

# dBSea General modelling tips

This document lays out general tips for modelling underwater noise propagation using for various scenario types. The focus is on enabling the reader to tune their specific model to maintain accuracy while reducing computing cost.

*Note that this document is not a guideline for best practise.*

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# 1. Definitions

Table 1. Level definitions and the corresponding ISO 18045-2017 reference.

Unit	Definition	Comments
SPL (dB <sub>RMS</sub> ) ISO 18405- 2017: 3.2.1.1	$SPL = 10 \cdot \text{Log}_{10} \left( \frac{\frac{1}{t_2 - t_1} \cdot \int_{t_1}^{t_2} p(t)^2 dt}{1 \cdot 10^{-12} Pa} \right)$	Functionally equivalent to deprecated $20 \cdot \text{Log}_{10} \left( \frac{RMS}{1 \cdot 10^{-6} Pa} \right)$
L <sub>p</sub> (dB <sub>Z-p</sub> ) ISO 18405- 2017: 3.2.2.1	$L_p = 20 \cdot \text{Log}_{10} \left( \frac{Pa_{max}}{1 \cdot 10^{-6} Pa} \right)$	This assumes that $Pa_{max}$ is equal or greater than $\sqrt{Pa_{min}^2}$
L <sub>p-p</sub> (dB <sub>p-p</sub> )	$L_{p-p} = 20 \cdot \text{Log}_{10} \left( \frac{Pa_{max} - Pa_{min}}{1 \cdot 10^{-6} Pa} \right)$	Often <sup>1</sup> equivalent to $L_p + 6.02 \text{ dB}$
L <sub>E</sub> (dB <sub>SEL</sub> ) ISO 18405- 2017: 3.2.1.5	$L_E = 10 \cdot \text{Log}_{10} \left( \frac{\int_{t_1}^{t_2} p(t)^2 dt}{1 \cdot 10^{-12} Pa} \right)$	For continuous sound this is equivalent to $SPL + 10 \cdot \text{Log}_{10}(t_2 - t_1)$ “t” is seconds

Impulse, signature, time series                      Time versus pressure data series of an event, usually an impulse.

Crossover frequency                                      Frequency where dBSea switches from its low-frequency solver to its high-frequency solver.

<sup>1</sup> If maximum pulse rarefaction is below ambient pressure and compression and rarefaction phases are of equal size.

## 2. Solver Choice and Detail

### 2.1 Impulsive Noise

If you're looking to model  $L_p$  or  $L_{p-p}$  use dBSeaRay and see sections 3.2,  $L_p$  / z-peak, p. 7 & 4.0, Impact Piling, p. 7.

If modelling LE or SPL see section 2.2 below

### 2.2 Non-Impulsive Noise

There is no one-size-fits-all for solver choice but there some general guidelines and some easy checks

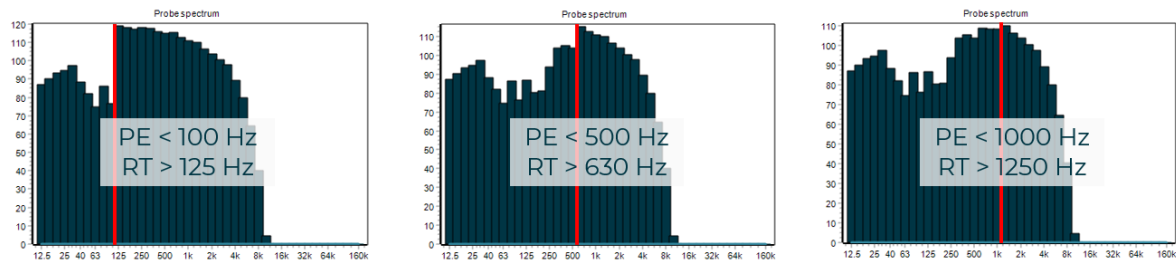
#### 2.2.1 GENERAL LIMITS

Solver name	Depth [m]	Context	Frequency [Hz]	Context
dBSeaPE	>50	dBSeaModes is better at modelling sediment interaction.  dBSea might use analytical starter at low depths – not good, change to some other solver.	<1000	<u>Slow</u> at higher frequencies.
dBSeaModes	<1000	dBSeaModes is very slow in deep or long-range scenarios	<500	<u>Even slower</u> at higher frequencies
dBSeaRay	$> \frac{C_w}{\left(\frac{\rho_b + C_b}{2000}\right) \cdot 5 - 7}$ $C_w$ : soundspeed of water. $\rho_b$ : Sediment density $C_b$ : Water density	Assumptions for model not met. Calculation produces unrealistic results, neglecting sediment penetration.	Depth-dependent, but generally >250	Sediment penetration not correctly calculated.

