HSJ14201

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Dear Matt

Review of Appendix A (Sea Level Considerations) in the Kotuku Park Ltd. District Plan submission

Kāpiti Coast District Council (KCDC) have requested comments on Appendix A (pages 27-28) of the District Plan submission by Kotuku Park Ltd.

Appendix A is a 2-page piece on sea level considerations by Mr Angus Gordon of Australia.

I have attached a PDF version of this Appendix preceded by the References cited.

I offer the following comments or additional information:

1. General comment—as mentioned in paragraph 2, the projections for sea-level rise are couched in terms of the mean global absolute (eustatic) sea level. Coastal margins locally respond to relative sea-level rise (RSLR), which is that measured relative to the land by a local tide gauge (if there were one). RSLR is also the rise that needs to be used as inputs to local adaptation plans to cope with rising sea levels.

   However, because future global mean sea level (MSL) projections are in absolute terms, we need to be able to downscale these to the New Zealand region and locally apply any adjustment for local land movement (subsidence or uplift).

2. 2nd paragraph—the 2007 IPCC 4th Assessment Report projections of sea-level rise are correctly stated for the 2090s (mid-point 2095) including the caveat for accelerated ice sheet loss which raised to upper estimate to 0.78 m (often rounded up to 0.8 m). What is required between these global-mean projections and the RSLR at the local level (as per the next paragraph in Appendix A) is an assessment of the regional NZ-wide departure of sea-level projections.

   The Ministry for the Environment (MfE) 2008 guidance manual for local government on *Coastal Hazards and Climate Change* included an additional 0.05 m sea-level rise by the 2090s for regional sea-level rise in the NZ-wide region as described in Section 2.2.5 and Figure 2.5 on page 16 of MfE(2008). This additional rise above the global-

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mean projections for the New Zealand region of up to 0.05 m by the 2090s was also recently confirmed by Ackerley et al. (2013). [1]

3. Paragraph 3 – discusses the importance to both tectonic movements and glacial isostatic adjustment (GIA) following the last ice age. These aspects have been considered in local studies of relative SLR in New Zealand, but generally are second-order effects to the eustatic rise in sea level apart from localised areas of New Zealand subject to significant tectonic movement, slow slip events or general subsidence. As the work of Beavan & Litchfield (2012)[2] show, the Kāpiti region is one of those areas affected by these effects on vertical land movement.

4. Paragraph 4 is based on some misinterpretation of Beavan & Litchfield (2012).

   From their Table 2, the Kāpiti region has been experiencing subsidence at rates from 0.7 mm/yr (PAEK-Paekakariki) to 4.5 mm/yr (LEV-Levin) based on 4 continuous GPS (cGPS) stations in the region. Beavan & Litchfield (2012) specifically mention on page 16 of their report that the Levin rate is biased high due to the short record (4 years only) and the concurrence of the record between slow-slip events (SSEs). They mention the rate is more likely to be closer to the nearby Otaki (OTAK) station at 1.3 mm/yr and Kāpiti Island (KAPT) at 2.1 mm/yr, where the latter is also probably too high. Consequently, the estimate of subsidence over the cGPS records in the Kāpiti region is probably around 0.7 mm/yr up to 2 mm/yr. An important caveat is these subsidence rates only apply to the length of the cGPS record (up to the past 10 years for PAEK, 8 years for KAPT and 5 years for OTAK). To extrapolate them "over the historical period of interest" and "that this trend is likely to continue for the next 50 to 100 years" leads to an erroneous conclusions in the following paragraphs of Mr Gordon's submission. Slow-slip events during the inter-seismic period (between significant earthquake ruptures) vary with time with durations of weeks to a year or more and at recurrence intervals of 5 years or more in the western North Island (p. 14; Beavan & Litchfield,2012).

   Emeritus Professor John Hannah (formerly University of Otago) adds that to extrapolate the 5-10 years of cGPS data across 50-100 years of tide-gauge data is not correct. Due to the uncertainty of the tectonic situation in Wellington and the fact that there is only 13 years of cGPS data at Wellington Airport, our best assessment of the regional tectonic subsidence is 1.7 mm/yr. Other (Kāpiti Coast) data sets are much shorter. Our best guess at this stage is that the subsidence reduces as one moves north from Wellington Airport, finally disappearing somewhere north of Palmerston North.

