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12 May 2016

James Whitaker
Wellington Boardriders Club

Dear James,

Re: DHI – Wellington Airport Runway Extension; Preliminary Shoreline Impact Assessment for Submerged Wave Focussing Structure – A Technical Review.

The following brief review considers the preliminary shoreline impact report by DHI. In summary, this report is fundamentally flawed; the model applied is inappropriate, and as a consequence the results do not conform to the large body of existing literature on shoreline impacts to offshore submerged structures. We have considered:

- Predefined coastal profile assumption?
- Offshore bars not included? Nearshore bathymetry? Closure depth?
- Sediment grain size?
- Wind generated currents?
- Circulation patterns? Model calibration? Model Validity!?

Constant coastal profile -

The first and most obvious pitfall of the MIKE 21 FM Sand Transport Module, and indeed most one-line models, is that they assume a constant predefined coastal profile, i.e. cross-shore transport is ignored. In some scenarios this is a valid assumption and a good representation of shoreline change can be derived, such as a case on an open stretch of coastline dominated by strong longshore transport. In other cases however, complex shorelines resulting from offshore breakwaters, groins, Submerged Wave Focussing Structure's (SWFS's) etc., wind and wave driven cross-shore sediment mobility can greatly contribute to, or even dominate the processes governing the shoreline position (Dabees and Kamphius, 1998). In an environment like Lyall Bay which has a history of problems with sand blasting during southerly wind events (27 km/h average wind speed, Wellington Airport wind-station) and is shown to have a naturally dynamic shoreline in response to the seasonal wave climate (approx. 20 m/yr – Figure 4.2 below), a better approach would be to incorporate these cross-shore effects into the model. The author has stated that "predicted shoreline changes would occur on top of the natural variability", in other words, modelled shoreline changes resulting from the SWFS would be a simple linear addition upon natural shoreline changes to achieve the final shoreline position. In reality there would be a complex interplay between the SWFS and natural processes that would be best represented by a model that accounts for cross-shore effects. Bailard's (1982) method for cross-shore wave driven transport, for example, could be used.

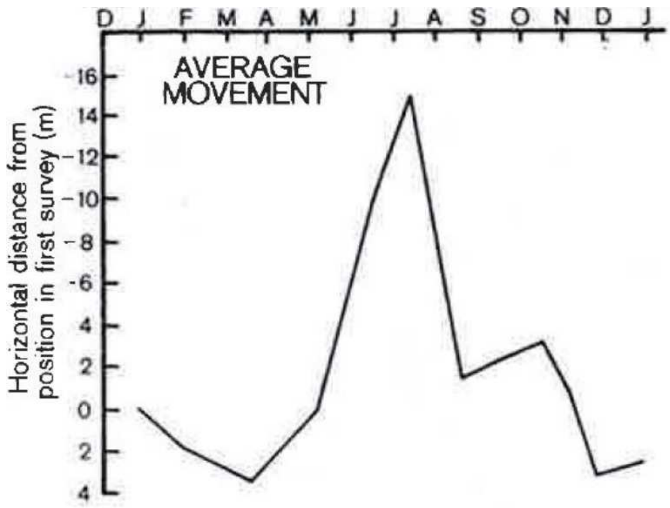

Figure 4-2: Average horizontal movement of contour lines on the beach, from Pickrill (1979). Negative movement means the depth contours are retreating landward.

Offshore bars and nearshore bathymetry -

Pickrill's (1979) beach profile dataset of Lyall Bay shows that most of the seabed elevation variability occurs out to 600 m from the shoreline. This encompasses the offshore bar/bars set up in winter during storm events which play an important role in breaking and dissipating wave energy during large swells. In addition, the size and location of the offshore bar/bars has a bearing on the magnitude and cross shore position of the longshore drift. The modelling undertaken in this report is run on a bathymetry that doesn't capture any longshore bars. This is because a reasonable gap exists between the 25 m gridded NIWA bathymetry dataset and the shoreline data in the nearshore meaning that the surf-zone bathymetry had to be interpolated. As explained in the report, a detailed surf-zone bathymetry dataset is necessary to better simulate the coastal impact of the SWFS.

