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Resonate

Boskalis Cambridge Gulf Marine Sand Proposal

Sand Production Vessel – Underwater Noise Assessment

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Glossary

AHD	Australian Height Datum
Ambient sound	Sound that would be present in the absence of a specified activity. Ambient sound can be anthropogenic (e.g. industrial or shipping) or natural (e.g. wind, biota).
Auditory frequency weighting	The process of band-pass filtering sounds to reduce the importance of inaudible or less-audible frequencies for individual species or groups of species of aquatic mammals. In other terms, a frequency weighting function that compensates for a species' (or functional hearing group's) frequency-specific hearing sensitivity.
AUD INJ	Damage to the inner ear that can result in destruction of tissue, such as the loss of cochlear neuron synapses or auditory neuropathy (Houser 2021; Finneran 2024). Auditory injury may or may not result in a permanent threshold shift (PTS).
dB	Decibel—a unit of measurement used to express sound level. Decibels express the ratio of sound relative to a reference level on a logarithmic scale. For airborne noise the reference level is 20 µPa, while for underwater noise the reference level is typically 1 µPa.
dBpeak	Peak sound pressure over the measurement period, expressed in dB re 1 µPa.
dBrms	Root mean square sound pressure over the measurement period, expressed in dB re 1 µPa.
CG	Cambridge Gulf
Frequency (Hz)	The number of times a vibrating object oscillates (moves back and forth) in one second. Fast movements produce high frequency sound (high pitch/tone), but slow movements mean the frequency (pitch/tone) is low. 1 Hz is equal to 1 cycle per second.
Hearing group	Category of animal species when classified according to their hearing sensitivity and to the susceptibility to sound. Examples for marine mammals include low-frequency (LF) cetaceans, high-frequency (HF) cetaceans, very high-frequency (VHF) cetaceans, otariid pinnipeds in water (OPW), phocid pinnipeds in water (PPW), sirenians (SI), other marine carnivores in air (OCA), and other marine carnivores in water (OCW). (Southall et al. 2019).
Hearing threshold	The hearing threshold represents the lowest signal level an animal can detect at a particular frequency, usually referred (and measured) as the threshold at which an animal will indicate detection 50% of the time.
HF	High frequency cetaceans hearing group.
Impulsive sound	Transient sound that has extremely short duration and a high peak sound pressure level.
LF	Low frequency cetaceans hearing group.

MFO Level 1	Marine Fauna Observer, Level 1. A person with qualifications in ecology, zoology or environmental sciences and demonstrated experience with the identification and management of dolphins or whales, including behaviour, as well as distance estimation (DIT 2023).
MFO Level 2	Marine Fauna Observer, Level 2. A person who has sufficient experience in marine fauna identification and distance estimation (DIT 2023).
MSL	Mean Sea Level.
Noise source	Premises, place or a vessel at which an activity is undertaken, or a machine or device is operated, resulting in the emission of noise.
OCA	Other carnivores in air hearing group.
OCW	Other carnivores in water hearing group.
OPW	Otariid pinnipeds in water hearing group.
One-third (1/3rd) octave band	The whole frequency range can be divided into a set of frequencies called bands. A One-Third Octave band is defined as a frequency band whose upper limit of the band is the lower limit of the band times cube root of two.
POA	Proposed area of operation
PPW	Phocid pinnipeds in water hearing group.
PTS	Permanent threshold shift (PTS) is a permanent reduction in hearing sensitivity caused by irreversible damage to the sensory hair cells of the ear.
SEL	Level of the sound exposure as defined in ISO 18405. In underwater acoustics, the reference value of time-integrated squared sound pressure is 1 μPa^2 s.
$SEL_{24\ hour}$	The cumulative sound exposure level, which includes multiple acoustic pulses from piling or the time duration of dredging within a 24 hour period. It is also assumed for intermittent, repeated exposure that there is no recovery between subsequent exposures.
SI	Sirenians hearing group.
Source level	Source level (SL) is the sound pressure level at a distance of 1 m from a hypothetical point source radiating the same amount of sound energy as the actual source. Units: dB re 1 μPa^2·m^2 (sound pressure level), dB re 1 μPa^2·m^2 s (sound exposure level).
SPL	Sound pressure level (SPL) is the root-mean-square sound pressure expressed in the decibel (dB) scale. Units: dB re 1 μPa^2 (underwater), dB re 20 μPa (air).
SPV	Sand production vehicle
TSHD	Trailing suction hopper dredger

TTS	Temporary threshold shift (TTS) is a temporary reduction in hearing sensitivity as a result of exposure to sound. Exposure to high levels of sound over relatively short time periods can cause the same amount of TTS as exposure to lower levels of sound over longer time periods. The duration of TTS varies depending on the nature of the stimulus.
TU	Marine turtle auditory frequency weighting
VHF	Very high frequency cetaceans hearing group.
Water Level	Positive or negative values indicate that the water level is above or below the mean sea level (MSL)

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1 Executive Summary

This report presents the results of an underwater noise assessment for proposed marine sand-sourcing and export activities using a Sand Production Vessel (SPV) based on a large Trailor Suction Hopper Dredger (TSHD) concept, in Cambridge Gulf (CG), Western Australia (WA). The assessment was conducted as part of the environmental assessment for Boskalis Australia Pty Ltd's proposed operations, in response to a request by the WA Environmental Protection Authority (EPA).

The analysis considers underwater noise emissions from three primary SPV activity types:

- Sand loading (with the expected controlling sound sources being the main engine, propeller, underwater pump and drag head),
- Sand loading with bow thruster operation at transect ends (sound sources being as per sand loading plus bow thruster use at transect ends); and
- Vessel transits into and out of CG via West Entrance (west of Lacrosse Island) (with the expected controlling sound sources being the main engine and propeller).

It has been advised that the bow thrusters might not be fitted, so this scenario has been included as a potential option.

Acoustic modelling was undertaken using the dBSea software to estimate received noise levels and assess the potential for auditory injury and behavioural disturbance in three key target species of marine fauna: two high-frequency cetaceans; specifically the snubfin dolphin (*Orcaella heinshoni*) and humpback dolphin (*Sousa sahulensis*); and the flatback turtle (*Natator depressus*). Impact thresholds were based on guidelines published by the United States National Oceanographic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS) (NMFS 2024a, b & c), as requested by the WA EPA.

The model considered key environmental effects including the sound absorption of the seabed and water, the effect of the currents, and the bathymetry. The sound absorption of the water in CG was found to be moderately high due to the high pH and very high suspended solids concentrations.

1.1 Key findings

Sand loading:

- Predicted threshold onset distances for potential <u>auditory injury</u> in the two target dolphin species were up to <40 m from the SPV.
- Predicted threshold onset distances for potential <u>temporary threshold shift</u> in the two target dolphin species were up to 120 m from the SPV.
- Predicted threshold onset distances for potential <u>behavioural responses</u> in the two target dolphin species were up to 3.5 km from the SPV.
- Predicted threshold onset distances for potential <u>permanent threshold shift</u> in flatback turtles were <40 m from the SPV.
- Predicted threshold onset distances for potential <u>temporary threshold shift</u> in flatback turtles were up to 120 m from the SPV.
- Predicted threshold onset distances for potential <u>behavioural responses</u> in flatback turtles were up to <40 m from the SPV.

Sand loading with bow thruster used at transect ends:

- Predicted threshold onset distances for potential <u>auditory injury</u> in the two target dolphin species were <40 m from the SPV.
- Predicted threshold onset distances for potential <u>temporary threshold shift</u> in the two target dolphin species were up to 160 m from the SPV.

- Predicted threshold onset distances for potential behavioural responses in the two target dolphin species were up to 3.8 km from the SPV.
- Predicted threshold onset distances for potential permanent threshold shift in flatback turtles were up to 160 m from the SPV.
- Predicted threshold onset distances for potential temporary threshold shift in flatback turtles were up to 80 m from the SPV.
- Predicted threshold onset distances for potential behavioural responses in flatback turtles were up to 320 m from the SPV.

SPV Transit (in and out of CG via West Entrance):

- Predicted threshold onset distances for potential auditory injury in the two target dolphin species were up to <40 m from the SPV.
- Predicted threshold onset distances for potential temporary threshold shift in the two target dolphin species were up to 80 m from the SPV.
- Predicted threshold onset distances for potential behavioural responses in the two target dolphin species were up to 2.6 km from the SPV.
- Predicted threshold onset distances for potential permanent threshold shift in flatback turtles were up to <40 m from the SPV.
- Predicted threshold onset distances for potential temporary threshold shift in flatback turtles were up to 80 m from the SPV.
- Predicted threshold onset distances for potential behavioural responses in flatback turtles were up to <40 m from the SPV.

Flatback turtle nesting sites:

- All known turtle nesting sites are well beyond the predicted behavioural threshold distances, with the closest site to the Proposed Operational Area (POA) (Lacrosse Island) being more than 50 dB below the response threshold
- Furthermore, the predicted potential for permanent threshold shift or temporary threshold shift in flatback turtles is negligible given that the predicted level is 53 dB and 33 dB below the threshold onset level respectively.

Based on the modelling with conservative assumptions, and the application of a risk assessment approach, the risk of significant impact on marine fauna is considered negligible. No additional mitigation measures are recommended beyond standard marine fauna observation and avoidance protocols, as routinely applied to similar operations across Australian coastal waters, as a precautionary approach. Monitoring is recommended to ensure the assumptions used in this assessment remain valid.

2 Introduction

2.1 Background

Boskalis Australia Pty Ltd (BKA) is proposing to develop a marine sand-sourcing and export operation in Cambridge Gulf (CG) near Wyndham in the north-east of Western Australia (WA) (Figure 1). The proposed operation will use a single Sand Production Vessel (SPV) based on the design principles of a very large Trailer Suction Hopper Dredger (TSHD), with a single suction arm and drag-head. Specifications for the SPV are listed in Section 5.

As an environmentally responsible company with stringent corporate environmental and social policies and procedures, BKA has undertaken a comprehensive set of environmental studies and stakeholder consultation. Furthermore, BKA have self-referred the proposal to the WA EPA under Section 38 of the WA Environmental Protection Act (EP Act) in September 2024, and to the Commonwealth under the Environment Protection & Biodiversity Conservation Act (EPBC Act) in January 2025.

There are known to be small numbers of Australian snubfin dolphins (*Orcaella heinshoni*) and Australian humpback dolphins (*Sousa sahulensis*) in CG and there are five flatback turtle (*Natator depressus*) nesting sites located in the general CG area (mainly on seaward coasts outside of CG). BKA is placing a high priority on ensuring that the proposed sand-sourcing operation does not result in unacceptable impacts on these species, including potential impacts from underwater noise emissions from the SPV.

In response to BKA's referral, the WA EPA has determined that the proposal will be assessed under the Environmental Protection Act (EP Act) and has issued an additional Request for Information (RFI), which includes a requirement for modelling underwater noise emissions from the SPV as outlined in Section 3 of this report.

To address this requirement, BKA engaged Resonate Consultants to undertake the underwater noise assessment presented herein.

2.2 General Description of the Proposed Operation

Key facts relating to the proposed operation include:

- **Project lifespan**: Up to 15 years from commencement of operations.
- **Zero coastal or land-based development**: The proposal does not involve the construction and operation of any shore-based facilities and does not involve the alteration of the coastline in any way. It will be an entirely vessel-based operation.
- **Marine area**: The proposed operational area (POA) is located in the central part of the main body of CG where there is a significant seabed sand resource, covering an area of ~100 km^2 as shown on Figure 1. Water depths within the area average -25 m MSL. The seabed within and around the POA comprises highly-dynamic sand-waves with very little biota and no significant benthic communities, due to the constantly moving substrate, strong tidal currents (>2 m/s), constantly high suspended sediments and permanent lack of benthic light.
- **Single vessel**: The proposed operation will involve a SPV based generally on the design of a large TSHD. It will be an internationally-registered vessel subject to all relevant regulatory requirements of the International Maritime Organization (IMO) and the Australian Maritime Safety Authority (AMSA). While the design is conceptual, indicative specifications are Length Overall (LoA) of ~350 m, draft of ~19 m, sand capacity 75,000 m^3 to 135,000 m^3 and crew of ~25. There will be no refuelling or waste discharges in CG.
- **Zero activity in CG for 86% of time**: The SPV will self-load sand in CG for one to two days every two weeks. It will then sail to the sand delivery port in Asia and return to CG two weeks later to repeat the cycle. This means that the SPV will only operate in CG for 52 days per year, or 14% of the time. There will be zero operational activity in CG for 86% of the time during the project's lifespan of up to 15 years.

- **Sand volumes**: Exploration surveys indicate that there is a minimum of 300 million m^3 of sand in the POA and likely several times more. There are several orders of magnitude higher volumes of sand throughout CG overall. It is proposed to export up to 70 million m^3 of sand. This is a maximum of only 23% of the minimum volume of 300 million m^3 of sand estimated to occur in the POA, and a much smaller % of the volume of sand that occurs throughout CG overall. A minimum of 230 million m^3 or 77% of the minimum existing sand resource in the POA will be left in the POA, and likely more.
- **Low footprint each loading cycle**: During each one- to two-day sand loading cycle, the SPV will work over an area of ~0.5 km^2 within the POA, with a drag-head width of ~6 m. The SPV will remove a layer of approximately 40 cm of sand from the seabed during each loading cycle.
- **End of project seabed condition**: At the end of the 15-year project timeframe, if the proposed 70 million m^3 of sand is exported, the area within the POA will be on average <1 m deeper than the pre-project seabed. It will still comprise sand with similar seabed morphology, dynamics and habitat features as before sand sourcing.

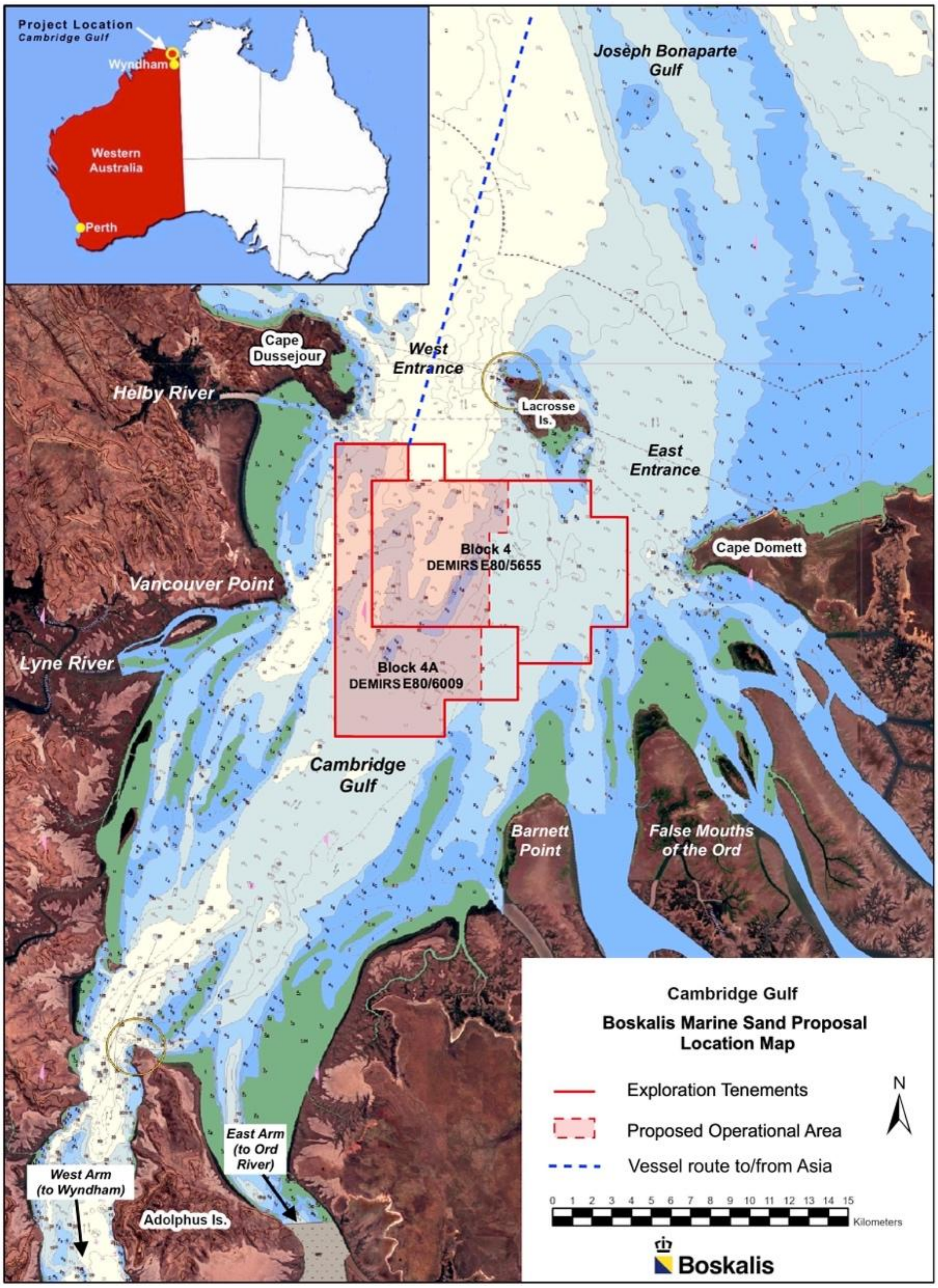


Figure 1 Location of the proposal in Cambridge Gulf near Wyndham in the northeast of Western Australia.

3 Study objective and tasks

3.1 Objective

The overall objective of the study is to address the EPA's RFI which states:

Undertake underwater noise modelling and include discussion of the results in the context of the proposal that includes an assessment of:

- *All vessel noise (e.g. includes noise generated from the dynamic positioning system) to confidently assess the potential impacts of noise on marine fauna. The impact assessment should include potential impacts to marine fauna behaviour along with potential risks of temporary and permanent injury.*
- *The evaluation of impacts and subsequent monitoring and management which will be undertaken in particular for the listed species know to occur within Cambridge Gulf, including but not limited to consideration of sensitive ecological periods for marine fauna.*
- *Please ensure the underwater noise assessment is consistent with the updated Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 3.0) (NMFS 2024).*

Note that BKA have advised that the SPV will not be equipped with a dynamic positioning system, so that element of the RFI is not relevant and is thus not included in the assessment. The SPV's underwater sound sources are described in Section 5.3.

3.2 Tasks

To achieve this objective, the assessment was undertaken in accordance with the following two tasks.

Task 1 – Underwater Noise Modelling

Model predicted underwater noise emissions from the SPV (engine, other on-board machinery, propeller, bow thruster, suction arm and pumps, individually and combined). This will include:

- Predicting (as relevant) Source Level (SLs), Sound Pressure Level (SPL), Propagation Loss (PL) and Received Level (RL) for each of the listed sound sources and all sound sources combined, using relevant, internationally accepted measures and units for each of SL, SPL, PL and RL, that also relate to and enable the assessment of potential impacts on the target species under Task 2 - i.e. for each target species, as relevant, the:
  - temporary threshold shift (TTS),
  - permanent threshold shift (PTS),
  - auditory injury (AUD-INJ) onset criteria,
  - weighted SEL_{24hr}
  - harassment and behavioural acoustic thresholds.
- Mapping contours of sound propagation, dispersion and attenuation distances from the SPV at representative source (considering environmental conditions including bathymetry, very high natural suspended sediment loads and very high current velocities in the area).

Task 2 – Impact Assessment

Use the modelled underwater noise predictions from Task 1 to assess potential impacts of the modelled noise on the listed target species, in accordance with the US NOAA NMFS guidelines, including:

- Potential temporary and permanent hearing injury, including assessment of the modelled underwater noise emissions against the TTS, PTS, AUD-INJ onset criteria and weighted SEL_{24hr} for each target species, as outlined in the US NOAA NMFS guidelines.
- Potential behavioural changes, using the NOAA NMFS harassment and behavioural acoustic thresholds for marine mammals and marine turtles.

- Considering what is known about the audiograms, sound profiles and repertoires and sound sensitivities of these species and their close relatives (same genus or family) from the literature (no new field work).

4 Target Species

4.1 General species descriptions and presence in Cambridge Gulf

This section provides an overview of the three target species that are the subject of this assessment as communicated between the WA EPA and BKA.

4.1.1 Australian Snubfin Dolphin

- IUCN status: Vulnerable
- Commonwealth EPBC Act: Not listed as threatened. Protected as a marine mammal and migratory species (= Matter of National Environmental Significance MNES).
- WA Biodiversity Conservation Act: Migratory. Priority 4 = Rare, Near Threatened and other species in need of monitoring.

