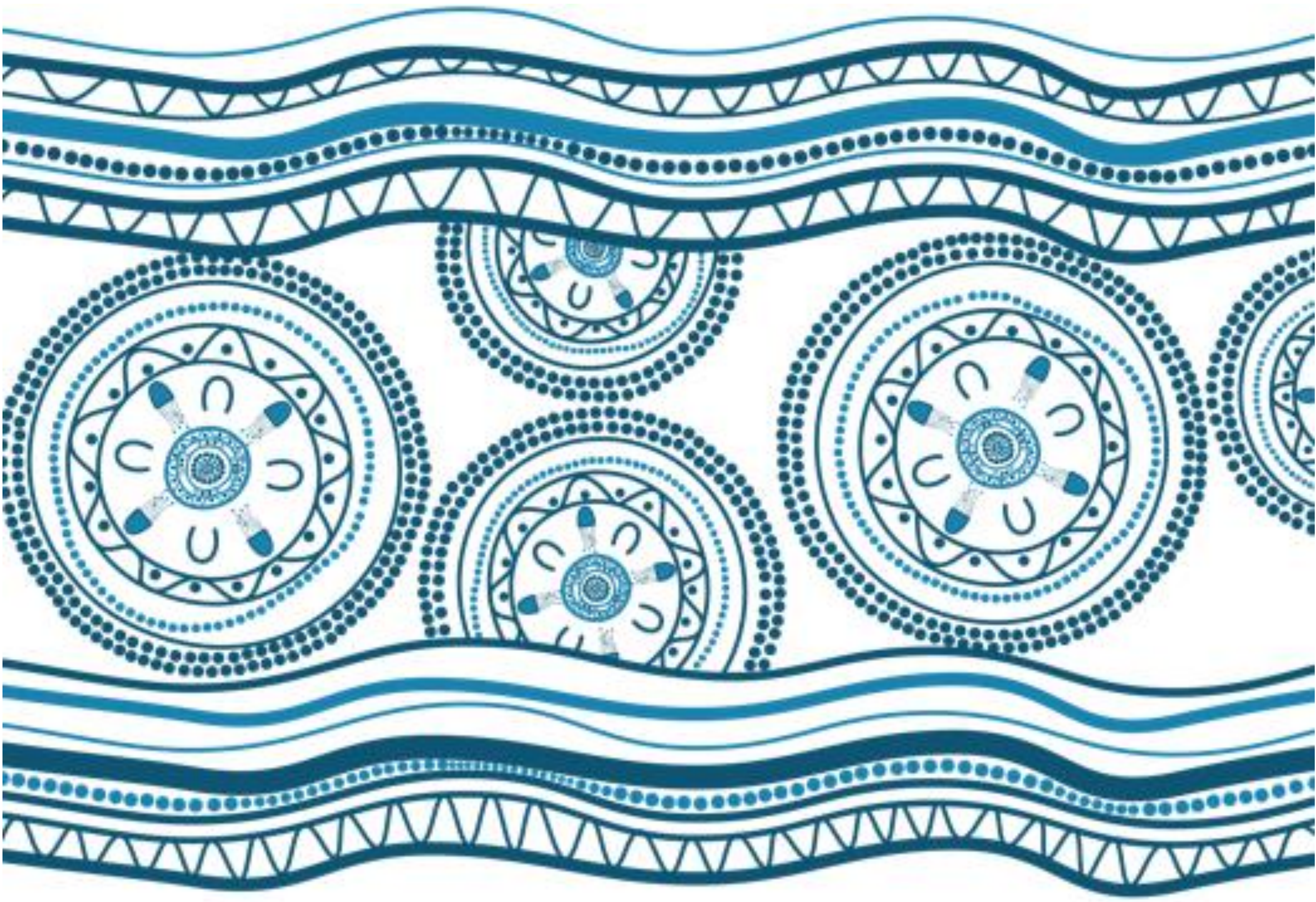
Chapter 16

Underwater noise and vibration



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16 Underwater noise and vibration

This chapter presents an assessment of the impacts of the project on underwater noise and vibration and identifies mitigation and management measures to minimise and reduce these impacts.

