Comments on a report by FOCUS (2012): **Coromandel East Coast Beaches: Potential Impacts of Projected Climate Change on Coastal Erosion over the Next Century and Review of Associated Coastal Setback**

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Background:

This report examines a report by FOCUS (2012), titled *'Coromandel East Coast Beaches: Potential Impacts of Projected Climate Change on Coastal Erosion over the Next Century and Review of Associated Coastal Setback'.*

Two previous reports, Dahm & Munro (2002) and Dahm & Gibberd (2009), identified a 'Current Coastal Erosion Line' (CCEL, formerly the 'Primary Development Setback' or PDS) which indicates the maximum extent of erosion likely in response to existing coastal processes (published in 2002 and updated in 2009). The 2009 report also identified a 'Future Coastal Protection Line' (FCPL, formerly known as the 'Secondary Development Setback' or SDS), which identifies the extent of erosion that could occur over the next 100 years. This line identifies "the further erosion that could occur over the next 100 years due to projected (global) sea-level rise". The FOCUS (2012) report updates the FCPL line based on new estimates of sea-level rise.

Scope of work:

The FOCUS (2012) report considers the effect of sea-level rise on shoreline stability. The impact of other climate change processes, including an increase in the frequency and intensity of coastal storms and reorientation of shorelines in responses to changes in wave climate are not examined. The sole focus of the report is, therefore, sea-level rise. The only method employed is to model beach response to sea-level rise using the 'Bruun Rule'.

Our understanding of climate change is far from complete, but the likely impact of climate change on New Zealand can be stated with growing confidence. These are summarised in a report released by the Office of the Prime Minister's Science Advisory Committee in July 2013. This report concludes that (i) the northeast of the North Island will be drier (precipitation will be up to 5% lower in the east by 2040); (ii) easterly winds will be more frequent; (iii) it will be hotter – at last 40 extra hot days (>25^{o}C) by 2100; (iv) there will be more and heavier extreme rainfall events; however (v) there will t also be more droughts. It is timely to examine how these processes will impact Coromandel beaches and communities, even if the effects cannot always be quantified. It is also timely to consider issues related to sea-level rise, other than erosion, including changes in groundwater elevation and groundwater salinity. It is no longer adequate to examine future coastal change only in terms of sea-level rise.

FOCUS (2012) employ the Bruun Rule (1962, 1988) to estimate shoreline retreat following a sea-level rise of 0.9m. The authors note that this level is not a worst-case scenario – with recent (upper) estimates of between 1.0 and 2.2m by 2100. Accordingly, consistent with the advice offered in the PMSAC report of this year, it would be prudent to examine the implications of a range of sea-level rise scenarios in conjunction with other processes. For example, the interaction between the impact of drought on foredune vegetation, sea-level rise and increased easterly winds.

The Bruun Rule:

The Bruun Rule has been discredited over the last decade by the world's leading geomorphologists. Cooper and Pilkey (2004, p.166) concluded that *"because the Bruun Rule ignores various important geological and oceanographic principles, it does not and cannot predict shoreline retreat due to sea-level rise accurately"*. Davidson-Arnott (2005, p.1171) concludes "*from an examination of the hypotheses underlying the Bruun Model … it is questionable whether the basic premise that sediment is eroded from the land and deposited on the nearshore profile as a response to sea-level rise is realistic …*". Stive *et al.* (2009) and Ranasinghe and Stive (2009) concluded that the Bruun Rule was unsuitable for local scale assessments in which reliable estimates are required. Ranasinghe *et al.* (2012) conclude that probabilistic rather than deterministic (single value) estimates of coastal recession are now required. In other words, the Bruun rule is simplistic and it is not an appropriate method as we develop new risk-management approaches to coastal management. Ironically, the Bruun Rule has persisted because there is no simple, viable, quantitative alternative; and because management agencies are required to identify areas likely to subject to coastal hazards over a 100-year planning period. In New Zealand local authorities must give effect to policies in the New Zealand Coastal Policy Statement (2010) and the Waikato Regional Policy Statement.

The Bruun Model predicts a landward and upward displacement of the cross-shore sea-bed profile in response to sea-level rise (Figure 1). It is expressed as:

$$R = LS/(B+h)$$

Where, h = the maximum depth of exchange of sand offshore; L = horizontal distance from the shoreline to depth h, B = berm or dune elevation estate for the eroded area, S = sea level rise, and R = horizontal extent of coastal recession.