Closure depth -

The depth of closure is an important concept in one-line models and defines the offshore depth to which sediment can travel alongshore. Pelnard-Considere (1956) derived the one-line equation:

$$\frac{dy}{dt} = -\frac{1}{D_{cld}}\frac{dq}{dx}$$

Where *y* is the shoreline position, *t* is time, *q* is the longshore sediment transport, x is the longshore coordinate and D_{cld} is the closure depth. It can be seen that the amount of shoreline change with respect to time is inversely dependent on the closure depth and nowhere is this discussed in the report. Figure 5.6 below presents three coastal profiles taken from the interpolated bathymetry dataset at the East, Centre and West of the beach. From these, a linearly interpolated 'representative' beach profile was input into the MIKE 21 FM Sand Transport Module for shoreline position analysis. Since 5 m is the limiting depth on Figure 5.6, one can assume that this is the depth of closure used to calculate the shoreline positions in this study, however, given that Pickrill (1979) showed sediment mobility out to 600 m from the shoreline, a closure depth of at least 7 m would be pertinent.

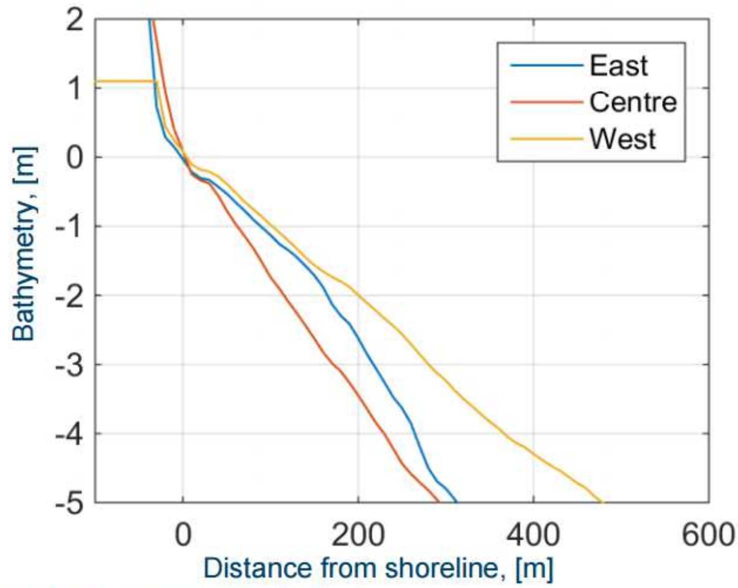

Figure 5-6: Selected coastal profiles.

Sediment grain size –

As addressed in Section 7 of the report, knowledge of the sediment grain size in the surf zone is imperative for this type of modelling work. This controls the amount of sand entrained and saltated by the littoral flow (parameter *q* in Pelnard-Considere's (1956) equation) and thus the shoreline evolution. The sediment samples summarised in Section 2 are almost exclusively taken from locations outside the surf zone (Figure 3.1 below) where grain sizes are expected to be finer than those inside it. Although the author never states the exact sediment grain size passed to the MIKE 21 FM Sand Transport Module, a median value (D_{50}) of approximately 0.15 mm is given from the sampling data which is assumed to be the value for model input. A recommendation for improved sediment sampling within the surf zone is discussed in Section 7, namely between the +2 m and -5 m depth contours at one meter intervals for three transects along the beach. However, following on from the depth of closure discussion above, we recommend that the offshore limit of this should be extended to a minimum of -7 m.