## 2.2.2 CHECK FOR SOLVER CHOICE AND CROSS-OVER FREQUENCY

Use the probe function to look for discontinuities in received level. We expect received band levels to be “smooth” if the source band levels are “smooth”. Correct crossover frequency will lie in region where solvers agree on the received level, indicating that they both function correctly at that frequency.

**Figure 1. Received level at various crossover frequencies for a source where all bands were 200 dB. Solvers “meet” where crossover frequency is 1000/1250 Hz (right graph), indicating both solvers function correctly there.**



## 2.2.3 SOLVER RESOLUTION/DETAIL

Generally all the solver agree on the propagation loss across a wide range of conditions, if they do not, it's a sign that you should increase the model resolution either in “Setup scenario/Source Solution” & “z depth points” or in “Preferences/Advanced”.

A notable exception is that we don't expect dBSeaRay to agree with dBSeaPE or dBSeaModes at low frequencies ( $\sim < 250$  Hz) and high frequencies ( $\sim > 2000$  Hz)

# 3. Impulsive Noise

## 3.1 $L_E$ / SEL / Exposure Level

### 3.1.1 SIMPLEST APPROACH, KEEP EVERYTHING IN UNITLESS DB

First go to “Preferences/Sound levels display” and make sure “Level type for display” is “Sound pressure level, dB SPL (Leq)”.

*Yes, do this even if you're interested in  $L_E$  results!*

The reason we ignore the “Sound exposure level” option is that it is meant for continuous noise sources where the active duration of the source is important. For the impulsive noise the important metric is the number of impulses.

When modelling  $L_E$  from impulses the easiest approach is to do some of the maths yourself, as it means you know exactly what to expect from dBSea.

When importing an impulse signature (time-pressure series) into dBSea, note down the band levels given in the bottom table in the “Time series” menu (Figure 2, below).

Figure 2. Example of an impulse from a 6 m diameter monopile, after import into dBSea.

