and air; and
- avoid or remedy any adverse activities on the environment.

[122] CCC's functions arising from s 57(a) RMA are also mandated to the extent that the council is required to pay 'particular regard to the effects of climate change' under s 7(a) RMA. This provision imposes a duty on CCC to be on inquiry about 'a change of climate that is directly or indirectly attributable to human activity that alters the composition of the global atmosphere'. And

[92] GHD Bundle of Documents, Original Terms of Reference for Tonkin & Taylor and Variation, Appendix B Agreement Variation between Tonkin & Taylor Limited and Christchurch City Council. Appendix A1 Scope, Purpose, Program and Completion Date for a Coastal Chapter – Coastal Hazard Assessment - Stage Two Project Purpose, b, 1.1.

that is in addition to natural climate variability observed over considerable time periods. The 'considerable time periods' identified in the Report are identified as 50 years and 100 years.[93]

[123] In commissioning the Report, CCC's action appears an initial initiative to meet the requirements of the NZCPS, the purpose of which is to state policies in order to achieve the purpose of s 56 RMA in relation to the coastal environment. As noted above, the NZCPS is the only mandatory statement in the legislation setting out objectives and policies to inform decision makers how to sustainably manage various aspects of the coastal environment, including climate change (s 57).

[124] Under s 75(3)(b) a district plan must give effect to the NZCPS. That provision identifies that 'this NZCPS is to be applied as required by … persons exercising functions and powers under the RMA'. It is therefore the role of CCC to apply the NZCPS provisions as it requires. NZCPS Policy 15 is designed to guide the formulation of regional and district planning documents which in turn guide consent authorities such as CCC when considering resource consents, formulating plans, and plan changes. What is in issue here is a plan change.

[125] The Report is thus intended to form a technical basis for a Plan Change. On the authority of *Sustain our Sounds Inc v The New Zealand King Salmon Company Ltd*[94] the Supreme Court held that when dealing with a plan change application in the coastal environment, the decision maker should undertake the necessary analysis under the NZCPS. Section 5 RMA therefore is not to be treated as the primary operative decision-making provision.

[126] The Report itself introduced Policies 24 and 27 which its authors thought were relevant to what it should encompass, and that was in the letter accompanying the Terms of Reference. CCC meanwhile is completely silent on what is relevant in the NZCPS. In fact, all the parties to the Report do not appear to have realised that Policy 24 is the only legal provision quoted in full in Ramsay et al in its guidance document, noting that after this policy is addressed, councils are ***then*** required to avoid increasing the risk of harm through addressing Policies 25, 26 and 27 NZCPS.[95]

[127] We return to the relevant policy – Policy 24 – below. But first, it is appropriate to assess when a s 32 RMA report is required. The community's questions 5, 9 and 11 all relate to an analysis being undertaken for an 'evaluation report' under s 32 RMA. Economics, future land use and the drafting of future rules are referred to in these questions and are introduced because it is considered by the community to relate back to the hazard areas mapped to a sufficient standard in the Report to be incorporated in the CRDP.

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[93] T&T Report 3 Previous Assessment Methodology. Environment Canterbury Regional Council (ECan) developed 2 CHZs for the Canterbury region set out in the Operative Regional Coastal Environment Plan (RCEP 2005), p 12.
[94] [2014] NZSC 38, (2014) 7 ELRNZ 442.
[95] Ramsay et al, Defining coastal hazard zones and setback lines. A guide to good practice. Appendix 1 Legislative framework, pp 88-89.

A Section 32 analysis

[128] The matters to be considered in preparing (or changing) a district plan are set out in s 74 and include the territorial authority's functions under s 31, the provisions of Part 2 (which includes the purpose of the RMA), and an evaluation of alternatives, benefits and costs. Section 74(1)(e) states:

> A territorial authority must prepare and change its district plan in accordance with –
>
> ...
>
> (e) its obligation to have particular regard to an evaluation report prepared in accordance with section 32; and ...'

[129] Section 75 'Contents of district plans' is the initiating provision for what may be contained within them, s 75(1) and (2). A commentary to the legislation identifies that the required contents of the district plan here are key, and that there are three substantive stages in deciding its contents plan:

- identification of the facts and the significant issues for the district arising out of the facts;
- the s 32 analysis;
- the ultimate issue of whether implementing the proposal would more fully serve its statutory purpose.[96]

[130] In the Panel's opinion the Report is intended to address *the first stage only* in a s 75 analysis - an identification of the facts to establish what may constitute hazard areas arising from coastal inundation and erosion and climate change. And to establish those facts, an analysis under NZCPS Policy 24(1)(a)-(h) is required.

[131] The second part of that initial stage – identification of the significant issues arising out of these facts – encompasses NZCPS Objective 5, Policy 3 and Policies 25, 26 and 27, and the application of risk management techniques and the precautionary approach to issues arising in those policies, the third stage with the conclusion of what the maps should encompass. This involves all stakeholders under the adaptive management approach.

[132] Only when those second and third stages are completed can an analysis for an evaluation report under s 32 be undertaken.

[133] The Report therefore does not have the status of an evaluation report under s 32 RMA. There is nothing in the Terms of Reference that this should be so. And the provisions of s 32(1) and (2) preclude that. The Panel identifies below those provisions below as a guide to what a s 32

[96] *Salmon Resource Management* Vol 1, RM 75.01, p 542.

evaluation report should encompass. It may be seen that it addresses many of the concerns of the community identified in their questions to the Panel, [97] and would come about as CCC builds its objectives, policies and rules around coastal hazard assessments and areas, and the community and CCC and others work together to address adaptive management of the risk.

[134] On inquiry, the CCC planners provided the Panel with their Section 32 Report on Natural Hazards, Chapter 5 Part 2. It is a large document, largely addressing flood risk, slope stability, some interim provisions in relation to climate change and sea level rise, changes in ground surface from earthquakes, and others. From this can be seen the extensive assessments across a raft of issues that have to be undertaken for any s 32 evaluation report, and clearly was carried out exhaustively by CCC officers for this chapter. Its focus in that document is NZCPS Policy 25.

[135] NZCPS Policy 24 is addressed here.

Provisions of the NZCPS

[136] The GHD Bundle of Documents[98] identifies an objective and policies of the NZCPS and several provisions that are 'directly relevant' to the assessment of coastal hazard. The Report identifies relevant policies to include:[99]

> Objective 5 NZCPS - ensures that coastal hazard risks, taking account of climate change, are managed by locating new development away from areas prone to these risks, considering

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[97] Section 32 states:

(1) An evaluation report required under this Act must –
- (a) examine the extent to which the objectives of the proposal being evaluated are the most appropriate way to achieve the purpose of this Act; and
- (b) examine whether the provisions in the proposal are the most appropriate way to achieve the objectives by –
  - (i) identifying other reasonably practicable options for achieving the objectives; and
  - (ii) assessing the efficiency and effectiveness of the provisions in achieving the objectives; and
  - (iii) summarising the reasons for deciding on the provisions; and
- (c) contain a level of detail that corresponds to the scale and significance of the environmental, economic, social and cultural effects that are anticipated from the implementation of the proposal.

(2) An assessment under subsection (1)(b)(ii) must –
- (a) identify and assess the benefits and costs of the environmental, economic, social, and cultural effects that are anticipated from the implementation of the provisions, including the opportunities for –
  - (i) economic growth that are anticipated to be provided or reduced; and
  - (ii) employment that are anticipated to be provided or reduced; and
- (b) if practicable, quantify the benefits and costs referred to in paragraph (a); and
- (c) assess the risk of acting or not acting if there is uncertain or insufficient information about the subject matter of the provisions.

[98] GHD Bundle of Documents, Appendix E.

[99] Tonkin & Taylor Report, Section 2 Background Information, Statutory Legislation, New Zealand Coastal Policy Statement 2.1.1.1, p 2.

responses, including managed retreat for existing development in this situation, and protecting or restoring natural defence to coastal hazards.

Policy 3 – requires a precautionary approach in the use and management of coastal resources potentially vulnerable to effects from climate change, so that avoidable social and economic loss and harm to communities does not occur.

Policy 24 – requires the identification of areas in the coastal environment that are potentially affected by coastal hazards (including tsunami) and giving priority to the identification of areas at high risk of being affected. These should take into account national guidance and the best available information on the likely effects of climate change for each region.

Policy 25 – promotes avoiding increasing the risk of social, environmental and economic values to erosion hazard in areas potentially affected by coastal hazards over at least the next 100 years.

Policy 27 – promotes reducing hazard risk in areas of significant existing development likely to be affected by coastal hazards.

[137] The only policy directly relevant at the initial stage of producing the technical report is Policy 24. Nor is Objective 5 relevant to what the Report is required to identify at this initial technical stage under the Terms of Reference. Objective 5 relates more directly to Policies 25-27 (above).

[138] Questions from the community on the NZCPS query whether the document refers to sea level rise at all; another questions whether Policy 3 Precautionary approach applies to what the Report should encompass; another queries whether the Report appropriately has regard to each of the required matters in NZCPS Policy 24(1)a)-h); and finally, is the interpretation given in the Report to the words 'likely' and 'possible' as used in Policies 24 and 27 turned into quantitative analytical parameters, and is the interpretation and application of those terms appropriate?

[139] One of the community questions whether the NZCPS does in fact refer to the term 'sea level rise' at all. It does in several places:

Policy 10(2) Reclamation and de-reclamation

… the potential effects on the site of climate change, including sea level rise, over no less than 100 years.

Policy 19 Walking access –

Maintain and enhance public walking access to and along the coastal marine area by …

> 2(c)(iv) identifying opportunities to enhance or restore walking access resulting from subdivision use or development where 'the long-term availability of public access is threatened by erosion or sea level rise …'
>
> Policy 24: Identification of coastal hazards
>
> … Hazard risks over at least 100 years are to be assessed having regard to
>
> physical drivers and processes that cause coastal change including sea level rise …
>
> …
>
> cumulative effects of sea level rise, storm surge and wave height under storm conditions …
>
> taking into account the most recent available national and international guidance on the likely effects of climatic change on the region or district.

[140] There can be no issue that sea level rise has been omitted from the NZCPS.

[141] It is also identified as a characteristic of climate change in the key national document relevant here – MfE (2008b).[100]

Policy 3 The Precautionary approach

[142] The statutory status of the precautionary approach (Policy 3) is an issue, one important to examine as a further step in the evaluation of the relevant parameters of the NZCPS (2010) because it affects one part of its scientific assessment.