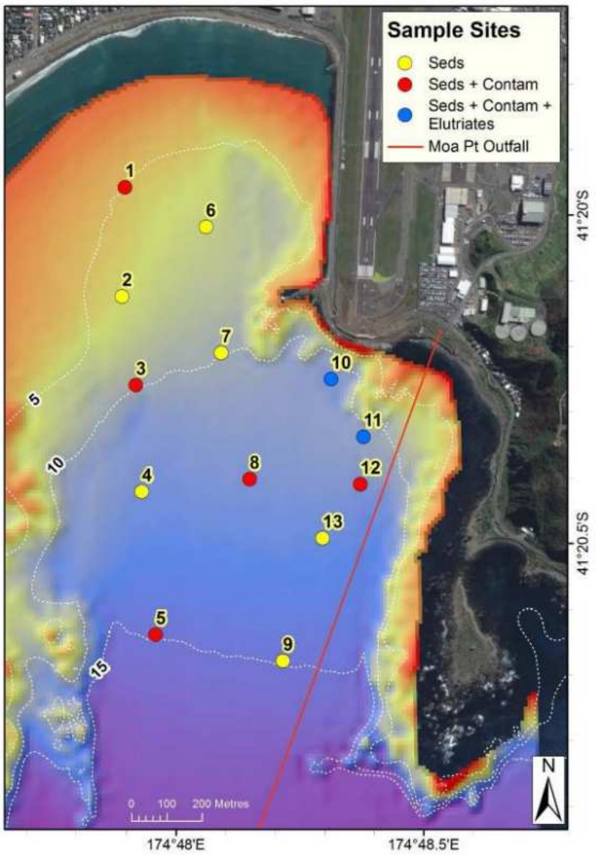

Figure 3-1: Locations for the sediment sampling, from NIWA (2015).

Wind generated currents –

Wind is omitted from the model which underpins this study. With regard to wind generated currents the author states that "the currents are not very dependent on wind speed" when referring to Figure 3.4 below. This is true for the most part but it can be seen that in the absence of a significant wave event, winds control the currents observed, i.e. September 11th and October 2nd. Although these current speeds are only in the order of 0.1 m/s, the Hjulstrom curve shows that grains of up to 2 mm in diameter are able to be transported under these conditions. Keeping in mind that the D_{50} for this analysis is set to 0.15 mm, it can be said that wind should be incorporated into this model for improved accuracy, especially since a good wind record in close proximity to Lyall Bay is available (Wellington International Airport wind station).

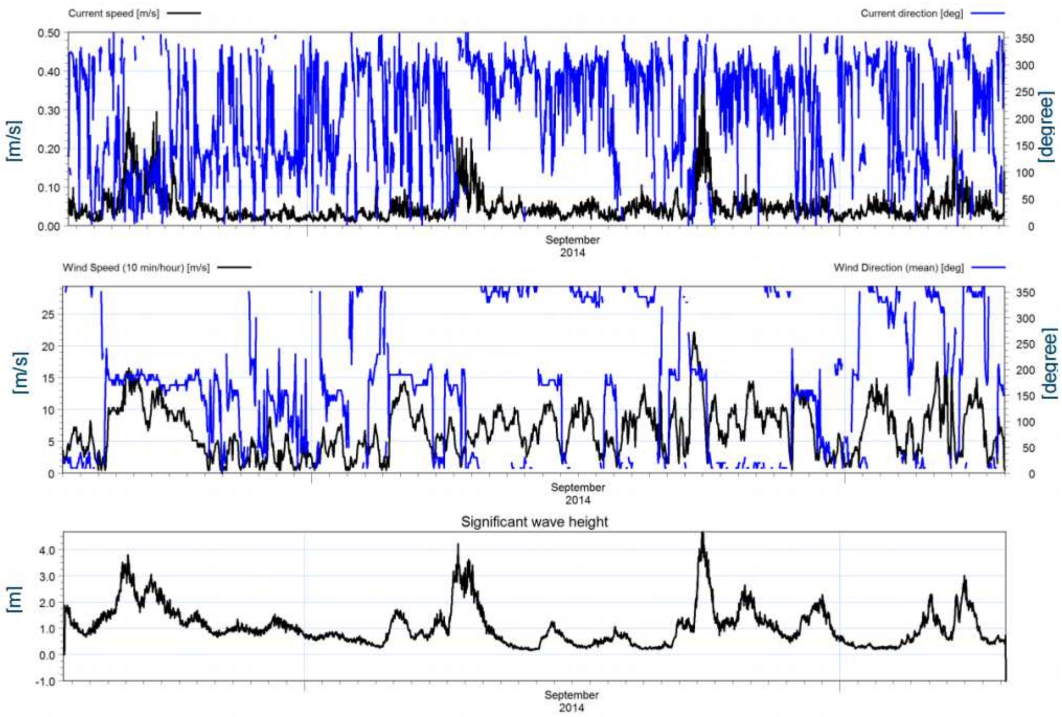

Figure 3-4: Depth averaged current speed and direction measured at the Site 1 shown in Figure 3-2.