The assessment presented in this chapter draws on information from Appendix P (Underwater Noise Assessment).

16.1 Assessment methodology

The underwater noise method involved:

- Identifying existing noise sources
- Characterising the underwater noise environment in Botany Bay
- Identifying underwater noise-sensitive receivers
- Identifying the appropriate criteria where a response to underwater noise may be experienced
- Determining the construction and operation activities that would generate underwater noise
- Modelling how underwater noise would propagate (disperse)
- Assessing the potential for temporary and permanent impacts on noise sensitive receivers
- Developing mitigation and management measures to reduce noise impacts.

The following terminology is used to describe underwater noise impacts:

- *Sound pressure level* (SPL, L_p) is the change in water pressure generated from underwater noise that is typically used to assess a behavioural response
- *Peak pressure* (PK, L_{pk}) is the maximum change in water pressure associated with underwater noise. This is also referred to as peak impulsive noise and is typically used to assess sudden shock and startle response health and welfare impacts
- *Sound exposure levels* (SEK, $L_{E,24h}$)[1] is the cumulative level of energy contained within underwater noise and is typically used to assess health and welfare impacts. This is also referred to as the "noise dose".

Sound and peak pressure levels are measured in decibels (dBs). They are typically reported against a standard reference value of 1 µPa (one micro pascal). This is different to sound levels in air, which are reported using a reference value of 20 µPa. Because of this, and the fact that sound travels much slower in water than air, the noise levels cannot be directly compared.

16.1.1 Modelling

Underwater noise modelling was carried out to assess how piling and vessel noise would disperse in Botany Bay accounting for features such as seedbed properties and physical characteristics such as sediment composition. Section 5 in Appendix P (Underwater Noise Assessment) describes this in detail. Some of the key assumptions and limitations of the model included:

- Modelling the noise form a single point source as the construction boundary is small enough not to affect the results
- Using published typical source noise levels which may vary from the actual source
- Using average values to represent the seabed, sediment and other physical conditions in Botany Bay as the modelling tools are not able to account for this. There may therefore be localised differences across parts of Botany Bay
- Assumption that each pile would be struck 600 times. If the number of strikes is greater or lower then this would affect the cumulative noise levels.

[1] *Lp* refers to the root mean squared sound pressure relative to a reference value. L_{pk} refers to the maximum sound pressure relative to a reference.

Background (ambient) noise levels in Botany Bay are currently affected by a range of port, maritime, industrial, commercial and recreational activities. However, these background noise levels were not included in the modelling. This is because the underwater noise assessment was made against fixed threshold criteria, where ambient noise levels are not a factor in predicting impacts. Also, background noise levels have a negligible effect close to the underwater noise source because the source dominates. Moving away from the source, ambient noise would start to have more of an influence. Eventually, the ambient noise would become the dominant source meaning any proposal generating underwater noise would have negligible influence. The effect of considering existing ambient noise would only reduce the size of the predicted zones of impact (eg the effect of the project activities would no longer be audible against ambient noise).

16.1.2 Assessment

Species display different behavioural responses to underwater noise. Noise characteristics are also important because impulsive noise, such as the noise created from piling, has a different impact on marine species compared to continuous noise. The frequency of the noise also affects how species respond. These differences were considered in the literature listed in Appendix A of Appendix P (Underwater Noise Assessment). They were used to assess four key potential underwater noise impacts:

- Temporary impacts:
  - Behavioural response
  - Temporary hearing loss.
- Permanent impacts:
  - Permanent hearing loss
  - Physical injury.

16.1.3 Policy framework

As there are no underwater noise assessment methods in NSW, various Australian and International Standards were used to carry out the impact assessment. The principal documents are listed below. Appendix P (Underwater Noise Assessment) includes additional literature sources that were used in the assessment.

- Underwater Piling Noise Guidelines (Government of South Australia, 2012)
- Great Barrier Reef underwater noise guideline: discussion and options paper (McPherson *et al*., 2017)
- ISO 18405 Underwater Acoustics (International Standards Organisation, 2017)
- Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects (Southall *et al*., 2019).

