Appendix 9:

Clarification Note Underwater Noise

Aberdeen Harbour Expansion Project

Clarification Note: Underwater noise

Scottish Natural Heritage (SNH), in its combined response to the consultation on the three consent applications for the Aberdeen Harbour Expansion Project (AHEP), raised a concern that there was insufficient mitigation proposed in the Habitats Regulations Appraisal (Volume 4 of the Environmental Statement (ES)) to allow a conclusion of no adverse effect on the population of bottlenose dolphin from the Moray Firth Special Area of Conservation.

Aberdeen Harbour Board and their underwater noise consultant Peter Ward met with SNH and Marine Scotland on 27 January 2016 to discuss this issue in more detail. This clarification note describes the information and data sources that were discussed at the meeting, drawing on information presented in Chapter 15 and Appendix 13-B of the ES.

Partial construction of breakwaters

To reduce the propagation of underwater noise resulting from marine impact piling during the construction of the AHEP, SNH has requested that a mitigation measure is included in the Marine Licence and Harbour Revision Order to require the breakwaters to be partially constructed prior to the commencement of impact piling in the marine environment. Suggested wording for this condition is as follows:

'Impact piling in the marine environment is not permitted in 'open water' – i.e. impact piling can only be carried out in areas in which it is screened from the open water by the presence of a partially or fully constructed breakwater(s), so that there is no 'direct line of sight' between the impact piling location and the open water.'

It is proposed that the details of how this will be achieved are contained within the Construction Environmental Management Plan (CEMP), upon which SNH will be consulted prior to construction commencing.

Sound propagation may be described very simply using a geometrical spreading approach *viz.*

$$SPL = SL - N \log10(R) \qquad (1)$$

where SPL is the sound pressure level in decibels [dB] at a given range R in metres [m] from the point of origin; SL is the source level in dB re 1 μPa at 1 m; and the constant N is equal to 20 or 10 for spherical spreading or cylindrical spreading respectively. When the sound propagates freely in all directions, spherical spreading and hence N=20 is applied. When sound is constrained by the sea surface and the seabed (and this scenario is especially relevant to a shallow water channel such as that in Nigg Bay), the acoustic wavefronts propagate cylindrically and N=10 is used[1].

The loss of acoustic energy is, however, dependent on more than just the distance from the noise source, and the simple expression given above is rarely sufficiently accurate to describe fully all the effects that arise during shallow water propagation. For a broadband source, not all frequency components propagate equally: the simple expression above fails to provide any insight as to the limitations imposed on propagation in a shallow water channel. Below a certain frequency defined as the cut-off frequency, sound energy does not propagate and tends to become absorbed into the seabed1. The cut-off frequency f_0 is given by

$$f_0 = c_w/\{4 H [1-(c_w/c_b)^2]^{0.5}\} \qquad (2)$$

where c_w and c_b are the sound speeds in the water and seabed respectively; and H is the water depth. For a water depth of 5 m (representative of Nigg Bay), the cut-off frequency is approximately 380 Hz.

[1] Urick, Robert J. (1983), Principles of Underwater Sound, 3rd Edition. New York. McGraw-Hill.

This means that energy having a frequency below 380 Hz will not propagate. As the remaining sound propagates, it undergoes attenuation which arises due to an acoustic-initiated chemical reaction with the salts that are dissolved in sea water. The effect is proportional to frequency and becomes significant at frequencies above 10 kHz.

Figure 1 shows a typical frequency spectrum for marine impact piling noise. It can be seen that the peak levels are found between 100 Hz and 200 Hz while outside this frequency range, spectral levels are considerably lower. Figure 2 shows the cumulative acoustic energy as a function of frequency and this indicates that approximately 70% of the total acoustic energy occurs at frequencies below cut-off at 380 Hz. From these two figures it may be concluded that only energy in the frequency range 400 Hz to 10 kHz is likely to contribute substantially to the propagated acoustic field.