Circulation patterns –

Hydrodynamics in this study are dealt with by the MIKE 21 FM Hydrodynamic Module which is forced by the wave field derived from the MIKE 21 FM Spectral Wave Module, both of which are computed on the same flexible mesh (Figure 5.2 below). The resolution of this in the surf zone is approximately 6 m dropping to about 20 m offshore.

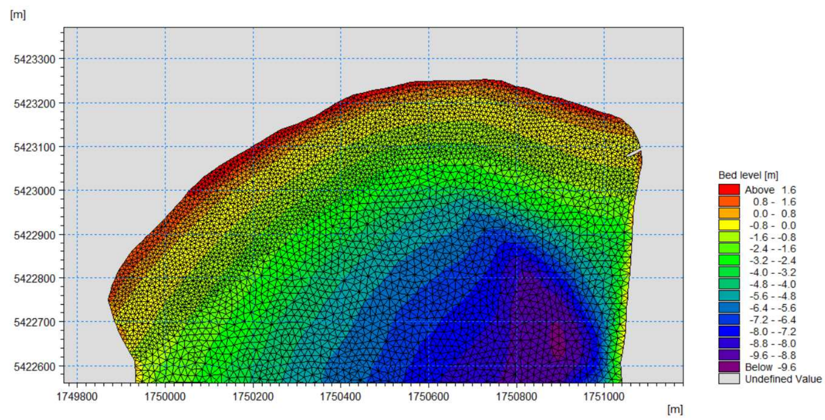

Figure 5-2: The mesh resolution in the surf-zone and the initial bathymetry defined by the shoreline model.

Model calibration –

Measured vs. modelled significant wave heights, current speeds and directions are presented in Figure 5.8 below for a location labelled “Site 2” in Figure 5.9. Note that a location 50 m to the east is presented also, labelled “Close 2”. Waves calibrated well, however currents are overrepresented in magnitude between wave events and misrepresented in direction throughout. The author has stated that these discrepancies are due to the formation of large and small eddies (that may or may not be resolved in the model) in the vicinity of Site 2. Should the position and size of any simulated eddies be different to those in reality, a poor calibration will result. While this may explain some of the observed differences between measured and modelled current directions, it doesn't explain the large predicted current speeds relative to those measured during periods of low wave activity. These circulation patterns are important for the beach and shoreline response during all wave conditions, especially when complex flows in the lee of a SWFS are introduced (e.g. Ranasinghe *et al*., 2006).