The Australian snubfin dolphin (*Orcaella heinshoni*) inhabits turbid inshore waters, bays and estuaries such as CG. The Commonwealth has designated a breeding, calving, foraging and resting Biologically Important Area (BIA) for this species over CG.

The presence of small numbers of snubfin dolphins in CG is clearly established, including through surveys by Brown et al. (2016 & 2017), BKA's Marine Mega-fauna Surveys (MMF) surveys in July 2023 and February 2024 and anecdotal reports from relevant stakeholders that were consulted. Individuals that have been sighted in CG appear to be part of a population that is present in the broader area of Joseph Bonaparte Gulf (JBG) located immediately offshore from CG, and along the coasts to the west and east of CG (Brown et al. 2016 & 2017).

As part of broader environmental assessment studies, BKA commissioned comprehensive marine mega-fauna (MMF) surveys in CG in the northern summer wet season (February 2024) and in the winter dry-season (July 2023), using standardised vessel-based MMF survey methods supported by aerial drones (BKA 2024a). The February 2024 survey ran for nine-days and covered over 800 km of transects throughout CG, supported by 20-days of incidental observations, which together recorded four sightings of snubfin dolphins in CG, including two sightings in the POA. The July 2023 survey ran for eight-days and also covered over 800 km of transects, also supported by 20-days of incidental observations, which together recorded 11 sightings in CG, including three sightings in the POA. In both surveys most sightings were in the southern part of CG towards and around Adolphus Island, which is 20 km south of the closest (southern) boundary of the POA (BKA 2024a).

The main local commercial fisherman who has over 20-years of experience working in CG, confirmed that snubfin dolphins are mostly seen near and around Adolphus Island (Douglas pers comms 2024). This may be where their preferred food source is located – small fish, crustaceans and cephalopods (Marshe et al. 1989). However, as there were two and three sightings in the POA in BKA's 2024 and 2023 surveys respectively, they do appear to pass through this area.

A nine-day survey over a much larger area than CG in August 2016 by Brown et al. (2016) recorded 34 sightings, mainly near Cape Dussejour and outside of CG in JBG and along the coast to the west of CG, and none in the POA. The number of sightings cannot be directly compared to the BKA surveys as in addition to CG, they also surveyed out into JBG and 50 km westward along the coast to the Berkley River and up that river.

It should be noted that for all surveys, different sightings could possibly be the same individual(s), so the actual number of dolphins may be less than the number of sightings. Positive, photographic identification of two separate individuals was obtained in the February 2024 survey and none in the July 2023 survey (BKA 2024a), and six by Brown et al. (2016 & 2017) (noting that, that survey extended out into JBG and 50 km westwards along the coast and up the Berkely River). This indicates that the population of snubfin dolphins within CG could be in the order of less than 10 individuals or a few tens at most. These numbers are extremely low compared to other sites such as Roebuck Bay at Broome with an estimated population of ~130 Snubfin Dolphins (DBCA 2025), and other areas with higher numbers such as Cone Bay and Cygnet Bay in the West Kimberley (Brown et al. 2016). This may be reflective of the extreme environmental conditions in CG, which may not be as suitable for this species as the areas further west, where waters are less turbid and food sources more abundant (Brown et al. 2016).

4.1.2 Australian Humpback Dolphin

- IUCN status: Vulnerable
- Commonwealth EPBC Act: Not listed as threatened. Protected as marine mammal and migratory species (= MNES).
- WA Biodiversity Conservation Act: Migratory. Priority 4 = Rare, Near Threatened and other species in need of monitoring.

Like snubfin dolphins, the Australian humpback dolphin (*Sousa sahulensis*) also inhabits turbid inshore waters, and CG is within their overall geographical range. BKA's survey in February 2024 recorded one sighting just to the north of the POA, towards Cape Dussejour, and the survey in July 2023 had no sightings (BKA 2024a). The broader-area survey in August 2016 by Brown et al. (2016) recorded 42 sightings, mostly near Cape Dussejour and outside and to the west of CG, and none in the POA. There is an area of expansive inter-tidal sand-banks along the coast just south of Cape Dussejour, and humpback dolphins are known to target such areas for feeding (Parra & Jefferson 2017). This may be why most sightings have been in that area.

As above, for all surveys different sightings could possibly be the same individual(s), so the actual number of dolphins may be less than the number of sightings. These numbers are quite low considering that typical local area population sizes for humpback dolphins average ~50 to 90 individuals (Parra & Cagnazzi 2016).

4.1.3 Flatback Turtle

- IUCN status: Data deficient.
- Commonwealth EPBC Act: Vulnerable. Protected as marine species and migratory species (= MNES).
- WA Biodiversity Conservation Act: Vulnerable.

The flatback turtle is endemic to northern Australian waters with sightings reported in south-eastern Indonesia and Papua New Guinea. As outlined in Section 1 above, there are five flatback turtle nesting sites located in the general CG area, as shown on Figure 1. The main nesting beach is the Cape Domett Seaward Beach located east of Cape Domett, as surveyed by Whiting et al. (2008).

The WA Department of Biodiversity Conservation & Attractions (DBCA) has been undertaking annual surveys of nesting at the Cape Domett Seaward Beach since 2012, and the results from these surveys are presented in Price & Raaymakers (2024). In summary, the 10-years of DBCA data analysed by Price & Raaymakers (2024) indicate that:

- Over the ten-year period; a total of 130 nights were surveyed, the average number of nights surveyed annually was 13; a total of 6,270 track sets were counted, the average number of track sets counted per survey was 627; a total of 858 hatched nests were counted, the average number of hatched nests counted per survey was 85.7; a total of 84 predated nests were counted, and the average number of predated nests counted per survey was 8.4.
- This data supports earlier, more comprehensive studies by Whiting et al. (2008) which found that Cape Domett is a significant nesting site for flatback turtles. In addition, evidence of nesting by Green Turtles was counted on 12 occasions over 7 years within the ten-year period, equating to an average of 1.7 per year, indicating that Cape Domett is not a significant nesting site for this species.
- Because there were differences in the number of survey nights between years it is not possible to directly compare total observations between years. Mean overnight track count, mean overnight hatching nest count and mean overnight predated nest count were therefore applied to the ten-years of data.

- For mean overnight track counts there is no obvious linear trend over the 10-year period with similar counts year-to-year. The highest mean overnight track count of 63.4 in 2021 compares to 70.8 to 73.7 from Whiting et al. (2008), further indicating no significant changes over time.
- For mean overnight hatched-nest counts for each annual survey 2013 to 2022 inclusive and shows no obvious linear trend over the 10-year period, however mean overnight hatched-nests spiked in 2015 and even more in 2019 and 2021 compared to other years, with dips before and after those three high years.
- Most nesting occurs towards the eastern end of the Cape Domett Seaward Beach, although there are some years such as 2018 and 2021 where some sectors further west had higher numbers.
- Overall, despite some minor limitations in the data, it appears that generally, flatback turtle nesting numbers at Cape Domett Seaward Beach may not have changed significantly since the surveys by Whiting et al. (2008), although more rigorous data collection and analysis would be required to confirm this.

BKA commissioned aerial drone video surveys of the five turtle nesting sites in both the dry-season (July-August 2023) and wet-season (February 2024), and the aerial videos were assessed to map and count any identifiable turtle nesting tracks and nests. The results for the dry-season surveys (near peak nesting season) are shown in Table 1. The results for the wet season survey were a single set of tracks at the Cape Domett Seaward Beach (BKA 2024a).

BKA also commissioned boat-based marine mega-fauna (MMF) surveys of the CG area in both the dry-season (July-August 2023) and wet-season (February 2024). These each covered over 800 km of transects over eight to nine days with two dedicated, trained MMF observers, supported by aerial drones and an additional 20-days of incidental observations during each period. On-water sightings of marine turtles were extremely low as follows. Refer BKA 2024a for details:

Dry-season:

- Flatback turtle: 6 (all outside the POA)
- Green turtle: 1 (outside CG in Joseph Bonaparte Gulf to west)
- Unidentified turtle: 7 (all outside the POA except 1 in south part of POA)

Wet-season:

Unidentified turtle: 2 (1 in POA)

Given the importance of Cape Domett and nearby beaches for nesting, the Commonwealth has designated a Biologically Important Area (BIA) for inter-nesting habitat for flatback turtles, within a 60 km radius around Cape Domett and Lacrosse Island. Inter-nesting areas are where turtles rest on the seabed between nesting attempts to regain energy for the next nesting attempt. The inter-nesting BIA extends into CG and thus overlaps BKA's POA. The 60 km radius is an arbitrary designation and BKA's assessment is that it would be difficult for any flatback to 'rest' on the seabed inside CG, as there are tidal currents up to 4 knots.

Given the extreme currents in CG and the extremely low numbers of turtles observed within CG itself, during both dedicated marine fauna surveys and incidental observations, including near peak nesting season, it seems more likely that they go straight offshore from the beaches into the more hospitable waters of the inner Joseph Bonaparte Gulf for inter-nesting (BKA 2024b).

Table 1: Turtle nest and track counts from aerial drone surveys in CG in July 2023 (BKA 2024b)

Site	Beach Length (km)	No. Track Sets	No. Nests	Likely Species[(1)]
1. Cape Domett Seaward Beach	1.9	449	190	Flatback
1A. Cape Domett Small Beach	0.4	7	7	"

Site	Beach Length (km)	No. Track Sets	No. Nests	Likely Species[(1)]
2. Turtle Beach West (W of Cape Dussejour)	3	34	28	“
3. Turtle Bay (Lacrosse Island)	0.3	6	6	“
4. Barnett Point	2.9[(2)]	82	13	“

(1) Based on track characteristics.

(2) Approx. only. Separate sections combined.

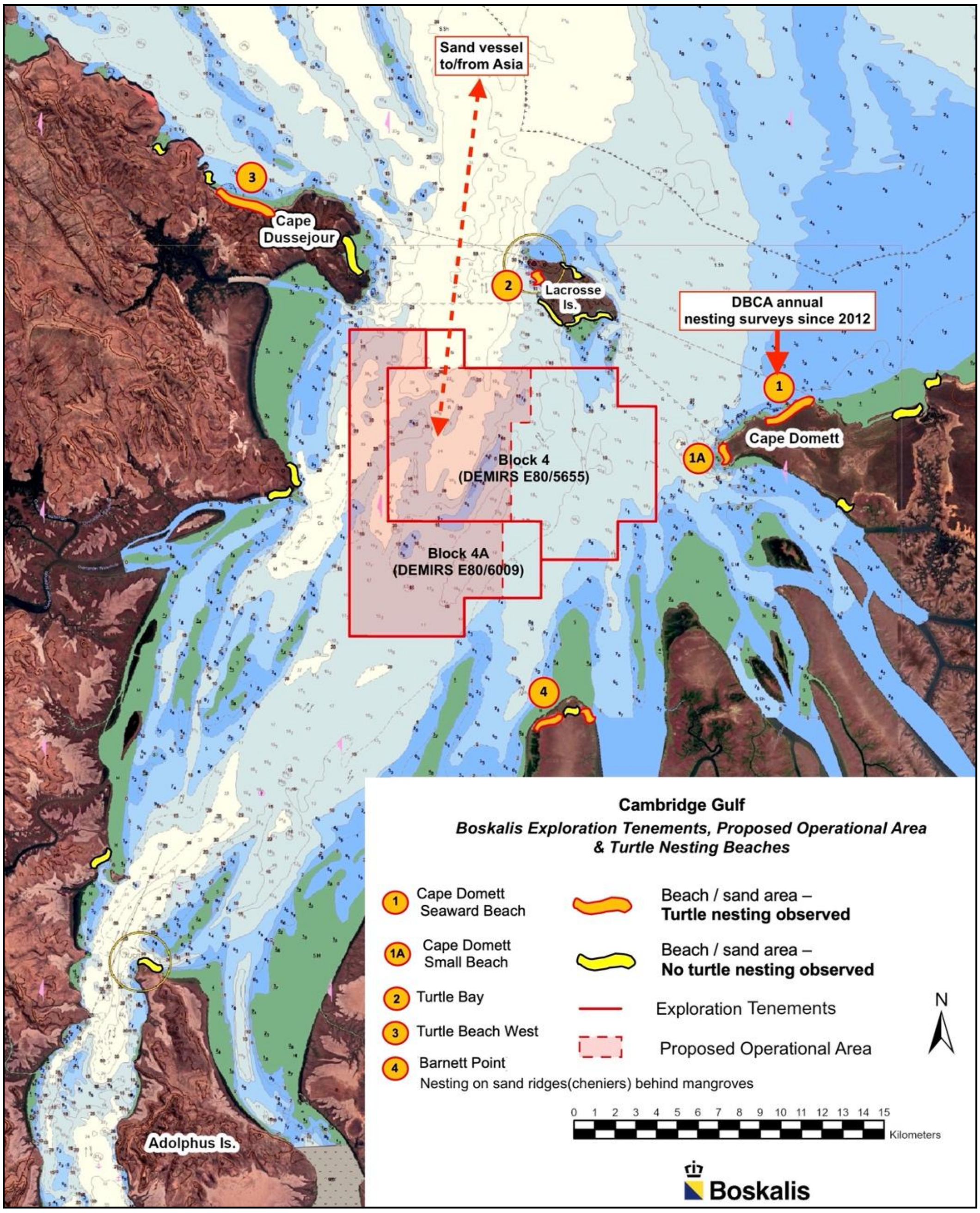


Figure 2 Turtle Nesting Beaches in the CG area.

4.2 Seasonality factors and sensitive periods for target species

4.2.1 Australian Snubfin Dolphin and Australian Humpback Dolphin

As outlined in Section 4.1.1, BKA's nine-day MMF survey covering over 800 km of transects throughout CG in February 2024 (west season) recorded four snubfin dolphin sightings, and the eight-day survey in July 2023 (dry-season) also covering over 800 km of transects, recorded 11 snubfin dolphin sightings. This indicates that there is possibly a lower presence in CG in the wet season, although other factors might have contributed to differences in the number of sightings.

As outlined in Section 4.1.2, BKA's nine-day MMF survey covering over 800 km of transects throughout CG in February 2024 (west season) recorded one humpback dolphin sighting, and the eight-day survey in July 2023 (dry-season) also covering over 800 km of transects recorded zero humpback dolphin sightings. This is not sufficient to deduce any seasonal difference. The main local commercial fisherman, who has over 20-years of experience working in CG, advised BKA that there is a marked reduction in sightings of dolphins in CG in the wet season, as they seem to move to other areas, possibly offshore away from the wet season freshwater and terrestrial sediment inputs (Douglas pers. comms 2024).

4.2.2 Flatback Turtle

Flatback turtles in the CG area are part of the JBG genetic stock and exhibit year-round nesting, with a peak during the winter months of August and September (Commonwealth of Australia 2017; Limpus 2004; Whiting et al. 2008).

Hatching also occurs at beach habitat throughout the year, with the seasonal peak likely to occur approximately 45 to 50 days after the peak in nesting (i.e. September to October).

4.3 Species audiograms and functional hearing group

4.3.1 Australian Snubfin Dolphin

Australian snubfin dolphins (*Orcaella heinsohni*) are acoustically active odontocetes that employ a diverse vocal repertoire including echolocation clicks, burst pulses, and whistles. These vocalisations serve critical roles in navigation, foraging, and social interaction, particularly in turbid, nearshore habitats where visual cues are limited.

Echolocation click characteristics

A study undertaken by de Freitas et al. (2018) provide detailed characterisation of the Australian snubfin echolocation clicks:

- **Mean source level**: 200 ± 5 dB re 1 µPa (peak-to-peak)
- **Centroid frequency**: 98 ± 9 kHz
- **Root-mean-square (RMS) bandwidth**: 31 ± 3 kHz
- **Click duration**: 12 ± 1 µs
- **Directivity index**: 23.5-24 dB
- **Typical inter-click interval (ICI)**: ~52 ms

These biosonar characteristics indicate that snubfins employ high-frequency, narrow-beam echolocation typical of small delphinids, allowing for high-resolution spatial discrimination in complex shallow-water environments (de Freitas et al. 2018).

Frequency range of social calls

The vocal repertoire, as analysed in Banfield et al. (2024), includes:

- **Burst pulses**: Broadband, ranging from <1 kHz to >22 kHz (recording system limited)
- **Click trains (echolocation)**: Similar broadband profile to burst pulses, also extending >22 kHz
- **Whistles**: Narrowband, frequency-modulated signals typically ranging between 3.2 ± 1.6 kHz and 9.1 ± 4.4 kHz, with a maximum observed frequency of ~19.4 kHz.

These call types are associated with various behavioural contexts:

- **Foraging**: Dominated by click trains and burst pulses
- **Socialising**: Higher proportion of whistles
- **Resting/travelling**: Reduced overall vocal activity.

Hearing sensitivity

While direct audiogram data for Australian snubfin dolphins is not available, their vocalisation patterns – particularly the use of echolocation clicks with centroid frequencies ~98 kHz – suggest an upper hearing sensitivity at or above this range, which is consistent with other small odontocetes such as the *Sousa* spp. and *Tursiops* spp. This implies sensitivity spanning:

- **Low-frequency limit**: ~1 kHz (for burst pulses)
- **Upper-frequency limit**: Likely up to ~150-180 kHz, as per typical odontocete capabilities and the click spectrum roll-off.

According to Southall et al. (2019), odontocetes such as the Australian snubfin dolphin fall within the High-Frequency (HF) cetacean functional hearing group with an estimated auditory bandwidth of 150 Hz to 160 kHz. This range defines the general hearing sensitivity of HF cetaceans, including the range over which noise exposure should be considered for auditory impact assessments.

Furthermore, according to NMFS (2024a), the Australian snubfin dolphin continues to be classified within the HF cetacean hearing group. This classification aligns with the framework established in Southall et al. (2019) and is maintained in the 2024 update.

However, while the specific frequency range for HF cetaceans remains consistent with previous guidance, the 2024 update incorporates refinements based on new audiogram and temporary threshold shift (TTS) data. These refinements have led to adjustments in the auditory weighting functions and exposure thresholds (Refer Section 4.3.4).

4.3.2 Australian Humpback Dolphin

Australian humpback dolphins are a coastal odontocete species endemic to northern Australia. Like other delphinids, they rely on a complex acoustic repertoire comprising echolocation clicks, burst pulses, and whistles for navigation, foraging, and social communication, particularly in shallow and turbid coastal environments.

Echolocation click characteristics

Based on de Freitas et al. (2015):

- **Mean source level**: 199 ± 3 dB re 1 μPa (peak-to-peak)
- **Centroid frequency**: 106 ± 11 kHz
- **Energy flux density source level (SEL)**: 141 ± 3 dB re 1 $\mu Pa^2 \cdot s$
- **Click duration**: ~15 ± 2 μs
- **Typical inter-click interval (ICI)**: ~79 ± 33 ms

These echolocation signals are high frequency and broadband, consistent with those of other delphinids.

Frequency range of social calls

While detailed frequency content of burst pulses and whistles for Australian humpback dolphins is not as well resolved as for Australian snubfin dolphins, general observations include:

- **Whistles**: Observed across 3-16 kHz in other *Sousa* species (Van Parijs & Corkeron (2001)), with variable modulation depending on social context.
- **Click trains (echolocation)**: Broadband, extending beyond 100 kHz
- **Pulsed sounds**: Occur in social and foraging contexts but require further species-specific characterisation.

\We note that passive acoustic monitoring (PAM) has successfully detected Australian humpback dolphin vocalisations in high-use areas in the Kimberley region, though further refinement is needed to automatically distinguish them from Australian snubfin dolphin calls (Brown et al. 2017).

Hearing sensitivity

No direct audiogram is available for *Sousa sahulensis*, but the frequency content of their echolocation clicks (~106 kHz centroid) and comparison with similar species (e.g., *Tursiops aduncus*) support classification as HF cetaceans under both Southall et al. (2019) and NMFS (2024a).

4.3.3 Flatback turtle

The flatback turtle (*Natator depressus*) is a coastal marine turtle species endemic to northern Australia, primarily inhabiting shallow, soft-bottomed shelf habitats. Although no species-specific audiogram has been published, its auditory anatomy and ecological niche suggest similar hearing sensitivity to other *cheloniid* turtles such as loggerheads and green turtles.

The *Recovery Plan for Marine Turtles in Australia 2017–2027* identifies increasing levels of anthropogenic underwater noise—particularly from seismic surveys and pile driving—as an emerging threat to marine turtles. Although the plan does not quantify specific impacts, the inclusion of underwater noise highlights a growing recognition of its potential to affect marine turtle behaviour and ecology, warranting consideration in environmental assessments (Commonwealth of Australia, 2017).

