A Case Study of the Noise Propagation Observed from a Geotechnical Marine Seismic Survey in Coastal Perth, WA with Particular Reference to Human Receptors

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ABSTRACT

A marine geophysical geotechnical survey was commissioned for a major port development on the coast of Perth. This extended abstract presents the findings from a noise monitoring field trial of the marine seismic refraction survey element of that survey and compares the results to those of the desktop literature study.

EXTENDED ABSTRACT

1 INTRODUCTION

Nearshore marine seismic surveys undertaken for geotechnical purposes typically have a target depth of a few tens of meters below seabed level, whereas those for offshore oil and gas (O&G) exploration typically have a target depth of many hundreds of meters. Consequently the airguns used for nearshore geotechnical purposes differ from those used in O&G exploration by their far smaller airgun chamber capacity and lower operating pressures.

There are many studies published on the acoustic modelling and monitoring of O&G deep water marine seismic surveys (Jiménez-Arranz et al 2020, McCauley et. al. 2003, JASCO Public Reports), but very few on those for shallow water, nearshore geotechnical purposes. As a result there is a tendency for geotechnical desktop noise risk assessments to adopt O&G references in the absence, or near absence, of more appropriate scale studies. This tendency may lead to overly conservative operating conditions being placed on geotechnical marine geophysics surveys which may reduce their potential value and increase their cost.

Nearshore environments may also be more complex than O&G exploration sites in terms of human receptors, and, like the O&G modelling and monitoring, there is a far greater body of references for offshore O&G noise in relation to marine mammals than there is for recreational SCUBA divers. The impact of noise on marine mammals is highly regulated in Australia and elsewhere with layers of specific regulations, codes of practice and guidance (e.g. CoA, 2008) whereas impacts to human receptors may be covered solely through less-specific general health and safety or noise at work regulations, and national diver-specific guidance may be absent or wholly focussed on O&G industries (e.g. DMAC, 2020).

In offshore O&G environments the human receptors of underwater seismic noise will often be commercial operators with whom there is more potential for canvassing, communicating and coordinating diver-seismic operations than there is for recreational SCUBA divers. In a nearshore urban environment, recreational SCUBA divers may occur at any time from beaches or from boats without warning; divers may not heed signage or communications and dive bare-headed with no air gap between the noise-source and the receptor-ear. Furthermore, developers of nearshore construction projects may understandably be sensitive to the perception of their project by local stakeholders such as SCUBA diver communities and prefer to reduce survey areas rather than put controls in place to exclude stakeholder activities during surveys.

So whilst there is a superficial similarity between O&G seismic exploration and nearshore geotechnical seismic surveys, there are a number of distinct differences sufficient to infer that desktop refence sources from O&G experience may not be wholly applicable to nearshore geotechnical applications.

This paper presents the findings of marine noise monitoring for a geotechnical scale, nearshore marine seismic refraction survey with a view to provide an alternative reference-source for similar future geotechnical studies.

The nearshore marine seismic refraction survey presented here was commissioned for geotechnical purposes for a major port development on the coast of Perth. The port terminal is to be located in Cockburn Sound with a marine development footprint of approximately 460 ha and to its north the proposed navigation channel is 22 km in length in the deeper and more exposed waters between Rottnest Island and Fremantle.

2 METHOD

2.1 Desktop Assessment

As part of preliminary planning, an underwater acoustic specialist was commissioned to undertake a desktop noise risk assessment for the works.

The desktop assessment adopted the following parameters. The seismic source for the survey was a Bolt 2800-LLX airgun with a 0.328 ltr (20 cubic inch) chamber capacity.

- Operating frequency 90 - 200 Hz
- Chamber pressure 3,447 kPa (500 psi) to 7,584 kPa (1,100 psi)
- Source pulse duration of approximately 10 milliseconds (ms).
- Source peak sound pressure level (Pk SPL) is 221 dB re 1 µPa @ 1m, source root-mean-square sound pressure level (RMS SPL) is 202 dB re 1 µPa @ 1m.
- Seabed depth below water ranges 9 to 17m. Seabed materials are relatively thin silty sand or sandy silt over limestone.

