Jacobs

Memorandum

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Subject	**Akaroa Wharf Coastal Hazards Review: Report Addendum -Extreme Sea Level Risk**	**Project Name**	Christchurch Coastal Hazards Review
Attention	CCC: Carissa Ptacek, Kristine Bouw	**Project No.**	IS346200
From	Derek Todd & Kate MacDonald		
Date	March 1, 2021		
Copies to	Matt Bonis, Tom Arthur		

1. Introduction

This memo forms an addendum to the Jacobs Report "Akaroa Coastal Hazards Review" to Christchurch City Council (the Council) dated 12 September 2019, which presented extreme sea levels in a 1% Annual Exceedance Probability (AEP) coastal storm event in 2120 with sea level rise as per the four RCP scenarios presented by MfE (2017)[1]. The Council now wish to review the risk profiles for the future to determine a proposed build height for the new wharf. The purpose of this memo is therefore to provide advice to the Council as to what an appropriate wharf height would be from a coastal hazards perspective.

The following section briefly summarises the results of this analysis and the assumptions applied to reach the recommended sea level for design of the deck height of the new wharf from a coastal hazards perspective. A more detailed presentation of analysis is presented below the summary.

2. Summary

Based on the review blow, it is recommended that a sea level of 3.06 m LVD-37[2] or 12.10 m CDD[3] be used in the design of the deck height of the new wharf. This level is in the order of 0.5 m above the existing wharf height.

A risk profile of extreme sea levels at Akaroa was developed involving the highest RCP scenario (RCP 8.5+) over four different timeframes (2070, 2100, 2120, 2150) and five different storm frequencies (10%, 5%, 2%, 1%, 0.5% AEP's). From this risk profile, the components of the recommended design sea level included:

[1] Ministry for the Environment, (2017). Coastal Hazards and Climate Change: Guidance for local government.
[2] Lyttelton Vertical Datum 1937
[3] Canterbury Drainage Datum

- Current MHWS level[4]: 1.37 m LVD-37, 10.41 m CDD
- 1% AEP storm surge: 0.6 m
- Wave set-up: 0.05 m
- Sea level rise: 1.04m – RCP8.5+ scenario 2100, or RCP8.5 scenario 2120.

If designed to this level, the wharf deck would be 0.32 m above MHWS level in 2120 with sea level rise under the RCP8.5+ scenario, but is likely to be overtopped by storms on more than an annual basis by this time. However, under the RCP8.5 scenario, this level would be 0.63 m above MHWS level in 2120 and would be sufficient to avoid overtopping in a 1% AEP event. This level is in the order of only 0.5 m above the surrounding waterfront land levels, therefore connection between the wharf and the land should be more easily achieved that with a higher deck levels.

It is considered that applying the recommended design sea level meets the recommendations of the MfE (2017) *coastal hazard guidance* for incorporating sea level rise into asset planning. It is also considered that it is a practical level for the wharf deck, being in the in the order of only 0.5 m above the surrounding waterfront land levels, therefore connection between the wharf and the land should be more easily achieved that with a higher deck levels.

Any concerns for pedestrian safety on the wharf from storm overtopping could be addressed by a condition on consent closing the wharf during extreme events. However, the time when this may be required due to sea level rise is unlikely to occur much before 2100, well beyond the 35-year lifetime of consent required for construction and initial occupation.

3. Updated Input Data

3.1 Mean High Water Spring (MHWS)

There is no update in the level of MHWS from the Jacobs (2019) report, with LINZ secondary ports dataset, giving MHWS at Akaroa to be 1.2m above MSL. However, it is noted that these figures are only given by one decimal place, so could be in the range 1.15 m to 1.25 m above MSL. It also depends on how MWHS is defined, as the South Island East Coast experiences monthly perigean and apogean tides (Stephens et al, 2015)[4] with a single dominant spring tide per month rather than fortnightly spring and neap tides. Although the Coastal Calculator tool in Stephens et al (2015) does not include a site in Akaroa Harbour, it gives MHWPS[5] at the closest site (Birdlings Flat) as being 1.08 m above MSL and at Lyttelton as being 1.12 m above MSL. Therefore, although the tidal range appears to be larger in Akaroa Harbour, a MHWS level closer to 1.15 m above MSL is considered to be more likely. However, as a conservative approach for the updated analysis, a MHWS level of 1.2 m above MSL is retained.