Hearing characteristics

- **Estimated functional hearing range**: ~50-1000 Hz
  (Based on cheloniid analogues: Bartol et al., 1999; Piniak et al., 2012)
- **Likely peak sensitivity**: 100–400 Hz
  (Inferred from loggerhead and green turtle data: Lavender et al., 2010, 2011)
- **Detection mechanism**: Auditory evoked potentials (AEPs) and behavioural studies in related species suggest flatbacks detect both pressure and particle motion components of underwater sound.

Flatback turtles possess middle-ear structures consistent with other marine turtles, including a columella and subtympanal fat layer, which aid in underwater sound conduction (Bartol et al. 2006).

4.3.4 Auditory weighting functions

NMFS (2024a) provides auditory weighting functions for HF cetaceans and *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase III)* (Department of the Navy, 2017) provides guidance on the auditory weighting functions for marine turtles (TU). Note that while NMFS (2024c) provides threshold criteria for marine turtles, it does not define a species-specific auditory weighting function.

The TU-weighting function was derived using limited available anatomical and electrophysiological data from several hard-shelled turtle species (*cheloniids*), including loggerhead (*Caretta caretta*) and green turtles (*Chelonia mydas*), and assumes peak auditory sensitivity in the low-frequency range of approximately 100–

700 Hz, with sensitivity declining sharply outside this range. The function serves to emphasise frequencies within this band and de-emphasise those outside, aligning with the hypothesised auditory bandwidth of marine turtles.

This study has adopted the NMFS (2024c) threshold criteria for marine turtles combined with the auditory weighting function from Department of the Navy, 2017.

The auditory weighting functions for HF cetaceans and TU are presented in Figure 3.

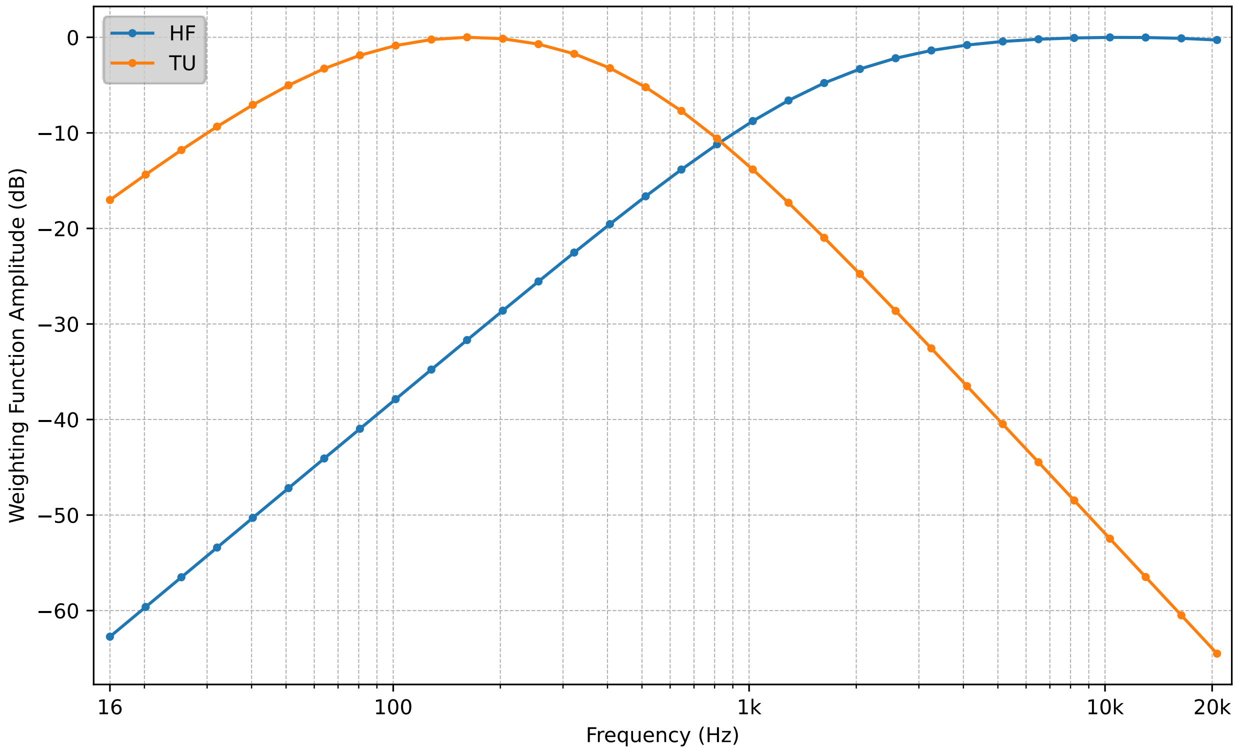


Figure 3 Auditory weighting functions amplitude over the frequency range assessed in this study for turtles (TU) and high-frequency cetaceans (HF).

5 Task 1 – Underwater noise modelling

5.1 Overview

The following sections describe our approach and assumptions for the underwater noise modelling for the proposed sand sourcing operations in CG. The study aims to predict underwater noise emissions from the SPV and assess potential impacts on local marine fauna, with particular focus on Australian snubfin and humpback dolphins, and flatback turtles, in accordance with NMFS (2024a & 2024b).

5.2 Environmental conditions in Cambridge Gulf and the effects on sound propagation

5.2.1 Overview of environmental conditions

CG is a large, highly dynamic and highly turbid embayment located on the tropical northeast coast of Western Australia (WA) (Figure 1). Geographically, CG is centered on 14º 52.00' S and 128º 16.00' E, facing northwards and seawards to the larger Joseph Bonaparte Gulf. The seaward mouth of CG is bounded to the west by Cape Dussejour and to the east by Cape Domett, with Lacrosse Island located centrally, dividing the mouth into a West Entrance and an East Entrance. The main body of CG extends ~40 km from its seaward mouth upstream to Adolphus Island, with the widest point being ~20 km. The mean water depth is approximately 12 m LAT (Wolanski et al. 2004).

There is a complex system of estuarine inlets located on the east side of CG, just inshore from Cape Domett, lined with relatively narrow bands of fringing mangroves and backed by tidal mudflats and salt-flats, known as the 'False Mouths of the Ord River'. This area includes the Ord River Floodplain Ramsar Wetland.
At Adolphus Island CG splits into West Arm, which extends for another 80 km upstream to the small port town of Wyndham, and East Arm, which is the true lower reach of the Ord River.

CG has a macrotidal environment with semi-diurnal tides and a spring tidal range of 8 m. The large tidal range causes high current velocities, which BKA has measured to exceed 2 m/s (4 knots), and the Australian Hydrographic Office marks 3 to 4 knots (1.54 to 2.06 m/s) in West Entrance and in the centre of CG on chart AUS32. This causes very high natural turbidity from constant suspension of sediments with every change of the tide, and permanent aphotic conditions at the seabed.

Five main rivers discharge into CG: the Durack, Forrest, King, Ord and Pentecost, along with a number of smaller tributaries. The rivers all discharge sediment into CG. Over time, this has formed multiple small deltas and tidal flats. The supply of sediment varies significantly due to the high variability in river discharges. Peaks in sediment supply occur in the wet season, with limited sediment supply during the dry season. The rivers supply a combination of sand and fine-grained silt and clay. The sediment deposited in CG is subject to regular reworking by the strong tidal currents, resulting in well-sorted sands being present in the main channels.

Coastal processes in CG are driven by the tidally dominated hydrodynamic system, with inputs of terrestrial sediments from the catchment, including large pulses during the wet season. The area has relatively normal sea temperature, salinity and pH, with expected variation between the dry- and wet-seasons. The area has relatively low chlorophyll-*a* concentrations, in both the dry- and wet-seasons, extremely high suspended solids and turbidity levels; and very low (zero or near zero) benthic light levels, throughout the year.

5.2.2 Sound absorption by the water

As sound propagates through water, some of the acoustic energy is absorbed. The amount of energy absorbed is frequency dependant and is described by the absorption coefficient:

$$\alpha = \alpha_w + \alpha_p + \alpha_b$$

Where α_w is the physico-chemical absorption, α_p is the plane wave attenuation by suspension of particle solids, α_b is the attenuation of bubbly water. α_p is further split as

$$\alpha_p = \alpha_v + \alpha_s$$

where α_v is the visco-inertial absorption and α_s is the attenuation coefficient associated with scattering by suspended particles (Etter 2018). The water in CG has extremely high suspended sediment concentrations (PCS 2025), and as such, has been considered as a potentially important source of acoustic absorption.

We have used a model by Shen and Hay (Shen & Hay, 1988) to predict the absorption due to scattering by suspended particles, a model by Urick (Urick, 1948) to predict the visco-inertial absorption, and a model by Francois and Garrison (Francois & Garrison, 1987) to predict physico-chemical absorption. The use of Francios and Garrison instead of the more common Anslie and McColm (Ainslie & McColm, 1998) model is due to the typical pH of CG being outside of the bounds for use of Anslie and McColm. We do not expect sufficient bubbles to be present to cause significant absorption; hence we will set $\alpha_b = 0$.

These models require the parameters presented in Table 2, which we have retrieved from various documents provided by BKA and additional sources. The values presented are selected based on average measurements over GC or measurements in the centre of the POA (denoted by AWAC-01) where possible.

Table 2: Parameters used in modelling the absorption of the seawater at Cambridge Gulf

Parameter	Value	Models used in	Notes	Source
Concentration of suspended solids	65 mg/L	Urick	We have used the median from AWAC-01	Table 3 of PCS (2025)
Typical radius of suspended solids	4 µm	Shen and Hay, and Urick	This is based on an average D50 of 8 µm	Email correspondence with Andrew Symonds of Port & Costal Solutions 26/05/2025
Salinity	30 ppt	Francois and Garrison	We have used the average salinity in time and position	Table 17 of PCS (2025)
pH	8.64	Francois and Garrison	We have used the average pH across all sites and depths	Vertical profiles provided by Boskalis: Site1_AllProfiles_Processed.csv, Site2_AllProfiles_Processed.csv, Site3_AllProfiles_Processed.csv

Parameter	**Value**	**Models used in**	**Notes**	**Source**
Temperature	26°C	Francois and Garrison	We have used the average temperature across all dates and locations.	Table 17 of PCS (2025)
Density of water	1000 kg/m^3	Shen and Hay, and Urick	Nominal value for absorption coefficient calculation	–
Density of suspended solids	2650 kg/m^3	Shen and Hay, and Urick	Assumed to be quartz based on Figure 101	Figure 101 of PCS (2025) (Lee, 2004)
Shear modulus of suspended particles	44 GPa	Shen and Hay	Assumed to be quartz based on Figure 101	Figure 101 of PCS (2025) (Lee, 2004)
Elastic modulus of suspended particles	95 GPa	Shen and Hay	Assumed to be quartz based on Figure 101	Figure 101 of PCS (2025) (Carmichael, 1989)
Kinematic viscosity of water	1.053×10^3 m^2/s	Urick	Standard value at 26°C	–
Bulk (volume) viscosity of water	0.003091 Pa.s	Shen and Hay	Value at 15°C	(Litovitz & Davis, 1965)

The main sources of absorption by the seawater were predicted using the parameters in Table 2 with the results presented in Figure 4. The result demonstrates that the physico-chemical absorption dominates the absorption up to 10 kHz where the visco-inertial absorption due to the suspended sediments begins to become an equal contributor. Absorption due to scattering was determined to be negligible and was not included in the analysis.

We note that there are slight variations in salinity, turbidity and temperature between wet and dry seasons. The seasonal variation of the salinity and temperature was taken from Table 17 of PCS (2025). Figure 5 shows the variation in absorption coefficients between the dry season (June-August) and the yearly average is negligible. The figure also shows that there is additional absorption during the wet season (June-August) across all frequencies, but especially at high frequencies. We have used the average absorption for our assessment as it best represents the site for the majority of the year.

Resonate

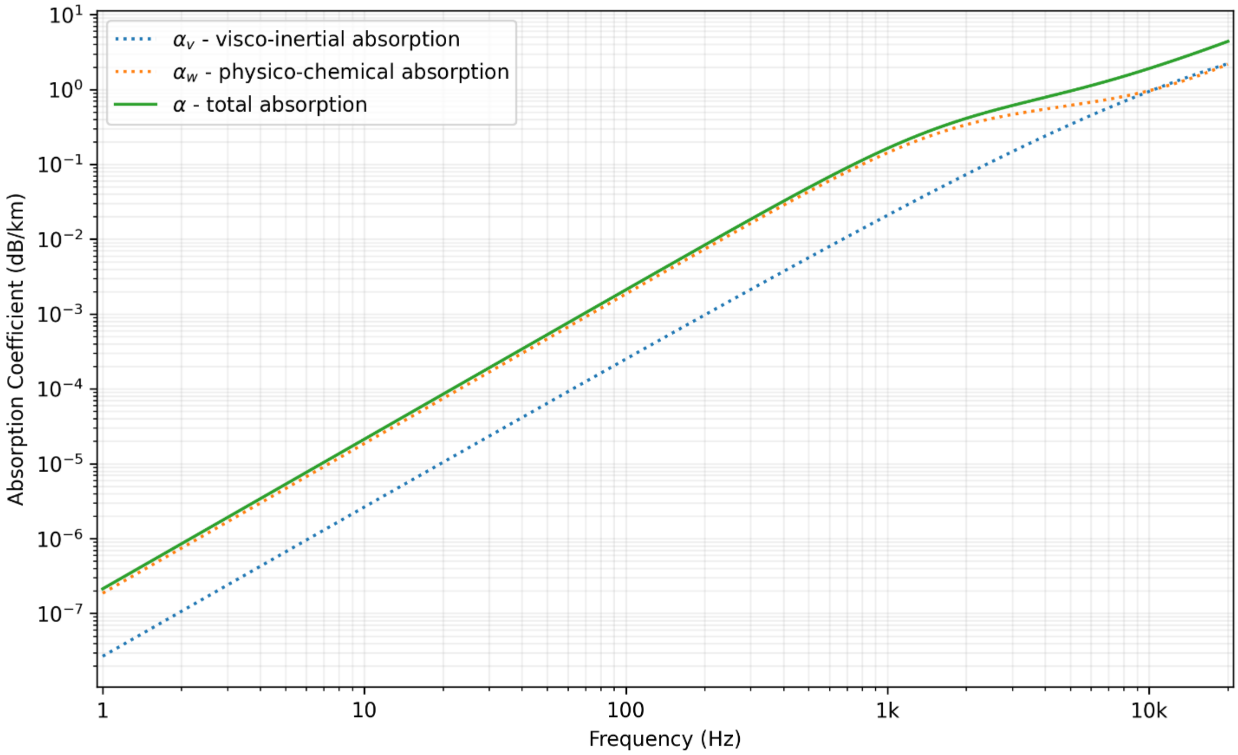


Figure 4 Prediction of the absorption coefficients based the assumed coefficients in Cambridge Gulf

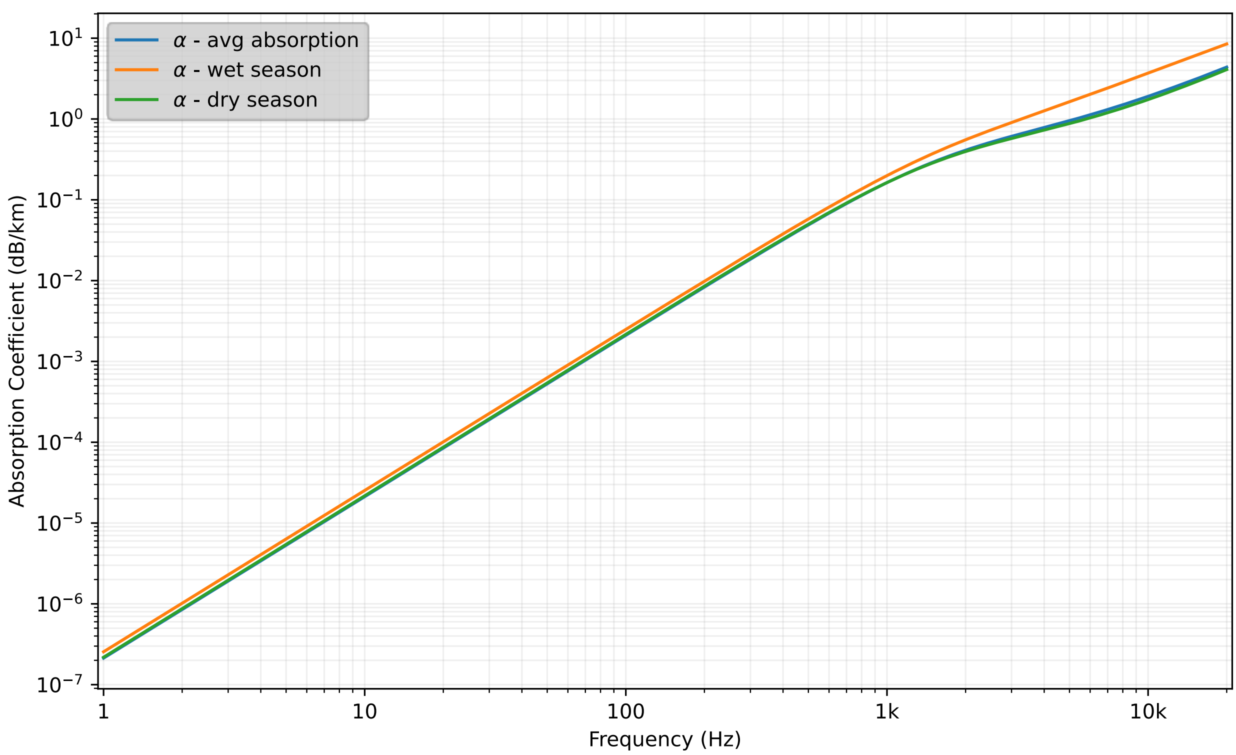


Figure 5 Comparison of the absorption coefficients between wet and dry seasons

5.2.3 Seabed structure

The seabed structure is another source of acoustic energy attenuation. The acoustic properties of the seabed structure are described by the speed of sound, density and attenuation of each layer. Section 3.6.1 of PCS (2025) notes that the predominant sediment type in the POA was medium sand with an average d50 of 303 µm. For this study we have assumed that there is a thick seabed of sand with an average d50 of 303 µm.

The noise model requires details of the speed of sound, density and acoustic attenuation of the seabed. We present the factors used for the medium sand in Table 3.

Table 3: Parameters used in modelling the seabed at Cambridge Gulf

Parameter	Value	Notes	Source
Speed of sound	1750 m/s		(Hamilton, 1980)
Density	1977 kg/m^3	Based on interpolation of data with grain sizes of 521 µm and 160 µm	(Hamilton, 1980)
Acoustic attenuation	0.84 dB/ λ	Based on the value of 0.48 dB/km/kHz for d50 300 µm and converted using the above speed of sound	(Hamilton, 1980)

5.2.4 Currents

The currents can impact the propagation of sound and as such is an important property to consider. Figures 18 and 20 of PCS (2025) present the currents at peak ebb and peak flood in large spring tides in the wet and dry seasons at AWAC-01, within the POA. These figures show an approximately linear variation in the current from the seabed to surface with speeds around 0.75 m/s at the seabed and around 1.5 m/s at the surface. We note that Section 2.1.2.1 of that report summarises the current speed throughout the areas as:

- The peak current speeds vary between the sites, with the lowest peak speeds (bed = 0.8 m/s, mid = 1.0 m/s, surface = 1.1 m/s) offshore of the East Entrance to CG (AWAC-10) and the highest peak speeds (bed = 1.6 m/s, mid = 2.2 m/s, surface = 2.5 m/s) at the northern entrance to West Arm (AWAC-08).
- The direction of the currents is shown in Figure 12 of PCS (2025) for AWAC-01 to typically be around 0° or 180° from north.

For the purposes of modelling, we will use a uniform current of 1 m/s at all depths, which is the depth-average current rounded to the nearest integer. We have considered the cases of both 0° and 180° from north which covers both extremes of acoustic propagation.

5.3 Vessel specifications and sound sources

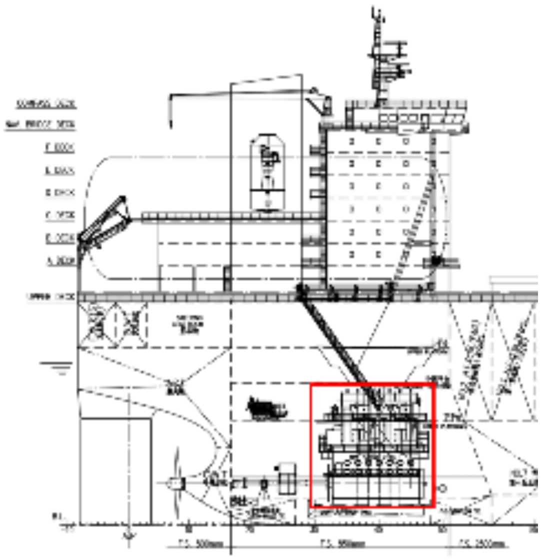
Table 4 lists the basic dimensions of the SPV. Table 5 summarises the identified main SPV sound sources considered for this study. Table 6 summarises additional SPV sound sources that were not modelled in this study, as they are expected to be negligible, given they are located above the water line and isolated from the SPV's hull. Tables 5 and 6 also list noise mitigation measures for each sound source as proposed by Boskalis.

