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Cooks Estuary (Longreach Subdivision) Erosion Hazard Assessment

Terms of references: To carry out an erosion hazard assessment for the Longreach subdivision frontage of the Cooks Beach estuary. To determine a building setback incorporating long-term change and allowance for 1 m of sea-level rise out to 2015 (100 yrs). This is a desktop assessment and no site inspection of field work was allowed for. Deliverables by 26 November 2014 are for a two to three page summary of the methodology and an electronic file of the resulting hazard line.
Information provided by T&T consisted of a scanned 1944 aerial photo), prints of a 1978 and 1996 aerial photo, 2012-13 electronic georeferenced orthophotos at 0.5 m pixel resolution, and 2012-13 LIDAR. In addition, CSL searched for relevant survey plans (pre-1940s) from the LINZ data-base; however, those identified (SO 5, ML15834 and SO 36291) failed to provide quantifiable data.

Erosion hazard assessment in areas subject to coastal processes (waves, tide and associated currents), typically determine values for several components: longer-term (systematic) shoreline change, shorter-term shoreline change, retreat associated with predicted sea-level rise, subsequent adjustment to a stable slope following an erosive event and inclusion of a safety margin to account for measurement error and uncertainties.

The 550 m long subdivision fronting the estuary was divided into 11 x 50 m long segments or sectors and numbered from the upstream end (Figure 1).

A geomorphological assessment should be incorporated into any coastal erosion hazard assessment, especially about inlets due to their complexity with such assessments defining and explaining the evolutionary history, present landforms, sediment types and vegetation. From the materials available it is evident that a sand barrier comprising a sequence of beach ridges (relict foredune) formed across the entrance to the Purangi River embayment perhaps 6000 yrs ago with lakes/swamps lying to the rear and these infilled over time. The subdivision straddles these units and this suggests sand will occur in the eastern part (sectors 4-11) and finer materials (including organics) in the western part (sectors 1 to 3). However, without more detailed information, the erosion hazard analysis assumed that the shoreline and embankment was composed of sand, this being the most erodible material.

The estuary bars, mud flats and channels appear particularly stable throughout the historical aerial record, and also on the earlier survey plans. Fronting the subdivision the main channel lies some 50 m off the western shoreline (sector 1), 130 m from the central sector shoreline (sectors 3 to 6) then reduces to 60 m fronting sectors 10 and 11 (see Figure 1). The closer proximity of the main channel in the eastern sectors correspond with a secondary channel closer to the shoreline that increases in size adjacent to Sectors 6-7, and this morphological change appears to have consequence for shoreline stability described below. The recent occurrence of mangroves, evident in the western sectors in the 1996 and 2012-13 aerial photos, may modify sedimentation and shoreline erosion processes in the future; however, the nature and extent of such process change is unclear so such effects cannot be incorporated into this hazard assessment.

Figure 1 *One hundred year erosion hazard line (red) on 2012-13 aerial photo. Sampling sectors 1 to 11 marked. MSL depicted by dashed line. The tick blue arrow marks the Purangi River while the think blue arrow marks a secondary channel closer to the subdivision shoreline.*

The 1944, 1978 and 1996 aerial photos were scanned and geo-referenced off the 2012-13 orthophoto files. However, the resulting images were not well constrained in terms of georeferencing and shoreline detection. Ideally the negatives should have been scanned (for detail), orthophotos generated (to remove distortions) and 3D (stereo) imagery coupled with field inspection used to define control points and shoreline indicator. In addition, a temporally more extensive set of aerial photos should be processed and analysed, but the New Zealand Aerial Mapping archive is not presently operating. The 1944 aerial photo had a well-defined scarp top so this was used as the shoreline indicator as it was also defined reasonable well in the 2012-13 aerial by draping this image over the LIDAR DTM. It was not possible to define this shoreline indicator on the 1978 and 1996 imagery and a site inspection and stereo analysis would be required to define image signatures for other indicators. However, all images were able to provide useful information on the estuary topography/morphology.

Derived erosion prediction distances are measured landward of the **reference shoreline,** this being the 2012-13 aerial-based shoreline which consistently lay landward of the 1944 shoreline. Smaller scale spatial variation was evident and comparison with the LIDAR indicates that this is associated with topographic variation (sand dune morphology) on top of the embankment, while larger scale spatial variation appears associated with estuary morphology as noted above.