The Underwater Piling Noise Guidelines have been the main resource and benchmark for determining underwater noise requirements for marine mammals in Australia since 2012. However, recent scientific findings, particularly the study by Southall *et al.* (2019), have now revised the impact thresholds established in the Underwater Piling Noise Guidelines. Appendix P (Underwater Noise Assessment) was therefore guided by this more recent literature.

16.2 Existing environment

Underwater noise can impact marine mammals (whales, dolphins, porpoise, seals, and dugong), fish, sharks, rays, sea turtles, marine reptiles, birds, invertebrates, squid, and crustaceans. It can also affect divers and other recreational users. The following section lists the receivers in Botany Bay that could be impacted by underwater noise. It also considers the ambient underwater noise environment.

16.2.1 Ambient underwater noise

Ambient underwater noise in Botany Bay is affected by a range of port, maritime, industrial, commercial, and recreational activities. The main underwater noise source is from the frequent movement of ships. This currently includes around nine vessel movements per day to or from Port

Botany or the Kurnell Port and Berthing Facility. It is forecast that total vessel numbers associated with Port Botany are expected to grow by 45 per cent over the next 30 years (NSW Ports, 2015). There is also various subsea infrastructure under Botany Bay that potentially generates underwater noise.

Ambient noise levels around Australian coastal waters are around 120 dB (re: 1 µPa) (Government of South Australia, 2012). Ship-generated underwater noise is intermittent. It varies depending on the type and size of ship. Larger cargo ships and tankers generate noise up to a maximum of 209 dB (re: 1 µPa, Bowles and Graves, 2007).

While no baseline monitoring was carried out near the project areas, ambient underwater noise is likely to be influenced by shipping movements through the headlands. While ambient noise levels could vary as high as 190 dB (re: 1 µPa), this would only last for a short period while ships pass through the area. The noise would also attenuate to around 120 to 150 dB (re: 1 µPa, Bowles and Graves, 2007).

16.2.2 Marine species

Despite the levels of ambient underwater, there are various noise-sensitive marine mammals that (potentially) occur in Botany Bay. Chapter 10 (Marine biodiversity) lists these species. Table 16-1 lists those species that are considered noise sensitive.

Table 16-1: Listed threatened/protected noise sensitive species

Group	Species
Cetaceans	Humpback whales Southern right whales
Sirenians	Dugong
Otariids	Australian fur seals New Zealand fur seals
Sea Turtles	Green sea turtles Loggerhead turtle
Fish	Black Rockcod Sygnathiformes (pipefish, sea horses and sea dragons)
Sharks	Grey nurse sharks
Birds	Wandering and diving birds including various species of albatross Little blue penguin
Invertebrates	Calamari squid Crayfish

16.2.3 Human swimmers and divers

People swim, dive, recreationally/spear fish, snorkel, boat, kite surf, and carry out water sports (see Chapter 14 (Socioeconomic)). Most activity takes place close to the shore in and around: Congwong Beach; Frenchmans Beach; Yarra Bay at La Perouse; and Silver Beach at Kurnell.

16.3 Noise sources and criteria

The project would generate impulsive and non-impulsive underwater noise. Impulsive noise would be generated from piling works during construction while construction vessel movements and the operational ferries would generate non-impulsive noise. It would take around eight months to pile the wharf foundations. Construction vessels would be used for about 13 months. During operation, ferries would travel between both wharves once every 30 minutes.

16.3.1 Marine species

The literature referenced in section 4.1.1 of Appendix P (Underwater Noise Assessment) includes threshold limits above which there is the potential for marine species to be impacted by underwater noise. These limits define when species may:

- Display behavioural changes or avoid noise-impacted areas
- Have their hearing temporarily or permanently impacted
- Be injured or die.

Marine species are typically more severely affected when they are closer to a noise source. Also, impulsive noise sources can cause something known as 'acoustic shock'. This can cause greater damage than a continuous or non-impulsive noise source.

Table 16-2 summarises the sound and peak pressure levels that were adopted to assess underwater noise impacts. They are taken from the literature in Appendix P (Underwater Noise Assessment) and show the lowest level that could cause an impact response in any of the species in Table 16-1 and/or humans. Appendix P (Underwater Noise Assessment) provides the full list of data for each species. Certain values are weighted. This considers (weights) the frequency of the noise, as certain species are more sensitive to certain noise frequencies.