[143] Policy 3 Precautionary approach is required to apply towards 'proposed activities' whose effects on the coastal environment are uncertain, unknown or little understood, and to apply to the 'use and management of those activities' in the coastal environment. But the Report has applied it to determining sea level rise projections in the following manner:

> Adopted sea level values 4.1.4.5 Effects of sea level rise ('SL')
>
> Utilising the most recent projections (IPCC, 2014) and adopting a precautionary approach required by NZCPS (2010) and in keeping with recommendations in MfE (2008), this assessment has adopted sea level rise values projected for the *RCP8.5 scenario – emissions continue to rise in the 21st century* ('business as usual'). This is considered prudent until evidence of emission stabilising justify use of a lower projection scenario. These sea levels range from 0.27 to 0.47 metres by 2065 and 0.62 to 1.27 metres by 2115 (refer to Section 2.2.1.5).[101]

[100] MfE (2008) 9 Glossary, p 92. 'Sea-level rise – Trend of annual mean sea level over timescales of at least three or more decades. Must be tied to one of the following two types: global – overall rise in absolute sea level in the world's areas; or relative net rise relative to local landmass (that may be subsiding or being uplifted). Ramsay et al Defining Coastal Hazard Zones for Setback Lines, a guide to good practice sets out a useful graph providing an adaptive management approach reflecting the uncertainties around sea level rise within a planning timeframe: see Figure 17, p 36.

[101] Tonkin & Taylor Report 4.1.4.5 Effects of Sea Level Rise (SL), p 26.

[144] Adopting a Precautionary approach in the Report to the identification of areas susceptible to coastal hazards (inundation and erosion) is wrong. Policy 3 relates directly to the management of risks identified around specific social, economic and environmental issues (among others) identified in Policies 25, 26 and 27. The Report is inappropriately using the wrong directive statutory terminology. Its use in the document also predicates uncertainty around its 'likely' and 'probable' statistics referred to below.

[145] One submitter summarised the difficulty directly on behalf of CCRU:

> The whole trigger for the application of the precautionary approach (Policy 3(1)) is where matters 'are uncertain, unknown, or little understood, but potentially significantly adverse'. This can only be known once the scientific assessment has been done. If the science ignores the uncertainties and consistently errs on the side of caution as it estimates relevant information, it becomes impossible to know the cumulative effect.
>
> This is one area where DoC[102] has developed guidance in respect of the NZCPS 2010 and it is clear:
>
> The application of the precautionary approach is a risk management approach rather than a risk assessment approach (NZCPS 2010 Guidance note Policy 3: Precautionary approach, page 6, Department of Conservation).

[146] Thus in the context of climate change, the use and risk management of coastal resources (including coastal properties) that are required to be identified in regional and district plans, should be precautionary having regard to economic losses and other damage that may result from the physical changes in the coastal environment to people, making them vulnerable, and to property that will be at risk owing to climate change (among a number of other issues).

[147] The good practice guide (Ramsay et al, 2012) for defining coastal hazard zones for setback lines makes this approach clear in several parts of its document.[103] It refers to the key principles to be incorporated in all aspects of local authority planning, identifying one of them to be a 'Precautionary Approach':

> **Precautionary approach**: A precautionary approach is adopted when making planning decisions relating to **new development**, and to **changes to existing development** within coastal margins. Decision-making takes account of the level of risk, utilises existing scientific knowledge and accounts for scientific uncertainties.

[148] The guide identifies that after assessing the various drivers that cause coastal change through sea level rise (Policy 24), the planners, coastal scientists, economists and engineers et al are then required through NZCPS Policy 25 and Policy 27 to avoid increasing the risk of harm from coastal hazards in affected areas through careful management of subdivision, land use and coastal protection works. 'The most common approach where existing development is at risk from coastal

[102] GHD Bundle of Documents, 4.2 Legal.
[103] Ramsay et al. Defining coastal hazard zones for setback lines: a guide to good practice, p 7 Box 1, p 9, p 89.

hazards is to apply the above information in the form of coastal setbacks through a range of rules in planning documents.'[104]

[149] It is therefore inappropriate in Section 4.1.4.5 Effects of sea level rise[105] for Tonkin & Taylor to take a Policy 3 'Precautionary approach' to its identification of 'adopted sea level values' because the phrase has confused the community, and those who read this assessment about the Report's purpose in bringing in issues that are not within the coastal scientists' expertise at this stage, or the Terms of Reference.

[150] But even then, in section 4.3.2 of the good practice guide 'Moving from deterministic predictions to probabilistic projections', that document identifies current approaches to defining uncertainties in one of the three ways as follows:

- Direct application of a multiplication factor of safety to some or all of the setback terms.
- Detailed calculations of error for each setback term.
- Application of 'precaution' throughout process (for example, taking maximum likely values for each factor rather than averages).

[151] The Panel initially considered that the third criterion here possibly confuses the use of the word 'precaution' further in the applied science of climate change. But on reflection, it relates to safety and setbacks which require the NZCPS Precautionary approach (Policy 3) because both involve what is at risk in NZCPS Policies 25 and 27.

[152] In a telephone conference with Richard Reinen-Hamill, Project Director for the Report, he was questioned as to whether the scientists added some percentage around those projected for sea level rise to give the results identified in 4.1.4.5 SL because of the Precautionary approach (NZCPS Policy 3) to the *determination* of the hazard rather than the *consequences* of the hazard. His response was no, that the only use of precaution in effect was in use of the RCP8.5 scenario [RCP IPCC 2014] rather than a lower projection and that its mention was unnecessary in this part of the Report. We accept his explanation because RCP8.5 is only one scenario of a number (that may or may not happen) and by definition, what RCP8.5 encompasses is very high emissions, atmospheric concentrations, air pollutant emissions and land use conditions at a global level.

[153] We concluded the reference to the Policy 3 Precautionary approach should be removed from the Report for it does not add anything and does not apply to the relevant issues to which it applies.

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[104] Ramsay et al. Defining coastal hazard zones for setback lines – a guide to good practice. Appendix 1 Section 7 Legislative framework, p 89.
[105] T&T report (2014) Vol 2 4.1.4.5; IPPCC (2014) Chapter 13, 1181.

NZCPS Policy 24(1)(a)-(h)

[154] As noted earlier, the Terms of Reference itself makes no mention of NZCPS Policy 24 – it was introduced in some of its aspects by Tonkin & Taylor on its own initiative.[106] The details of the policy are set out here:

> **Policy 24 Identification of coastal hazards**
>
> (1) Identify areas in the coastal environment that are potentially affected by coastal hazards (including tsunami), giving priority to the identification of areas at high risk of being affected. Hazard risks, over at least 100 years, are to be assessed having regard to:
>
> (a) physical drivers and processes that cause coastal change including sea level rise;
>
> (b) short-term and long-term natural dynamic fluctuations of erosion and accretion;
>
> (c) geomorphological character;
>
> (d) the potential for inundation of the coastal environment, taking into account potential sources, inundation pathways and overland extent;
>
> (e) cumulative effects of sea level rise, storm surge and wave height under storm conditions;
>
> (f) influences that humans have had or are having on the coast;
>
> (g) the extent and permanence of built development; and
>
> (h) the effects of climate change on:
>
> (i) matters (a) to (g) above;
>
> (ii) storm frequency, intensity and surges; and
>
> (iii) coastal sediment dynamics;
>
> taking into account national guidance and the best available information on the likely effects of climate change on the region or district.

[155] These provisions require aspects of the definition of 'hazard risk' to be applied as appropriate to the coast and harbour – identification of areas of the coast 'potentially' subject to coastal hazards - that is, an assessment of its likelihood and consequences and including those at high risk. 'Risk' is expressed in the NZCPS in terms of a combination of the consequences of an event (including changes in circumstances) and the associated likelihood of occurrence[107]. This requires a close examination of the 'likely' effects of climate change on the Christchurch jurisdictional district. Policy 24(1) accords a priority assessment to areas of high risk.

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[106] GHD Bundle of Documents Appendix B Original Terms of Reference for Tonkin & Taylor and Variation 2014. Consultancy Services Agreement for Coastal Chapter – Coastal Hazard Assessment between Tonkin & Taylor Ltd and Christchurch City Council, p 22.
[107] AS/NZS ISO31000.2009 *Risk Management – Principles and Guidelines* – November 2009.

Background to the identification of areas potentially subject to coastal hazard risk

[156] Environment Canterbury Regional Council (ECan) developed two CHZs for the Canterbury region as set out in the Operative Regional Coastal Environment Plan (RCEP, 2005):

> Coastal Hazard Zone 1 (CHZ1) – landward limit of the active beach system including any long-term rates of erosion to 50 years.
>
> Coastal Hazard Zone 2 (CHZ2) – landward limit of the active beach system including any long-term rates of erosion to about **100 years.**

[157] These coastal hazard zones were identified on the basis of the previous NZCPS (2004) and not NZCPS (2010), and by definition do not include inundation, and they do not require measurements of over at least 100 years as stated in NZCPS Policy 24(1).

Identification in the Report of areas potentially subject to coastal hazard risk

[158] The Report indicates areas of coastal hazard risk from inundation and erosion and climate change (sea level rise) and its scope identifies the extent of the coastal settlements and communities located on non-consolidated sediment shorelines within the Christchurch region:

Open coast

> Southern Pegasus Bay from Waimairi Beach to Southshore including the South Brighton spit.
>
> (The Southern Pegasus Bay shoreline was assessed to be an accreting shoreline and therefore only CHZ1 was mapped at the landward limit of the active beach system in this area.)
>
> Sumner and Taylors Mistake

Harbour coast

Avon-Heathcote Estuary	Akaroa Harbour
Lyttelton Harbour	Akaroa Township
Allandale	Takamatua
Teddington	Duvauchelle
Charteris Bay	Wainui
Purau	Brooklands Lagoon[108]

[108] T&T Report, 3 Previous Assessment Methodology, p 12.

Policy 24(1)(a) Physical drivers in processes that cause coastal change including sea level rise

[159] Understanding these aspects of the causes of coastal change is a key issue that must be carried out to enable a robust coastal risk hazard assessment.

[160] The physical drivers and processes are set out in clear detail in the Report under 2.2 Coastal Processes. These include water levels with their key components (including medium term fluctuations such as astronomical tides, atmospheric factors such as seasons, El Nino-Southern Oscillation (ENSO) and Inter-decadal Pacific Oscillation (IPO) which can all affect the mean level of the sea at a specific time (refer to Figure 2-2). The combined effect of these fluctuations may be up to 0.25 m according to Bell (2012).[109] These fluctuations should be measured when time allows.

[161] Storm surge, storm tide levels, wave effects, long term sea levels and the Waimakariri River sediment supply are also presented as drivers. [110] The Waimakariri River is a major source of sediment for the Southern Pegasus shoreline, resulting in an historic trend of shoreline and a major source of accretion.

[162] New data collection relating to shorelines and the natural cross-shore beach profile is identified.

Policy 24(1)(b) Short and long term dynamic fluctuations of erosion and accretion

[163] Dynamic shoreline fluctuations are taken to be variations about an assumed equilibrium or baseline position due to the effects of erosion and accretion.