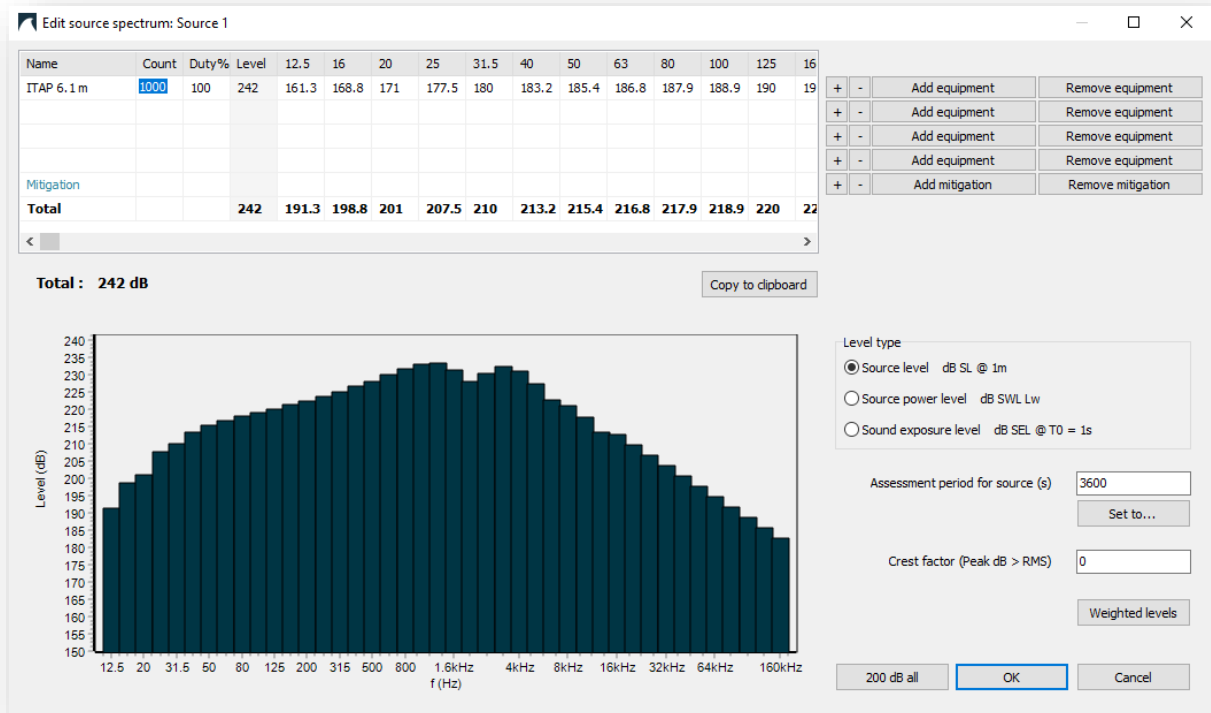


Paste these band levels into the “Spectrum<sup>2</sup>” menu (“Add equipment/New database equipment”) to get a band-wise representation in dBSea (Figure 3).

You can now adjust the total level by adjusting the “Count” (top left cell in “Spectrum” menu) to the number of impulses in your current event. You do *not* need to “re-solve” the scenario after this change.

<sup>2</sup> This menu might soon be renamed “Band levels”

Figure 3. Band levels from impulse in Figure 2. Note that “Total” has been adjusted to 1000 blows (count set to 1000, highlighted in blue).



Your results, after solving, will now be the total  $L_E$  for the number of impulses you have used.

### Bonus tip when making impact maps in GIS:

Keep total count to “1” in exports and only export result from 1 impulse. Adjust limits down to reflect more impulses as:

$$New\ limit = Old\ limit - 10 \log_{10}(n_{impulses}).$$

This will speed up the process of generating results for multiple impulse counts as, even though dBSea does not need to “re-solve” after adjusting count, updating millions of values still take time. It’s much quicker to update a single raster layer colouring in GIS.

### 3.1.2 COMPLICATED APPROACH, CONVERT TO SPL AND INCLUDE TIME

Get source band levels as described in 3.1.1 above, then convert from  $L_E$  to SPL by adjusting the  $L_{E-single\ impulse}$  by the impulse repetition frequency (1 divided by time between impulses) as:

$$SPL = L_{E-single\ impulse} + 10 \log_{10}(f_{repetition})$$

E.g. with a repetition every 2 seconds the SPL would be 3.01 dB lower than the  $L_{E-single\ impulse}$ .

In “Preferences/Sound levels display” set “Assessment period for results” to the desired time, or set the moving source to the desired time.

### 3.1.3 REALLY SLOW APPROACH

In “Preferences/Sound levels display” set “Level type for display” to “Sound exposure level”.

Set number of impulses in “Count” (upper right corner of “Time series” menu”).

Solve model using dBSeaRay.

### 3.2 $L_p$ / z-peak

First go to “Preferences/Sound levels display” and make sure “Level type for display” is “Peak sound pressure level”.

#### 3.2.1 MINIMAL SOLVE, THE QUICK WAY

Go to “Frequencies and solvers” and set “Assessment bandwidth” to “Octave” and “Master spectrum Frequencies” to “Octave”

In the “Time series” menu note the band of maximal energy.

Now chose a significance limit, e.g. 16 dB (-0.1 dB in results) and note, starting from the lowest band, where the level reaches the maximal energy minus your limit, e.g.:

The impulse has most energy in band centered on 1000 Hz –  $L_E$  of 203.6 dB

Threshold:  $203.6 - 16 = 187.6$

Going from band centered on 12.5 the first band with  $> 187.6$ , in this case that's band at 63 Hz.

Now from the highest frequency, 8 kHz is last band  $> 187.6$  dB.

Our frequency range is now 63 Hz to 8 kHz, this will be much quicker to model than 12.5-160000 Hz, and only -0.1 dB wrong.

16 dB limit leads to -0.1 dB in overall level:

$$error = 10 \log_{10} \left( 1 - \frac{1}{10^{16/10}} \right)$$

We rely on the fact that dBSea propagates the entire impulse regardless, but results are only stored as  $L_p$ , with no frequency specific information.