Table 4: General specifications for the SPV (indicative and subject to final vessel design).

Property	Dimension
Length overall (LOA):	~350 m
Breadth:	~62 m
Draft:	~19 m

Property	Dimension
Sand capacity:	~75K to 125K m^3
Speed when loading sand in CG:	<2 knots
Drag-head width	6 m
Crew:	~25

Table 5: SPV main sound sources expected to contribute to the underwater noise emission of the vessel

Sound Source	Description / Specs[1]	Noise Mitigation Measures
Main engine	• Main engine power 22.000 kw at 58 rpm. • The main engine will be 2-stroke, dual-fuel optional (methanol) mode. • See below diagram of the SPV engine location. 	• Location of engine at normal aft-ship location. • Due to the size of main engine no variations are possible regarding locations or mounting. • Engines will be compliant with IMO 2023 URN guidelines.
Propeller (single screw)	• Controllable Pitch Propeller (CPP) will be installed rather than a Fixed Pitch Propeller (FPP). • Number of blades is four. • Propeller diameter 9.8 m. • A (tentative) design pitch of 0.897 is used and a blade area ratio of 0.41. • Propulsion at maximum continuous rating is around 20,000 kw with 58 rpm.	• Lower pitch values and noise levels can be reached with a CPP than FPP. • CPP design, power consumption and noise levels will be optimised during design phase to reduce the propeller load and cavitation noise.
Bow thrusters	• May not be installed but have been included in the noise modelling (both with and without) in case they are installed. • Assume bow thruster of 4,300 kW.	

Sound Source	Description / Specs[1]	Noise Mitigation Measures
Underwater suction pipe and pump	The suction pipe and underwater pump will be the same as that used on the existing Boskalis TSHD *Gateway*. • Suction pipe Ø1,200 mm • Suction pump Ø1,100 mm • Discharge pump Ø1,100 mm • IHC and Boskalis designed and manufactured. • The dredge pump drive will have 3,500 kw power at 310 rpm. • Efficiency at BEP 89.5%	
Drag head	• Operates by suction of sand-water mixture via negative pressure. • 6 m wide and 2 m length. • 45 ton. IHC manufactured.	• The dredging process could be started-up slowly, to gradually increase the generated noise. CEDA (2015) states that the suction process at the seabed is not considered as a dominant contributing sound source (Pages 7,14). TNO – DV 2010 C335, de Jong C. et al. (2010)

(1) BKA advise these are the maximum possible specifications.

Table 6: SPV sound sources <u>not</u> expected to contribute to the underwater noise emission of the vessel

Sound Source	Description / Specs[1]	Noise Mitigation Measures
Generators / other on-board machinery	• The SPV will have three sets of auxiliary generators, approximately 1,400 kW each. These are used during transit sailing. • Approximately 6 MW of generator sets will be additionally installed for sand-loading operations in CG.	• The generators installed for sand-loading operations will likely be positioned on deck or above the waterline, thereby minimising underwater noise transmission. • The installed generators will be mounted on vibration isolation mounts thereby minimising the potential structure-borne noise radiating from the vessels hull. It is expected that underwater noise from generators and other onboard machinery will be negligible in comparison to the main engine and associated propellor noise. • Power management of the diesel electric generators will be optimised to minimise the consumed power. • Selective operation of generator sets will be applied where possible, based on ‘quiet ship profile’.

Sound Source	Description / Specs[1]	Noise Mitigation Measures
Other pumps	• Relatively small water-jet pumps will be installed, capability to be determined. These will be installed inboard.	• Power consumption verifications will be made whether additional auxiliary generators are required to have jet power available during the sand-loading operations. • Given the expected small size of the jet pumps, and the potential mounting possibilities, a negligible impact is expected on underwater noise.

(1) BKA advise these are the maximum possible specifications.

During design phase of the SPV and subsequently where required during operational phase, BKA advise that additional tests will be conducted to evaluate the underwater sound sources.

5.4 Underwater sound sources

The SPV for the proposal is similar to a TSHD. This means the main noise sources will be (also illustrated in Figure 6):

- The propeller, engine and onboard machinery.
- A single (1) draghead when sand sourcing.
- An underwater suction pump for sand sourcing.
- Bow thrusters – it is noted that the vessel may not have bow thrusters installed but these have been included in the assessment to assess the noise impact with/without thrusters. If installed, they will have an output of 4,300 kW.

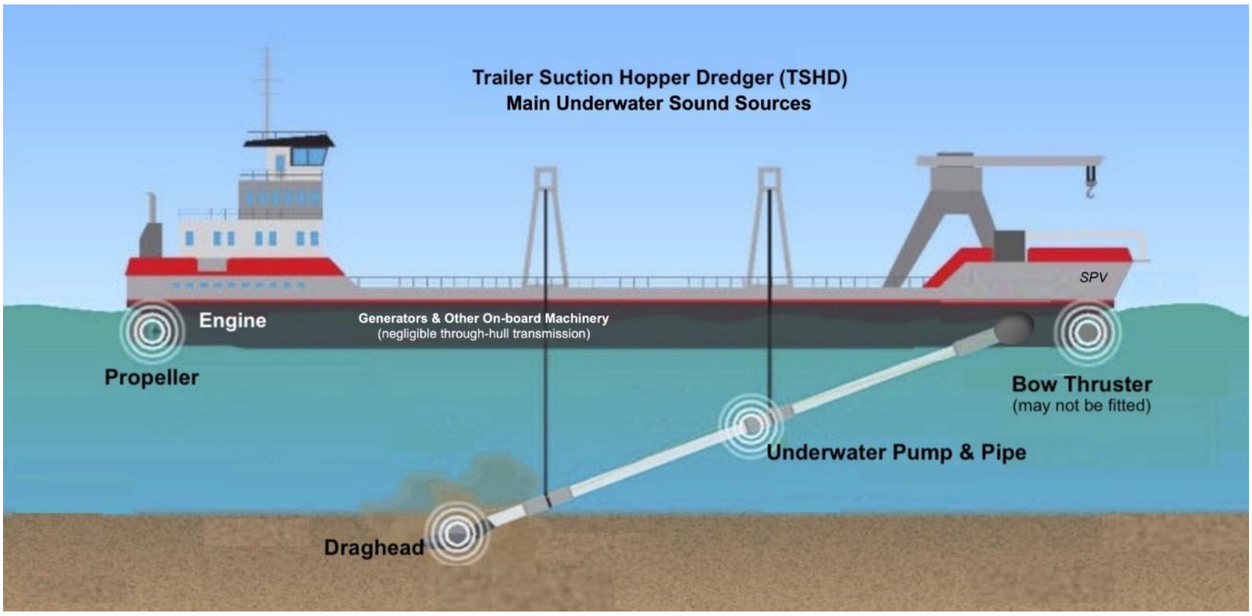


Figure 6 Typical underwater sound sources from a typical TSHD. These will all be present on the SPV as shown. The propeller and bow thruster are the more significant sound sources (source: WODA)

5.4.1 Vessel sand loading and transit noise

Determining the specific source level (SL) of a vessel that has not yet been constructed is typically done by using measurements of similar vessels. Measurements of vessel noise generally do not differentiate between the different noise sources i.e. between propeller noise and engine noise, or auxiliary noise sources. As such, it necessitates that we simplify the multiple noise sources present on the proposed SPV to a single noise source under various operations. The one exception is thruster noise as some limited sources of thruster alone measurements exist.

A similar vessel to the proposed SPV is the Queen of the Netherlands (QoN), which is currently Boskalis' largest TSHD that has had detailed acoustic measurements during both sand loading and transit (Subacoustics 2004). We have used the measured SL and narrowband spectra from that report to determine levels of the one-third octave band SL during sand loading and transit which are presented in Figure 7.

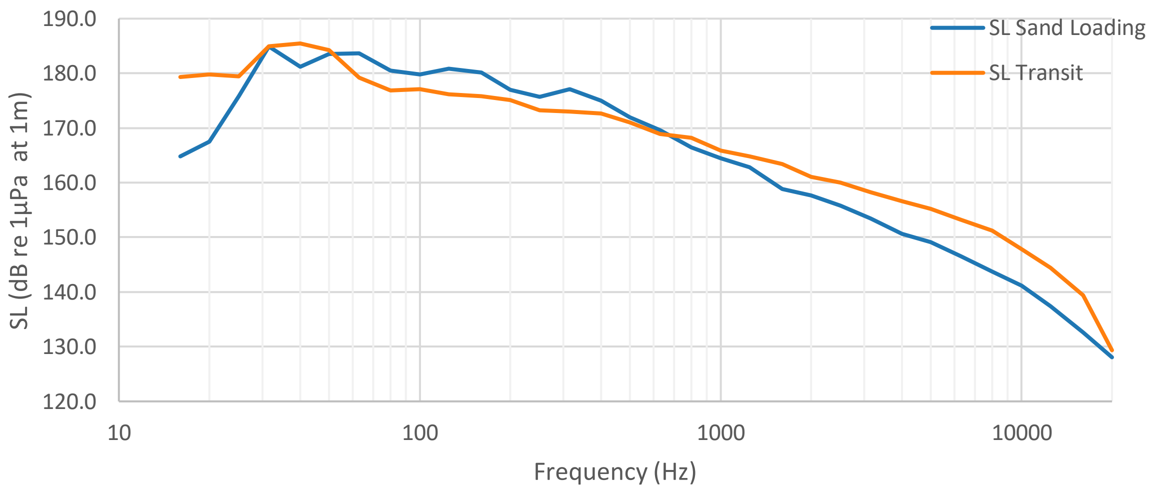


Figure 7 Source level (SL) of the Queen of the Netherlands during sand loading and transit.

These levels are slightly higher than measurements of similar sized vessels presented in literature reviews (Sudel et al. 2019) (McQueen, Suedel, & Wilkens, 2019). We present a comparison between the QoN and six other TSHD vessels with power ratings 8,000 – 30,000 kW in Figure 8.

The QoN was manufactured in 1998 and has installed power of around 27,600 kW. Due to the lower power of the proposed SPV and proposed modern sound mitigation measures, we expect the new SPV to be quieter than the QoN. The average overall SL from the similar sized vessels in Figure 8 is 185 dB re 1 µPa at 1 m which compares to the QoN of 192 dB re 1 µPa at 1 m.

A review of dredging noise found that the median TSHD vessel noise was around 166 dB re 1 µPa at 1 m and that the upper quartile of noise was around 183 dB re 1µPa at 1m; however, we note that these values were based on measurements of predominantly smaller vessels (Sudel et al. 2019). We believe that reducing the SL of the QoN by 7 dB to 185 dB re 1µPa at 1m is a reasonable estimation for the proposed SPV during sand loading. We will additionally apply this 7 dB re 1 µPa at 1 m reduction to the QoN transit SL for an estimate of the SL of the SPV in transit.

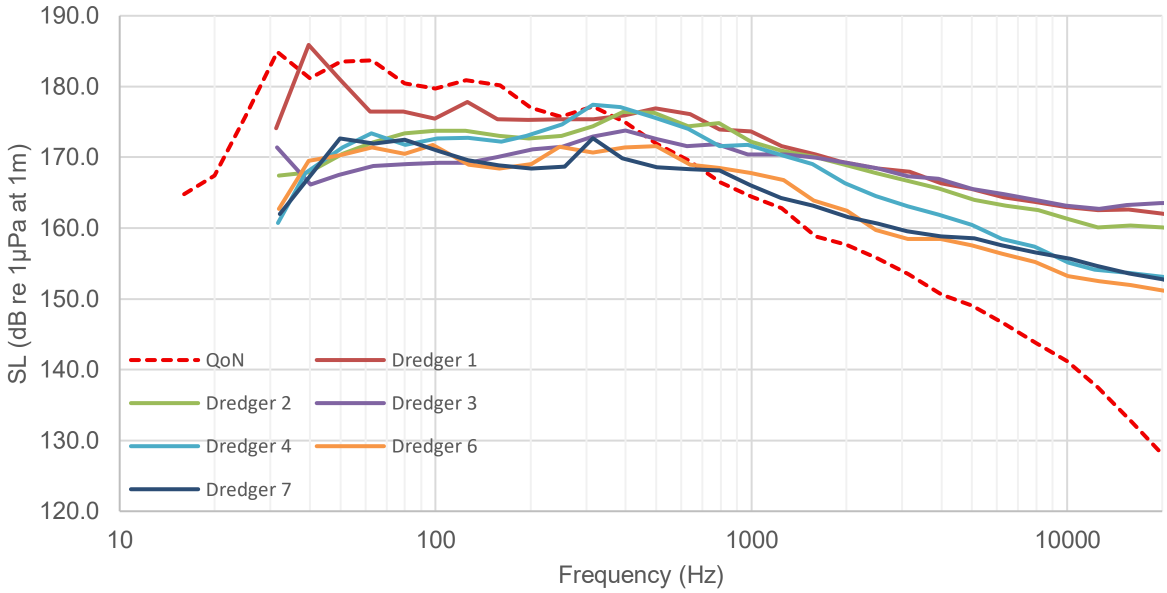


Figure 8 Comparison between the SL during sand loading and the SL of six other similar sized TSHD vessels while sand loading.

5.4.2 Bow thruster noise

There are few measurements of underwater noise from thrusters, with the most relevant study to our knowledge being Roth et al. (2013) who performed measurements of the U.S Coast Guard Cutter *Healy*'s acoustic signature, which included presenting source levels for a 1865 kW thruster. These measurements determined the SL of the vessel to be 193 dB re 1 µPa at 1 m and presented the one-third octave band levels. Figure 9 compares the level of the thrusters from the Healy to the assumed source levels of the SPV in Section 5.4.1. We have assumed that the noise from the proposed SPV with thrusters is the sum of the SL sand loading and the thruster level from the *Healy*.

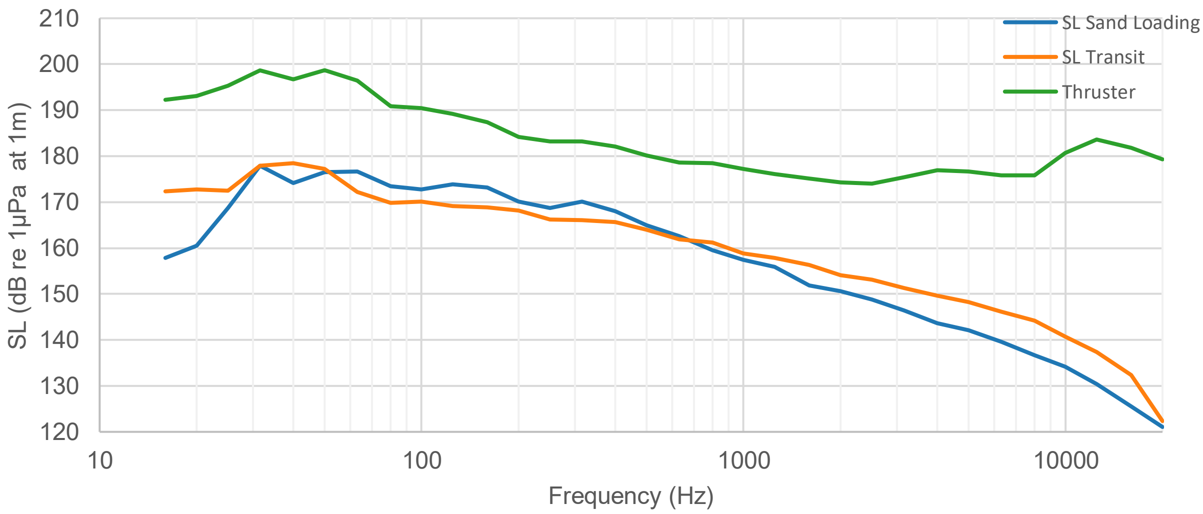


Figure 9 Comparison of the assumed SL for the SPV during sand loading, transit and while the thruster is operating.

5.4.3 SPV sound source characterisation

Sand loading activities (i.e. dredging), including the use of bow thrusters, are typically classified as non-impulsive noise sources due to their continuous or quasi-continuous acoustic output, lacking the high-intensity, rapid rise-time pressure transients characteristic of impulsive sources such as impact piling or seismic airguns. These non-impulsive sounds are generally broadband, of longer duration, and lower peak pressure, resulting in different propagation characteristics and potential effects on marine fauna than impulsive sounds.

5.5 Underwater noise predictions

5.5.1 Scenarios modelled

The following scenarios have been modelled with a lower resolution grid to understand their effect:

- Water levels (relative to MSL) –a +3.25 m high water level and a -4 m low water level (based on Figure 8 of PCS (2025) which shows the water levels at AWAC-01) has been simulated. This scenario uses an east-west transect and the SL for sand loading without thrusters.
- Currents – currents of 1 m/s in both 0° and 180° from north have been simulated. This scenario uses an east-west transect and the SL for sand loading without thrusters.
- Transect direction – this scenario compares a north-south and east-west transect. This scenario uses the SL for sand loading without thrusters.
- Thruster usage – this scenario uses an east-west transect and compares the scenarios of sand loading without thrusters to sand sourcing with continuous bow thruster usage.

Additional scenarios which were informed by the above scenarios were modelled with a higher resolution grid. The tide was set as +0 m and the currents were set as 0 m/s for the following scenarios:

- Sand sourcing in an east-west transect without thrusters,
- Sand sourcing in a north-south transect without thrusters,
- Sand sourcing in an east-west transect with bow thrusters at the ends of the transect
- Sand sourcing in a north-south transect with bow thrusters at the ends of the transect
- The SPV transiting into and out of CG via the West Entrance.

The investigated transects were selected to provide representative sound source locations from both within and outside of the boundaries of the POA. In reality the SPV will follow a less regular sand-loading route, following the sand resource within the POA as it loads. The following transects are used:

- East-west – an east-west transect originating and terminating at the midpoints of the POA boundaries
- North-south – a north-south transect originating and terminating at the midpoints of the POA boundaries
- Transit – Into and out of CG via the West Entrance

All scenarios used the assumed SL discussed above. BKA have provided advice that the simple north-south / east-west transect that is modelled in this report would take approximately 20 hours to load and 5-10 hours additional for repositioning which is more likely to require thrusters. Based on this advice, this report assumes that this scenario will require thrusters 30% of the time and that they would only operate at the ends of the transects.

5.5.2 Bathymetry

The modelling used two sets of bathymetry with two different scales:

- A coarse grid with digitised bathymetry for CG from the navigation chart, and
- 5 m bathymetry for the entire POA measured in two phases on 7-14 February 2024 and 3-6 March 2024 (BKA 2024).

This bathymetry was combined and interpolated to a 20 m grid for the acoustic modelling. This level of spatial resolution is expected to capture any influence of the sandwaves that are present on the seabed within the POA on the acoustic propagation.

5.5.3 Modelling software and approach

Underwater acoustic propagation was modelled using dBSea which is software developed by Marshall Day Acoustics and Irwin Carr Consulting. dBSea integrates multiple solvers to simulate sound propagation in marine environments, accommodating complex bathymetry, water column properties, and seabed characteristics. Furthermore, dBSea incorporates the NOAA NMFS 2024 frequency weighting functions that compensates for a species' frequency-specific hearing sensitivity.

The modelling encompassed frequencies from 16 Hz to 20 kHz, divided into one-third octave bands. Two solvers were employed with a crossover frequency because of limitations in the accuracy of each model at high and low-frequencies:

- Parabolic Equation (PE) Solver: Applied from 16 Hz to 1 kHz. The PE method is well-suited for low-frequency, range-dependent scenarios, effectively handling complex bathymetric variations and sediment interactions.
- Ray Tracing (RT) Solver: Utilized from 1.2 kHz to 20 kHz. The RT method is appropriate for high-frequency modelling, tracing multiple rays from the source to receivers and accounting for reflections and refractions within the water column.

A crossover frequency of 1.2 kHz was selected to ensure optimal solver performance across the frequency spectrum. Both the PE and RT solvers are 2-dimensional (2D) solvers, so a series of slices radially from the source were simulated to predict the sound propagation in 3-dimensions (3D). The results from the 2D slices are interpolated to the 3D grid. The maximum value from a vertical column was used to create contours of the simulated noise level.

The 3D simulation grid used an 80 m horizontal spacing with 1.2 m vertical spacing. The 2D simulations were performed with 1° angular slices and 250-meter radial points. The motion of the vessel was modelled as a series of 51 point sources.