   So to ascribe these rates from very short cGPS records to periods of centuries is problematic.

   Angus Gordon also mentions GIA rebound ("… a rebound is a lifting of the land mass of 0.3 mm/yr") is additional – actually the GIA for NZ is a gradual subsidence not an uplift or rebound. The 0.3 mm/yr is a long-term average estimate from crustal modelling over New Zealand. The cGPS stations measure vertical land movement irrespective of their sources (which includes any GIA contribution). Beavan &

[1] Ackerley, D., Bell, R.G., Mullan, A.B., McMillan, H. (2013) Estimation of regional departures from global-average sea-level rise around New Zealand from AOGCM simulations. *Weather & Climate*, 33: 2–22, Journal of the Meteorological Society of New Zealand (Inc).

[2] Beavan, R.J., Litchfield, N.J. (2012) Vertical land movement around New Zealand coastline: Implications for sea-level rise. *GNS Science Report* 2012/29, September 2012: 41.

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Litchfield (2012) also point out on page 9 (Section 5.0) that in practice cGPS observations can have a bias of up to 1 mm/yr in defining absolute land movement rates. So to add in an additional 0.3 mm/yr for GIA to the cGPS rates is misleading as includes it twice and anyway is below the uncertainty or bias in the cGPS observations.

Angus Gordon also points out the paradox, that the Kāpiti coastline is uplifting at an average geological rate of 0–1 mm/yr inferred from marine terrace uplift over a period of 125,000 years. This paradox is explained by Beavan & Litchfield (2012) – where major earthquake events can cause ruptures (either uplift or downthrust) with a different inter-seismic trend between rupture events. In preparing plans under the RMA and associated New Zealand Policy Statement, the planning horizon is only a 100 years or more. As we can't predict when the next major earthquake rupture will occur in the Kāpiti region, we have to put to one side the geological uplift rate and focus on the average trend during the inter-seismic period, which for Kāpiti is subsidence. The cGPS records give us a glimpse of the trend over period of up to a decade, but as the record length increases, the average inter-seismic subsidence trend will emerge.

5. Paragraph 5: The historical rate of rise in absolute global-mean sea level over the past 100 years is correctly quoted. However, one can't simply add a subsidence rate from a short-term cGPS record onto that long-term global trend to get the relative SLR. The historic rate of rise at the local/regional level, relative to the land, can be determined directly from tide gauge records, which is discussed further by Angus Gordon in the next paragraph. It is this relative SLR (that tide gauges measure) that the local coastal morphology will respond to as discussed by Mr Gordon.

6. Paragraph 6: The 1st sentence correctly reports on the result from Bell and Hannah (2012) for the Wellington tide gauge analysis[3] that the relative SLR over the past 120 years (1891–2011) has been rising at an average rate of 2.03 mm/yr. To complete the picture on historic trends from this gauge, Table 7-1 from Bell and Hannah (2012) provides historic trends published earlier for different periods: 1.73 mm/yr (1901–1988) and 1.78 mm/yr (1891–2001). What this time progression in rates of relative SLR show is there has been an increase in the overall rate by an additional 0.3 mm/yr by just adding the first decade of this century. Some of this is due to climate variability (e.g., the 20–30 year Interdecadal Pacific Oscillation changed phases around 1999-2000), but comparing Wellington with other NZ gauges (Hannah and Bell, 2012) demonstrates that the recent rise in relative sea level in Wellington has been compounded by the subsidence from SSEs. The past decade also corresponds to the length of cGPS records (discussed above), which confirms this subsidence contribution to an increased rate, but prior to that it is not known what the subsidence from SSEs was for Wellington – nor how it may trend in the near future.

   Therefore, the assumption by Angus Gordon of simply subtracting the past-decade local Wellington subsidence rate from the long-term rise in relative sea level of 2.03 mm/yr to arrive at an absolute[4] SLR of 0.33 mm/yr produces an anomalous result. This type of calculation to determine absolute SLR in the NZ region is more appropriately analysed from more stable areas of NZ e.g Dunedin, Auckland and previously Lyttelton (prior to the earthquakes). This analysis has been undertaken on

[3] Bell, R.G., Hannah, J. (2012) Sea-level variability and trends: Wellington Region. Prepared for Greater Wellington Regional Council by NIWA and Vision NZ Ltd., *NIWA Client Report* No. HAM2012–043: 74.
[4] Gordon erroneously called this 0.33 mm/yr a RSL (or relative sea-level rise) – relative SLR (RSLR) is the rate measured directly by the gauge e.g., in Wellington RSLR is 2.03 mm/yr for period 1891–2011.