[164] The variations can occur in space – locations along the coast respond differently to specific drivers. In the case of the open coast in Christchurch evidence indicates that the patterns of shoreline response vary between southerly and northeasterly storms.

[165] More importantly for Policy 24(1)(b), variations can occur at a range of different time-scales. The Report has effectively considered two time scales as identified in their Equation 2 for the Open Coast CEHZ:[111]

> Short-term fluctuations that include storm cut (and subsequent post-storm recovery); this determined by analysis of approximately 6 monthly beach profile data for 1990-2014, and hence represents the cumulative shoreline response to a range of processes as observed via the almost 30 years of 6 monthly monitoring data. This would include effects of storms, fair-weather periods, and any seasonal effects (winter versus summer).

[109] Bell, R (2012). Sea Levels for New Zealand Give us a Number Please. Presentation at Sea Level Rise: Meeting the Challenge Conference, Wellington 10-11 May 2012.
[110] T&T Report 2.2 Coastal Processes, pp 3-7.
[111] T&T Report 1999: Study of the Effects of Sea Level Rise for Christchurch, p 74.

Long-term rate determined by DSAS analysis of aerial photographs between 1941 and 2001. This represents the cumulative shoreline response to a range of processes over 70 years.

[166] Overall, the short-term rate requires updating now, and short-term and long-term should be reassessed in the future to better address the requirements of Policy 24(1)(b).

Policy 24(1)(c) Geomorphological character

[167] As the methodology used for assessing coastal hazards evolves towards a probabilistic assessment of risk, issues like this should be addressed. The Tonkin & Taylor Northland Report sets out an extensive description of Northland's geomorphological character.[112] For this Report, the geomorphology was treated as being the same for all coastal cells, and all low-lying areas fringing the harbours and estuaries. Given the time-frame that this Report was prepared in, the simplification of the geomorphology is understandable. However, an assessment of coastal hazards should be more cognisant of varied geomorphology around the coastline.

Policy 24(1)(d) The potential for inundation of the coastal environment, taking into account potential sources, inundation pathways and overland extent

[168] All of these issues are summarised in Section 1 Findings and Recommendations in the Report.

[169] We note the word 'potential' is identified as a qualification to the meaning of 'effect' under s 3 RMA Meaning of Effects.[113] The Environment Court has held under s 104(1) RMA (a resource consent application) that each potential effect raised in evidence should be assessed quantitatively and/or qualitatively in the light of the principles of the RMA and relevant objectives and policies.[114]

Policy 24(1)(e) Cumulative effects of sea level rise, storm surge and wave height under storm conditions

[170] The cumulative effects of these factors are included in the historical data. The difficulty arises with the assessment of the future cumulative effects. Due to the specific identification of

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[112] Tonkin &Taylor Report: Coastal Erosion Hazard Zone Assessment for Selected Northland Sites 2014, 3 Coastal Processes, 3.1 *Geology and Geomorphology*, p 14.

[113] **3 Meaning of effect**
In this Act, unless the context otherwise requires, the term **effect** includes –
(a) Any positive or adverse effect; and
(b) Any temporary or permanent effect; and
(c) Any past, present, or future effect; and
(d) Any cumulative effect which arises over time or in combination with other effects – regardless of the scale, intensity, duration, or frequency of the effect;
(e) Any potential effect of high probability; and
(f) Any potential effect of low probability which has a high potential impact.

[114] *Clifford Bay Marine Farms Ltd v Marlborough District Council* (EC) C131.03.

climate change in Policy 24(1)(h), Policy 24(1)(e) suggests that the evaluation of coastal hazard should include assessment of the future cumulative effects of these processes *without the effects of climate change*, that is, before the additional effects of climate change are incorporated.

[171] In other words, the Report should include a scenario that only applies historical trends in Equation 2 to illustrate what the risks would be without climate change, for that is the way the particular sub-policies are worded. The suggestion appears to come from the Tonkin & Taylor (Options) Report (1999) Conclusions and Recommended Responses[115] but was not identified within the Terms of Reference. We note, however, that the previous ECan CHZ may have all the data required as it assessed coastal hazards without climate change effects, and this data is recommended to be included in Tonkin & Taylor's revised report.

Policy 24(1)(f) Influences an assessment that humans have had or are having on the coast

[172] For the purposes of this Report, the dune system along the coast and inundation pathways are one of the issues: see Table 4-2 Coastal Inundation Hazard and Component Values. The results indicate:

> The elevation of the foredunes located along the open coast from Waimari to the Avon-Heathcote Estuary mouth are agreed as generally sufficient to mitigate coastal inundation hazard. These foredunes covered in Marram grass are the constant focus of maintenance and care from CCC's Rangers. Originally these dunes were covered in native vegetation such as pingao but early European Christchurch pastoralists grazed the New Brighton Spit dunes, leading to the loss of their palatable vegetation. When it was realised that this had created a sand stability problem, the spit was replanted but using the introduced marram grass as a dominant species. Marram grass creates tall, narrow dunes. It is arguable that space may no longer exist for the lower profile, wider pingao dunes to be fully re-established along the spit due to the presence of backsore infrastructure and development, although this concept is worth scientifically testing through the trial plantings undertaken.
>
> Many areas of the Southshore suburb are at risk from inundation from both the Avon-Heathcote Estuary side as well as from open coast dune inundation or erosion (note the dunes at the southern end of the New Brighton Spit are relatively low compared to most other locations along this coast).
>
> There are three sites at New Brighton where the foreshore dunes have been highly modified such that they are left with inundation pathways through the foredunes because of the siting of the New Brighton Library, the North Brighton Community Centre and North Brighton Beach Surf Lifesaving Club. Placing inundation in such a sensitive area gives pause for reflection.
>
> But because the inundation pathways are relatively narrow, the volume of water able to travel inland will be restricted within the time period of a typical storm event. But what of the effect of sea level rise over and above a typical storm event? These three locations also represent significant tsunami inundation vulnerabilities today[116].
>
> The Main Road behind the dunes may be vulnerable in the long term.

[115] T&T Report 1999: Study of the Effects of Sea Level Rise for Christchurch, p 74.
[116] Hart, DE, and Knight, GA (2009). Geographic information system assessment of tsunami vulnerability on a dune coast. *Journal of Coastal Research*, 131-141.

> Creation and modification of sea walls along the southern Sumner beach may be a major issue for the future, depending on the rate of inundation and erosion. Hard protection structures can be eroded away, leaving land, infrastructure, and buildings behind at risk (as have the foundations of the Esplanade at St Clair, Dunedin).

Policy 24(1)(g) The extent and permanence of the built environment

[173] The Terms of Reference identify the locations that Tonkin & Taylor were expected to assess. These are identified above. Thus the extent of the study includes the coastal settlements based on non-consolidated sediment shorelines within CCC's boundaries. The permanence of the built environment in these areas is not within the Terms of Reference and will be more appropriate when Policies 25 and 27 are addressed in the second and third stages of adaptive management of (inter alia) existing and future development and/or under s 32 RMA.

Policy 24(1)(h) The likely effects of climate change on the district on all of the above (a) to (h) of the policy

[174] This provision indicates an over-ride to all of the above – clearly separated out in the wording of the policy.

[175] The Report has focused primarily on one process (sea level rise) as the issue for potential changes over and above other processes.[117] The Bell (2001) assessment[118] of the impacts of climate change for the Canterbury Coast notes that 'Sea-level rise gets the publicity, but climate change will also affect other important coastal 'drivers' such as waves, winds, river flow, and storms, which in turn could substantially alter sediment supply to the coast with the potential to cause further erosion in some areas'.

[176] Nevertheless, we consider that Tonkin & Taylor did take into account the effects of climate change on river flows and on sediment budget. It used NIWA's medium term forecast for this. We consider, however, that these NIWA forecasts are too narrow as they don't take account of anthropogenic water demand.

[177] It would be helpful if the Report could identify more clearly any baselines apart from sea level rise to distinguish between that and other drivers to the impact of the change in climate.

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[117] Tonkin & Taylor (2015). Coastal Hazard Zone Assessment for Christchurch City – Stage Two. Coastal Erosion Hazard, p 5. 'The mapping will identify areas susceptible to coastal erosion hazard by using the passive inundation extent (erosion due to sea level rise) as a baseline and applying an additional buffer to allow for both the SF and LT parameters.'

[118] Bell, R., 2001. Impacts of climate change on coastal margins in Canterbury. NIWA Client Report CHC01/69, prepared for Environment Canterbury, July 2001. 22 pp.

[178] In the MfE (2008b) Guidance Manual[119] a definition of climate change is provided as 'a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer)'.

[179] The definition of climate change in s 2 RMA identifies that the concept means 'a change of climate that is attributed directly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability over a considerable time period'.[120]

[180] The constant in both definitions appears to be:

> a statistical variation in either the mean state of the climate or its variability …
>
> a change of climate that allows for the changes in the composition of the global atmosphere due to human activities and **that is in addition** to natural climate variability …

[181] What NZCPS Policy 24(1) requires is an examination of the mean state of the current climate and its variable adjustments, a statistical characterisation of that data, or an assessment of potential climate change in addition to natural climate variability in order to provide (with medium confidence) the likely effects on the Christchurch district.

[182] IPCC AR5 Table 25-1 provides a chart of climate variables including mean air and sea surface temperatures, precipitation (rainfall), fine weather, drought, severe storms, snow and ice. The categories include projected change, its direction, examples of projected magnitude of change relative to, for example, 1990 with additional comments.[121]

[183] An assessment incorporating those factors would assist the community in identifying statistical shifts in the statistics as it and CCC working together providing scientific markers (RCPs) to underpin their adaptive management policies.

[184] The term 'likelihood' is defined in MfE (2008b) as 'Likelihood is a qualitative (and possibly quantitative) measure of the probability or chance of something happening'. Ramsay et al (2012) consider that 'Quantifying uncertainty to underpin risk-based decision making' identifies that quantification of this uncertainty can bring a much richer level of information to hazard decision making as it is required in New Zealand'.[122]

Areas Mapped to a Standard Suitable for Inclusion in the District Plan

[185] It is arguable that mapping is an initial way of identification of coastal hazard risk assessment areas under NZCPS Policy 24(1) at the first stage of addressing the issue.

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[119] MfE (2008b) Coastal Hazards and Climate Change, 9 Glossary, p 87.
[120] Resource Management Act 1991, s 2.
[121] IPCC AR5 Chapter 25 25.3 Australasia Socioeconomic Trends Influencing Vulnerability and Adaptive Capacity, pp 1380-1381.
[122] Ramsay et al. footnote to come

[186] If the word 'mapping' is to be used at all, it should have been qualified with the word 'draft' and not merely identified as a revision of previous mapping.