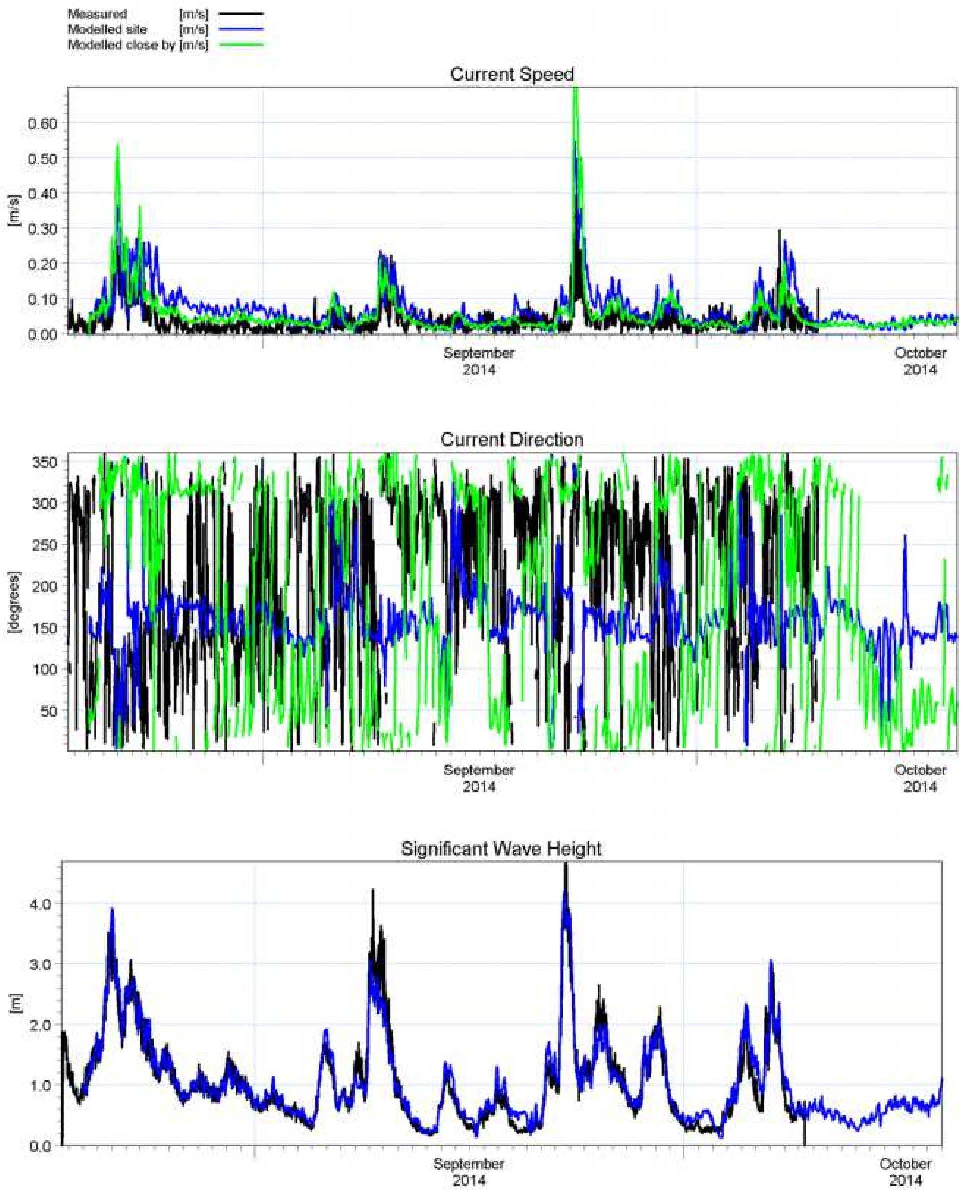

Figure 5-8: Comparison between measured and modelled current speed (top), current direction (middle) and significant wave height (bottom) at Site 2. The locations are shown in Figure 5-9.

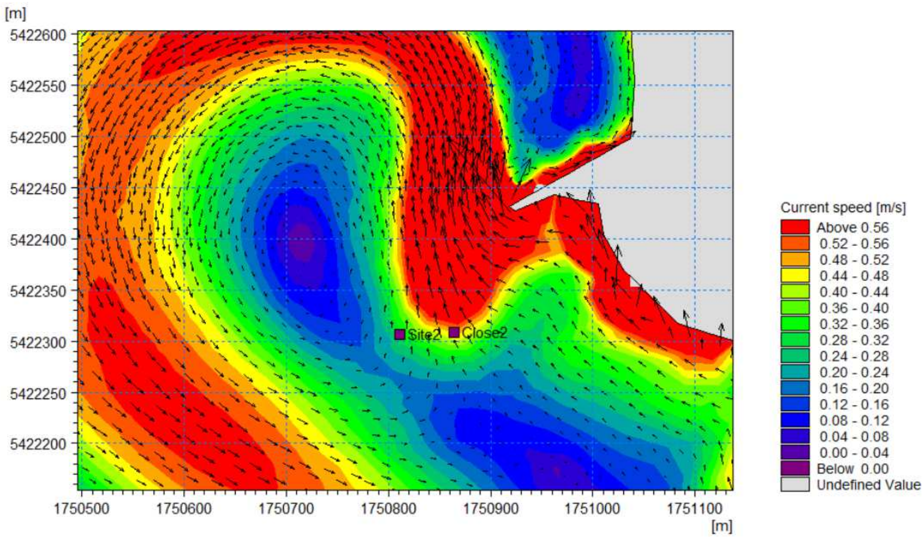

Figure 5-9: Current speed and vectors around the measurement location. Top: During a wave event.