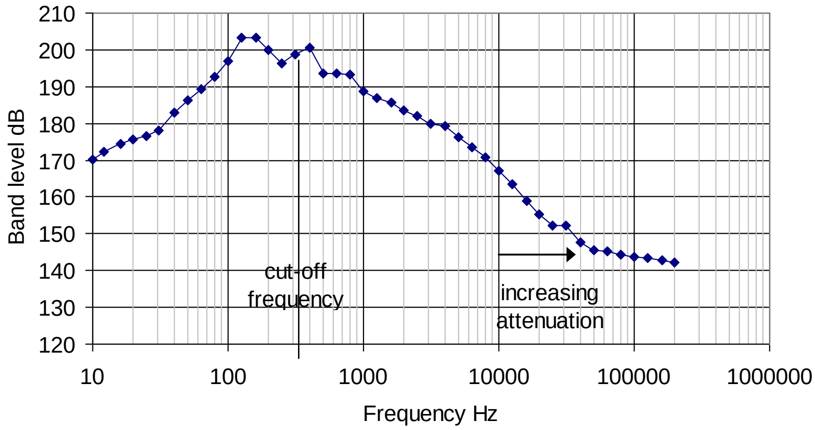


Figure 1: Representative frequency spectrum for impact piling

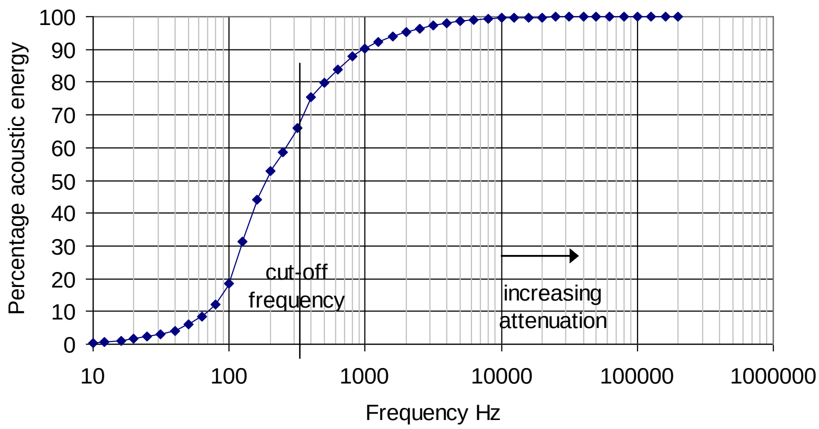


Figure 2: Cumulative energy as a function of frequency

In order for impact piling noise to propagate from the pile site to the wider environment, there has to be a clear and unimpeded pathway. The presence of a breakwater impedes the propagation of impact piling noise thus preventing it from spreading out into the wider Aberdeen Bay. When impact piling takes place behind it, the breakwater creates a shadow zone beyond which sound levels will be significantly lower than in front. It is possible, however, that some sound may bend round the end of the breakwater by means of diffraction and it is therefore necessary to determine the extent of the zone over which the diffracted sound propagates.

The computation of the distance over which sound diffracts lies beyond the functionality of most of the acoustic propagation programs and models currently available. Indeed, a literature search revealed very little guidance on this subject. One paper[2] investigated the diffraction of sea waves around the end of a long straight breakwater by considering the mathematically analogous problem of the diffraction of light. The penetration of waves through a single gap in a long breakwater was modelled and the result was shown to depend on the size of the gap relative to the wavelength of the incoming wave trains. The second paper[3] showed that waves in the lee of the small gap in a breakwater spread as if from a point source and subsequently propagate over a distance of several wavelengths. The behaviour of impact piling noise in the vicinity of the breakwater may thus be inferred.

It is estimated that the diffraction zone behind the breakwater extends to a distance of several wavelengths of sound of a given frequency – 'several' is a somewhat loose definition hence a range of values in the region of 5x to 10x may be assumed. At a frequency of 100 Hz, the zone could extend over a maximum distance of 150 m while at 1 kHz, the zone extends 15 m or thereabouts.

For a breakwater gap of 165 m, for example, energy at a frequency of 20 Hz or less will be diffracted through the gap. Subsequently, sound will propagate as from a point source and this is illustrated in Figure 3.