Table 16-2: Weighted sound and peak pressure levels

Impacts	Impulsive (from piling)	Non-impulsive (from vessels)
Behavioural response	120 SPL[1]	120 SPL
Temporary hearing loss	140 SEL[2]	153 SEL
Permanent hearing loss	155 SEL	173 SEL
Recoverable injury	190 SPL	170 $SPL_{48hours}$

[1]SPL | sound pressure level, [2]SEL | sound exposure level

16.3.2 Humans

Table 16-3 summarises the effects of underwater sound on humans from sources in the literature. This identifies that divers may be affected by the noise up to 170 dB. Above 184dB there is the risk of physical damage.

Table 16-3: Effects of underwater sound on humans

Received sound power level (dB)	Effect Source: Parvin, 2005
>184	Liver haemorrhage and soft tissue damage likely*
>170	Tolerance level for divers and swimmers. Sound causes lung and body vibration
148-157	The loudness and vibration levels become increasingly aversive. Some divers will contemplate aborting an open water dive.
140-148	A small number of divers rate the sound as "very severe"
136-140	The sound is clearly audible. Most divers tolerate the sound well with only "slight" aversion
130	Divers and swimmers able to detect body vibration
80-100	Auditory threshold

*Based on extrapolation from animal models of pressure-induced damage.

16.3.3 Modelling criteria

Appendix P (Underwater Noise Assessment) details the modelling approach, criteria, assumptions, and limitations.

Underwater noise modelling

Modelling was carried out to assess how underwater noise would disperse during construction and operation due to piling and vessel movements. As noise propagation (dispersion) is affected by water depth (bathymetry), water density, and the composition of the marine sediments, these factors were included in the model.

Three source locations were used to carry out the underwater noise modelling. One at each proposed wharf location to assess piling and vessel noise impacts, and one in the middle of the two headlands to assess vessel movement impacts between both sites during construction and operation.

Piling noise levels

As the exact piling method has not been confirmed a conservative approach was applied based on data presented in Buehler *et al.*, 2015 where a pile may be struck up to 600 times. Table 16-4 lists the adopted exposure and pressure levels used in the underwater noise assessment.

Table 16-4: Piling source levels for the project

Metric	Source level for 0.9 m diameter pile (re: dB 1 µPa)
Sound exposure level from one strike	206
Sound pressure level from multiple strikes	222
Peak pressure	232

Note: cumulative exposure is measured to a reference of re 1 μPa^2-s

Vessel noise levels

The following cumulative sound exposure levels (referenced to 1 μPa^2-s) were adopted based on a literature review described in Appendix B of Appendix P (Underwater Noise Assessment).

- Commercial shipping 209 dB
- Construction vessels 199 dB
- Ferries 207 dB.

16.4 Assessment of potential impacts

The following sections summarise the predicted underwater noise impacts during construction and operation.

Despite there being acknowledgement around certain species being impacted by underwater noise, the science is not sophisticated enough to reliably determine threshold levels. Appendix P (Underwater Noise Assessment) provides detail around these limitations. For that reason, the assessment focuses on those impacts that can be reliably modelled and assessed. Because the modelling, impact assessment and mitigation is conservative and adopts precaution, the literature suggests that it would protect all noise-sensitive species.

16.4.1 Construction impacts

The following section reports the unweighted model predicted noise levels. The tables show the unweighted sound (and peak) pressures levels at set distances from the piling/vessels and the exposure levels (the amount of energy) at the same set distances. The tables report the results out to one kilometre.

Appendix E of Appendix P (Underwater Noise Assessment) confirms the modelled extent of the impacts, which extend out to 2.25 kilometres in some instances. The existing background noise levels would reduce this predicted zone of impact. Section 16.1.1 summarises the likely predicted impacts.

Shading has been used to show the predicted worst-case impact where:

- Green shading shows the potential for behavioural impacts.
- Light orange shading shows the potential for temporary hearing loss.
- Dark orange shading shows the potential for permanent hearing loss.