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gauge records from these other 3 main ports and inferred for another six port gauges by Hannah and Bell (2012).[5] Their finding was the adding a NZ-wide average GIA contribution of 0.3 mm/yr to the average relative sea-level rise across these other port gauges of 1.7 ±0.1 mm/yr means the estimate for absolute SLR of around 2 mm/yr is entirely consistent within the band for the global-average rate of 1.7 ±0.5 mm/yr for the last 100 years. Also projected NZ regional sea levels are likely to be slightly higher than the global mean (Ackerley et al. 2013), which also is consistent with the historic estimate of absolute SLR of 2 mm/yr being in the upper half of the uncertainty range of the global average (1.7 ±0.5 mm/yr).

7. Paragraph 7 (p. 28): Because of the erroneous assumptions in preceding paragraphs, the comments in this paragraph are incorrect. Never have we said that "current trends will continue for the next 50 to 100 years". The historic absolute trend in NZ is also not at 20% of what the global trend has been. In fact, as my previous paragraph has shown, the absolute rate for historic SLR has been slightly higher than the average global SLR – which means global MSL projections can be used here in NZ, with appropriate allowance for the regional difference in projections relative to the global mean (at this stage up to 0.05 m higher) and locally accounting for land movement (where a net subsidence trend over time increases the relative sea-level rise that has to be adapted to). The SLR values used in the Ministry for the Environment guidance manual for local government *Coastal Hazards and Climate Change* (MfE, 2008)[6] adopts this approach, although doesn't specify local vertical land movements to use (being different in time and between localities).

8. Paragraph 8: Again an incorrect assumption is made that the "subsidence rate for the New Zealand coast is similar to the historic global sea level rise trend of 1.7 mm/yr". Most of the sea-level records for New Zealand analysed by Hannah and Bell (2012) were in more stable areas – it is mainly the Wellington and Hawkes Bay regions that have demonstrated significant land movement trends based on the short 10-year cGPS records. So there is no disconnect with absolute global sea-level trends. Also incorrect to say that using global SLR projections will significantly overestimate the "expected RSL in New Zealand". RSL or relative sea level is that measured by tide gauges – and locally, the Wellington gauge is currently showing an increasing trend in RSL (currently up to 2.03 mm/yr since 1891) because of the measured subsidence over the past decade from SSEs. If the inter-seismic subsidence continues, then the Wellington region may need to adopt higher RSL projections than the most other parts of New Zealand.

9. Paragraph 9: The issue of whether acceleration has occurred in the last few decades is keenly debated and is comprehensively discussed in Bell and Hannah (2012). The trend over the satellite era from 1992 to present continues to climb at a rate over 3 mm/yr which is around 50% higher than the longer-term historic rate of 1.7 mm/yr. If this continues for another decade, then it is very likely that a statistically-significant acceleration can be shown. The latest IPCC 5th Assessment Report projections for SLR shows slow acceleration occurring in the next two decades but still reaches global MSL increases between 0.28 and 0.98 m by 2100, with the higher values for a business-as-usual emissions scenario.

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[5] Hannah, J., Bell, R.G. (2012) Regional sea level trends in New Zealand. *Journal of Geophysical Research–Oceans 117*, C01004: doi:10.1029/2011JC007591 http://www.agu.org/pubs/crossref/2012/2011JC007591.shtml

[6] Ministry for the Environment (2008) Coastal Hazards and Climate Change. A Guidance Manual for Local Government in New Zealand. 2nd edition. Revised by Ramsay, D. & Bell, R. (NIWA), *Report ME892 published by the Ministry for the Environment*, viii + 127 p.

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Trust this sheds more light on the reasons for using IPCC global-mean projections for SLR and apply offsets to include the effects of regional departures in SLR from the global mean and local vertical land movement.

Professor Emeritus John Hannah (formerly University of Otago) has reviewed my comments and agrees with them.

Yours sincerely

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