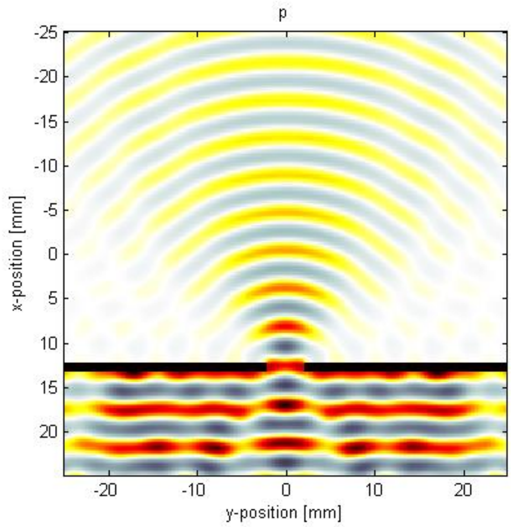


Figure 3: Schematic demonstrating diffraction through a gap

The analysis undertaken in ES Appendix 13-B indicates that as impact piling noise propagates from the pile site to the breakwater gap over a distance of approximately 550 m, it loses over 50 dB in sound pressure level. The gap thus acts as the location of a secondary source with a source level 50 dB less than the original source level at the piling site. Note however that not all frequencies in the original outgoing signal will have propagated. Those below the cut-off frequency will have become absorbed into the seabed while those above 10 kHz or so will be further attenuated due to chemical reactions (as described above).

Provided marine impact piling takes place behind a partially- or a completely-constructed breakwater as described at the beginning of this note, then the presence of the barrier will largely impede the propagation of sound. Some diffraction around the breakwater may occur; the distance over which this occurs is assumed to be approximately 100-200 m. The low-frequency part of the impact piling noise spectrum will become absorbed into the seabed. Signals above 10 kHz are unlikely to propagate to

[2] Penney W. G., Price A. T., (1952), "Part I. The Diffraction Theory of Sea Waves and the Shelter Afforded by Breakwaters", Philosophical Transactons of the Royal Society B Biological Sciences 244(882):236-253.

[3] Rogers J. S., Monismith S. G., Feddersen F., Storlazzi C. D., (2013), "Hydrodynamics of spur and groove formations on a coral reef", Journal of geophysical Research: Oceans 118:1-15.

great distances because of the attenuating effect of acoustically-induced chemical reactions in the salts dissolved in the seawater.

It is therefore concluded that, in relation to marine impact piling, the mitigation measure of partially constructing the breakwater(s) will significantly reduce the propagation of underwater noise outside of Nigg Bay. This supports the conclusion in the Habitats Regulations Appraisal (Volume 4 of the ES) that underwater noise generated by marine impact piling will have no adverse effect on site integrity for the Moray Firth Special Area of Conservation.

Rock blasting

Drilling and blasting is required to remove rock in areas above the level to be dredged/levelled within Nigg Bay. Figure 3.9 in Chapter 3 of the ES shows the areas where rock is known to be present, based on site investigations undertaken to date. A copy of this figure is provided in Appendix A of this note, for ease of reference.

The quantity of rock to be removed is estimated to be between 220,000 m^3 and 250,000 m^3; this is a greater quantity than was estimated in the ES (109,000 m^3), as recent site investigation has provided a more accurate indication of the quantity. However, the exact quantity to be removed will be dependent on the contractor's chosen methodology and design, which will be detailed in the CEMP. As stated in the ES, all rock will be reused and will not be disposed to sea.