[187] Meanwhile, the phrase 'to a standard for inclusion in the District Plan' should have been excluded altogether from the Terms of Reference. It is not a requirement under Policy 24(1) and is altogether a step too far. For this phrase, together with the pressure the consultant and CCC were placed under to meet the timing of the relevant legislation, has resulted in the anger and frustration of the coastal communities most potentially vulnerable. There were no rights of appeal from the Hearings Panel under that process except on questions of law.

[188] If CCC had instigated and kept strict control of the Policy 24 process then the situation the Panel is addressing here would not have developed because:

- Policy 24 a first stage in identifying 'risk' to the coastal communities opens up the consequences of risk that can only be addressed once CCC and the community enter into the second and third stages of consultation and collaboration over the issues addressed in NZCPS Objective 5, Policy 25 and Policy 27. Only after all those matters have been finalised could mapping to a standard be ready for inclusion in the district plan.

- The community would have been assured of a clear pathway forward without final mapping at the first stage going into potential vulnerability assessments under adaptive management in Policy 25 and Policy 27.

Conclusion

[189] After this review of the Report in the context of the statutory documents, only one has direct relevance to mapping to a standard suitable for the district plan – and that is Policy 24(1)(a)-(h). There is no cross-reference in the Report to indicate it was followed in all its directives and the Panel was left to infer whether or not it was adequately addressed.

[190] In this case of such importance to CCC, the community, and the authors of the Report, it was important for CCC officials/lawyers to brief the scientists as to the statutory underpinnings of what they would be expected to assess around plan change. Such briefing may have occurred here, but the documentation around the Terms of Reference and the 20 day completion limit for the Report may well be a factor that prevented such a briefing, with the result there is a lack of clarity whether the appropriate provision met with what was legally required.

Are the findings in the Report appropriate for their intended purpose – informing planning for future land use? Do the methods and assumptions made in the report compare to those used nationally and internationally to inform decisions on a response to sea level rise?

[191] Firstly, it is necessary here to reiterate that the purpose of producing the Report 'to inform planning for future land use' ought to have been to produce 'a technical assessment as a first stage in the process of developing the information needed to inform planning and future land use'.

Guidance issues

[192] There are two inter-related aspects generally considered as a consequence of sea level rise: coastal inundation due to higher mean sea levels, and the interaction of higher sea levels with other coastal processes including erosion. Ramsay et al (2012) provide a national guide to good practice, which is similar to those produced for individual states in Australia (Victoria, New South Wales, and Queensland[1]) as well as overall for engineers in Australia. The Ramsay et al (2012) good practice guide is also similar to approaches used in the USA and EU. While the MfE (2008) document was the base report from which the NZCPS provisions emerged.

[193] The Tonkin & Taylor reports (V1 and V2) do not follow the practice for community involvement indicated in Figure 1 and Box 3 of Ramsay et al (2012). Table 1 in Ramsay et al (2012),[2] however, does not identify community involvement as a key consideration in scoping a coastal hazard assessment and it appears Tonkin & Taylor chose to follow the model in Table 1.

[194] The Panel is endorsing no community involvement in the technical first stage of identifying areas of coastal hazard risk (that is, the Report), but community involvement after that in assessing the consequences of the risk in the second and third stages before maps are included in the CRDP.

[195] It is reiterated that for the subsequent exercise of assessing adaptation options, the results of including additional RCPs in the Report is recommended.

Conclusion

[196] The Tonkin & Taylor technical report is only the first step, albeit a very important one, for informing parties as to what they are required to assess next – NZCPS Objective 5 and Policies 25-27.

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[1] That a member of the Panel is aware of and has viewed.
[2] Ramsay et al identify local residents as potential sources of information on the importance of different processes, and suggests the local community may contribute (inter alia) to deciding on the interpretation, synthesis and presentation of results, p 10.

[197] The Panel has found aspects of the Report that are required to be addressed by Tonkin & Taylor now, and others which the Panel suggests should be reassessed around 10 years hence.

[198] The Panel considers that many of the methods and assumptions made in the Report, but not all, follow best practice recommendations in New Zealand and Australia.

Did the Tonkin & Taylor assessment allow the subsequent use of adaptive planning management responses by CCC?

[199] An adaptive management approach to the risks associated with sea level rise and climate change involves making several interventions over time to manage risk in contrast to making single major investments such as large sea walls, for example, that have a finite life over, say, 50 years. The coastal communities as the most vulnerable potentially to be affected should be involved in deciding what the trigger points might be to these intensities, along with the other stakeholders.

[200] Adaptation has been described as the adjustment in human and natural systems in response to climate change stresses and their effects which moderates damage and helps to exploit opportunities for benefit.'

[201] The nature and scale of adaptation need to be continually re-evaluated and adjusted in the light of the trajectories of greenhouse emissions in response to scientific predictions.[123] This will require an interventional approach on the part of regional and local authorities to address the complex emerging regulatory issues associated with the process.[124] The United Nations Framework Convention on Climate Change (UNFCCC) requires not only that parties mitigate emissions but they also cooperate in adapting to its impact.

[202] As noted above, the IPCC assigns no probabilities, only possibilities, to the scenarios it describes as RCP2.6, RCP4.5, RCP6.0 and RCP8.5. Accordingly, the projection of sea level rise should be described as a range of scenarios in order to be able to identify the resulting hazard lines. And these may well change as the scientific results do.

[203] The IPCC, as does the Report, provides this range of possibilities over a 50-100 year time frame where sea level rise issues will have some effect. The likelihood range for sea level rise presented for each scenario by IPCC is based on a particular emission level possibly occurring. What is described above is only one likely scenario that can then be used to inform ongoing discussions and the development of the adaptive pathways of adaptive management.

[204] The residential stakeholders have a right to be informed at the various three key stages the different possibilities provide, and plan accordingly after the technical report is completed.

[205] Once the technical science surrounding the identification of areas in the coastal environment potentially affected by coastal hazards has been established with priority given for

[123] Munasinghe M and Swart R. Primer on Climate Change and Sustainable Development: Facts, Policy Analysis and Applications (Cambridge University Press, 2005), p 172.
[124] The Federation Press (2010). Legal Responses to Climate Change

areas of 'high risk',[125] and the requirements in NZCPS Policy 24(1)(a)-(h) have been addressed more thoroughly, then the first stage in the planning process will be complete.

[206] Then, as the Parliamentary Commissioner advises 'decision makers [after this first stage] should then take the modelling outputs including estimates of uncertainty, and openly and transparently decide how cautious to be in delineating hazard zones'.[126] Establishing the levels of coastal hazard and climate change risks to the communities and the local and national infrastructure is a second stage in planning with its own technical implications.

[207] Thus, for the time being, the conclusions in the first and second stages should not extend to firm up hazard lines designed for inclusion in the CRDP as maps or zones.

[208] Adaptive management in evaluating options to avoid and manage the expected effects from climate change - Policy 25 and Policy 27(2)(b) - enters the planning frame at this stage, as does the application of the Policy 3 Precautionary approach to evidence of the risk related to management of coastal resources potentially vulnerable to effects from climate change so that available social and economic loss and harm to communities does not occur.

[209] This second stage of adaptive management for coastal hazard assessment from climate change should provide a number of levels of risk technically established with input from the community – not just at the high end with which to inform authorities of how to deal with the identified risk. Some of the community questions around the Report relate to this issue.[127]

[210] Analysis of defined risk and adaptive management planning processes which go with it can provide pathways for stakeholders to go hand in hand with management of the risk and should apply also at the third stage of the planning process. These processes can develop implementation pathways that can be developed for the range of scenarios predicated in the RCPs and to an even more detailed extent after consultation, so that a full range of consequences can be established. Open communication among stakeholders in a time of such uncertainties particularly around climate coastal hazard risk, is required.

[211] Adaptation pathways are thus a sequence of linked strategies that are triggered by a change in environmental conditions, and in which initial decisions can have low regrets and preserve options for future generations. Central to these approaches is the principle that adaptation cannot be solved through a single action, but is rather a process to be managed over time. An adaptation pathway is a decision strategy that entails a vision for the entity exposed to climate risks, to be met

[125] Parliamentary Commissioner for the Environment (2015). Preparing New Zealand for Rising Seas: Certainty and Uncertainty, p 78. The Parliamentary Commissioner sees the first stage of defining areas of coastal hazard risk as the gathering and provision of information, including accurate maps of elevation in coastal areas.
[126] Ibid n 1. 8.6 Engaging with Communities, p 78.
[127] See GHD Bundle of Documents, Appendix F Sumner Community Residents Association: Questions and Requests for Clarification on Coastal Hazard Report (Tonkin & Taylor). Questions 1, 2, 10, 11, 13.

through a sequence of manageable steps over time, each of which is triggered by a change in environmental or social conditions – adaptation trigger points. Process is as important as outcomes – because it is essential the process endures.

[212] The adaptive pathways planning approach is used at the options analysis stage and helps develop an implementation pathway which can be done for a range of scenarios (across the RCPs) so the full range of possible consequences can be investigated. Otherwise, highlighting a number for decisions today such as RCP8.5 runs the risk that it will be redundant or wrong, and the activities that last at least 100 years will be detrimentally affected. Ways have to be found of generating a number of different pathways and identifying decision points along the way at which the course can be changed and still meet the objectives of the adaptive plan.

[213] The New Zealand Climate Change Research Institute (NZCCRI) at Victoria University of Wellington ran a series of workshops on adaptive risk management (Lawrence and Manning, 2010) that have demonstrated how and what can be achieved using an adaptive management concept; in the Wellington, Tasman and Nelson regions with engineers, planners, council officers and politicians involved. This has led in the Wellington region to its use for evaluating and deciding the options for the Hutt River City Centre Upgrade (Greater Wellington Regional Council, 2015) project, and the adoption of the following provision in its Climate Change Strategy in the Regional Plan:

> **Greater Wellington Regional Council Climate Change Strategy and Implementation Plan 2015**
>
> 'GWRC commits to an approach that enables us to make decisions in the face of uncertainty.'
>
> **Adaptation policy includes**:
>
> 'Consider the effects of climate change as an integral part of planning and decision-making. Increase long-term adaptive capacity through the use of adaptive planning tools and techniques.
>
> **Implementation plan includes**:
>
> 'Use adaptive planning concepts to understand and evaluate the potential long-term consequences of different policy actions using Sustainable Delta Game workshops which are underway.'

[214] A researcher of the NZCCRI has investigated a dynamic adaptive pathways planning approach (DAPP) for crafting flexible decisions that are robust over whatever outcomes evolve, and that is being put into practice. [128]

[215] The Parliamentary Commissioner recommends a much slower process that actively engages with those affected before final (planning in this case) decisions are made.[129]

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[128] Lawrence, J citing Haasnoot et al (2013). Dynamic adaptive policy pathways: A method for crafting robust decision for a deeply uncertain world. *Global Environmental Change* 23 (20) 485-490.
[129] Ibid.