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[4] Stephens, S, Allias, M, Robinson, B & Gorman, R, (2015). Storm-tides and wave runup in the Canterbury Region. Prepared for Environment Canterbury. Includes a Coastal Calculator tool for calculating storm tide, storm surge, wave set and run-up at multiple sites along the Canterbury open coast.
[5] MHWPS: Mean High Water Perigean Spring

For reference to land elevation datum (LVD-37), we have used a +0.17 m adjustment to MSL to account for sea level rise (SLR) since 1937 (e.g. avg SLR 2mm/yr), hence the elevation of MHWPS at Akaroa is taken as being 1.37 m (LVD-37). In terms of Christchurch Drainage Datum (CDD), this level is 10.413 m.

3.2 Storm Surge

The Jacobs (2019) assessment applied two 1% AEP storm surge elevations of 0.6 m and 0.8 m based on the calculations in DTec (2008)[6] and the upper level commonly applied in New Zealand from Bell et al (2000)[7] respectively. For this updated assessment, these storm surge levels were sensitivity tested against an inferred 1% AEP storm surge level from the storm tide[8] levels given in the Canterbury Coastal Calculator (Stephens et al, 2015) for Birdlings Flat, being the closest site in the calculator to Akaroa. This storm surge level is inferred as it assumes a MHWS astronomical tide level at the time of the 1% storm tide level. It is recognised that from the joint probability of astronomical tide and storm surge, a higher surge could be combined with a lower astronomical tide to produce the same storm tide level. However, extreme storm tides require high levels of both factors. Although Birdlings Flat is an open coast site, the processes driving storm surge (low barometric pressure and wind stress – particularly in southerly storm conditions) are most likely to be similar within Akaroa Harbour, hence storm surge is likely to be comparable between these sites.

The resulting inferred 1% AEP storm surge levels at Birdlings Flat from the Canterbury Coastal Calculator is 0.54 m, which is the same order of magnitude to the 0.6 m calculated for Akaroa Harbour by DTec (2008). It is therefore considered that a 0.6 m storm surge level is a more appropriate 1% AEP contribution to extreme storm tide levels than 0.8 m, and is suitable to use in the extreme water level calculations to allow for the possibility of slightly higher surge levels than 0.54 m as discussed above.

Applying the above assumptions on the 1% AEP storm surge level, similar minor adjustments to the 10%, 5%, 2%, and 0.5% AEP storm surge levels inferred from the coastal calculator have been applied to obtain the distribution of surge levels presented in Table 1.

Table 1: Inferred storm surge elevations for Akaroa for different frequencies of coastal storm events

Frequency (% AEP)	10%	5%	2%	1%	0.5%
Return Period	10 years	20 years	50 years	100 years	200 years
Storm Surge elevation (m)	0.50	0.53	0.57	0.60	0.63

Applying the above storm surge to MHWS, results in a 2% AEP storm tide level of 1.94 m LVD-37 or 10.983 m CCD, and a 1% AEP storm tide level of 1.97 m LVD-37 or 11.013 m CCD.

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[6] DTec, (2008). Akaroa Harbour Basin Settlements Study – Coastal Erosion and Inundation Project. Prepared for Christchurch City Council Strategy and Planning Group.
[7] Bell, R. G; Goring, D. G and de Lange, W. P, (2000). Sea-level change and storm surge in the context of climate change. Institute of Professional Engineers of New Zealand (IPENZ). *IPENZ Transactions,* General 27(1): 1-10.
[8] Storm tide is the water level from the combination of astronomical tide and storm surge

3.3 Wave Set-up

There is no reason to update the wave set-up component of the extreme water levels, remaining a conservative value of 0.05 m.