### 3.3 SPL / $L_{eq}$ / RMS

Follow steps in section 3.1.2, p. 6, but set total assessment time in “Preferences/Sound levels display” set “Assessment period for results” to “1” second (or set moving source to move a total of 1 second).

### 3.4 SPL instantaneous / SPL 1 sec

Follow steps in section 3.1.2, p. 6.

*Before solving* go to “Preferences/Sound levels display” set “Sound levels display” to “Peak sound pressure level”.

## 4. Scenario Types

### 4.1 Impact Piling

Impact piling can often be done with just 1 mid-water (or mid wet-pile point) source point:

Check that:

1. Ranges to relevant receivers are  $>5x$  depth at pile.
2. Bathymetry is relatively flat.
3. You don't care about the actual sound field close to the source.

### 4.1.1 FANCY MOVING SOURCE PILING MODEL

Use either  $L_E$  or  $L_p$  approach (Impulsive Noise, 3, p. 4) with a moving source with lots of “Sections”, moving at the speed of sound of the pile material (e.g. steel, 5000 m/s).

Tick box “Moving sources retain all calculated levels”.

Have patience while this solves (!)

Try to export as animation with “Export/Animated results tool”.

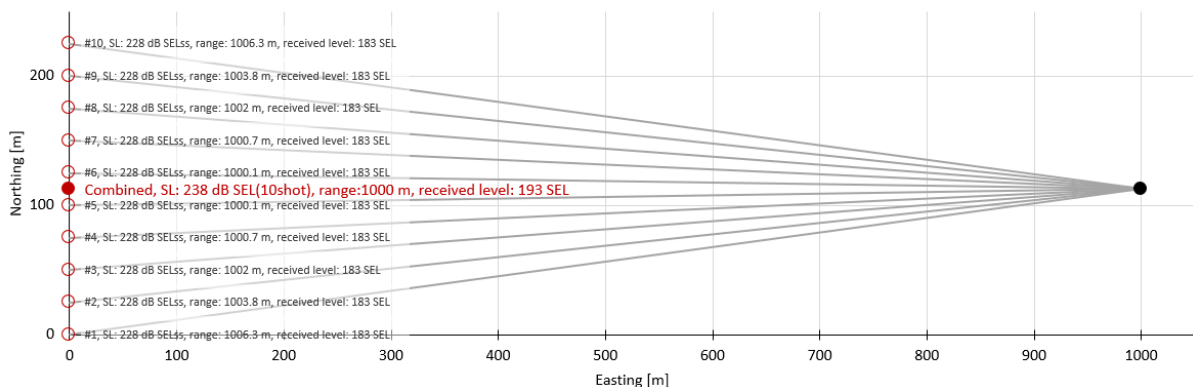
## 4.2 Seismic Surveys

### 4.2.1 TRACK MODELLING

#### 4.2.1.1 Multipoint to One

In a seismic survey individual shot are often very closely spaced, both in time and distance. Also, ranges to impact risks are often much greater than the distance between shots. This means that we can combine several shots into a single “multishot”, thereby saving modelling time by modelling fewer points in total (see Figure 4 below, for concept).

**Figure 4. 10 source points are “condensed” into one point of source level  $10\log_{10}(N\text{points})$  dB higher than the individual points. For receivers far away this is equivalent to having many source points in terms of SEL. Here difference at receiver is  $<0.02$  dB.**



Example:

- Shot spacing: 25 m
- Single shot level [ $L_E$ ]: 200 dB
- Number of shots in “multishot”: 7
- Multishot level [ $L_E$ ]: 208.45 dB
- Receiver range: 500 m

Using the above values we can estimate the difference in doing the calculation per single shot or per multishot:

**Table 2. Example of single-shot locations and received levels for a seismic survey.**

Shot location single-shot X [m] Y [m]	Range to receiver [m]	TL ( $-15\log_{10}(\text{range})$ ) [ $L_E$ ]	RL [ $L_E$ ] (at location X: 500, Y: 75) Total: 167.9 [ $L_E$ ]
0 0	505.6	-40.6	159.4



0	25	502.5	-40.5	159.5
0	50	500.6	-40.5	159.5
0	75	500.0	-40.5	159.5
0	100	500.6	-40.5	159.5
0	125	502.5	-40.5	159.5
0	150	505.6	-40.6	159.4