For simulations investigating the influence of tides, currents and the influence of thrusters, a coarser grid with horizontal spacing of 180 m with 2° angular slices was used. A series of 11 point sources were used to model the motion of the vessel. This reduced simulation will generate results with similar accuracy far away from the noise source but may not accurately resolve near the noise source. This serves the purpose of understanding the effect of tides, currents and thrusters without unnecessary computational expense.

A 20 m resolution bathymetric dataset was used, as detailed in Section 5.5.1. The seabed, seawater absorption, and other water properties were defined based on site-specific data, as described in Section 5.2.

6 Task 2 – Impact Assessment

6.1 Assessment Guidelines

The WA EPA required that the NOAA NFMS guidelines be used for this study, with the following being relevant:

- US NMFS (2024a) *Underwater Noise Marine Mammal Hearing Guidelines* (used to assess potential auditory injury to the two dolphin species found in CG).
- US NMFS (2024b) *Summary of Marine Mammal Acoustic Thresholds* (used to assess potential behavioural impacts on the two dolphin species found in CG).
- US NMFS (2024c) *Summary of Marine Mammal, Fish & Turtle Acoustic Thresholds 2024* (applied to marine turtles).

6.1.1 Physiological impacts on marine mammals

Table 7 summarises the NMFS (2024b) Auditory Injury (AUD INJ) and temporary threshold shift (TTS) onset threshold for marine mammals. In this case, the assessment criteria for the snubfin and humpback dolphin species are highlighted in **bold** in Table 7 and listed below for clarity:

- Functional hearing group = High-frequency Cetaceans (HF) (refer Section 4.3.4)
- Sand loading activities sound characteristics = non-impulsive (refer Section 5.4.3).

Table 7: Onset of Auditory Injury and Temporary Thresholds Shifts (NMFS 2024b) – marine mammals

Functional hearing group	Impact	Physiological noise exposure onset criteria	
		Impulsive	Non-impulsive
Low-frequency cetaceans (LF)	TTS	Peak 216 dB $SEL_{24\ hour}$ 168 dB(LF)	$SEL_{24\ hour}$ 177 dB(LF)
	AUD INJ	Peak 222 dB $SEL_{24\ hour}$ 183 dB(LF)	$SEL_{24\ hour}$ 197 dB(LF)
High-frequency cetaceans (HF) (Australian snubfin and humpback dolphin)	**TTS**	Peak 224 dB $SEL_{24\ hour}$ 178 dB(HF)	**$SEL_{24\ hour}$ 181 dB(HF)**
	AUD INJ	Peak 230 dB $SEL_{24\ hour}$ 193 dB(HF)	**$SEL_{24\ hour}$ 201 dB(HF)**
Very high-frequency cetaceans (VHF)	TTS	Peak 196 dB $SEL_{24\ hour}$ 144 dB(VHF)	$SEL_{24\ hour}$ 161 dB(VHF)
	AUD INJ	Peak 202 dB $SEL_{24\ hour}$ 159 dB(VHF)	$SEL_{24\ hour}$ 181 dB(VHF)
Pinnipeds (PW) (Phocid carnivores in water)	TTS	Peak 217 dB $SEL_{24\ hour}$ 168 dB(PCW)	$SEL_{24\ hour}$ 175 dB(PW)
	AUD INJ	Peak 223 dB $SEL_{24\ hour}$ 183 dB(PCW)	$SEL_{24\ hour}$ 195 dB(PCW)
Pinnipeds (OW)	TTS	Peak 224 dB $SEL_{24\ hour}$ 170 dB(OCW)	$SEL_{24\ hour}$ 179 dB(OCW)

Functional hearing group	Impact	Physiological noise exposure onset criteria	
		Impulsive	Non-impulsive
(other carnivores in water)	AUD INJ	Peak 230 dB SEL$_{24\ hour}$ 185 dB(OCW)	SEL$_{24\ hour}$ 199 dB(OCW)
Pinnipeds (PA) (Phocid Carnivores in Air[2])	TTS	Peak 156 dB SEL$_{24\ hour}$ 125 dB(PCA)	SEL$_{24\ hour}$ 134 dB(PCA)
	AUD INJ	Peak 162 dB SEL$_{24\ hour}$ 140 dB(PCA)	SEL$_{24\ hour}$ 154 dB(PCA)
Pinnipeds (OA) (Other Carnivores in Air[2])	TTS	Peak 171 dB SEL$_{24\ hour}$ 148 dB(OCA)	SEL$_{24\ hour}$ 157 dB(OCA)
	AUD INJ	Peak 177 dB SEL$_{24\ hour}$ 163 dB(OCA)	SEL$_{24\ hour}$ 177 dB(OCA)

(1) Note: TTS = Temporary threshold shift, AUD INJ = Auditory Injury

(2) dB re 20 μPa

We note that the NMFS (2024a) guidelines state:

> If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds are recommended for consideration.

However, typical vessel and sand loading noise is not sufficiently impulsive to exceed these levels without exceeding the non-impulsive criteria and so we will not assess to the peak sound pressure level.

6.1.2 Behavioural response of marine mammals

Summaries of behavioural responses of marine mammals to human-made noise show a large variability in the received levels (differing by many tens of decibels) and the severity in the response from minor to severe (Erbe et al. 2018). The current acoustic thresholds provided in NFMS (2024b) are summarised in Table 8. In this case, the relevant assessment criterion for the subject dolphin species is highlighted in **bold** for non-impulsive sources.

Table 8: Underwater onset of behavioural disturbance acoustic thresholds (NMFS 2024b) – marine mammals

Behavioural disturbance criteria	
Impulsive	Non-impulsive
SPL 160 dBrms	**SPL 120 dBrms**

6.1.3 Physiological impacts on marine turtles

Table 9 summarises the NMFS (2024c) permanent threshold shift (PTS) and temporary threshold shift (TTS) onset threshold for marine turtles.

Table 9: Onset of Auditory Injury and Temporary Thresholds Shifts (NMFS 2024c) – marine turtles

Functional hearing group	Impact	Physiological noise exposure onset criteria	
		Impulsive	Non-impulsive
Marine Turtles (TU)	TTS	Peak 226 dB $SEL_{24\ hour}$ 189 dB(TU)	**$SEL_{24\ hour}$ 200 dB(TU)**
	PTS	Peak 232 dB $SEL_{24\ hour}$ 204 dB(TU)	**$SEL_{24\ hour}$ 220 dB(TU)**

6.1.4 Behavioural response of marine turtles

NFMS (2024c) acknowledges that data on behavioural reactions of marine turtles to sound sources is limited. Table 10 provides the adopted flatback turtle behavioural disturbance criterion for this study. In this case, the relevant assessment criterion for the subject turtle species is highlighted in **bold** for non-impulsive sources.

Table 10: Underwater onset of behavioural disturbance acoustic thresholds (NMFS 2024c) – marine turtles

Behavioural disturbance criteria	
Source type	Threshold
All sources	**SPL 175 dBrms**

6.2 Study Findings for Task 1: Underwater Noise Modelling

In this section we present the results of the underwater noise simulations which are described in Section 5.5.

6.2.1 Modelling results

The assumptions about the sea water, seabed, source levels, and all other relevant constants are presented in Section 5. The impacts of tides, currents, thrusters and direction of transect were investigated using the methodology discussed in Section 5.5.3.

Figure 10 shows that the difference between simulations with a 3.25 m high tide and a -4 m low tide for an east-west transect is generally negligible. The differences arise due to the higher water level allowing sound to propagate further rather than an increase in levels due to the tides. Figure 11 shows the difference due to a 1 m/s current flowing from north to south and from south to north to be negligible for an east-west transect. The small variations observed are due to random fluctuations inherent in the simulation process, rather than any physical effect.

Figure 12 shows the difference in radiated sound pressure level from the SPV with and without thrusters operating throughout an east-west transect. This shows that the thrusters cause a general increase in the noise level, and that the increase is more significant near the POA. Figure 13 shows that the difference in the radiated sound pressure level from the SPV operating in a north-south transect with it operating in an east-west transect. Whilst there is a clear difference in the directivity from the different transect direction, there is not a significant difference at the edges of the simulation domain.

Pseudo-colour plots showing the sound pressure levels (dBrms), TU weighted sound exposure levels (dB(TU) SEL_{24hour}), and HF-cetacean weighted sound exposure levels (dB(HF) SEL_{24hour}) are presented in Appendix A.

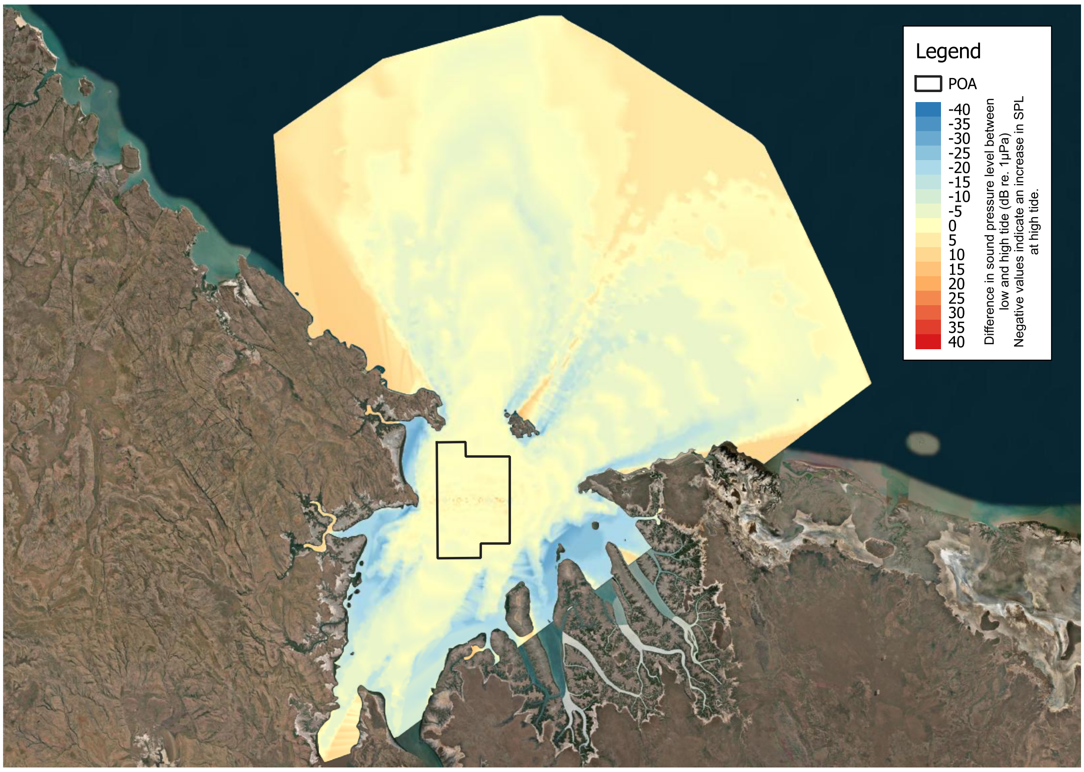


Figure 10 Difference in the radiated sound pressure level between a 3.25 m high tide and a -4 m low tide in an east-west transect.

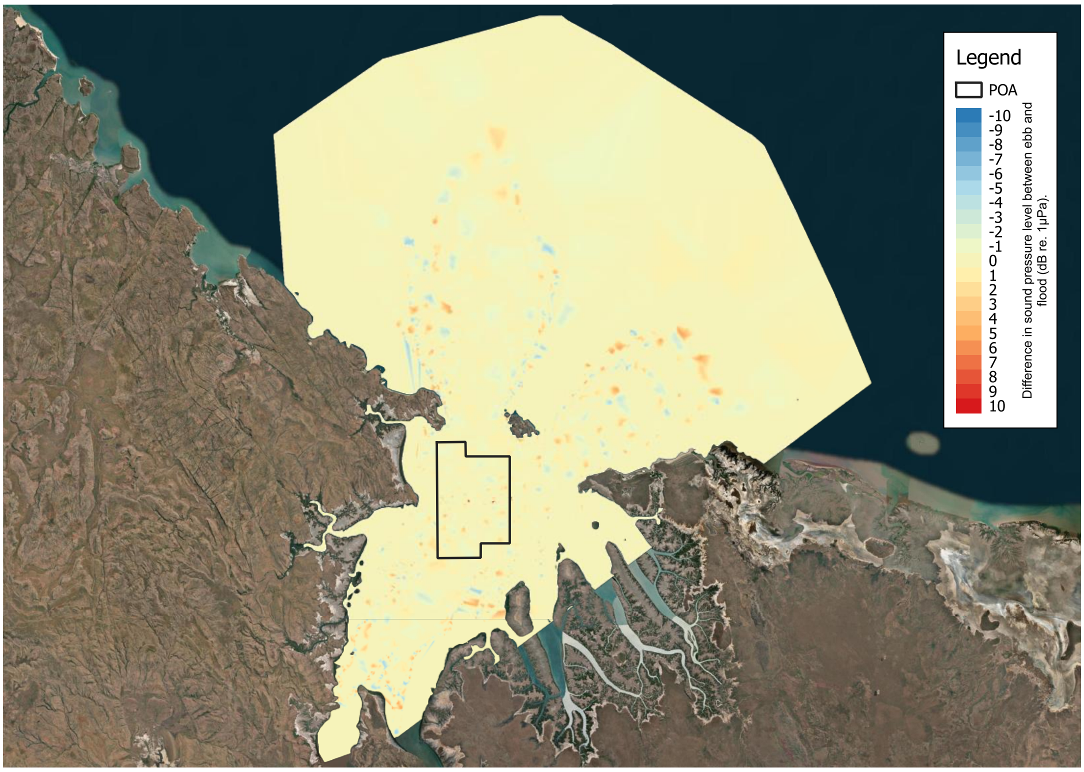


Figure 11 Difference in the radiated sound pressure level between a 1 m/s north current and a 1 m/s south current for an east-west transect.

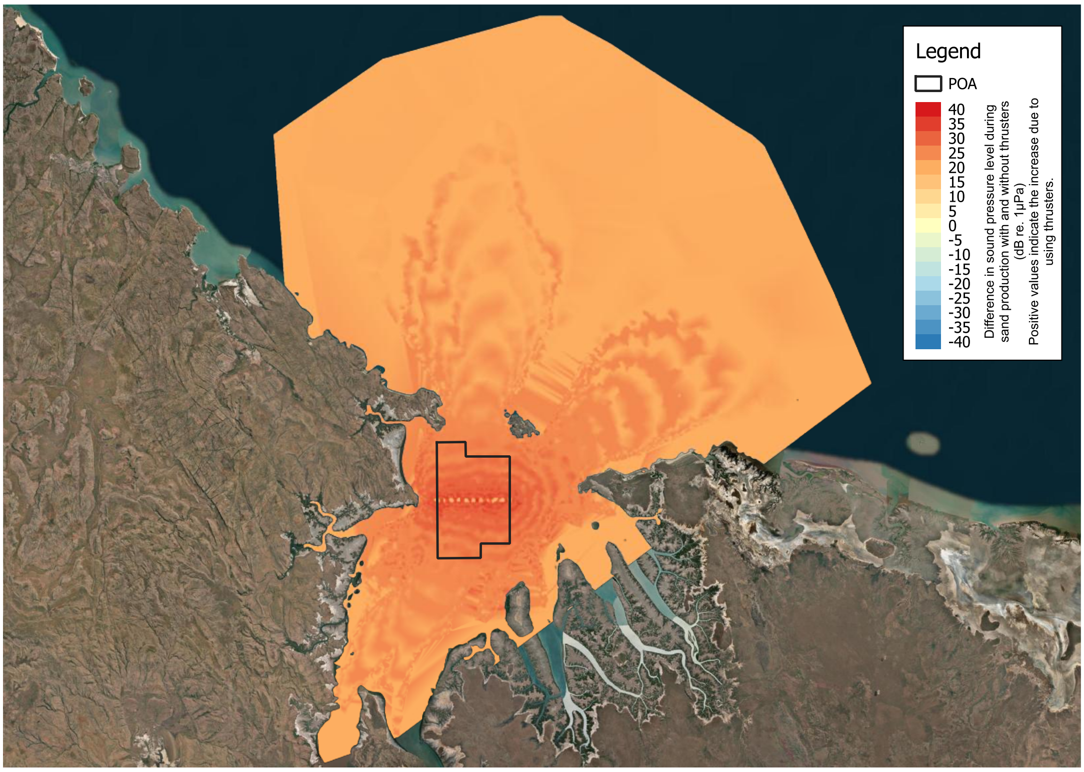


Figure 12 Difference in the radiated sound pressure level between the SPV operating with continuous bow thrusters and without any bow thrusters for an east-west transect.

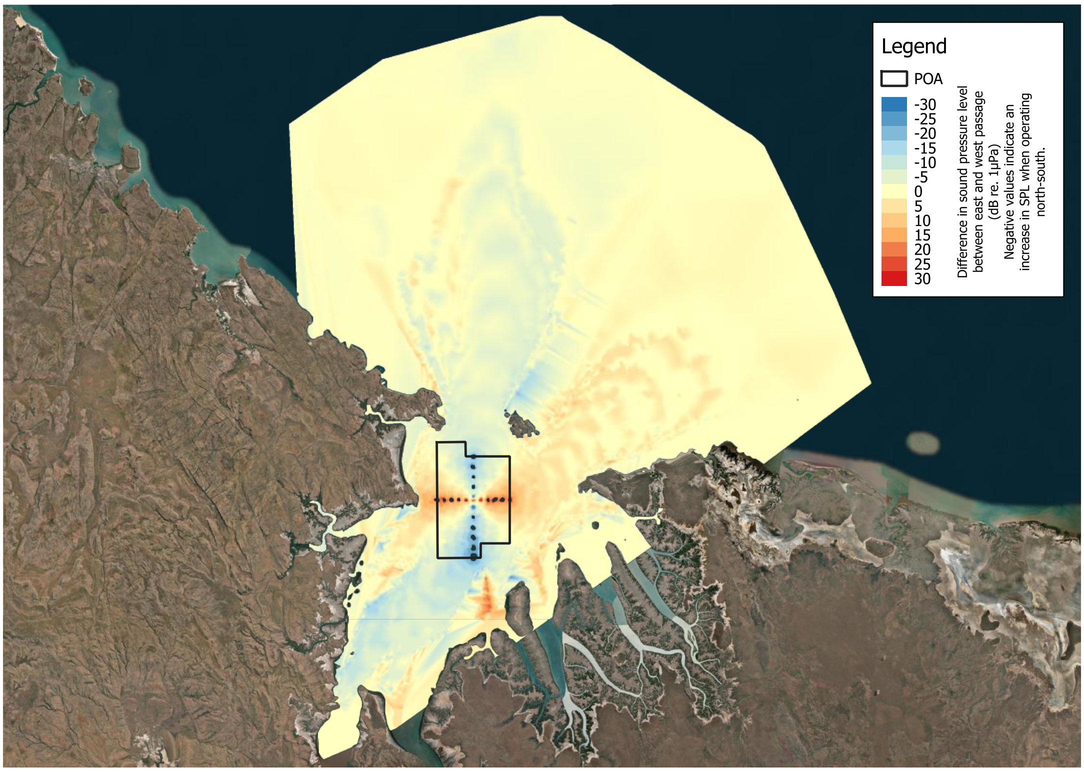


Figure 13 Difference in the radiated sound pressure level between the SPV operating in a north-south and an east-west transect.

6.2.2 Predicted threshold onset distances

Based on the simulations, the distances at which the thresholds for AUD INJ/PTS, TTS, and behavioural disturbances were identified and reported in Table 11. It is important to note that the spatial resolution of this model limits the distances of the threshold to no less than 40 m.

Table 11: Predicted underwater noise threshold onset distances for AUD INJ, TTS and behavioural disturbance

Hearing Group	Criteria	Sand loading	Sand loading with thrusters at transect ends	Transit
AUD INJ				
High-frequency cetaceans (HF) (snubfin & humpback dolphin)	$SEL_{24\ hour}$ 201 dB(HF)	< 40 m	< 40 m	< 40 m
PTS				
Marine Turtles (TU)	$SEL_{24\ hour}$ 220 dB(TU)	< 40 m	< 160 m	< 40 m
TTS				
High-frequency cetaceans (HF) (snubfin & humpback dolphin)	$SEL_{24\ hour}$ 181 dB(HF)	120 m	160 m	80 m
Marine Turtles (TU)	$SEL_{24\ hour}$ 200 dB(TU)	120 m	160 m	80 m
Behavioural disturbance				
High-frequency cetaceans (HF) (snubfin & humpback dolphin)	120 dB rms	3.5 km(1)	3.8 km(1)	2.6 km(1)
Marine Turtles (TU)	175 dB rms	< 40 m	< 320 m	< 40 m

(1) Due to the effects of bathymetry over the large distance, the presented values are nominal onset distances and are better represented through contours which are presented in Appendix B – Contours showing disturbance region.