Longer-term shoreline change (1944 to 2012-3) data are contained in Table 1. The maximum change per segment was used rather than average change to allow for minimum image samples (2) and the image processing limitations mentioned earlier. Annual rates of change were computed and 100 yr distances derived less adjustment for 68 yrs of historical sea-level rise (0.12 m). Results show shoreline erosion occurred throughout the study area with less change in the central sectors (3 to 6) which corresponds with more uniform estuary topography (minimal secondary channel development).

Shorter-term change component was not required due to the embankment top being used as the reference shoreline (short-term changes do not greatly affect this shoreline indicator compared with indicators at the base of the slope), and the reference shoreline happened to be the most landward shoreline.

Shoreline retreat associated with sea-level rise was based on a variation of the Bruun Rule. The Bruun Rule was developed for open coastal environments characterised by sand availability, waves and sediment transport continuity with no structures, reefs or other means to constrain potential sediment movement. Briefly, the model translates the critical profile section landward and upward by the predicted change in water level and computationally this equals the reciprocal of the average slope.

This model can be applied to non-open coastal environments such as estuaries, but the assumption constraints must be considered. In particular, in this estuary waves only impact the shoreline during higher tides so the slope values used in the model only relate to the uppermost profile. In addition, dense vegetation cover often occurs around estuary shorelines and on embankments and this reduces potential erosion as predicted by the model.

For the Cooks Beach estuary, the model was applied to the profile between 0.5 to 1 m above mean sea level with slope values derived via the LIDAR. These values are recorded in Table 1. The average slope per segment was used with spatial variation being accounted for by the Factor of Safety. Both historical retreat for SLR = 0.12 m, and future predicted retreat for SLR = 1 m were determined with the former being subtracted from the 68 yrs of historical shoreline change to remove any such contamination from that component. The resulting slopes were found to decrease from west to east (i.e. from inland to seaward).

The scarp adjustment component was not required because the reference shoreline (2012) is based on the embankment top and this appears to be stable, i.e. it has adjusted to previous erosion.

A factor of safety approach was used to account for uncertainty, this covers measurement error, inter-sector variation, processes uncertainties and other unknowns regarding future environmental change. For the present exercise, a value of 1.5 was used. While 1.3 is more commonly applied in coastal erosion assessments, the increased uncertainty in this case due to lack of shoreline samples, image processing constraints and shoreline derivation accuracy, and the lack of a site investigation.

Table 1 Data for deriving erosion hazard components and final erosion hazard distances for the 11 sectors

Sector	Erosion Rate	Erosion 100 yrs less hist SLR	TanB	Retreat SLR (0.12m)	Retreat SLR (1 m)	B + F	FOS = 1.5	Representative dists
1	0.044	3.5	0.132	0.9	7.6	11.1	16.65	20
2	0.084	7.3	0.114	1.1	8.8	16.1	24.15	25
3	0.055	4.2	0.093	1.3	10.8	15	22.5	25
4	0.055	4	0.081	1.5	12.3	16.3	24.45	25
5	0.029	1	0.065	1.9	15.4	16.4	24.6	25
6	0.044	2.9	0.083	1.5	12	14.9	22.35	25
7	0.059	3.5	0.05	2.4	20	23.48	35.22	35
8	0.059	3.8	0.057	2.1	17.6	21.4	32.1	35
9	0.066	4.7	0.63	1.9	16	20.7	31.05	35
10	0.081	6.1	0.06	2	16.7	22.8	34.2	35
11	0.081	5.7	0.05	2.4	20	25.7	38.55	39

The final **erosion prediction distance** thus consists of the longer-term shoreline change (less historical SLR retreat), plus retreat from predicted SLR, with their sum being multiplied by 1.5 (final column in Table 1). The results define two distinct reaches with the partition occurring between sectors 6 and 7 and this appears related to estuary morphology as described earlier. Overall the estuary morphology appears to be relatively stable indicating erosion extrapolation/prediction over a 100 yr time period can occur with some confidence. The maximum value for each reach was used to represent all sectors to further account for the range of uncertainty; in particular sectors 2 to 6 = 25 m, while sectors 7 to 10 = 35 m with the upstream value being 17 and the downstream extreme value being 39 m.
The resulting **erosion hazard line** is depicted in Figure 1.

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