3.4 Sea Level Rise (SLR)

For this analysis the SLR projections are limited to the RCP8.5+ scenario and have been updated from MfE (2017) to those presented in IPCC (2019) Special Report[9]. These more recent projections are 0.1 m higher by 2100 than those included in MfE (2017) due to a better understanding of the contribution that the melting of the Antarctic Ice Sheet will have on SLR over the next 100 years and beyond.

For this updated analysis, the base date for the SLR projection has also been adjusted from the 1986-2006 period (assumed mid-point base date of 1995) given in MfE (2017) to 2020 , so that all magnitudes of sea level rise are from current mean sea level. The resulting SLR from 2020 levels due to climate change under the RCP8.5+ scenario are set out in Table 2.

Table 2: RCP8.5+ SLR Projections from IPCC (2019) set to a 2020 base level

Timeframe	By 2070	By 2100	By 2120	By 2150
SLR rise under RCP8.5+ scenario (m)	+0.58	+1.04	+1.37	+1.93

4. Resulting Extreme Sea Levels

The resulting extreme water levels in terms of LVD-37 under the RCP 8.5+ SLR scenario across four different timeframes (2070, 2100, 2120, 2150) and five different storm frequencies (10%, 5%, 2%, 1%, 0.5% AEP's) are presented below in Table 3, and in terms of CCD to 2-decimal places in Table 4.

Table 3: Projected extreme sea levels for Akaroa under an RCP8.5+ SLR scenario. Levels are in terms of LVD-37.

Year	Time span	Sea level Rise (m)	AEP Extreme Water level + SLR under RCP8.5+ scenario (m LVD-37)				
			10%	5%	2%	1%	0.5%
2020	Current	0	1.92	1.95	1.99	2.02	2.05
2070	50 years	0.58	2.50	2.53	2.57	2.60	2.63
2100	80 years	1.04	2.96	2.99	3.03	3.06	3.09
2120	100 years	1.37	3.29	3.32	3.36	3.39	3.42
2150	130 years	1.93	3.85	3.88	3.92	3.95	3.98
Note Extreme sea level includes astronomical tide, storm surge and wave set-up							

[9] International Panel for Climate Change, (2019). Special Report on the Ocean and Cryosphere in a Changing Climate.

Table 4: Projected extreme sea levels for Akaroa under an RCP8.5+ SLR scenario. Levels are in terms of CCD.

Year	Time span	Sea level Rise (m)	AEP Extreme Water level + SLR under RCP8.5+ scenario (m CDD)				
			10%	5%	2%	1%	0.5%
2020	Current	0	10.96	10.99	11.03	11.06	11.09
2070	50 years	0.58	11.54	11.57	11.61	11.64	11.67
2100	80 years	1.04	12.00	12.03	12.07	12.10	12.13
2120	100 years	1.37	12.33	12.36	12.40	12.43	12.46
2150	130 years	1.93	12.89	12.92	12.96	12.99	13.02
Note Extreme sea level includes astronomical tide, storm surge and wave set-up							

It is noted that in comparison to the storm tide levels (e.g. extreme water levels – wave set-up) given in the Coastal Calculator (Stephens et al 2015) for Birdlings Flat , the above levels in Table 3 are 0.22 m higher due to a 0.16 m larger tidal range (including rounding error for one decimal place in Akaroa data), and 0.06 m greater storm surge. This indicates that the above extreme water levels can be considered to be conservative estimates of future water levels under the highest SLR scenario presented in MfE (2017) (RCP 8.5+ scenario).