[216] The first stage of the process should be to collect that information with most certainty, that is, land levels, geomorphology, asset exposure, land use. The second stage of the process should be to overlay a series of scenarios for sea level changes in discussion with those most affected. The two sets of information create an adaptation map which collates expert and local knowledge while establishing a mutually agreed level of risk exposure. The third stage is a completion of the above and agreed mapping.

Conclusion

[217] We make it clear that adaptive management occurs at the second and third stages of the assessment and planning process. We consider that overall the Report is fit for purpose, subject to revision of the calculations undertaken to determine the open coast CEHZ, and deletion of the mapped harbour coast CEHZ lines. We recommend that a revised report be used as a starting point for application of adaptive planning procedures for coastal hazard risk assessment. Only after this should any revised planning maps be included in the CRDP.

[218] There is a great deal of literature available now on how to proceed with adaptive management for coastal hazard risk. It requires support and understanding from all stakeholders.

The Way Forward

[219] CCC through GHD have asked the Panel to indicate ways forward in advancing planning for climate change once the Tonkin & Taylor Report is revised according to the recommendations in this review.

[220] This is outside our exact brief but there are related issues which we consider worth identifying, and appreciate the opportunity to do so here. They are in note form:

- CCC to initiate the concept of adaptive management to assist all stakeholders potentially affected by coastal hazard risk to resolve issues at large in NZCPS Objective 5 and Policies 25-27.
- CCC to require withdrawal of the hazard maps in the Report and put to one side until final mapping is agreed amongst all stakeholders in the second and third stages of adaptive management.
- CCC to advise the LIM authority that the withdrawal is necessary until the legal requirements of the NZCPS are complete because the current mapping may be legally unsound.
- CCC and ECan to move towards integrated management of the coastal environment (NZCPS Policy 4).
- CCC in preparing the coastal hazard chapter of the CDRP move to strategic planning as directed by NZCPS Policy 7.
- NZCPS Policies 4 and 7 are mandatory directives endorsed by Government.

Summary of recommendations

[221] This section outlines *recommendations* for work that the Panel indicates should be completed before the results of the current Tonkin & Taylor technical exercise are used to inform the next stages, to establish the final coastal hazard provisions for the CRDP. The next section outlines *suggestions* for future research that could be incorporated into the first reassessment of the coastal hazard zones that is planned to occur in or before 10 years' time. To be clear, the *recommendations* in this section are the only work that the Panel indicates needs to be done now.

For the present Report technical assessment exercise:

[222] We recommended that the **open coast CEHZ maps** are revised before they are used for planning purposes as follows:

a. The short-term (ST) and long-term (LT) component values should be re-assessed as indicated in this report. Specifically, ST and LT component estimates should be evaluated based on the measured probability distribution (ST) and a normal distribution (LT). Normal, rather than triangular, distributions should be considered for the other components in the probability analysis.

b. The Monte-Carlo simulations should be re-run taking into account the new ST and LT component estimates, and these should be based on individual coastal cell distributions.

c. We recommend that probabilistic modelling is undertaken for the sediment budget component - a range of sediment budget scenarios should be considered, with the current 'no change' scenario forming the middle scenario.

[223] For the **harbour coast CIHZ**, with respect to the Avon-Heathcote Estuary TUFLOW model, the calculations to justify the value of 0.4 m allowance for wave and wind setup should be included in the Report.

[224] We recommended that for **all harbour coast sites that the CEHZ** mapping is re-assessed, including the following:

a. The harbour CEHZ as currently mapped in the Report should be discarded.

b. More attention should be paid to detail and on-ground inspections, and profile slopes should be reviewed.

c. The 'high tide translation' method values should be discarded and only the 'equilibrium profile' values considered.

d. The zones should not extend up small inlets.

[225] In addition to the above hazard and zone specific scientific recommendations, the Report needs to be revised taking into account the requirements of Policy 24(1)(a)-(h) and to include results for more than one IPCC scenario.

[226] We recommend that a revised report, including the additional scenario assessments, be used as a technical starting point for the subsequent adaptive planning exercises needed to produce coastal hazard maps to be included in the CRDP.

[227] It is recommended that some thought be given to NZCPS Policy 4 Integration, a directive that should apply around coastal hazards and climate change. Both ECan and CCC together could well benefit.

Considerations for future reassessment

[228] For both the open coast and harbour coast CIHZ and CEHZ it is suggested that a review of published research be incorporated into each future reassessment.

[229] Where applicable:

[230] We suggest the incorporation of new photography, LiDAR or other ground elevation data, and ongoing ECan beach profile data in the first reassessment.

a. With respect to the above, we suggest that future LiDAR surveys of Canterbury cover the areas predicted to be affected by coastal hazards over the next 100 years in the Report, plus adjacent low-lying land.

b. We also suggest that a thorough analysis is undertaken of the extent of the increased flood vulnerability of estuary proximal areas once remediation of the red zone areas is fully completed.

[231] For both the open coast and harbour coast CIHZ:

a. We suggest that an updated thorough analysis is undertaken of extreme water levels for all water level monitoring stations in the Canterbury area for inclusion in the first reassessment.

b. In conjunction with the above, we suggest that the likelihood of concurrence of extreme waves and coincidence of peak wave setup and wind setup be investigated for inclusion in the first reassessment.

[232] For the open coast CIHZ:

a. We suggest that the deep water wave climate is updated, and that wave setup with transformation across the surf zone is re-evaluated using both the CEM and alternative methodologies (e.g. consider use of the Dally et al. (1985) surf zone wave transformation model that is incorporated in SBEACH). The effect of these updates on the total inundation levels should be assessed and, where necessary, the CIHZ mapping amended at the first reassessment.

b. We suggest that wave runup calculations are performed for likely levels and/or overwash, with assessment included of safety for people or vehicles and damage to property, especially in areas where overwash is likely such as the pier library area at New Brighton.

[233] For the open coast CEHZ:

a. We suggest that a Pegasus Bay coastal monitoring analysis report, including careful analysis of beach volume and excursion indices, is produced before the first reassessment. This report should include comparisons of beach profile analyses with existing sediment budget research.

b. We suggest that the above monitoring report is used to inform the ST and LT components used in the first reassessment.

[234] For both the **open coast and harbour coast CEHZ** mapping: We suggest that the location and condition status of structures (poor/inadequate OR good/engineering design standard) be indicated in the first reassessment.

[235] For the **harbour coast CIHZ mapping**: With respect to the TUFLOW modelling, it is suggested that the factors of river baseflows and coincident rainfall, and the influence of climate change on them, be incorporated in the first reassessment.

18 August 2016

S. E. Henderson R J Cox Deirdre Ellett
M. A. Smith

Glossary

AEP	Annual Exceedance Probability. Defines the probability of some phenomenon exceeding a specified condition (eg Coastal water elevation) at least once during a year. Commonly probabilities of 1% or 2% are used for hazard assessments.
AR4, AR5	The 4th and 5th Assessment Reports produced by the IPCC, which are sub-divided into 3 main working group reports (WGI, WGII, and WGIII). The earlier reports are referred to as the FAR, SAR and TAR for the 1st, 2nd and 3rd reports respectively.
Bathtub approach	A bathtub approach uses a DEM to represent the topography (normally within GIS software). All areas with an elevation below a specified water level, which have a connection to the flooding source (river or sea), are considered to be submerged.
CCC	Christchurch City Council
CEHZ	Coastal Erosion Hazard Zone
CES	Canterbury Earthquake Sequence. A series of earthquakes starting in 2010, including two significant damaging events in September 2010 and February 2011.
CHZ	Coastal Hazard Zones (under the Regional Coastal Plan 2005)
CIHZ	Coastal Inundation Hazard Zone
Conservative	In the assessment of coastal hazards, conservative generally means using a 'upper end' or a maximum, rather than an average or a 'lower end', estimate or approach. A conservative coastal hazard zone would be expected to be larger in extent than a non-conservative one.
CRPS	Canterbury Regional Policy Statement
CRDP	Christchurch Replacement District Plan
DEM	Digital Elevation Model
DS	Dune Stability factor
DSAS	Digital Shoreline Analysis System. This was developed by the US Geological Survey (USGS) for determining shoreline changes from digitized shoreline data.
ECan	Environment Canterbury (Canterbury Regional Council)
ENSO	El Niño-Southern Oscillation. A 2-7 year fluctuation in ocean and atmospheric circulation in the tropical Pacific Ocean characterised by two extremes: El Niño; and La Niña. ENSO is correlated with changes in precipitation, temperature, winds, sea level and wave conditions

	affecting New Zealand.
EQC	Earthquake Commission
GHD	Or GHD Pty Ltd (formerly known as Gutteridge Haskins & Davey) is the name of the consulting firm commissioned by CCC to manage the Christchurch Coastal Hazards Assessment public consultation and second peer review process.
GIS	Geographical Information System
GNS	Geological and Nuclear Sciences
HAT	Highest Astronomical Tide. The highest water level that can be expected to occur under average meteorological conditions over an 18 year period.
IFV	Increased Flooding Vulnerability
ILV	Increased Liquefaction Vulnerability
IPCC	Intergovernmental Panel on Climate Change
IPO	Interdecadal Pacific Oscillation. Multidecadal fluctuation in ocean and atmospheric conditions in the Southern Hemisphere. A similar pattern known as the Pacific Decadal Oscillation (PDO) occurs in the northern Pacific Ocean. The IPO is correlated with variations in sea level and precipitation patterns for New Zealand.
LiDAR	Light Detection and Ranging. A remote sensing technique that uses a pulsed laser to measure distances
LT	Long-term Trend for shoreline changes
MfE	Ministry for the Environment
NIWA	National Institute of Water and Atmospheric research
PCE	Parliamentary Commissioner for the Environment
RCP	Representative Concentration Pathway. The RCPs specify scenarios consisting of a time series of historical and future projected greenhouse gas concentrations, which are used to determine overall radiative forcing. The RCPs have also been expressed in terms of greenhouse gas emissions to meet the requirements of some models used to simulate climate. IPCC AR5 used 4 scenarios: RCP2.6, RCP4.5, RCP6.0 and RCP8.5. These correspond to an increase in radiative forcing relative to pre-industrial conditions of 2.6, 4.5, 6.0 and 8.5 $W.m^{-2}$ respectively.
Reassessment	The Tonkin and Taylor Report suggests that the coastal hazard assessment should be reassessed within 10 years' time. The Panel supports this suggestion.