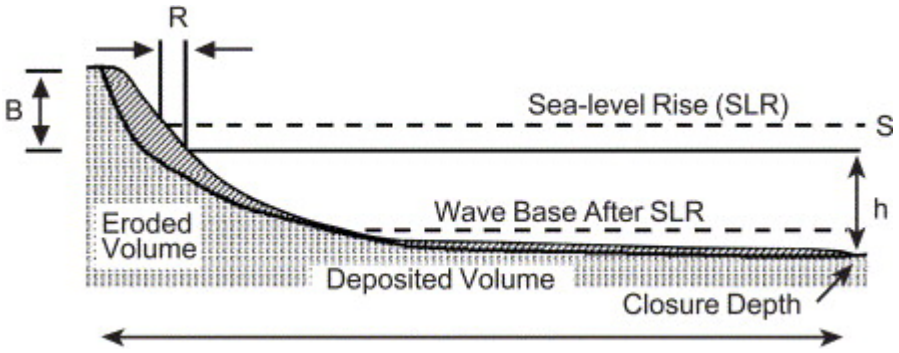

Figure 1. Schematic representation of the Bruun Rule for coastal erosion.

The Bruun Model assumes:

- Shore-normal sand movement, sand only moves onshore and offshore – no consideration is given to inputs or outputs alongshore (as commonly occurs even in swell-aligned beaches as a result of waves arriving from either a southeasterly or northeasterly quarter).

- The profile is an equilibrium profile entirely developed in sand – the profile reflects the wave climate and the sediment size.

- The sediment landward of the beach comprises easily erodible sand with characteristics similar to those of the nearshore.

- The wave climate frequently produces waves of sufficient size to erode, transport, and redistribute sediment over the profile.

- Waves erode the upper beach as a result of sea level rise, the sand eroded is deposited offshore; with the volume of sand eroded equalling the volume deposited; and the thickness of sand deposited on the sea floor equals the increase in sea level (Davidson-Arnott, 2005).

These assumptions are seldom if ever met because they do not reflect geomorphic reality. Consider the second of these five assumptions; many of the Coromandel beaches are NOT in dynamic equilibrium, that is, there cross-sectional form does not reflect the interaction of (just) currents and sand transport onshore and offshore by waves. Many Coromandel Beaches are modified by sea-walls or rip-rap, or the back-beach and foredune environment is intensively managed and modified as a result of dune construction and management (e.g. Whangapoua, Buffalo Beach Reserve). The Council has constructed or plans to construct seawalls and rip-rap at Brophy's Beach and Buffalo Beach. It is likely the Council will come under increasing pressure to consent structures at other sites. It is illogical to apply the Bruun Rule at sites such as Cooks Beach which are destined to be armoured by a rock rip-rap wall. In such circumstances the beach profile cannot evolve in equilibrium with variations in

wave energy because the beach is fixed at one end – at the landward end, adjoining the structure. The beach profile cannot migrate as sea level rises, and so it is inappropriate to apply the Bruun Rule.

Alternative approaches:

The FOCUS analysis privileges future sea-level rise in relying on the Bruun Rule. In fact the morphology of the modern coast is the result of multiple and interacting physical processes and the same will be true in a warmer world. The Bruun Rule yield lines on maps that are misleading. The assumptions underlying the model are seldom (if ever) met. Beach and dune systems (on which development is generally located) may well erode significantly more (or much less) than indicated by the FCPL proposed by FOCUS (2012). FOCUS applied a simple formula to all east coast beaches, as though the coast shared a uniform geomorphology. Some modifications to the FCPL were suggested where substrata might afford the hinterland some protection. Perversely, this circumstance violates one of the fundamental tenants of the Bruun Rule.

The response of individual beaches (i.e. coastal barriers) to climate change, including increased cyclogenesis and sea-level rise, will depend on the changes in environment associated with climate change and on local circumstances. These local circumstances include:

- the aspect and exposure of the beach to storm waves and storm surge
- the frequency and intensity of storm events
- the bathymetry/topography of the coast
- the hydrology of streams and estuaries
- the presence of natural and artificial obstacles to erosion/inundation
- the sand budget of the beach-dune system
- the capacity of pioneering foredune vegetation to form dunes, and to recover from episodes of erosion
- the potential for dunes to migrate (i.e. to advance within some accommodation space)

Ramsay *et al.* (2012) provide a guide to the principles that should be considered when local authorities respond to the imperative to define coastal hazard zones or development setbacks. Their Figure 21 summarises the basic components of a coastal erosion hazard assessment. Such assessments are, unfortunately, complex and inevitably probabilistic (rather than deterministic). They involve examining scenarios of future climate change, including sea-level change. How will variations in environment affect coastal processes and what will be the morphological response? Then, what is the probability a certain width of coast or topography will be eroded or inundated, or subject to groundwater issues?

There is little point applying the Bruun Rule, or indeed any similar model, to a coastline as though that coastline was undeveloped. Undeveloped sections of coastline may migrate across the hinterland, unimpeded by structures, and the natural character of the coast maintained. Elsewhere, the impact of climate change on the coast will depend on many

factors, including the ability and willingness of communities to plan for, and pay for, mitigation and avoidance strategies. The Current Coastal Erosion Lines derived by Dahm & Munro (2002) and Dahm & Gibberd (2009) are extremely valuable – they indicate the extent of potential inundation and/or erosion under current environmental conditions, based on substantial empirical evidence (e.g. the Coromandel beach profile records). However, given the current political and policy environment, is it likely that significant stretches of TCDC coastline will be allowed to erode to the point of significant property loss; either incrementally, or, during one or two closely spaced events? Moreover, such erosion and property loss could occur widely during the same 'worst-case' storm, whether now or in 2050, when sea-level may be 0.40m or more higher than present.