5. Recommended Sea level for Wharf Height Design

Assuming that engineering design allows for the deck of the wharf to be overtopped without structural damage to the wharf itself, from a coastal hazards perspective the height of the wharf will depend on the combination of the timeframe of sea level rise being considered and the frequency/magnitude of storm overtopping that is acceptable for pedestrians and accessory structures on the wharf. For example, from Tables 3 & 4, designing for 50 years of sea level rise and a 200-year return period storm would result in design sea level of 2.63 m LVD-37 or 11.67 m CDD, whereas designing for 100 years of sea level rise and only 10 year return period storm would result in a design sea level of 3.29 m LVD-37 or 12.33 m CDD. As can seem from these examples, it is the timeframe of sea level rise than dominates the design level.

For the consideration of sea level rise, the natural hazard objectives and policies of the NZCPS (2010)[10] (objective 5, Policies 24-27), are of little relevance in the case of a wharf, as the only reference to infrastructure is in Policy 25(d), being "*encourage the location of infrastructure away from areas of hazard risk where practicable*".

The MfE (2017) coastal hazards guidance recommends that for major new infrastructure, which the Akaroa wharf could be considered to be, hazard risk should be avoided by using a sea level rise over more

[10] NZCPS (2010); New Zealand Coastal Policy Statement, 2010. Is a mandatory policy statement under the RMA 1991

than 100 years and the RCP8.5+ scenario. Under this recommendation, from Table 3 & 4 the design sea level would be between 3.85 and 3.98 m LVD-37 or 12.89 and 13.02 m (CDD) depending on the frequency of storm overtopping (e.g. 10% to 0.5% AEP) that was acceptable. However, in the Akaroa context, constructing the wharf to these heights is considered to be impractical, being over 1 m higher that the local waterfront land levels. As well creating large difficulties in designing a practical connection to the land, during the extreme water level events the wharf would not be able to be accessed due to large scale inundation of the surrounding land. There is also the question of cost benefit, with the benefit of the additional height of the wharf in preventing overtopping of the deck only being realised after 100 years, which is likely to be beyond the design life of the structural components.

MfE (2017) also includes an alternative recommendation of allowance for 1 m of sea level rise for existing coastal developments and asset planning, which is more appropriate in the context of the Akaroa wharf. Under the RCP8.5+ scenario this magnitude of sea level rise is most likely to occur in around 80 years (i.e. 2100). It should be noted that this is the worst case sea level rise scenario presented in MfE (2017), and under the best case sea level rise scenarios (RCP2.6 & RCP4.5), this magnitude of rise would most likely occur sometime after 2150. Applying the 1.04 m sea level by 2100 from Table 3 & 4, and depending on the frequency of storm overtopping that is acceptable, the design water level would be between 2.96 and 3.09 m LVD-37 or 12.00 and 12.13 m CDD for 10% to 0.5% AEP storm events respectively.

With regard to acceptable storm frequency, MfE (2017) recommends use of the 1% AEP event as the most suitable for planning. Applying this storm frequency, the design sea level for the wharf deck is recommended to be 3.06 m LVD-37 or 12.10 m CDD.

It is noted that this level is in the order of only 0.5 m above the surrounding waterfront land levels, therefore connection between the wharf and the land should be more easily achieved. It is also noted that at this level, the deck would be 0.32 m above MHWS level in 2120 with sea level rise under the RCP8.5+ scenario, but likely to be overtopped in storm events on more than an annual basis by this time. However, under the RCP8.5 scenario, this level would be 0.63 m above MHWS level in 2120 and would be sufficient to avoid overtopping in a 1% AEP event.

On this basis, it is considered that applying this design sea level meets the recommendations of the MfE (2017) *coastal hazard guidance* for incorporating sea level rise into asset planning.

Any concerns for pedestrian safety on the wharf from storm overtopping could be addressed by a condition on consent closing the wharf during extreme events. However, the time when this may be required due to sea level rise is unlikely to occur much before 2100, well beyond the 35-year lifetime of consent required for construction and initial occupation.