SBEACH	Numerical model for simulating storm-induced beach profile changes. Originally developed by the Coastal Engineering Research Center of the US Army Corps of Engineers, it has evolved into a widely used model for predicting beach profile response to varying storm conditions.
SD	Standard Deviation
SL	Shoreline response to sea level rise
SLR	Sea Level Rise
ST	Short Term shoreline fluctuations
Suggestion	The Panel make *suggestions* for future research that could be incorporated into the first reassessment of the coastal hazard zones that is planned to occur in or before 10 years' time.
Tonkin & Taylor	Tonkin & Taylor Ltd
TOR	Terms of Reference
TUFLOW	A commercial numerical modelling package designed to simulate river flooding and coastal inundation by storm surges. It can also be used to simulate tidal flow behaviour in estuaries. It accounts for the effects of friction across land surfaces, and flow constrictions within urban drainage networks

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"A"

Appendix B – Original Terms of Reference for Tonkin and Taylor and Variation

V.2.

Tonkin & Taylor

T&T Ref: 851857.001
05 February 2015

Christchurch City Council
PO Box 73012
Christchurch 8140

Attention: Fiona Eunson

Dear Fiona

Coastal Hazard Zone Assessment for Christchurch City - Stage Two

1 Introduction

Following your recent meetings with Mark Ivamy (Tonkin & Taylor Ltd) and in accordance with your request we are pleased to confirm the basis on which we will provide professional services to re-assess the Coastal Hazard Zones (CHZ) for Christchurch City Council (Council) as our client.

The purpose of this assessment is to identify areas susceptible to coastal hazards (inundation and erosion) over both a 50 year (2065) and 100 year (2115) planning timeframe. These areas will be mapped to a standard suitable for inclusion in the District Plan.

The extent of the study includes the coastal settlements located on non-consolidated sand or gravel shorelines within the Christchurch City Council jurisdictional boundaries. The sites are listed below and are classified by their coastal environment as either Open Coast or Harbour/Estuary (Harbour Coast):

Open Coast

- Southern Pegasus Bay from Waimairi Beach to Southshore including the South Brighton spit
- Sumner.

Harbour Coast

- Avon-Heathcote Estuary
- Lyttelton Harbour
  - Allandale
  - Teddington
  - Charteris Bay
  - Purau
- Akaroa Harbour
  - Akaroa Township
  - Takamatua
  - Duvauchelle
  - Wainui.

Tonkin & Taylor Ltd - Environmental & Engineering Consultants, Level 1, The Hub on Cameron, 525 Cameron Road, Tauranga, New Zealand
PO Box 317, Tauranga, Ph: 64-7-571 7360, Fax: 64-7-571 7390, Email: tga@tonkin.co.nz, Website: www.tonkin.co.nz

2 Background

Tonkin & Taylor (T&T) completed an assessment of the effects of sea level rise for Christchurch City over a 100 year timeframe (T&T, 2013)[1]. The assessment included high level mapping of the areas susceptible to storm inundation for both the Avon-Heathcote Estuary and the Akaroa Harbour. The area of land susceptible to erosion due sea level rise over a 100 year timeframe was also mapped at a high level for these Harbour Coast sites (defined as passive inundation). The hazard mapping produced for this high level study needs to be refined for inclusion in the District Plan.

T&T have recently reviewed the existing coastal hazard zones (CHZ) along the Open Coast sites (T&T, 2014)[2] for a 2115 planning timeframe. The review was undertaken as Stage One to check whether the existing CHZ should be re-assessed based on best practice guidelines and current scientific knowledge. The review recommended re-assessing the existing CHZ because they do not adequately incorporate the potential effects of sea level rise as required under the New Zealand Coastal Policy Statement (NZCPS, 2010). The CHZ also need to be re-assessed to consider the coastal erosion hazard over a 50 year planning timeframe (2065). The storm inundation hazard also needs to be assessed for the Open Coast to identify low lying areas of land with coastal inundation pathways.

3 Methodology

We propose to implement separate methodologies to assess coastal hazards for the Open Coast and the Harbour Coast due to the different processes driving each of the two coastal environments. The assessment will identify areas susceptible to both coastal erosion and inundation hazard. The coastal hazard mapping will be undertaken for both the 2065 and 2115 timeframe and will be suitable for inclusion in the District Plan.

3.1 Open Coast

Coastal Inundation Hazard

The coastal inundation hazard for the Open Coast has not previously been identified. The inundation will be mapped by extrapolating the storm inundation level inland where pathways exist based on a digital elevation model (DEM) derived from LIDAR surveyed post the 2010-2011 Canterbury Earthquakes.

Coastal Erosion Hazard

The existing District Plan identifies the coastal erosion hazard over a 100 year timeframe (i.e. defined as CHZ2). The methodology for re-assessing the Open Coast Coastal Erosion Hazard considers both the CHZ1 (50 year timeframe to 2065) and CHZ2 (100 year timeframe to 2115) alignments and is based on best practice methods. The CHZ's will be established from the cumulative effect of four main parameters, which includes an allowance for uncertainty/likelihood:

$$CHZ = SF + DS + (LT \times T) + SLR \qquad \text{(Equation 1)}$$

[1] Tonkin & Taylor (2013): Effects of Sea Level Rise for Christchurch City

[2] Tonkin & Taylor (2014): Coastal Hazard Assessment – Stage One Draft Version 2

Where:

SF	=	Short term /horizontal coastline fluctuations including storm cut (m).
DS	=	Dune slope is characterized by the horizontal distance from the base of the eroded dune to the crest of a stable angle of repose (m).
LT	=	Long term rate of horizontal coastline movement (m/yr).
T	=	Timeframe (years). In this instance a period of 50 and 100 years will be used for CHZ1 and CHZ2 respectively (i.e. 2065 and 2115).
SLR	=	Horizontal coastline retreat due to possible accelerated sea level rise (m).

Note that the analysis undertaken for the Stage One review (T&T, 2014) has progressed defining the best estimate or mode values for both the LT and SLR parameters. The upper and lower parameter bounds will be assessed as part of this study. The DS parameter bounds can be calculated based on the dune crest elevation surveyed from either beach profile data or LIDAR. The SF parameter bounds can be calculated by further analysis of the beach profile data utilised in Stage One. We understand ECan are available to undertake the beach profile analysis based on their beach profile dataset. Due to the frequency of the beach profile data and time gaps over the record, the maximum erosion cut may not have been recorded. Therefore, we propose to check the results using SBEACH modelling. SBEACH provides design storm cut volumes and horizontal movement of the dune toe.

The Envirolink guide to good practice[3] recommends moving from deterministic predictions to probabilistic projections, and that the recognition and treatment of uncertainty is a key source of variance between CHZ predictions by practitioners. We propose to adopt a probabilistic approach which is consistent with the Envirolink guide, and includes the following steps:

- Use probability distribution function to contain the best estimate (mode), lower and upper bounds of the four parameters (excludes T which is fixed) based on either available data or heuristic reasoning based on experience.
- Probability distributions constructed for each parameter are randomly sampled and the extracted values used to define a potential CHZ distance. This process is repeated 10,000 times using a Monte Carlo technique and a probability distribution of the resultant CHZ width is forecast (Figure 1).
- Utilise the probabilistic distributions to map the range of CHZ distances for each time frame and assign a pragmatic probability or likelihood for each CHZ.

The probabilistic approach recognises there will always be inherent uncertainties associated with projections and provides a much more transparent way of capturing and presenting such uncertainty. We note that this method results in a range of potential hazard zone distances and that the selection of the appropriate probabilistic value will be based on discussions with Council. The probabilistic method also aligns with risk assessment approach where the results can be aligned with a range of likelihood scenarios if required.

A risk-based approach to managing coastal hazard is advocated by the NZCPS (2010). For example, the policy statement suggests consideration of areas both 'likely' to be affected by hazard (Policy 27) and areas 'potentially' affected by hazard (Policy 24). Refer to Attachment C for a copy of the two NZCPS (2010) Policies. While the term likely may be related to a likelihood over a defined timeframe based on guidance provided by MfE (2008), (i.e. probability greater than 66% as shown in Table 1), the term potential is less well defined. This assessment therefore aims to derive a range of hazard

[3] http://www.envirolink.govt.nz/Envirolink-tools/

zones corresponding to differing likelihoods which Council can select based on the planning methods applied.

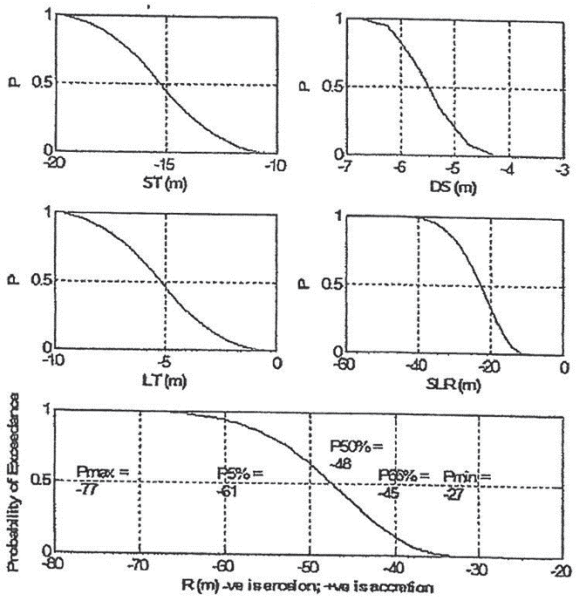

Figure 1 Example cumulative distribution functions of parameter samples and the resultant CHZ distances

Table 1 Likelihood of scenario occurring within the selected planning horizon

Designation	Frequency	Description	IPCC definition
			Virtually certain (> 99% chance that a result is true)
A	Almost certain	Is expected to happen, perhaps more than once	Very likely (90–99%)
B	Likely	Will probably happen	Likely (66–90%)
C	Possible	Might occur; 50/50 chance	Medium (33–66%)
D	Unlikely	Unlikely to occur, but possible	Unlikely (10–33%)
E	Rare	Highly unlikely, but conceivable	Very unlikely (1–10%)
			Exceptionally unlikely (< 1%)

Note: Adopted from MfE (2008), Likely frequency highlighted as an example of the likelihood referred to in Policy 27 of the NZCPS(2010).

The low lying areas along the South Brighton Spit will also be assessed. The CHZ1 and CHZ2 for the South Brighton Spit zone will be offset from the Inlet Migration Curve (IMC) baseline due to the shoreline fluctuation in this area. The IMC is defined as the most inland shoreline position over the fluctuating spit area. The assessment will include the changes that have occurred since the

Canterbury earthquakes due to changes in land level and assess potential effect of future sea level rise. We understand ECan will supply a set of historical shorelines for the South Brighton Spit based on digitising the dune toe from georeferenced aerial photographs.

3.2 Harbour Coast

Coastal Inundation Hazard

The assessment of the inundation hazard for the Harbour Coast will revise the previous mapping of the storm inundation extent produced in the T&T (2013, 2014) reports. The revision will include a check on tidal dampening for the Avon-Heathcote Estuary site, which will be assessed using the TUFLOW model (Flood and Coastal Simulation Software). Tidal damping may restrict the inland extent of the inundation mapping due to the limited time available over the tidal cycle to force sea water inland.