To calculate the maximum exposure level for human SCUBA receptors, the desktop assessment adopted the work of Parvin (Parvin 1998, Parvin et. al 2002, Parvin 2005). For low frequency range (100-500 Hz) sources for recreational divers and swimmers, Parvin (2005) recommended a guidance threshold level of 145 dB re µPa RMS.

In order to estimate the threshold distance of this level, the sound transmission loss (TL) prediction used in the desktop assessment was based on a simplified formula:

$$TL = N \times \mathrm{Log10}(R)$$

Where R is the distance between the source and the receiver. The attenuation factor N is close to 20 for a very shallow water environment due to the strong interaction between the sound signal and seafloor, resulting in high attenuation. As a precautionary measure, two attenuation factors (N = 18 and N = 20) were included in the estimates, representing an upper and lower range of transmission loss for the assessed shallow water environment. Based on these inputs the following estimated threshold distances were derived.

Table 1: Estimated threshold distances

Survey equipment	Threshold level *(dB re 1 µPa RMS)*	Estimated threshold distance (*m*) *TL – 18log10(R)*	*TL – 20log10(R)*
Airgun	145	1,100	750

Whilst significantly lower than the 27 km action thresholds suggested for seismic airgun sources in DMAC (DMAC 2020), excluding surveys within 1100 m of the shore still would have resulted in excluding approximately 50% of the terminal area from MSR survey methods and excluding beach users from entering the water within 1100m of the survey would have closed several beaches for an extended period. Furthermore it was found difficult to discern a vessels “diver down” flag at 1100 m, even with binoculars, when on a small moving vessel such as the one used for the survey. Thus, the MSR survey may also have had to assume all distant vessels were dive vessels and significant down time would have been incurred, or a separate diver spotter vessel commissioned.

Such impacts were not tolerable to the project so a simple site-specific field trial was commissioned to derive the actual threshold distance given the specific survey equipment, seabed and environmental conditions in the hope that a threshold distance lower than 1100 m might be justified.

2.2 Field Trial

The field trial consisted of a fixed monitoring location based on a stationary monitoring vessel while seismic sources on survey vessels moved along transect paths.

The first monitoring location had a water depth of 17 m (the deep-water location) in the middle of Cockburn Sound and the second a depth of 9 m (shallow water location) to the east of the Sound.

Survey vessels traversed a series of transect paths with a maximum distance of 2.0 km and a minimum distance of 50 m from the monitoring locations. Traverses were undertaking from both north to south and south to north in multiple passes to provide approaching and retreating scenarios and passes were run at three airgun pressures 3,447 kPa (500 psi), 5,515 kPa (800 psi) and 7,584 kPa (1,100 psi).

A hand-held data recording system was used for the field measurement - a Reson hydrophone TC4033-1, connected to a Reson VP1000 preamplifier, and then to a Sound Devices (SD) 702T Recorder. The SD 702T was calibrated with a sine function noise generator at 1 kHz and a total system calibration was undertaken. Continuous monitoring was conducted with proper gain settings to record background noise and survey signals for each transect path, with the sampling rate of 96kHz and total gain of 12 or 26 dB.

The collected survey noise recordings were processed based on the following procedures:

- Broadband signal processing, with Hanning Window applied and 50% window overlap.
- Window lengths selected as per corresponding nominal source pulse durations, i.e. airgun source pulse 10 milliseconds.
- The source devices recorded the coordinates and timestamp of each source emission.

3 RESULTS

The received levels (in RMS SPL re 1 µPa) versus receiving distance for identified survey pulse signals are presented in Figure 1.