6.2.3 Predicted underwater noise levels at turtle nesting sites

The levels at the turtle nesting sites shown in Figure 2 are presented in Table 12.

Table 12 Sound levels at turtle nesting sites

ID	Name	Sand loading		Sand loading with thrusters at transect ends		Transit	
		SEL_{24hour}	RMS SPL	SEL_{24hour}	RMS SPL	SEL_{24hour}	RMS SPL
1	Cape Domett - Seaward Beach	128 dB(TU)	89 dB	131 dB(TU)	90 dB	125 dB(TU)	87 dB
1A	Cape Domett - Small Beach	149 dB(TU)	102 dB	144 dB(TU)	105 dB	126 dB(TU)	86 dB
2	Lacrosse Island - Turtle Bay	166 dB(TU)	118 dB	167 dB(TU)	122 dB	166 dB(TU)	121 dB
3	Cape Dussejour - Turtle Beach West	N/A	N/A	N/A	N/A	126 dB(TU)	89 dB
4	Barnett Point	131 dB(TU)	91 dB	131 dB(TU)	91 dB	115 dB(TU)	75 dB

6.3 Study Findings for Task 2: Impact Assessment

This section describes the potential hearing impact on each considered species for this study.

6.3.1 Potential hearing injury impacts on Snubfin & Humpback Dolphins

The predicted threshold onset distances for auditory injury (AUD INJ) and temporary threshold shift (TTS in high-frequency (HF) cetaceans are as follows:

- **AUD INJ:** <40 m for all scenarios (Note: The model's spatial resolution limits minimum threshold distance estimates to 40 m).
- **TTS:** 120 m during sand loading, 160 m with bow thruster operation at transect ends, and 80 m during vessel transit.

These thresholds assume that the target species remain at the specified distance from the sound source for a continuous 24-hour period. This is highly unlikely to occur as both the SPV and target species are mobile. As the animals get closer to the SPV, they will be exposed to increasing noise levels. Since the limiting factor for AUD INJ and TTS are sound exposure levels, a brief incursion inside these thresholds may not result in an exceedance if their exposure for the remainder of the 24-hour period is lower. However, these thresholds denote the safe distance that ensures that an exceedance does not occur.

Overall, the likelihood of AUD INJ / TTS to HF cetaceans is considered negligible. This is due to several factors:

- the spatial constraints of SPV operations within the POA,
- the short duration of the presence of the SPV in the POA during each sand loading cycle (between 24 and 48 hours), whereafter the SPV will depart CG for two weeks to deliver the sand to Asia and return to CG,
- the expected avoidance response of mobile species to localised sand loading activity.

Additionally, most of the sound energy produced by the SPV occurs at frequencies where HF cetaceans exhibit relatively low hearing sensitivity (see Figure 3 and Figure 9), further reducing the potential for hearing-related impacts.

6.3.2 Potential behavioural impacts on Snubfin & Humpback Dolphins

The modelled distances at which snubfin and humpback dolphins may exhibit behavioural responses to underwater noise are approximately as follows:

- **Sand loading:** <3.5 km
- **Sand loading with bow thruster operation at transect ends:** <3.8 km
- **Vessel transit:** <2.6 km

The north-south dimension of the POA is approximately 15 km at the longest axis and the west-west dimension of the POA is approximately 9 km.

These distances suggest that dolphins could begin to exhibit avoidance behaviour or altered activity patterns before entering the POA. For example, sand loading and thruster noise has the potential to elicit behavioural responses at distances up to 3.5 km and 3.8 km, respectively. Transit-related noise may also cause behavioural changes up to 2.6 km from the SPV as vessels enters and departs CG via West Entrance.

Notably, most snubfin dolphin sightings during BKA's marine fauna surveys occurred in the southern section of CG, particularly around Adolphus Island, which is approximately 20 km south of the nearest (southern) boundary of the POA (BKA 2024). Previous surveys by Brown et al. (2016) indicate that humpback dolphins are more commonly associated with the intertidal sandbanks located just south of Cape Dussejour.

In this context, it is unlikely that snubfin dolphins will be significantly affected by underwater noise associated with POA operations. However, humpback dolphins may experience behavioural disturbance when the SPV operates near the northwestern boundary of the POA, particularly if foraging near the coastal sandbanks.

6.3.3 Potential hearing injury impacts on Flatback Turtles

The predicted threshold onset distances for permanent threshold shift (PTS) and temporary threshold shift (TTS) are as follows:

- **PTS:**
  – <40 m during sand loading
  – <160 m during sand loading with thruster operation at the ends of a transect
  – <40 m during vessel transit through West Entrance
  (Note: The model's spatial resolution limits the minimum threshold distance to 40 m.)
- **TTS:**
  – 120 m during sand production
  – 160 m during sand loading with thruster operation at the ends of a transect
  – 80 m during vessel transit through West Entrance

Overall, the likelihood of PTS/TTS to marine turtles is considered negligible, for the same reasons as listed for dolphins above.

In contrast to HF cetaceans, marine turtles are most sensitive to the lower-frequency range where the majority of the SPV's sound energy occurs (see Figure 3 and Figure 9). However, the modelled results indicate that all known turtle nesting sites are well below the TTS threshold. The closest predicted exposure (at Lacrosse Island) is at least 33 dB below the TTS threshold, with the next closest site 57 dB below, suggesting a negligible risk of auditory impact to nesting turtles.

6.3.4 Potential behavioural impacts on Flatback Turtles

The modelled threshold onset distances for a potential behavioural response in flatback turtles due to underwater noise are as follows:

- **Sand loading:** <40 m
- **Sand loading with thruster operation at the ends of a transect:** <320 m
- **Vessel transit:** <40 m
  (Note: The model's spatial resolution limits minimum distance estimates to no less than 40 m.)

Importantly, all known flatback turtle nesting locations in the region are well beyond the predicted zones of potential disturbance. The closest nesting beach – on Lacrosse Island – is predicted to experience received noise levels at least 53 dB below the 175 dB RMS behavioural threshold. Other nesting sites are even further removed, with lower predicted noise levels, confirming a negligible risk of behavioural disturbance to nesting females or hatchlings.

6.4 Risk assessment

This section outlines the risk assessment undertaken to identify if further control measures are required.

6.4.1 Risk assessment approach and criteria

This section outlines the risk assessment undertaken, applying the outcomes of the noise modelling and impact assessments presented above, to identify if further control measures might be required.

The assessment of risk is based on the following internationally accepted definition of risk:

- Likelihood × Consequence = Risk.

To enable the determination of risk, it is necessary to define categories and criteria for both likelihood and consequence, and to define the resulting risk rankings. These are presented in Table 13, Table 14 and Table 15 respectively, based on parameters that are relevant to the assessment of potential significant impacts on marine fauna under the WA *Environmental Protection Act*, WA *Biodiversity Conservation Act* and the Commonwealth *Environment Protection & Biodiversity Conservation Act*, and related guidelines.

Three likelihood categories have been used as follows:

- Likely
- Possible
- Unlikely.

Three consequence categories have been used as follows:

- Major
- Moderate
- Minor.

These have been combined to derive the following nine possible risk rankings:

- Likely × major consequence = **high risk.**
- Likely × moderate consequence = **medium risk.**
- Likely × minor consequence = **low risk.**

- Possible × major consequence = **medium risk.**
- Possible × moderate consequence = **low risk.**
- Possible × minor consequence = **negligible risk.**

- Unlikely × major consequence = **medium risk.**
- Unlikely × moderate consequence = **low risk.**
- Unlikely × minor consequence = **negligible risk.**

Table 13: Likelihood categories and criteria

Likelihood Category	Criteria
Likely:	Might occur during every sand-loading cycle when the SPV is present in the POA.
Possible:	Might occur during the occasional sand-loading cycle when the SPV is present in the POA.
Unlikely:	Not expected to occur during any sand-loading cycle when the SPV is present in the POA.

Table 14: Consequence categories and criteria

Consequence Category	Criteria
Major:	Population numbers impacted negatively.
Moderate:	Potential impacts on several individuals but not on population.
Minor:	Potential impacts on the occasional individual but not on population.

Table 15: Risk rankings

Likelihood	× Consequence	= Risk Ranking
Likely	× major	= high
Likely	× moderate	= medium
Likely	× minor	= low
Possible	× major	= medium
Possible	× moderate	= low
Possible	× minor	= negligible
Unlikely	× major	= medium
Unlikely	× moderate	= low
Unlikely	× minor	= negligible

6.4.2 Risk assessment outcomes

The likelihood and consequence categories and risk rankings described in Section 6.4.1 have been applied to derive the risk assessment outcomes for the two target dolphin species in Table 16 and for flatback turtles in Table 17, which include descriptions of the rationale for each assessment, including considering the intensity and duration of potential underwater noise impacts.

Table 16: Risk assessment outcomes for the two target dolphin species

Potential Impact	Likelihood		Consequence		Risk Ranking
	Category	**Rationale**	**Category**	**Rationale**	
Auditory injury from sand loading operations	**Unlikely**	Short duration of presence of the SPV in the POA during each sand-loading cycle (24 to 48 hours every two weeks) relative to the threshold, which requires continuous 24-hour exposure. Constant mobility of both the SPV and the animals which makes 24-hr exposure highly unlikely during any sand-loading cycle. Short AUD INJ and TTS distance (<40 m and 120 m respectively) from the SPV) and low likelihood that animals would enter into this distance, given: • Very low presence of the animals in the POA as indicated by comprehensive site surveys (BKA 2024a). • The large area of the POA (>100 km^2) and the main body of CG (~ 2,000 km^2) relative to the footprint of the SPV (350 m long). • The naturally shy and illusive behaviour of the two target dolphin species, with a natural tendency to move away from operational vessels (Brown et al. 2016) • Implementation of Marine Fauna Observation & Avoidance (MFOA) procedures on the SPV (see Appendix C for Boskalis' capabilities).	**Minor**	Sound energy produced by the SPV is non-impulsive. Most of the sound energy produced by the SPV occurs at frequencies where HF cetaceans exhibit relatively low hearing sensitivity, reducing the potential for hearing-related impacts. Any isolated auditory injury that might occur to an individual (which is highly unlikely for the reasons stated) would not have population-level impacts.	**Negligible**

Potential Impact	Likelihood		Consequence		Risk Ranking
	Category	Rationale	Category	Rationale	
Auditory injury from sand loading operations, with bow thruster used at transect ends	Unlikely	NOTE: It is most likely that the SPV will not be fitted with a bow thruster, however this scenario is included as a possible option. Rationale is the same as for sand loading above, except that the TTS distance is slightly larger at ≤160 m from the SPV.	Minor	As per sand loading above.	Negligible
Auditory injury from SPV transit via West Entrance	Nil	The SPV's transit time through West Entrance when entering and departing CG will be ~30 mins, so it will be impossible for the continuous 24-hr exposure period, which constitutes the threshold, to be reached during the transit scenario.	Nil	If there is nil likelihood there is nil consequence.	Nil

Potential Impact	Likelihood		Consequence		Risk Ranking
	Category	**Rationale**	**Category**	**Rationale**	
Behavioural changes e.g. avoidance from sand loading operations,	**Possible**	Short duration of presence of the SPV in the POA during each sand-loading cycle (24 to 48 hours every two weeks). Constant mobility of both the SPV and the animals which makes the potential disturbance beyond a short duration unlikely during any sand-loading cycle. Threshold distance (≤3.5 km from the SPV) is within the dimensions of the POA (15 km × 9 km) and low likelihood that animals would enter into this distance, given: • Very low presence of the animals in the POA as indicated by comprehensive site surveys (BKA 2024a). • The large area of the POA (>100 km^2) and the main body of CG (~ 2,000 km^2) relative to the footprint of the SPV (350 m long). • The naturally shy and illusive behaviour of the two target dolphin species, with a natural tendency to move away from operational vessels (Brown et al 2016) • Implementation of Marine Fauna Observation & Avoidance (MFOA) procedures on the SPV (see Appendix C for Boskalis' capabilities).	**Minor**	Should any behavioural change occur it is most likely to be avoidance of the SPV by moving away from it – given the naturally shy and illusive behaviour of the two target dolphin species. The very large area of the POA (>100 km^2) and the main body of CG (~ 2,000 km^2) relative to the footprint of the SPV (350 m long) provide significant area to allow ease of movement of the animals away from the SPV. Any isolated behaviour changes that might occur would be to an individual or a few individuals (if they are in a group) and for a short duration only and would not have population-level impacts.	**Negligible**

Potential Impact	Likelihood		Consequence		Risk Ranking
	Category	Rationale	Category	Rationale	
Behavioural changes e.g. avoidance from sand loading operations, <u>with bow thruster used at transect ends</u>	Possible	NOTE: It is most likely that the SPV will not be fitted with a bow thruster, however this scenario is included as a possible option. Rationale is the same as for sand loading above, except that the threshold distance is slightly larger at <3.8 km from the SPV.	Minor	As per sand loading above.	Negligible
Behavioural changes e.g. avoidance from SPV transit via West Entrance	Unlikely	As per sand loading above, except that likelihood is even less as transit times through West Entrance will only be ~30 mins each transit.	Minor	As per sand loading above, except that consequence is even less as transit times through West Entrance will only be ~30 mins each transit.	Negligible

Table 17: Risk assessment outcomes for flatback turtles

<table>
<tr><th rowspan="2">Potential Impact</th><th colspan="2">Likelihood</th><th colspan="2">Consequence</th><th>Risk Ranking</th></tr>
<tr><th>Category</th><th>Rationale</th><th>Category</th><th>Rationale</th><th></th></tr>
<tr><td>Auditory injury from sand loading operations</td><td>Unlikely</td><td>Short duration of presence of the SPV in the POA during each sand-loading cycle (24 to 48 hours every two weeks) relative to the threshold, which requires continuous 24-hour exposure.
Constant mobility of both the SPV and the animals which makes 24-hr exposure highly unlikely during any sand loading cycle.
Short PTS/TTS distance (≤40 m and 120 m respectively from the SPV) and very low likelihood that animals would enter into this distance, given:
• Very low presence of the animals in the POA as indicated by comprehensive site surveys (BKA 2024a).
• The large area of the POA (>100 km^2) and the main body of CG (~ 2,000 km^2) relative to the footprint of the SPV (350 m long).
• Implementation of Marine Fauna Observation & Avoidance (MFOA) procedures on the SPV (see Appendix C for Boskalis' capabilities).</td><td>Minor</td><td>Sound energy produced by the SPV is non-impulsive.
Most of the sound energy produced by the SPV occurs at frequencies where marine turtles exhibit relatively high hearing sensitivity, creating potential for hearing-related impacts. However, the threshold onset distances are small (tens of metres) in comparison to the size of the vessel and distance to known nesting areas.
Any isolated auditory injury that might occur to an individual (which is unlikely for the reasons stated) would not have population-level impacts.</td><td>Negligible</td></tr>
</table>

Potential Impact	Likelihood		Consequence		Risk Ranking
	Category	Rationale	Category	Rationale	
Auditory injury from sand loading operations, <u>with bow thruster used at transect ends</u>	Unlikely	NOTE: It is most likely that the SPV will not be fitted with a bow thruster, however this scenario is included as a possible option. Rationale is the same as for sand loading above, except that the threshold distance is slightly larger at <160 m from the SPV.	Minor	As per sand loading above.	Negligible
Auditory injury from SPV transit via West Entrance	Nil	The SPV's transit time through West Entrance when entering and departing CG will be ~30 mins, so it will be impossible for the continuous 24-hr exposure period, which constitutes the threshold, to be reached during the transit scenario.	Nil	If there is nil likelihood there is nil consequence.	Nil

Potential Impact	Likelihood		Consequence		Risk Ranking
	Category	**Rationale**	**Category**	**Rationale**	
Behavioural changes e.g. avoidance of sand loading operations	**Possible**	Short duration of presence of the SPV in the POA during each sand-loading cycle (24 to 48 hours every two weeks). Constant mobility of both the SPV and the animals which makes the potential disturbance beyond a short duration unlikely during any sand-loading cycle. Threshold distance (<40 m) from the SPV) is within the dimensions of the POA (15 km × 9 km) and low likelihood that animals would enter into this distance, given: • Very low presence of the animals in the POA as indicated by comprehensive site surveys (BKA 2024a). • The large area of the POA (>100 km^2) and the main body of CG (~ 2,000 km^2) relative to the footprint of the SPV (350 m long). • Implementation of Marine Fauna Observation & Avoidance (MFOA) procedures on the SPV (see Appendix C for Boskalis' capabilities).	**Minor**	Should any behavioural change occur it is most likely to be avoidance of the SPV by moving away from it. The very large area of the POA (>100 km^2) and the main body of CG (~ 2,000 km^2) relative to the footprint of the SPV (350 m long) provide significant area to allow ease of movement of the animals away from the SPV. Any isolated behavour changes that might occur would be to an individual and for a short duration only and would not have population-level impacts.	**Negligible**

Potential Impact	Likelihood		Consequence		Risk Ranking
	Category	Rationale	Category	Rationale	
Behavioural changes e.g. avoidance from sand loading operations with bow thruster used at transect ends	**Possible**	NOTE: It is most likely that the SPV will not be fitted with a bow thruster, however this scenario is included as a possible option. Rationale is the same as for 'no bow thruster' above, except that the threshold distance is larger at ≤320 m from the SPV.	**Minor**	As per sand loading above.	**Negligible**
Behavioural changes e.g. avoidance from SPV transit via West Entrance	**Unlikely**	As per sand loading above, except that likelihood is even less as transit times through West Entrance will only be ~30 mins each transit.	**Minor**	As per sand loading above, except that consequence is even less as transit times through West Entrance will only be ~30 mins each transit.	**Negligible**

6.4.3 Risk assessment certainty

In our opinion, there are no material sources of uncertainty in the impact assessment that would result in a greater risk to the target species than has been modelled. The assessment is supported by comprehensive data across key parameters, including detailed specifications of SPV sound sources, site-specific environmental conditions in Cambridge Gulf influencing sound propagation and attenuation, and robust information on the presence, abundance, and distribution of the target species.

6.4.4 Risk summary and recommended control measures

Overall, the risk assessment finds that the risks of significant auditory and behavioural impacts from underwater noise from the SPV on the two target dolphin species and flatback turtles are negligible for all scenarios. As a precautionary measure it is recommended that BKA should:

- Implement and maintain marine fauna observation and avoidance (MFOA) protocols during operations in CG (see Appendix C for Boskalis' capabilities).
- Reassess noise modelling if operational scenarios materially change.

Resonate

7 Conclusion

The underwater noise assessment predicts negligible impacts on marine fauna within Cambridge Gulf from the proposed sand production activities by the SPV. Threshold onset distances for potential hearing injury and behavioural responses are limited in spatial extent and duration, and do not overlap significantly with key habitat areas for high-frequency cetaceans or flatback turtles. Consequently, the risk of long-term or population-level impact is considered negligible.

7.1 Recommendations

- Implement and maintain marine fauna observation and avoidance (MFOA) protocols during operations in CG (see Appendix C for Boskalis' capabilities).
- Reassess noise modelling if operational scenarios materially change.