The detailed methodology for rock blasting will be determined once a contractor has been appointed. However, during recent meetings with Aberdeen Harbour Board, all five contractors tendering for the project gave a description of their intended methodology. The following list describes the sequence and duration of drilling and blasting activities, and includes the range of options being considered by the contractors:

- Holes will be drilled in the rock prior to charges being placed.
- The number of holes to be drilled per day will be between 25 and 100.
- Charges will be placed in the pre-drilled holes and each charge will be detonated in sequence, with milliseconds separating each blast, so the duration of the blast will be very short.
- There will be a maximum of two blast detonations per day.
- Blasting will only take place during daylight hours.
- After a period of 4 to 7 days, depending the size of the area, the blasted materials will be removed by means of dredging, after which the drilling and blasting will continue.
- It is likely that blasting will be undertaken in a single phase (i.e. without a significant break in activities). However, there may be a break in activity during the winter months.
- The duration of blasting activities is variable; contractors have indicated timescales of between 3 and 7 months.

The underwater noise acoustic study (ES Appendix 13-B) discussed the propagation and impact of the noise generated through the activity of rock blasting. When an explosive charge is detonated in open water the blast wave propagates freely in all directions. By contrast, when the blast is contained in a hole drilled in bedrock, the magnitude of the outgoing blast wave is significantly attenuated. A search of the published literature revealed a report that modelled the propagation of blast noise from charges embedded in holes in a bedrock[4]. For a charge weight of 20 kg buried in a charge hole 2.5 m deep, the peak pressure is estimated at 262 dB re 1 μPa at a distance of 1 m; this is some 20 dB less than what would occur if the blast took place in open water. An impact model based on work undertaken by

[4] Munday D. R., G. L. Ennis, D. G. Wright, D. C. Jefferies, E. R. McGreer, J. S. Mathers, (1986), "Development and evaluation of a model to predict effects of buried underwater blasting charges on fish populations in shallow water areas", Can. Tech. Rept. Fish Aquat. Sci. 1418: x+49p.

Yelverton *et al.*[5] showed that the 'No-Injury' impact criterion was dependent on the body weight of the test subject. For a body weight of 10 kg (corresponding to a newborn harbour seal), the animal would avoid injury if it was beyond a distance of 14 m from the blast site. Similarly, a full grown harbour porpoise would avoid injury if it was more than 9 m from the blast site. The more precautionary Level A-Auditory Injury criteria for pinnipeds and cetaceans are met at ranges of 200 m and 820 m respectively.