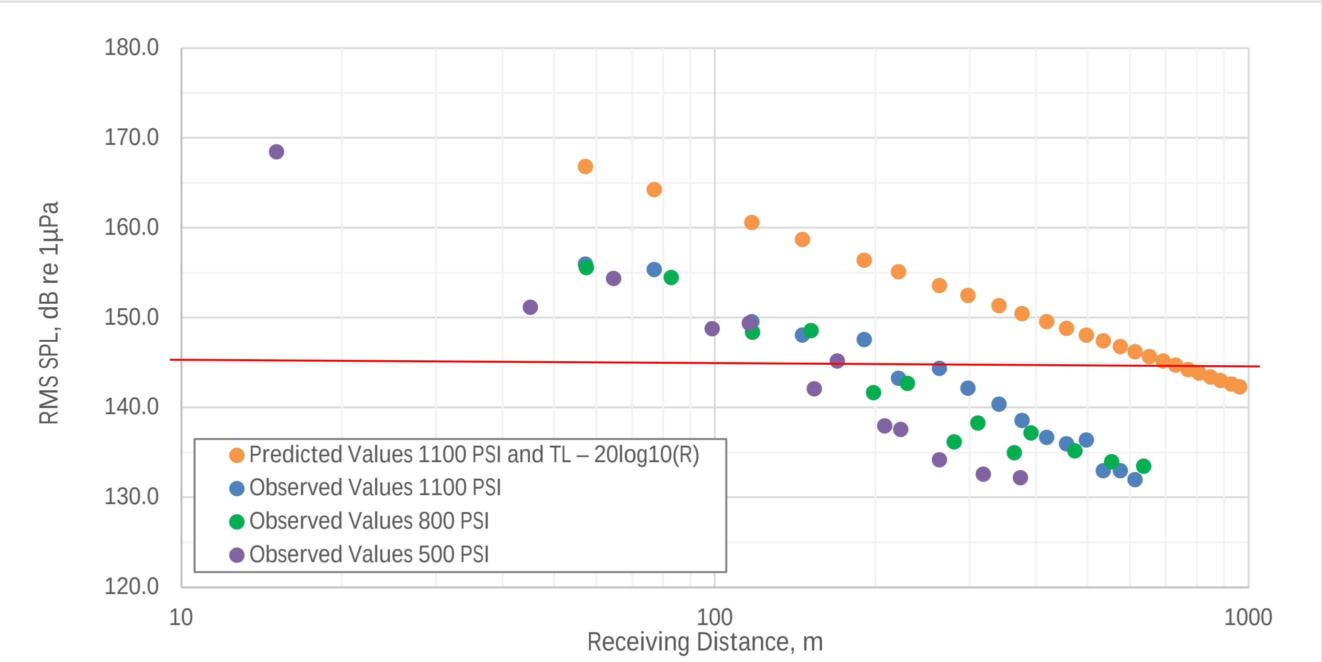

Figure 1 identified airgun pulses of three source pressure scenarios (1,100 psi, 800 psi and 500 psi) at the 17 m deep-water monitoring location with the RMS SPL 145 dB threshold highlighted in red.

4 CONCLUSION

The following major findings have been drawn based on the analysed results:

- Overall, received RMS SPL's are 5 – 15 dB lower than predicted levels at the same distances.
- Impact zones based on a threshold level of 145 dB re 1µPa RMS are all below 300 m, much lower than predicted values (750 m – 1,100 m at 1,100 psi).
- Measured attenuation curves are higher than 20log10(R), expected to be due to shallow water depths and more absorptive seabed properties.

5 DISCUSSION

As a result of this study it was possible to justify reduced no-dive exclusion zones. The project was able to adopt a 400m "no dive" zone from beaches and 500m zone from dive-flagged vessels. 400m was adopted to allow for divers to traverse at least 150m from shore before encountering the 145dB threshold, 150m in the authors experience would be a longer than average distance for a SCUBA shore dive. The additional 100m applied to dive flagged vessels was included because estimating distances from a small moving vessel is more difficult than estimating distances from shoreline which may be done by the vessel's chartplotter. Dive flags are tolerably visible from 500m and therefore the need for a spotter vessel was avoided. The 400m shore limit meant that divers were only excluded from a very short section of a single beach and for only a short duration. The survey was completed without diver impacts, but on at least two occasions a recreational dive flagged vessel was observed near the 500m limit, at which point the airgun was stopped and the survey vessel relocated to another part of the project until the vessel had moved on.

Subsequent to the field trial, Duncan (Duncan et. al., 2024) published a chart of measured propagation loss vs. range and frequency for the Central Basin of Cockburn in 19 m water depth. For the frequency range of 90-200 Hz the chart indicated losses in the range of 40-60 dB at 300 m, our observed losses at 300 m were approximately 50 dB.

Overall the work demonstrated that a multidisciplinary and collaborative approach, even with the simplest of acoustic field trials, could bring significant benefits to a geotechnical project compared to desktop study alone.

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