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Appendix A – Noise maps

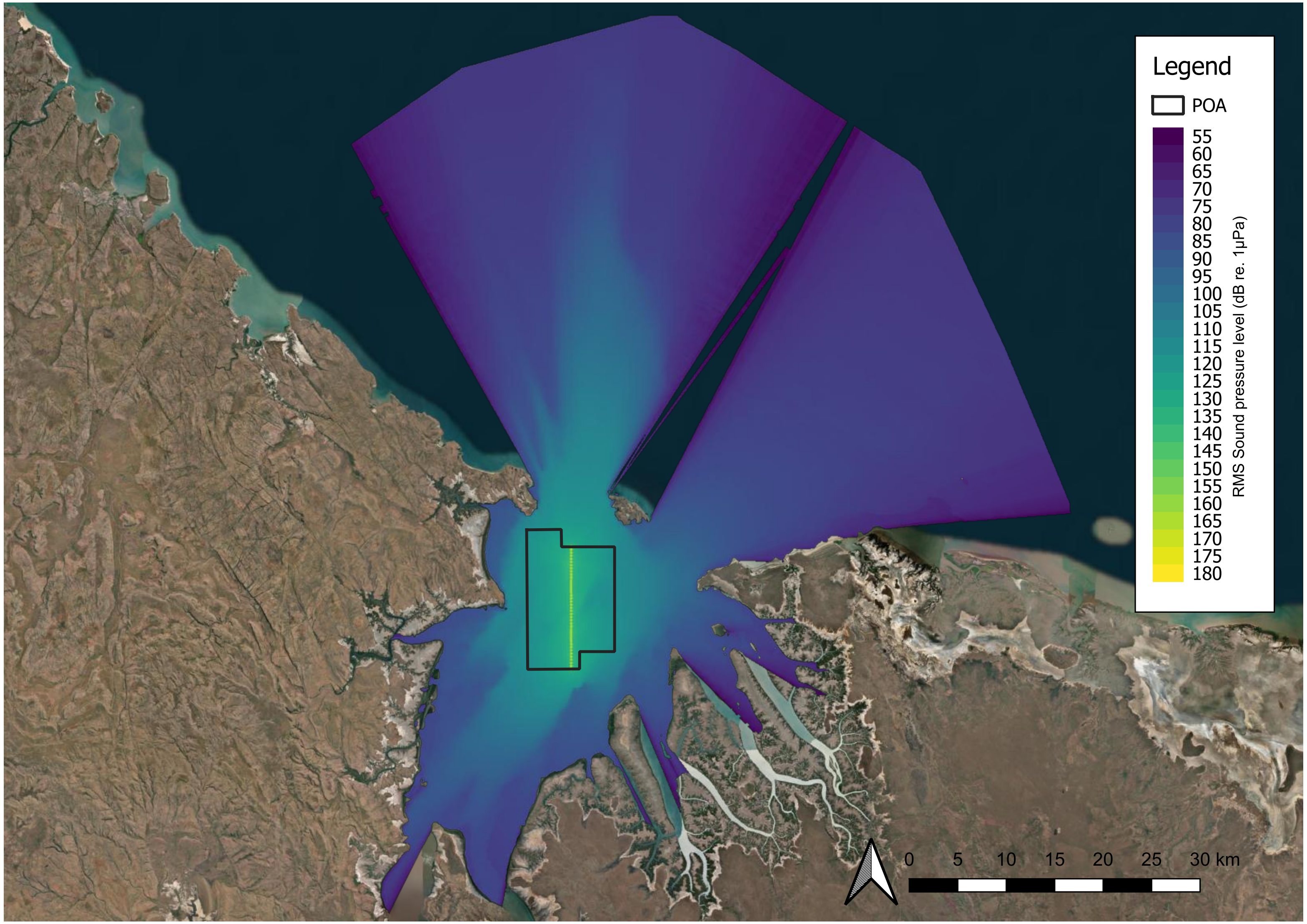


Figure 14 RMS sound pressure levels from the SPV performing a north-south sand loading transect without thrusters.

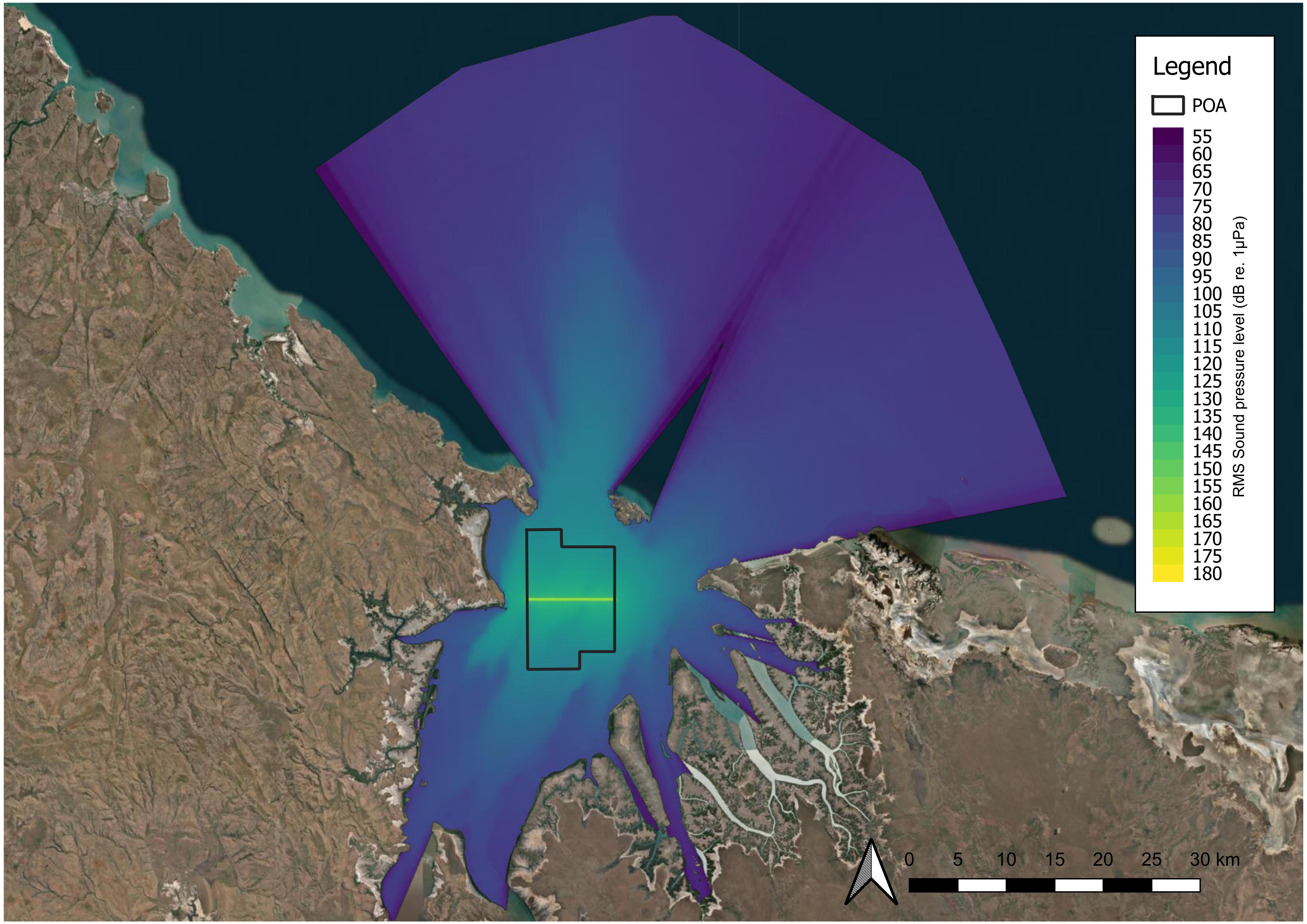


Figure 15 RMS sound pressure levels from the SPV performing an east-west sand loading transect without thrusters.

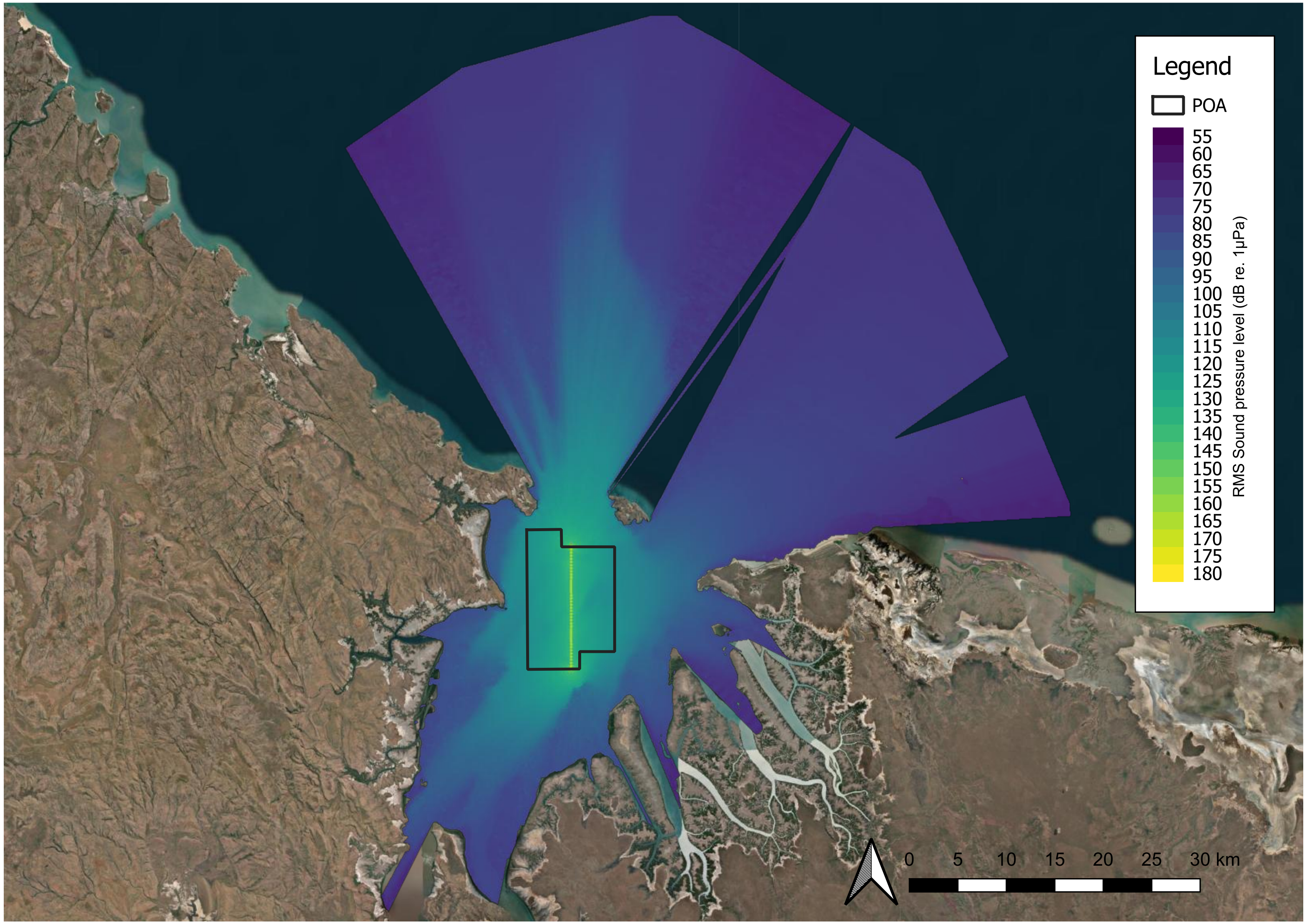


Figure 16 RMS sound pressure levels from the SPV performing a north-south sand loading transect with bow thrusters operating at the end of a transect

Resonate

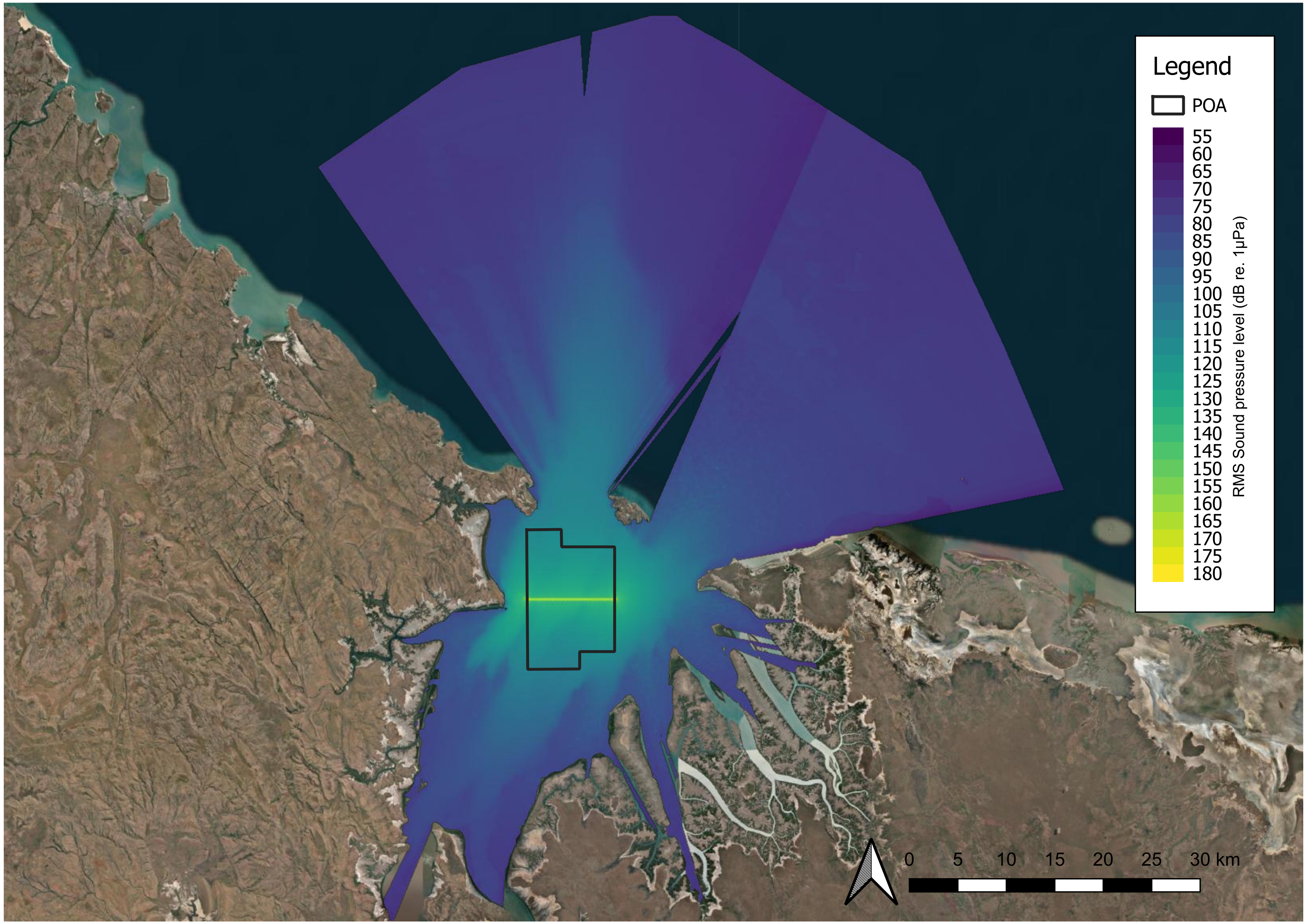


Figure 17 RMS sound pressure levels from the SPV performing an east-west sand loading transect with bow thrusters operating at the end of a transect

Resonate

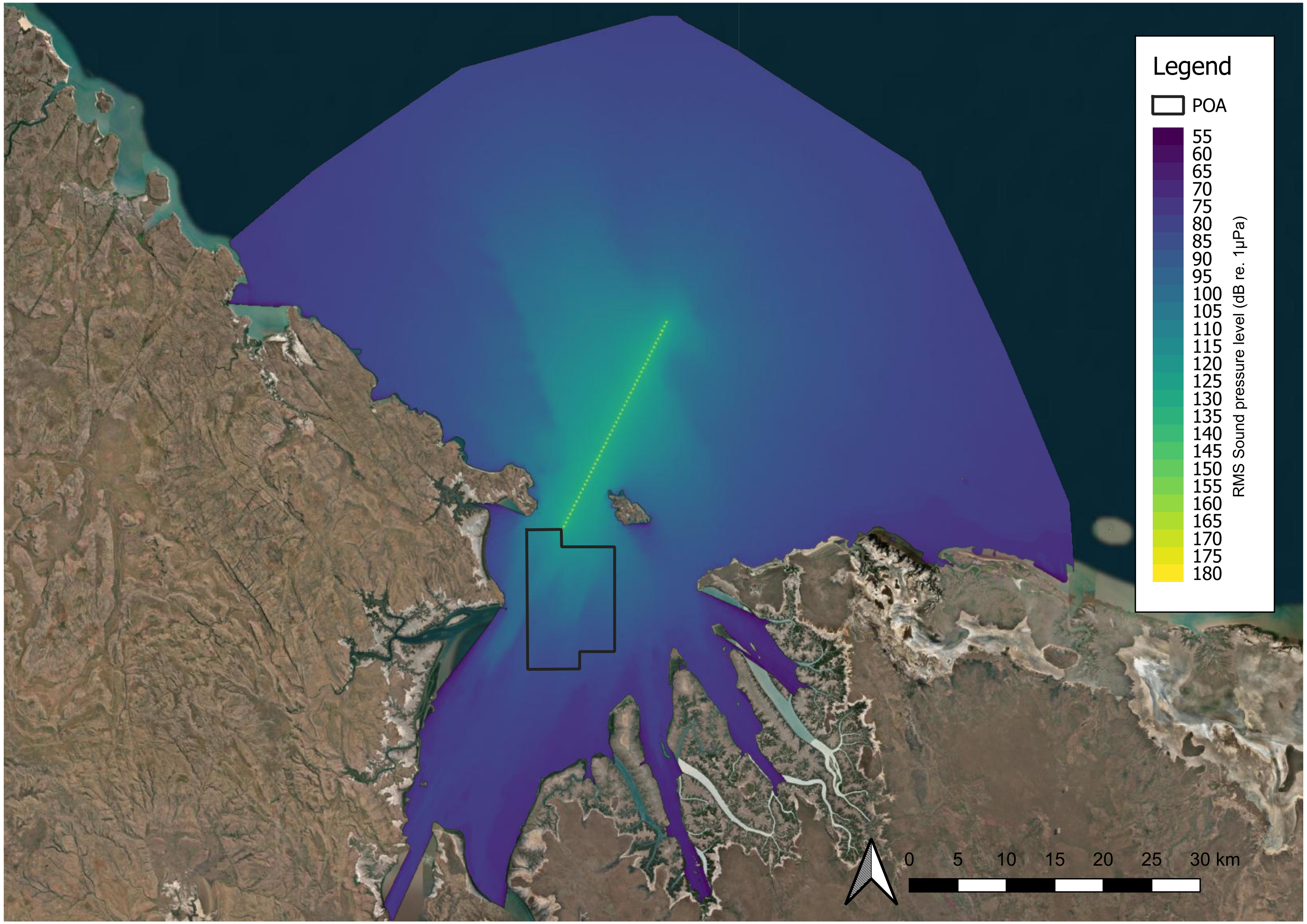


Figure 18 RMS sound pressure levels from the SPV transiting into (and out of) the POA.

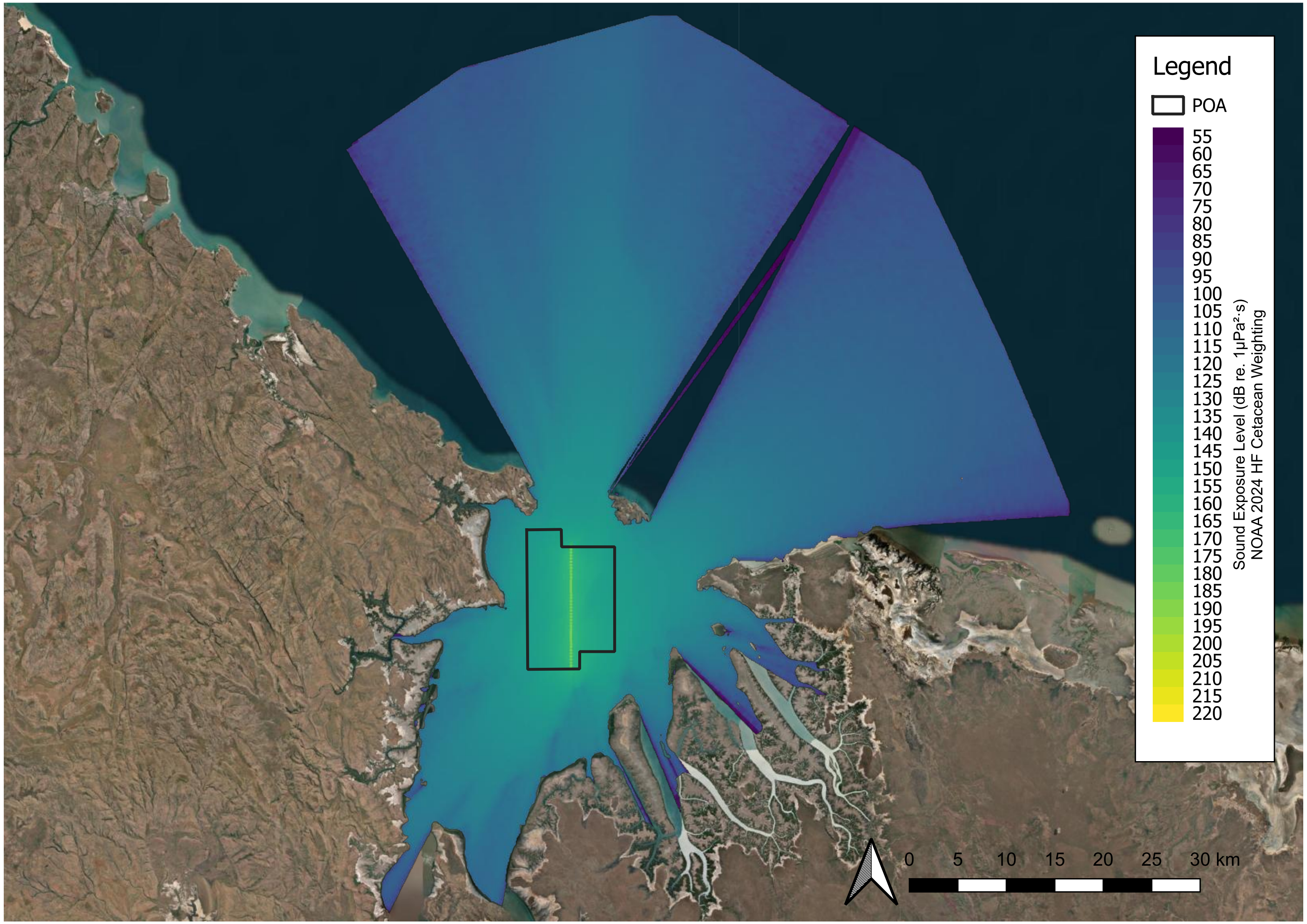


Figure 19 Sound exposure level with HF cetacean weighting from the SPV performing a north-south sand loading transect without thrusters.