**Table 3. Example of effect of combining points from above Table 2, to single “multipoint” to simplify modelling.**

Shot location multishot		Range to receiver [m]	TL $(-15\text{Log}_{10}(\text{range}))$ [L <sub>E</sub> ]	RL [L <sub>E</sub> ]
X [m]	Y [m]			(at location X: 500, Y: 75) Total: 168.0 [L <sub>E</sub> ]
0	75	500.0	-40.5	168.0

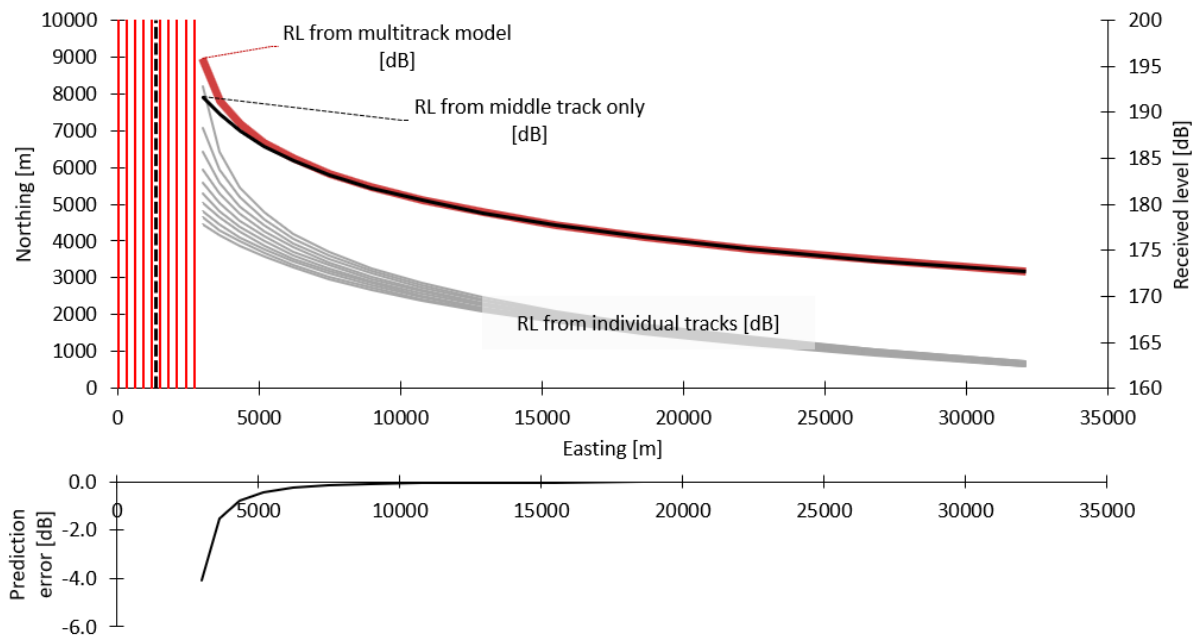
The difference between the two approaches above is <0.1 dB, but the modelling cost has reduced sevenfold.

Note that this approach will give you conservative results, as it will increase the shortest impact ranges (where your shot spacing is too large, you’ve combined too many points).

#### 4.2.1.2 Multitrack to One

Just like we can combine several source points into one, we can also combine multiple tracks to a single track (see Figure 5). As we get further away from a series of several tracks their combined received level [L<sub>E</sub>] will approach that of a single track line of a higher source level (equal to the combined energy of the contributing track lines).

**Figure 5. A single line with higher source level will have very similar received level to the total received level from all ten tracks, making the modelling of all ten tracks superfluous over medium ranges.**



#### 4.2.1.3 Sweep

For seismic surveys we are often interested in the impact range of the broadside emissions from the seismic array, and impact ranges are often measured in multiple kms from the track. This means that calculation of numerous slices/radials that run close to parallel to the track are irrelevant for the impact ranges. For a track that runs from SW to NE at a 45-degree compass heading, setting dBSea to use “8” “Radial slices” will be enough to ensure that we have modelled the closest point of approach to each point in the scenario. Modelling fewer radials also mean that you can increase the number of shot points in your modelling, while keeping the modelling load reasonable.

**Figure 6.** With 16 slices/radials we have too many radials simply calculating transmission loss in the direction of travel for the track. We could limit this to 8 radials and get the same result.