Moreover, much of the coastal development on east-coast Coromandel barriers covers relatively flat (or flattened) former dunes or dune ridges. Where foredunes are absent, or present as low incipient foredunes, a substantial width of the barrier may be inundated and/or eroded before the beach profile has a chance to adjust vertically or migrate landward. A change of state may occur well before sea level (for example) reaches levels suggested for 2100.

The impact of climate change will in some large measure depend on the incidence of storm events, and the coincidence of circumstances. A severe storm (strong onshore winds, low atmospheric pressures, large waves) may strike the coast during the neap tidal cycle, causing minimal erosion. The storm may strike during low tide and backshore or dune erosion may also be minor. In both cases the effect of elevated sea-level and/or more intense storms is negated. Conversely, as occurred in 1978, successive storms, major cyclones, spaced only weeks apart, could correspond with high tides at a higher base elevation due to sea-level rise. It would be relatively straightforward to model the impact of these storms were they to occur in 2050 or 2100.

The Council might resolve to derive FCP Lines (or multiple lines, each for a different scenario) along coasts that are not defended by an artificial or natural structure, or where coastal development is on elevated ground or well set back from the coast. It might also plot such lines where there is no intention of protecting infrastructure (e.g. roading) or private property. There seems little point, however, in delineating a FCPL where the decision to protect property has already been made or is inevitable. Perhaps the Council should classify the coast accordingly and dedicate a portion of rates to future mitigation measures following a decision to protect a particular settlement. This would avoid ad hoc decision making as successive settlements were adversely and persistently affected by erosion. The Council might promote a strategy of approving protection structures where the adverse effects of such structures can be adequately mitigated.

Applying the Bruun Rule to derive FCP Lines, an overly simple model derived long before our current understanding of how beaches and dunes work, is ill-advised. Yes, it is an appealing method because it is simple and cheap to apply. But it cannot reasonably predict the width of coastal lands subject to erosion associated with sea-level rise. Further, the focus on sea-level alone cannot be justified and there is now scope to examine a wider range of processes associated with climate change. Unfortunately, while the NZCPS and related policy establish the imperative to delineate hazard lines, the available guidance,

summarised in Ramsay et al. (2012) is, simply, guidance. No particular method is prescribed. The Council has the opportunity to employ a wide range of methods and models to indicate, with varying degrees of certainty, the likely development of its coastline over the next 100 years. Sophisticated geomorphic modelling will be required to gain reasonable estimates of future coastal change. Good science and good planning will be needed to implement good hazard avoidance strategy.

References:

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Ramsay, D., Gibberd, B., Dahm, J., and R. Bell (2012) **Defining Coastal Hazard Zones for Setback Lines: A Guide to Good Practice**. National Institute of Water & Atmospheric Research Ltd, Hamilton, New Zealand.

Appendix A: (Andrew Wharton, T.C.D.C.)

Future Coastal Erosion Directives and Options

This is a summary of the policy that directed the future coastal erosion lines on the draft planning maps. The District Plan must give effect to (see sn 75(3) RMA) the New Zealand Coastal Policy Statement (NZCPS) and the Waikato Regional Policy Statement (RPS).

NZCPS

Policy 24 Identification of coastal hazards

(1) **Identify** areas in the coastal environment that are potentially affected by coastal hazards ... 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**;
(e) **cumulative effects of sea level rise**, storm surge and wave height under storm conditions;
(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 27 Strategies for protecting significant existing development from coastal hazard risk

(2) In evaluating options under (1):

(b) take into account the nature of the coastal hazard risk and how it might change over **at least a 100-year timeframe**, including the **expected effects of climate change**;

RPS (Decisions Version)

Method 4.1.9

Regional and district plans **shall**:

b) recognise the long timeframes at which natural physical processes operate (e.g. coastal erosion and accretion cycles) and **adopt at least a 100-year planning timeframe** to allow for changes in these processes;
c) **adopt a precautionary approach** towards any proposed activity whose effects are as yet uncertain, unknown or little understood, including the use and management of **coastal resources particularly vulnerable to climate change**;

Method 4.1.14

Local authorities should, and regional and **district plans shall**, recognise and provide for the **projected effects of climate change**, having particular regard to:

aa) historic long-term local climate data;

b) **projected increase in sea level**, taking into account the most recent national guidance and **assuming a minimum increase in sea level of 0.8 m by 2090** (relative to 1990 levels).

Method 13.2.1A

District plans shall identify the location of areas:

a) **potentially affected by coastal hazards**, prioritising the identification of those areas at high risk;