The predicted impacted species are also listed. They do not directly relate to the shading. They are provided to help simplify the reporting.

Piling

Table 16-5 shows the predicted maximum unweighted underwater noise levels at fixed distances from where the wharf piles would be installed. Appendix G of Appendix P (Underwater Noise Assessment) shows graphs of the predicted piling noise levels.

Table 16-5: Maximum unweighted underwater noise levels from piling

Metrics	Maximum noise level (dB) at specified distances from pile				
	50 m	100 m	300 m	500 m	1 km
Sound Pressure Level (single strike)					
La Perouse	200	195	187	184	181
Kurnell	199	195	187	184	181
Model predicted impacts: ***Behavioural response*** | marine mammals, sea turtles, diving birds and humans.					
Peak Pressure Level (single strike)					
La Perouse	210	205	197	194	191
Kurnell	209	205	197	194	191
Model predicted impacts: ***Permanent hearing loss*** | (high frequency) cetaceans, sea turtles, fish and sharks					
Sound Exposure Level (single strike)					
La Perouse	184	179	171	168	165
Kurnell	183	179	171	168	165
Model predicted impacts: ***Temporary hearing loss*** | (low frequency) cetaceans					
Sound Exposure Level (cumulative strikes)					
La Perouse	214	208	201	198	195
Kurnell	210	206	198	196	193
Model-predicted impacts: ***Permanent hearing loss*** | (low and high frequency) cetaceans, dugong, sea turtles, fish, sharks, and diving birds. ***Temporary hearing loss* |** (mid frequency) cetaceans, and seals.					

Construction vessels

Table 16-6 shows the predicted maximum unweighted underwater noise levels at fixed distances from where the construction vessels would be used. Appendix G of Appendix P (Underwater Noise Assessment) shows graphs of the predicted piling noise levels.

Table 16-6: Maximum unweighted underwater noise levels from the construction vessels

Metrics	Maximum noise level (dB) at specified distances from pile				
	50 m	100 m	300 m	500 m	1 km
Sound Pressure Level					
La Perouse	137	133	129	127	124
Kurnell	136	133	128	126	124
Model-predicted impacts: ***Behavioural response*** | marine mammals and diving birds.					
Sound Exposure Level (one vessel)					
La Perouse	171	167	163	161	158
Kurnell	170	167	162	160	158

Human impacts

In terms of humans, they are likely to hear the piling if they are in the water or diving in Botany Bay and no mitigation was introduced. The noise levels will become increasingly uncomfortable for distances closer to the piling to the point where divers are unlikely to wish to remain in the water. Even at levels below the tolerance limit, there is the potential that noise levels may result in indirect safety impacts for divers (particularly for inexperienced divers) if sudden noise levels result in a startle or panic reaction. This highlights the importance of effective community notification of piling and the need for a soft start regime so that noise levels do not suddenly increase.

Within about 300 metres of the works there is the potential for physical injury to anyone in the water if no mitigation was introduced.

16.4.2 Operation

Operational ferries (at the wharves)

Table 16-7 shows the predicted maximum unweighted underwater noise levels at fixed distances from where the ferries would operate near the wharves. Appendix G of Appendix P (Underwater Noise Assessment) shows graphs of the predicted piling noise levels.

Table 16-7: Maximum unweighted underwater noise levels from the operational ferries at the wharves

Metrics	Maximum noise level (dB) at specified distances from pile				
	50 m	100 m	300 m	500 m	1 km
Sound Pressure Level					
La Perouse	145	141	137	135	132
Kurnell	144	141	136	134	132
Model-predicted impacts: ***Behavioural response*** | marine mammals and diving birds.					
Sound Exposure Level (one vessel)					
La Perouse	179	175	171	169	166
Kurnell	178	175	170	168	166

Operational ferries (travelling between the wharves)

Table 16-8 shows the predicted maximum unweighted underwater noise levels at fixed distances from where the ferries would operate between the wharves. Appendix G of Appendix P (Underwater Noise Assessment) shows graphs of the predicted piling noise levels.