The revision will also include a sensitivity test of the Sumner tide gauge in relation to setting an extreme storm tide level for both the Avon-Heathcote Estuary and Akaroa Harbour sites. This assessment method will be consistent with the recent methodology used for Lyttelton Harbour sites documented in the T&T (2014) report[4], including checks on wind and wave setup. The main revision for the Lyttelton Harbour sites is identifying the inundation hazard for the 2065 planning timeframe, which was not originally assessed.

Coastal Erosion Hazard

The assessment of the erosion hazard for the Harbour Coast will revise the previous mapping of the passive inundation extent (erosion due to sea level rise) produced in the T&T (2013, 2014) reports. The revision to the passive inundation extent will include the same check on tidal damping as identified in the coastal inundation method above. The coastal erosion assessment will also analyse two additional erosion parameters (i.e. short term erosion (SF) and long term erosion (LT)). This assessment will be undertaken in collaboration with ECan and include reviewing previous reports and background information. The mapping will identify areas susceptible to coastal erosion hazard by using the passive inundation extent (erosion due to sea level rise) as a baseline and applying an additional buffer to allow for both the SF and LT parameters.

4 Proposed scope of works

We propose to complete the following scope of works to map areas of land susceptible to coastal hazards (inundation and erosion) over both a 2065 and 2115 planning timeframe. The mapping will be suitable for inclusion in the District Plan:

Open Coast

- Review assessment of both the LT and SLR parameters undertaken in the Stage One report (T&T, 2014) and select mode, lower and upper bound values.
- Analyse the ECan beach profile dataset to define the SF parameter bounds. Undertaken in collaboration with ECan.
- Undertake a check of the beach profile derived SF parameter bounds using the SBEACH model and confirm the SF mode, lower and upper bound values.
- Analyse the LIDAR data to define the DS parameter, including selecting mode, lower and upper bound values.

[4] Tonkin & Taylor (2014): Coastal Hazard Assessment Draft Version 2

- Undertake probabilistic assessment of all four parameters. Resulting in a probabilistic distribution of the CHZ distance for both 2065 (CHZ1) and 2115 (CHZ2) timeframes.
- Determine likelihood frequency for both CHZ1 and CHZ2 in consultation with Council.
- Analyse historic movement of the South Brighton Spit zone to determine appropriate inlet migration curve (IMC) baseline for this area.
- Map the resulting CHZ1 and CHZ2 distances offset from the 2014/2015 dune toe baseline for the purpose of Natural Hazard planning. Note the CHZ1 and CHZ2 for the South Brighton Spit zone will be offset from the Inlet Migration Curve (IMC) baseline due to the shoreline fluctuation in this area.
- The inundation hazard will be mapped by extrapolating the storm inundation level inland where pathways exist based on a digital elevation model (DEM) derived from LIDAR surveyed post the 2010-2011 Canterbury Earthquakes.
- Undertake reporting of Open Coast coastal hazard assessment including detailing the methodology and results for both erosion and inundation.

The Open Coast assessment for the Sumner site is limited to the inundation hazard only. Council considers that the Sumner rock revetment protects a strategic asset (The Esplanade) and will continue to be maintained to protect the land from coastal erosion. Therefore, the coastal erosion hazard will not be assessed for the Sumner site.

Harbour Coast

- Revise the initial high level storm inundation mapping undertaken for the T&T (2013) report including the following checks
  - tidal dampening for the Avon-Heathcote Estuary, based on TUFLOW modelling
  - sensitivity test of the Sumner tide gauge in relation to setting an extreme storm tide level for Avon-Heathcote Estuary and Akaroa Harbour, including analysis of variation in wind and wave setup.
- Assess and map the storm inundation for the all Harbour Coast sites for a 2065 planning timeframe. The mapping will be based on the same methodology above, but will use a suitable 50 year projection for sea level rise (to be agreed with Council and ECan).
- Revise the initial high level passive inundation mapping (erosion due to sea level rise) for the Avon-Heathcote Estuary undertaken for the T&T (2013) report. The revisions will focus on analysis of tidal dampening based on TUFLOW modelling.
- Review previous reports and available background data to assess additional erosion parameters for Harbour Coast sites (i.e. SF and LT).
- Map the area of land susceptible to coastal erosion hazard by using the passive inundation extent (erosion due to sea level rise) as the baseline and applying an additional buffer to allow for both the SF and LT parameters.
- Undertake reporting of the Harbour Coast coastal hazard assessment including detailing the methodology and results for both inundation and erosion.

Note the final report will be compiled as one document which comprehensively covers the methods and results of the coastal hazard assessment for both the Open and Harbour Coasts.

Timeframe and costs

We will commence immediately on instruction to proceed and expect to present our draft report within four weeks of commencing.

The work will be carried out in accordance with our attached Conditions of Engagement. Our fee for the services required will be on a time and expenses basis, with a budget estimate of $32,000 (exclusive of GST).

We will endeavour to complete the work within our budget estimate. However, because of the nature of the work being undertaken, it is not always possible to estimate accurately the time required.

We trust that this satisfactorily confirms our discussions. Please sign and return a copy of the signatory form to us to confirm acceptance by email to mivamy@tonkin.co.nz. We look forward to working with you on this project. Please refer any further enquiries or correspondence to Mark Ivamy.

Yours sincerely

Richard Reinen-Hamill
Project Director

Attached: Signatory form
Conditions of Engagement
Relevant NZCPS Policies

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5 February 2015

851857.001

AGREEMENT VARIATION

VARIATION NUMBER 1 TO AGREEMENT NUMBER CN4600001337
DATED 1 October 2014

CONSULTANCY SERVICES AGREEMENT FOR COASTAL CHAPTER - COASTAL HAZARD ASSESSMENT

Between

Tonkin & Taylor Limited

And

Christchurch City Council

1. Addition of Appendix A1 - Scope, Purpose, Program and Completion Date for a Coastal Chapter - Coastal Hazard Assessment Stage Two
2. Addition of Appendix B1 - Fees, Expenses and Payments for a Coastal Chapter - Coastal Hazard Assessment Stage Two
3. Addition of Appendix C - Methodology from Proposal from Tonkin & Taylor dated 5 February (T&T Ref: 851857.001)
4. All other terms and conditions remain extant.

Variation approved: Tonkin & Taylor Ltd Signed: Name: R.A. Reinen-Hamill Position: PROJECT DIRECTOR Dated: 17/02/2015	**Variation approved:** Christchurch City Council Signed: Alan Matheson Name: Alan Matheson Position: City Planning Team Leader - Strategy & Planning Group Dated: 24/2/2015
Witnessed by: Name: Bridget Foxell Signed: Position: Business Support Co-ordinator Location: Auckland, New Zealand. Dated: 17/02/2015	**Witnessed by:** Name: Julian Clark. Signed: Position: Procurement Officer Location: CCC Dated: 24/2/2015.

APPENDIX A1 - SCOPE, PURPOSE, PROGRAMME AND COMPLETION DATE FOR A COASTAL CHAPTER - COASTAL HAZARD ASSESSMENT - STAGE TWO

1. Project Purpose

1.1 The purpose of the Coastal Chapter - Coastal Hazard Assessment Stage Two is to identify areas susceptible to coastal hazards (inundation and erosion) over both a 50 year (2065) and 100 year (2115) planning timeframe. These areas will be mapped to a standard suitable for inclusion in the District Plan.

1.2 The extent of the study must include the coastal settlements located on non-consolidated sand or gravel shorelines within the Christchurch City Council jurisdictional boundaries. The sites are listed below and are classified by their coastal environment as either Open Coast or Harbour/Estuary (Harbour Coast):

Open Coast

a. Southern Pegasus Bay from Waimairi Beach to Southshore including the South Brighton spit

b. Sumner.

Harbour Coast

c. Avon-Heathcote Estuary

d. Lyttelton Harbour

- Allandale
- Teddington
- Charteris Bay
- Purau

e. Akaroa Harbour

- Akaroa Township
- Takamatua
- Duvauchelle
- Wainui.

2. Scope of Services

The consultant will complete the following scope of services to map areas of land susceptible to coastal hazards (inundation and erosion) over both a 2065 and 2115 planning timeframe. The mapping will be suitable for inclusion in the District Plan:

2.1 Open Coast

a. Review assessment of both the LT and SLR parameters undertaken in the Stage One report (T&T, 2014) and select mode, lower and upper bound values; Where;

LT = Long term rate of horizontal coastline movement (m/yr).

SLR = Horizontal coastline retreat due to possible accelerated sea level rise (m).

b. Analyse the ECan beach profile dataset to define the SF parameter bounds. Undertaken in collaboration with ECan.

c. Undertake a check of the beach profile derived SF parameter bounds using the SBEACH model and confirm the SF mode, lower and upper bound values.

d. Analyse the LiDAR data to define the DS parameter, including selecting mode, lower and upper bound values.

e. Undertake probabilistic assessment of all four parameters. Resulting in a probabilistic distribution of the CHZ distance for both 2065 (CHZ1) and 2115 (CHZ2) timeframes.

f. Determine likelihood frequency for both CHZ1 and CHZ2 in consultation with Council.

g. Analyse historic movement of the South Brighton Spit zone to determine appropriate inlet migration curve (IMC) baseline for this area.

h. Map the resulting CHZ1 and CHZ2 distances offset from the 2014/2015 dune toe baseline for the purpose of Natural Hazard planning. Note the CHZ1 and CHZ2 for the South Brighton Spit zone will be offset from the Inlet Migration Curve (IMC) baseline due to the shoreline fluctuation in this area.

i. The inundation hazard will be mapped by extrapolating the storm inundation level inland where pathways exist based on a digital elevation model (DEM) derived from LiDAR surveyed post the 2010-2011 Canterbury Earthquakes.

j. Undertake reporting of Open Coast coastal hazard assessment including detailing the methodology and results for both erosion and inundation.

k. The Open Coast assessment for the Sumner site is limited to the inundation hazard only. Council considers that the Sumner rock revetment protects a strategic asset (The Esplanade) and will continue to be maintained to protect the land from coastal erosion. Therefore, the coastal erosion hazard will not be assessed for the Sumner site.