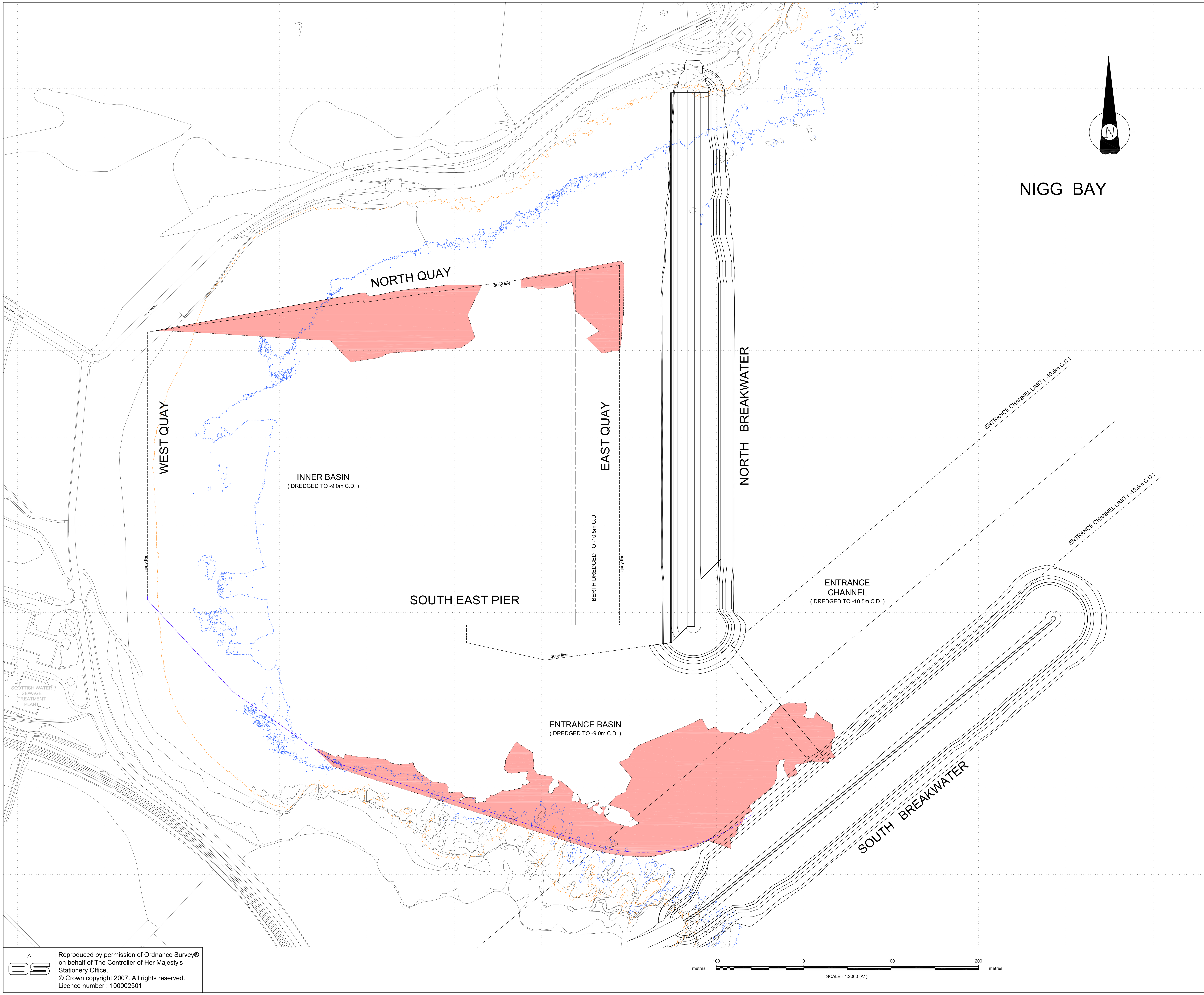
At these distances, the mitigation measures proposed in Chapter 15 of the ES, i.e. to utilise Marine Mammal Observers and Passive Acoustic Monitoring with a mitigation zone of 1 km, and to adhere to the JNCC blasting guidance, will prevent injury to marine mammals by ensuring that blasting does not take place when marine mammals are in the vicinity. Due to the intermittent nature of the activity (only one or two blasts per day over a limited period), the effects of disturbance are considered to be limited.

The information presented above is considered to support the conclusion in the Habitats Regulations Appraisal (Volume 4 of the ES) that underwater noise generated by blasting activities will have no adverse effect on site integrity for the Moray Firth Special Area of Conservation.

February 2016

[5] Yelverton, J. T., Richmond, D. R., Hicks, W., Saunders, K., and Fletcher, E. R. (1975). "The Relationship Between Fish Size and Their Response to Underwater Blast." Report DNA 3677T, Director, Defense Nuclear Agency, Washington, DC.

Appendix A



NOTES...:-

1. ALL LEVELS ARE GIVEN IN METRES ABOVE ADMIRALTY CHART DATUM (mC.D).
2. CO-ORDINATES ARE TO ORDNANCE SURVEY GRID (O.S.G.B.1936)

DRAWING LEGEND...:-

- AREA OF ROCK REMOVAL
- M.H.W.S — MEAN HIGH WATER TIDE LIMIT
- M.L.W.S — MEAN LOW WATER TIDE LIMIT

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Arch Henderson 1919
Civil Engineers
Structural Engineers
Architects
CDM Co-ordinators
Geotechnical services
Environmental services
26 Rubislaw Terrace, Aberdeen. AB10 1XE.
Tel : 01224 631122 · Fax : 01224 632233.
www.arch-henderson.co.uk · email : aberdeen@arch-henderson.co.uk
Offices in : Aberdeen, Dundee, Falkland Islands, Glasgow, Lerwick, Stromness and Thurso

PROJECT :
ABERDEEN HARBOUR BOARD
Aberdeen Harbour Expansion Project

TITLE :
DREDGING WORKS - EIA REPORT
INDICATIVE AREAS OF ROCK DREDGING

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