

Appendix 20.2 – Taranis impact piling model

RPS has developed a hybrid model for prediction of source levels from impact piling – “Taranis”. The model is part numerical and part empirical, taking the best of both worlds in that it is fast like an empirical model, but also able to predict source levels from sites where no data exists, like a numerical model. The model has been validated against a large dataset of measured data from installation of piles from 0.5 - 9 m diameter in both nearshore and offshore settings for varying sediment conditions and hammer sizes and types. By outputting both per-blow band levels & time-series impulses it is an excellent tool for prediction of impact piling source levels. Additionally, because the model has a large validation dataset it reports the statistical uncertainty for the generated output, to give the user a full understanding of the confidence they can have in any given set-up.

The model was compared and calibrated against a range of real-world recordings that were back-calculated, using a combination of simple spreading relations, Rogers model (Rogers, 1981) and dBSea¹ propagation modelling software, accounting for the specific environment of the recording location. This means that the model has greater validity when used within the range of conditions of the measurements, and within those bounds we further know the statistical uncertainty of the model. Outside those bounds the model is essentially extrapolating, but care has been taken to ensure the model is “stable” and results outside the bounds change in a predictable manner.

Below is a graphical representation of the model coverage.

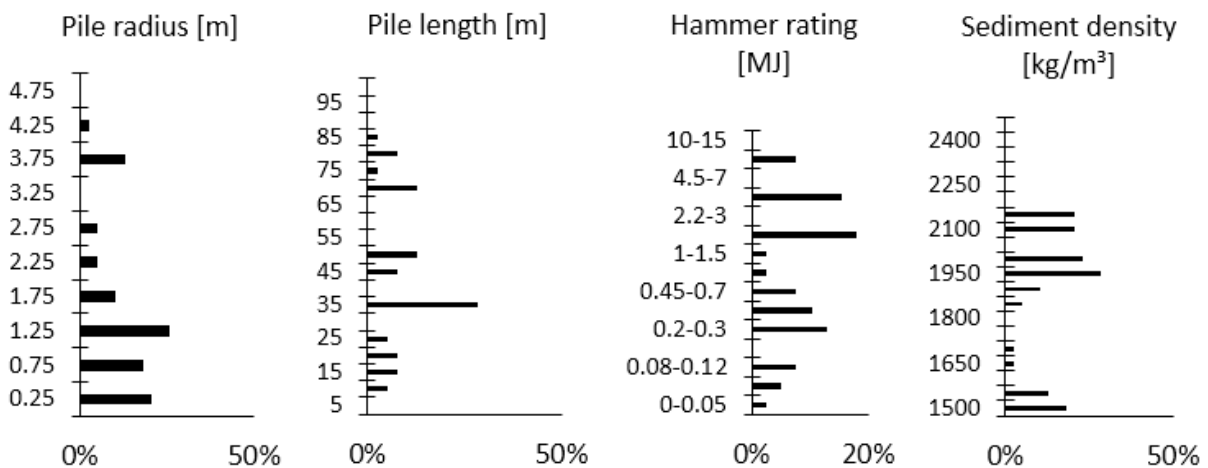


Figure 1. Overview of equipment and environmental parameters covered in the validation.

These cover a multidimensional space, and even if within all parameter limits, that particular combination of parameters might not have been tested, but given that the model has shown no “run-away” predictions we are confident that such combinations will still give representative results.

Table 1. Overview of the Taranis model’s inputs.

| Model part | Parameter [unit] (default value) |
|------------|--|
| Sediment | Density [kg/m ³] as list (2100) Soundspeed [m/s] as list (2000) |

¹ www.dBSea.co.uk

| Model part | Parameter [unit] (default value) |
|------------|--|
| | Grain size (diameter) [m] as list (0.35) |
| Water | Depth at piling site [m] Salinity [psu] (35) Temperature [degrees C] (15) |
| Hammer | Minimal blow energy [kJ] Maximal planned blow energy [kJ] Maximal rated blow energy [kJ] |
| Pile | Length [m] Radius [m] Penetration at desired installation depth [m] Density [kg/m ³] (8050) Young's modulus [Pa] (2e11) Soundspeed [m/s] (5900) Wall thickness [m] (radius/50) Raking angle [degrees] (0.0) |