Model Validity –

The author provides reference to two publications for further details on the MIKE 21 FM Shoreline Model; Kaergaard and Fredsoe (2013) and Kristensen *et al.* (2012). The first paper does a good job of describing the model in more detail, as expected, but fails to validate the model against any real spatial shoreline migration observational data. Two scenarios are instead presented which both involve a coastline subjected to non-varying very oblique incident waves. The first is a theoretical benchmark test and is essentially a numerical comparison between the MIKE 21 FM Shoreline Model and that of Peterson *et al.* (2008). The test involved an initial shoreline that bends 90° (Figure 8 below) in order to allow the growth of a spit.

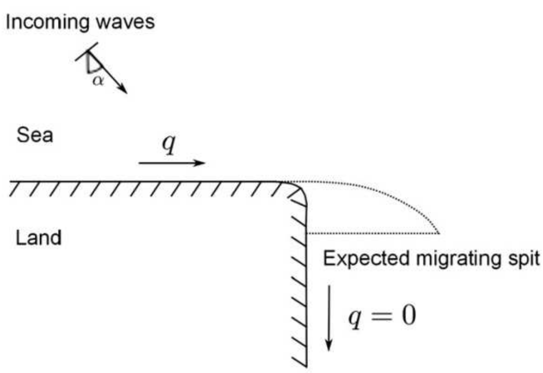

Fig. 8. The initial shoreline and the hypothetical migrating spit.

The second scenario was aimed at reproducing the littoral drift rate, spit width and spit growth rate of the Skaw Spit in northern Denmark. The Danish Coastal Authority provided wave climate data for model input, namely, Hs = 1.3 m, Tp = 5 s and an estimated littoral drift rate of 1.5 M m^3/year. Initial model testing with these wave parameters returned a littoral drift rate "much smaller" than what was realistic and so Hs and Tp were increased to 2.5 m and 6 s respectively to achieve a value of "around" 1.5 M m^3/year. This is noted as a compensation for the cross-shore gradient smoothing effect (and the associated underestimated longshore sediment transport rate) that a time and space averaged constant coastal profile yields. The resulting modelled spit width was between 3.5 and 4 km and the spit growth rate was around 6 m/year. The observed spit width (in Google Earth) at the locality of Skagen is in the order of 3.2 km, not 3.5 km as stated in the paper, and the dated progradation of the spit is around 5 m/year. Kaergaard and Fredsoe (2013) state that "the biggest limitation in this approach is that the actual evolution of the shoreline is not described by the model, therefore the model is not very flexible as it cannot be used for other purposes".

The second paper (Kristensen *et al.* (2012)) aims to validate the MIKE 21 FM Shoreline Model simulations against observed shoreline responses to detached breakwaters, both offshore (outside surf zone) and coastal (inside surf zone). The study is split into two parts: Firstly, the model is applied to a case in Cape Town South Africa where a grounded ship in 2009 has created a salient in its lee, effectively acting as an offshore breakwater. Secondly, a new version of the model is presented which allows for cross-shore sediment redistribution via a diffusion algorithm designed to represent non-resolved cross-shore processes. This model version is applied to a straight shoreline coastal breakwater scenario in order to establish an evolving shoreline morphology in agreement with existing rules i.e. does the model simulate sensible shoreline responses to varying breakwater configurations (ratio of breakwater length to its distance from shore), varying wave incidence angles and varying distances to the shoreline relative to the surf zone width? While this work may present interesting results regarding breakwaters, nowhere does it consider SWFS's. In addition, the second part of the study almost completely disregards constraint to any real field data. Only the modelled salient advance is compared to a 1982 laboratory study and a 1976 field study, showing just a reasonable agreement to both.

Another paper (Kaergaard and Fredsoe (2013) Part 2) aims to compare MIKE 21 FM Shoreline Model output to two naturally occurring shorelines, and again, similar to Kaergaard and Fredsoe (2013), only deals with oblique to very oblique incident waves, however, a varying wave climate is introduced in both cases.

Based on the supporting literature provided by DHI, the MIKE 21 FM Sand Transport Module has not been validated for shoreline evolution in response to a SWFS, and certainly not for an environment comparable to Lyall Bay where oblique incident waves do not exist.

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