2.2 Harbour Coast

a. Revise the initial high level storm inundation mapping undertaken for the T&T (2013) report including the following checks

- tidal damping for the Avon-Heathcote Estuary, based on TUFLOW modelling

- sensitivity test of the Sumner tide gauge in relation to setting an extreme storm tide level for Avon-Heathcote Estuary and Akaroa Harbour, including analysis of variation in wind and wave setup.

b. Assess and map the storm inundation for the all Harbour Coast sites for a 2065 planning timeframe. The mapping will be based on the same methodology above, but will use a suitable 50 year projection for sea level rise (to be agreed with Council and ECan).

c. Revise the initial high level passive inundation mapping (erosion due to sea level rise) for the Avon-Heathcote Estuary undertaken for the T&T (2013) report. The revisions will focus on analysis of tidal damping based on TUFLOW modelling.

d. Review previous reports and available background data to assess additional erosion parameters for Harbour Coast sites (i.e. SF and LT).

e. Map the area of land susceptible to coastal erosion hazard by using the passive inundation extent (erosion due to sea level rise) as the baseline and applying an additional buffer to allow for both the SF and LT parameters.

f. Undertake reporting of the Harbour Coast coastal hazard assessment including detailing the methodology and results for both inundation and erosion.

3. Reporting

The final report will be compiled as one document which comprehensively covers the methods and results of the coastal hazard assessment for both the Open and Harbour Coasts.

4. Methodology

4.1 Separate methodologies as outlined in Tonkin & Taylor's proposal dated February 5th 2015 (T&T ref: 851857.001) will be used to assess coastal hazards for the Open Coast and the Harbour Coast due to the different processes driving each of the two coastal environments. (See Appendix C)

4.2 The assessment will identify areas susceptible to both coastal erosion and inundation hazard.

4.3 The coastal hazard mapping will be undertaken for both the 2065 and 2115 timeframe and will be suitable for inclusion in the District Plan.

5. GIS/CAD Data

5.1 A GIS or CAD data file with the extent of the area(s) should be topologically correct, consistent and supplied in the following format:

a. MapInfo Tab file, ArcGIS Shape File, GeoMedia SmartStore, AutoCad (Version 12, 2D) or Microstation (Version 7, 2D).

b. CAD format features allowed include point, line and area/polygon. B-spline features are not acceptable.

c. Polygons must be used to represent areas where an area feature is depicted.

d. Lines must only be used for straight features, and should not be used to represent polygons.

e. If data is required to be provided in other formats, please contact the DPR GIS team to discuss options. Please email to: Amanda.Cockcroft@ccc.govt.nz .

5.2 Co-ordinate System: All data shall be in NZMG coordinate system or Geodetic 1949.

5.3 Metadata: As a minimum please supply a map in PDF format showing the geographic extents of the data supplied, a description of any attributes or codes used in the GIS/CAD files, the processing undertaken and the terms of use for the data (ideally provide a metadata record compliant with ANZLIC Metadata Profile http://www.linz.govt.nz/geospatial-office/about/projects-and-news/anzlic-metadata-profile).

5.4 The Christchurch City Council will retain ownership of the data and therefore has the right to use the data for any purpose.

6. Timeframe

6.1 Because the Council is working to a truncated timeframe to accommodate the requirements of the Canterbury Earthquake (Christchurch Replacement District Plan) Order 2014 (which replaces the requirements of the Resource Management Act 1991 for the District Plan Review) we request the Consultant provides drafts of components of the report by the 13th February 2015 and 20 February 2015 and the completed report by 27th February 2015.

APPENDIX B

Provisions from NZCPS (2010)

Objective 5

To ensure that coastal hazard risks taking account of climate change, are managed by:

- locating new development away from areas prone to such risks;
- considering responses, including managed retreat, for existing development in this situation; and
- protecting or restoring natural defences to coastal hazards.

Policy 3 Precautionary approach

(1) Adopt a precautionary approach towards proposed activities whose effects on the coastal environment are uncertain, unknown, or little understood, but potentially significantly adverse.

(2) In particular, adopt a precautionary approach to use and management of coastal resources potentially vulnerable to effects from climate change, so that:

(a) avoidable social and economic loss and harm to communities does not occur;

(b) natural adjustments for coastal processes, natural defences, ecosystems, habitat and species are allowed to occur; and

(c) the natural character, public access, amenity and other values of the coastal environment meet the needs of future generations.

Policy 4 Integration

Provide for the integrated management of natural and physical resources in the coastal environment, and activities that affect the coastal environment. This requires:

(a) co-ordinated management or control of activities within the coastal environment, and which could cross administrative boundaries, particularly:

(i) the local authority boundary between the coastal marine area and land;

(ii) local authority boundaries within the coastal environment, both within the coastal marine area and on land; and

(iii) where hapū or iwi boundaries or rohe cross local authority boundaries;

(b) working collaboratively with other bodies and agencies with responsibilities and functions relevant to resource management, such as where land or waters are held or managed for conservation purposes; and

(c) particular consideration of situations where:

(i) subdivision, use, or development and its effects above or below the line of mean high water springs will require, or is likely to result in, associated use or development that crosses the line of mean high water springs; or

(ii) public use and enjoyment of public space in the coastal environment is affected or is likely to be affected; or

(iii) development or land management practices may be affected by physical changes to the coastal environment or potential inundation from coastal hazards, including as a result of climate change; or

(iv) land use activities affect, or are likely to affect, water quality in the coastal environment and marine ecosystems through increasing sedimentation; or

(v) significant adverse cumulative effects are occurring, or can be anticipated.

Policy 6: Activities in the coastal environment

1. In relation to the coastal environment:

a. recognise that the provision of infrastructure, the supply and transport of energy including the generation and transmission of electricity, and the extraction of minerals are activities important to the social, economic and cultural well-being of people and communities;

b. consider the rate at which built development and the associated public infrastructure should be enabled to provide for the reasonably foreseeable needs of population growth without compromising the other values of the coastal environment;

c. encourage the consolidation of existing coastal settlements and urban areas where this will contribute to the avoidance or mitigation of sprawling or sporadic patterns of settlement and urban growth;

d. recognise tangata whenua needs for papakāinga[3], marae and associated developments and make appropriate provision for them;

e. consider where and how built development on land should be controlled so that it does not compromise activities of national or regional importance that have a functional need to locate and operate in the coastal marine area;

f. consider where development that maintains the character of the existing built environment should be encouraged, and where development resulting in a change in character would be acceptable;

g. take into account the potential of renewable resources in the coastal environment, such as energy from wind, waves, currents and tides, to meet the reasonably foreseeable needs of future generations;

h. consider how adverse visual impacts of development can be avoided in areas sensitive to such effects, such as headlands and prominent ridgelines, and as far as practicable and reasonable apply controls or conditions to avoid those effects;

i. set back development from the coastal marine area and other water bodies, where practicable and reasonable, to protect the natural character, open space, public access and amenity values of the coastal environment; and

j. where appropriate, buffer areas and sites of significant indigenous biological diversity, or historic heritage value.

2. Additionally, in relation to the coastal marine area:

a. recognise potential contributions to the social, economic and cultural wellbeing of people and communities from use and development of the coastal marine area, including the potential for renewable marine energy to contribute to meeting the energy needs of future generations;

b. recognise the need to maintain and enhance the public open space and recreation qualities and values of the coastal marine area;

c. recognise that there are activities that have a functional need to be located in the coastal marine area, and provide for those activities in appropriate places;

d. recognise that activities that do not have a functional need for location in the coastal marine area generally should not be located there; and

e. promote the efficient use of occupied space, including by:

i. requiring that structures be made available for public or multiple use wherever reasonable and practicable;

ii. requiring the removal of any abandoned or redundant structure that has no heritage, amenity or reuse value; and

iii. considering whether consent conditions should be applied to ensure that space occupied for an activity is used for that purpose effectively and without unreasonable delay.

Policy 7 Strategic planning

(1) In preparing regional policy statements, and plans:

(a) consider where, how and when to provide for future residential, rural residential, settlement, urban development and other activities in the coastal environment at a regional and district level; and

(b) identify areas of the coastal environment where particular activities and forms of subdivision, use and development:

(i) are inappropriate; and

(ii) may be inappropriate without the consideration of effects through a resource consent application, notice of requirement for designation or Schedule 1 of the Act process;

and provide protection from inappropriate subdivision, use, and development in these areas through objectives, policies and rules.

(2) Identify in regional policy statements, and plans, coastal processes, resources or values that are under threat or at significant risk from adverse cumulative effects. Include provisions in plans to manage these effects. Where practicable, in plans, set thresholds (including zones, standards or targets), or specify acceptable limits to change, to assist in determining when activities causing adverse cumulative effects are to be avoided.

Policy 15: Natural features and natural landscapes

To protect the natural features and natural landscapes (including seascapes) of the coastal environment from inappropriate subdivision, use, and development:

a. avoid adverse effects of activities on outstanding natural features and outstanding natural landscapes in the coastal environment; and

b. avoid significant adverse effects and avoid, remedy, or mitigate other adverse effects of activities on other natural features and natural landscapes in the coastal environment; including by:

c. identifying and assessing the natural features and natural landscapes of the coastal environment of the region or district, at minimum by land typing, soil characterisation and landscape characterisation and having regard to:

i. natural science factors, including geological, topographical, ecological and dynamic components;

ii. the presence of water including in seas, lakes, rivers and streams;

iii. legibility or expressiveness – how obviously the feature or landscape demonstrates its formative processes;

iv. aesthetic values including memorability and naturalness;

v. vegetation (native and exotic);

vi. transient values, including presence of wildlife or other values at certain times of the day or year;

vii. whether the values are shared and recognised;

viii. cultural and spiritual values for tangata whenua, identified by working, as far as practicable, in accordance with tikanga Māori; including their expression as cultural landscapes and features;

ix. historical and heritage associations; and

x. wild or scenic values;

d. ensuring that regional policy statements, and plans, map or otherwise identify areas where the protection of natural features and natural landscapes requires objectives, policies and rules; and

e. including the objectives, policies and rules required by (d) in plans.

Policy 24 Identification of coastal hazards

(1) Identify areas in the coastal environment that are potentially affected by coastal hazards (including tsunami), giving priority to the identification of areas at high risk of being affected. Hazard risks, over at least 100 years, are to be assessed having regard to:

(a) physical drivers and processes that cause coastal change including sea level rise;

(b) short-term and long-term natural dynamic fluctuations of erosion and accretion;

(c) geomorphological character;

(d) the potential for inundation of the coastal environment, taking into account potential sources, inundation pathways and overland extent;

(e) cumulative effects of sea level rise, storm surge and wave height under storm conditions;

(f) influences that humans have had or are having on the coast;

(g) the extent and permanence of built development; and

(h) the effects of climate change on:

(i) matters (a) to (g) above;

(ii) storm frequency, intensity and surges; and

(iii) coastal sediment dynamics;

taking into account national guidance and the best available information on the likely effects of climate change on the region or district.

Policy 25 Subdivision, use, and development in areas of coastal hazard risk

In areas potentially affected by coastal hazards over at least the next 100 years:

(a) avoid increasing the risk[1] of social, environmental and economic harm from coastal hazards;

[1] Risk as defined in the Glossary.