Generally (>50 % of cases) the model predicts band levels within 6 dB of recorded levels with broad band levels being within 4 dB and peak levels within 7.5 dB (Figure 2, p. 3). There seems to be a bias in the band-wise errors showing a tendency for Taranis to underpredict levels at higher frequencies. This tendency is driven by a single validation case where Taranis' predictions for higher frequencies were >20 dB below the recorded. This case is included in the data, but remind the reader that something was likely different about this case making it a non-representative case. It is likely that the piling was done with the piles somewhat restricted and not free to move as assumed by the model (piles are assumed to be fixed at one end only).

The approach for model validation was to collate available data for recordings of impact piling where information on the hammer, the pile dimensions, the sediment and the water conditions where available. Recorded levels were back-calculated to an "equivalent monopoint source²". The back-calculation was mostly done using "Roger's model" (Rogers, 1981) when bathymetry was flat, dBSeaPE for longer ranges in range-dependent scenarios, and spherical spreading if the range to the source from the receiver was shorter than the depth. Roger's model and dBSea take into account the additional loss at low frequencies often not accounted for in simpler transmission loss calculations.

The main metrics used for accuracy estimation are:

- Band-wise error: The per decidecade band error for single blow SEL in dB
- Broadband error: The broadband error for single blow SEL in dB
- Peak error: The error in predicted L_P in dB

² Non-existing quantity used to compare source levels at 1 meter from a point. In reality pile act like line or moving sources that have a "mach cone" (supersonic pressure front).

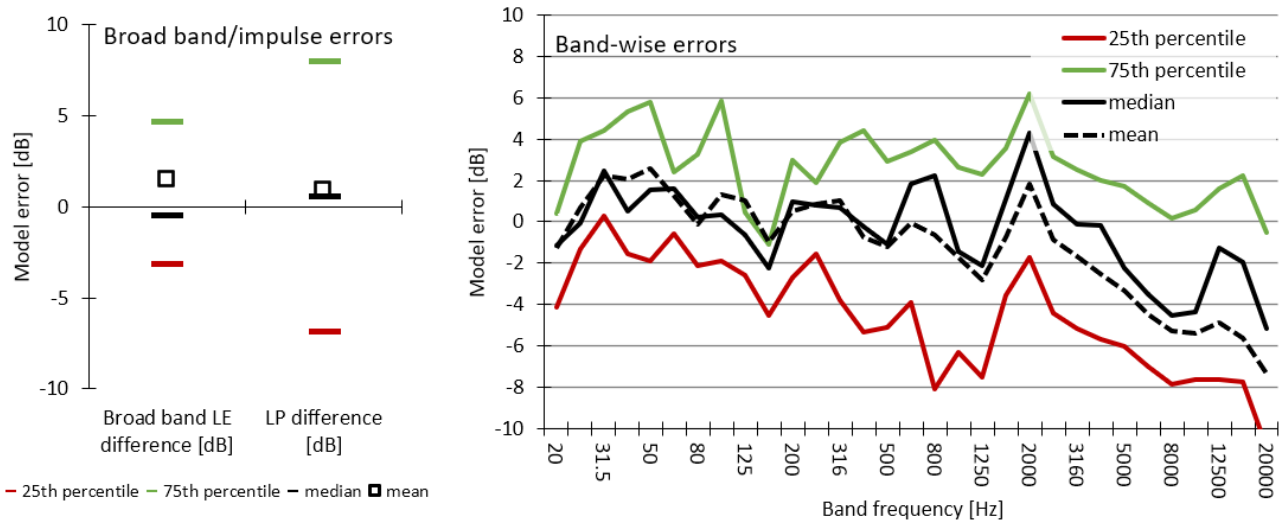


Figure 2. An overview of the broadband, peak and band-wise performance of the Taranis model.

Comparisons against other models (here a FE model) are favourable to this model for the 3 cases we have data for, where the FE model used in the case report has 50 % of its predictions within 14.6 dB, Taranis is within 3.3 dB. This serves only as an example that in at least this case the simpler approach from Taranis was not inferior to an FE model that's being used commercially by other actors.