Table 16-8: Maximum unweighted underwater noise levels from the ferries operating between the wharves

Metrics	Maximum noise level (dB) at specified distances from pile				
	50 m	100 m	300 m	500 m	1 km
Sound Pressure Level					
In transit	148	143	138	135	132
Model-predicted impacts: ***Behavioural response*** | marine mammals and diving birds.					
Sound Exposure Level (one vessel)					
In transit	182	177	172	169	166

16.4.3 Impact summary

The modelling predicted the following marine species impacts if no mitigation was introduced:

- Behaviour changes would occur because of the piling works and construction vessel and operational ferry movements. The extent of the behavioural changes would depend on the scale and duration of the construction works, the species, the masking effect of other existing noise sources (as these were not included in the modelling), other behavioural pressures (eg presence of food sources, migration routes and how used (habituated) the species would be to noise.
- Temporary hearing loss would only occur between 10 metres and 330 metres when piling (depending on the species). The impact may extend beyond this limit when the animal is continuously exposed to piling noise. In this case the modelling predicts that these impacts could occur up to 2.25 kilometres.
- Permanent hearing loss would occur within 100 metres when piling. The impact may extend beyond this when the animal is continuously exposed to piling noise.
- Injury or death would not occur.

In terms of humans, they are likely to hear the piling if they are in the water or diving in the Bay and no mitigation was introduced. Noise levels are predicted to be uncomfortably loud in most of the Bay during piling works without any mitigation. Within about 300 metres of the works there is the potential for injury to human divers if no mitigation is introduced.

16.5 Environmental management measures

This section describes how the underwater noise impacts would be managed.

The guidelines in Chapter 3 of Appendix P (Underwater Noise Assessment) have been used to define three zones to reduce underwater noise impacts.

- **Zone 1** | where work should stop.
- **Zone 2** | where work-restrictions (exclusions) should be introduced.
- **Zone 3** | where spotters would observe for noise-sensitive species entering the area.

The zones can only be confirmed once the final construction method is known and onsite monitoring is carried out to verify the noise propagation. This is to overcome the limitations in the modelling described in section 16.1 above. The proposed zones below account for this uncertainty meaning they are conservative.

The proposed 75 metre marine exclusion zone around the piling works would limit the risk of underwater noise impacts on humans in the water or diving. While there may still be the potential for impacts outside of this zone, these can be likely managed using mitigation.

Therefore, it should be possible reduce the zones and manage human impacts by introducing the measures listed in Table 16-9 below.

Table 16-9: Environmental management measures for underwater noise

Impact	ID	Environmental management measure	Responsibility	Timing
Construction underwater noise management	UN1	Underwater noise management measures will be included as part of a Construction Noise and Vibration Management Plan (CNVMP). The CNVMP will include: a. Identification of potential significant underwater noise and vibration generating activities b. Management measures that will be guided by section 5 of the SA Underwater Piling Noise Guidelines	Contractor	Pre-construction and construction

Impact	ID	Environmental management measure	Responsibility	Timing
		(Government of South Australia, 2012). This will include: • Investigating the use bubble curtains to reduce the severity of the energy of the sounds caused by the driving of the piles. • Carrying out observations for 30 minutes before starting work in all zones. • A slow-start process for the piling works that would last for 10 minutes. • Implement a stand-by and shut down process. • Prepare and maintain a compliance and siting report while piling takes place. • Notify the recreational user groups in the area and post notices at the key beaches warning people of the ongoing piling works so that can expect potential underwater noise. • Aim to avoid piling on weekends and during public holidays.		
Underwater noise impacts on humans	UN2	Public communication, including website updates and notices at the project areas, will be carried out before any piling starts. This will be included as part of the CLIP.	Contractor	Pre-construction and construction
Underwater noise impacts on marine fauna	UN3	Underwater noise monitoring may be carried out before the main construction works starts. This will be used to define three zones in accordance with section 5.2 of the Underwater Piling Noise Guidelines (Government of South Australia, 2012): • Zone 1: stop work • Zone 2: introduce work restrictions • Zone 3: use marine spotters. A specialist marine spotter will be responsible for observing and implementing the three zones during piling activities.	Contractor	Construction