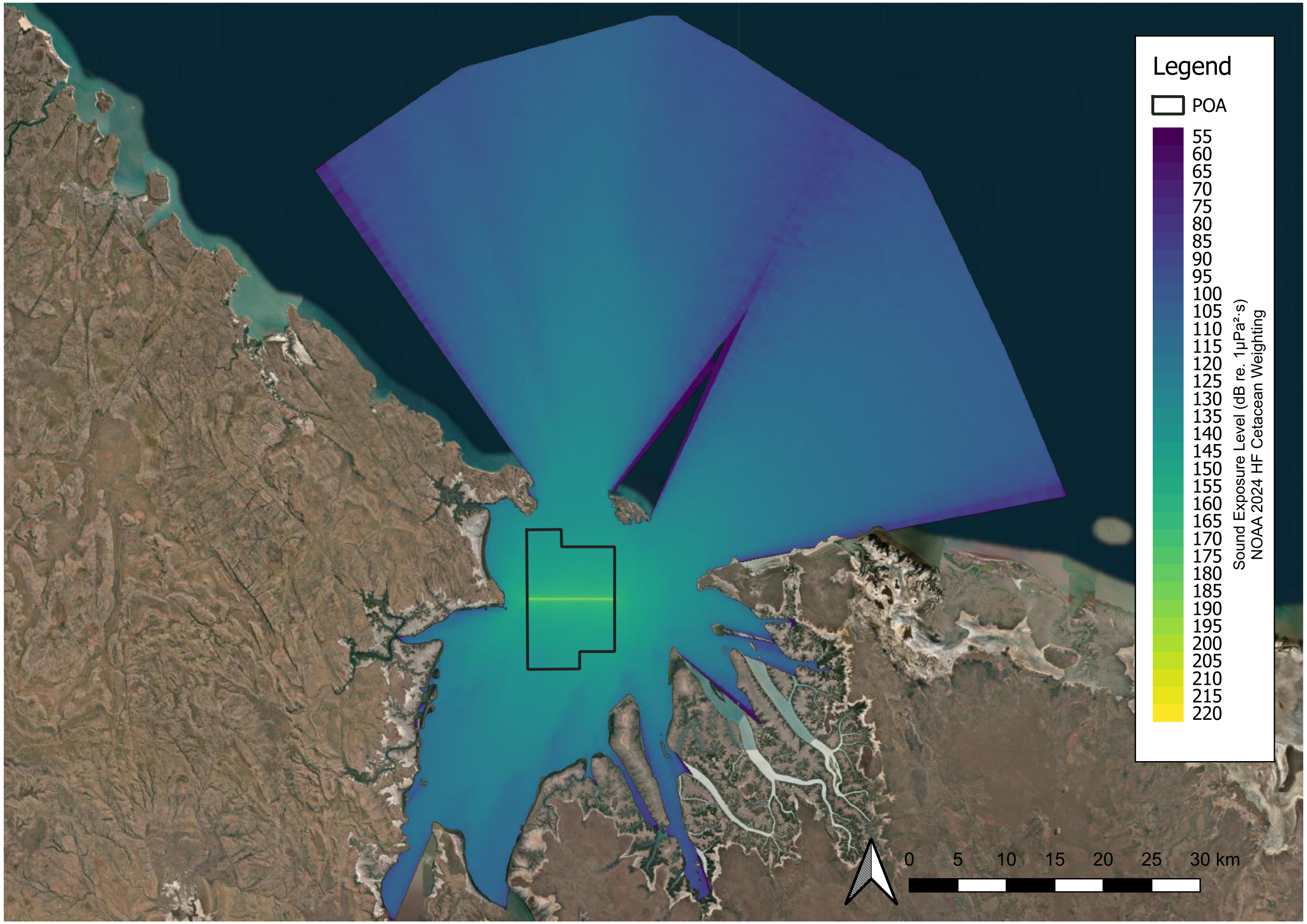


Figure 20 Sound exposure level with HF cetacean weighting from the SPV performing an east-west sand loading transect without thrusters.

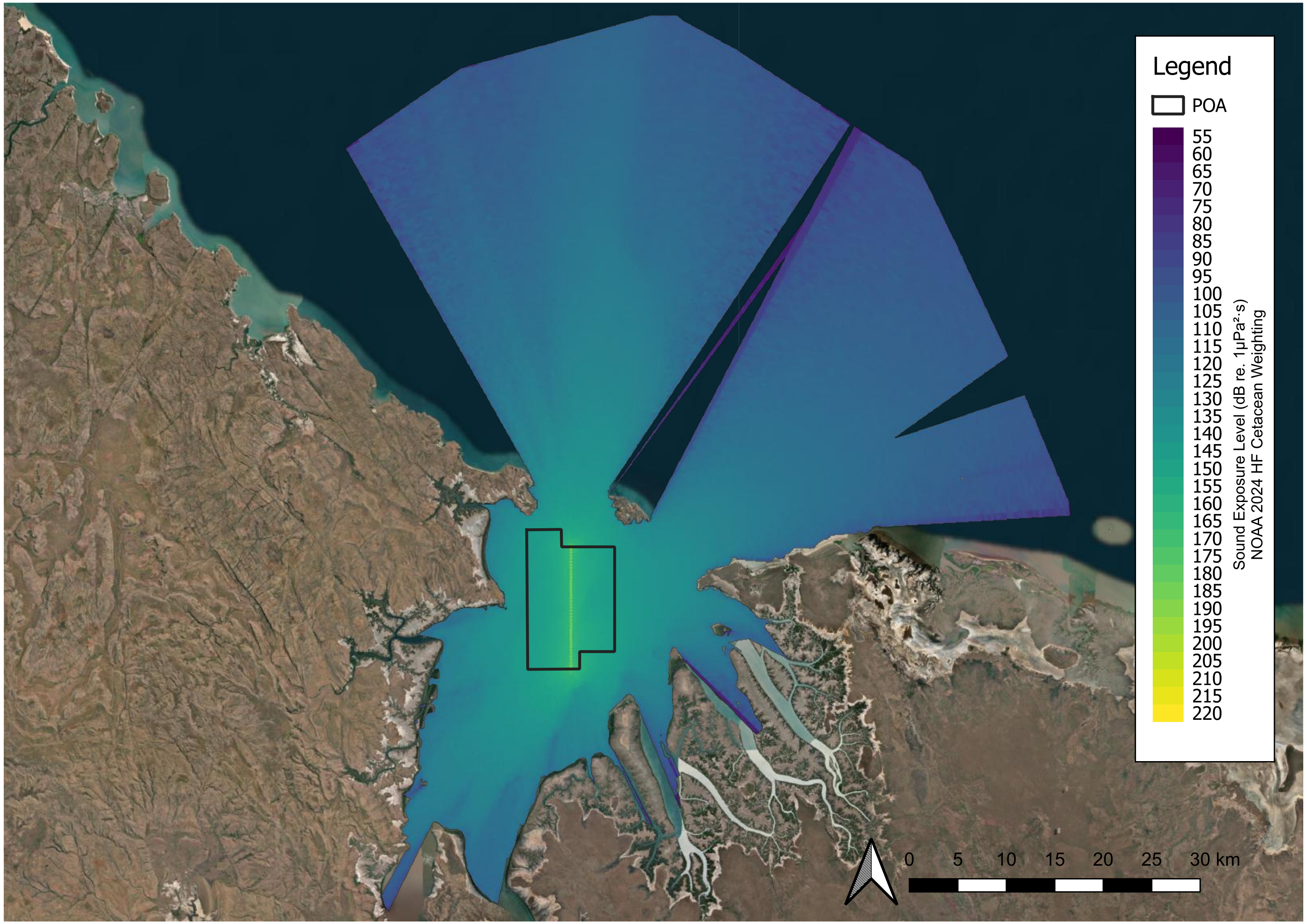


Figure 21 Sound exposure level with HF cetacean weighting from the SPV performing a north-south sand loading transect with bow thrusters operating at end of transect.

Resonate

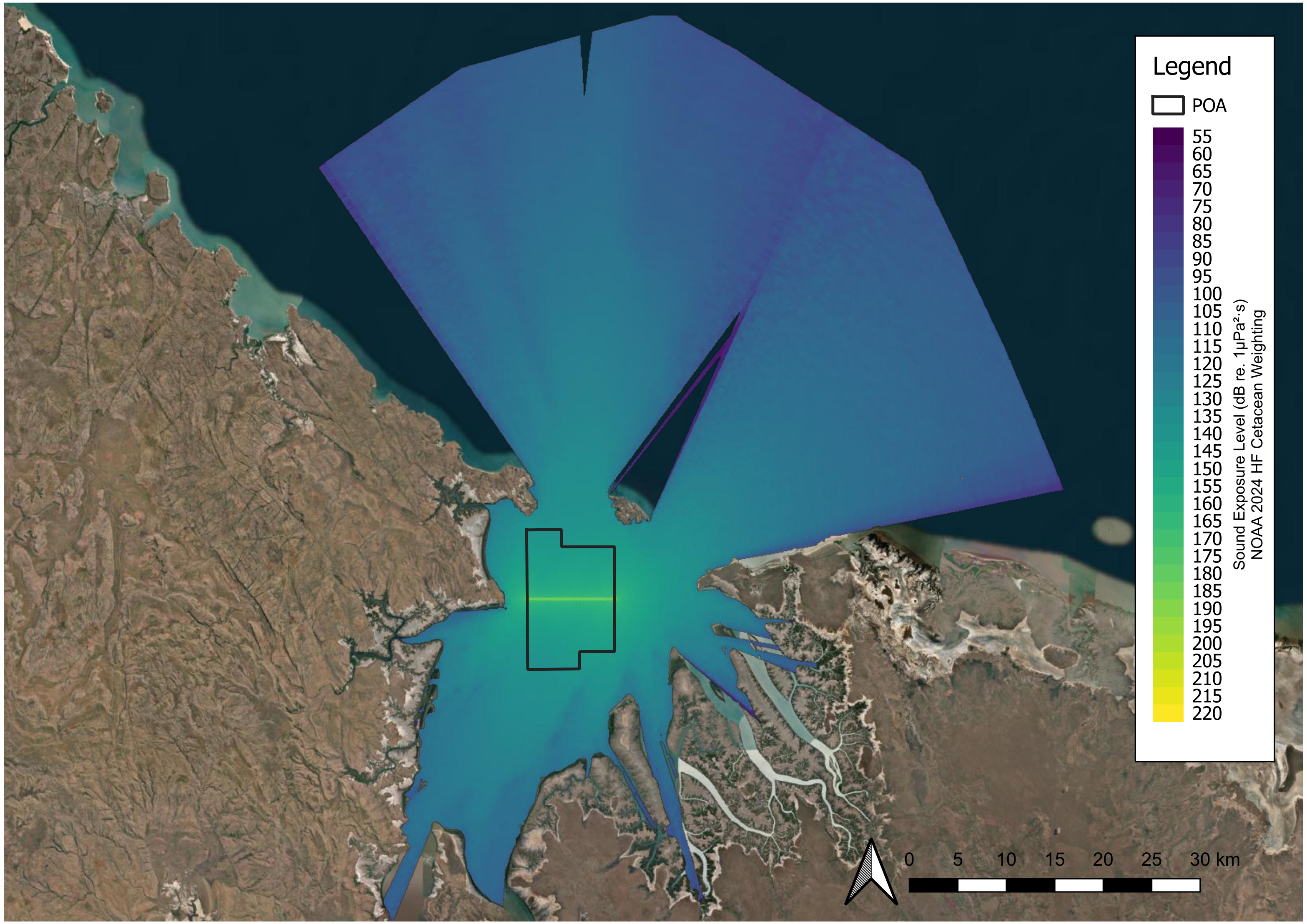


Figure 22 Sound exposure level with HF cetacean weighting from the SPV performing an east-west sand loading transect with bow thrusters operating at end of transect.

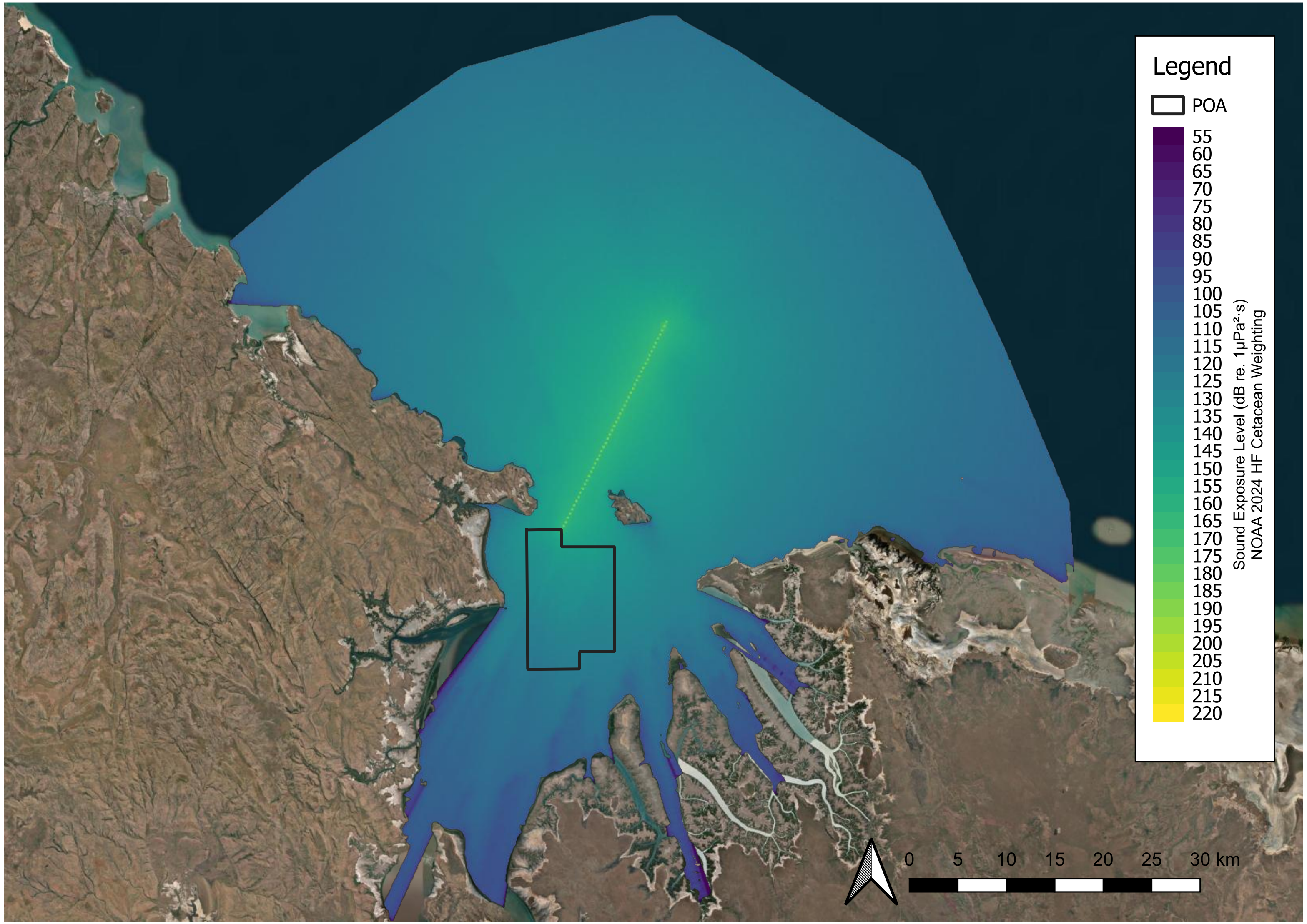


Figure 23 Sound exposure level with HF cetacean weighting from the SPV transiting into (and out of) the POA.

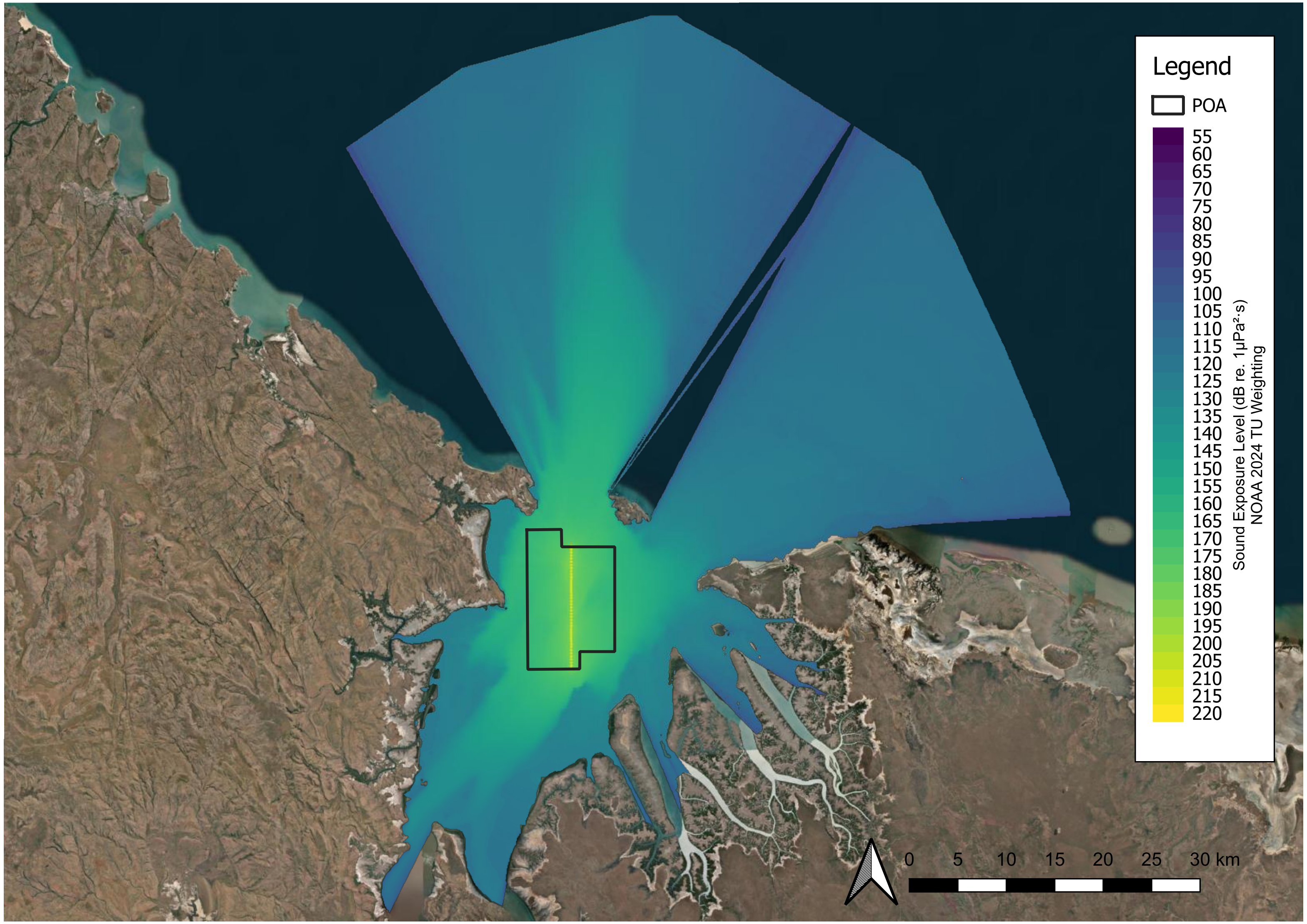


Figure 24 Sound exposure level with TU weighting from the SPV performing a north-south sand loading transect without thrusters.

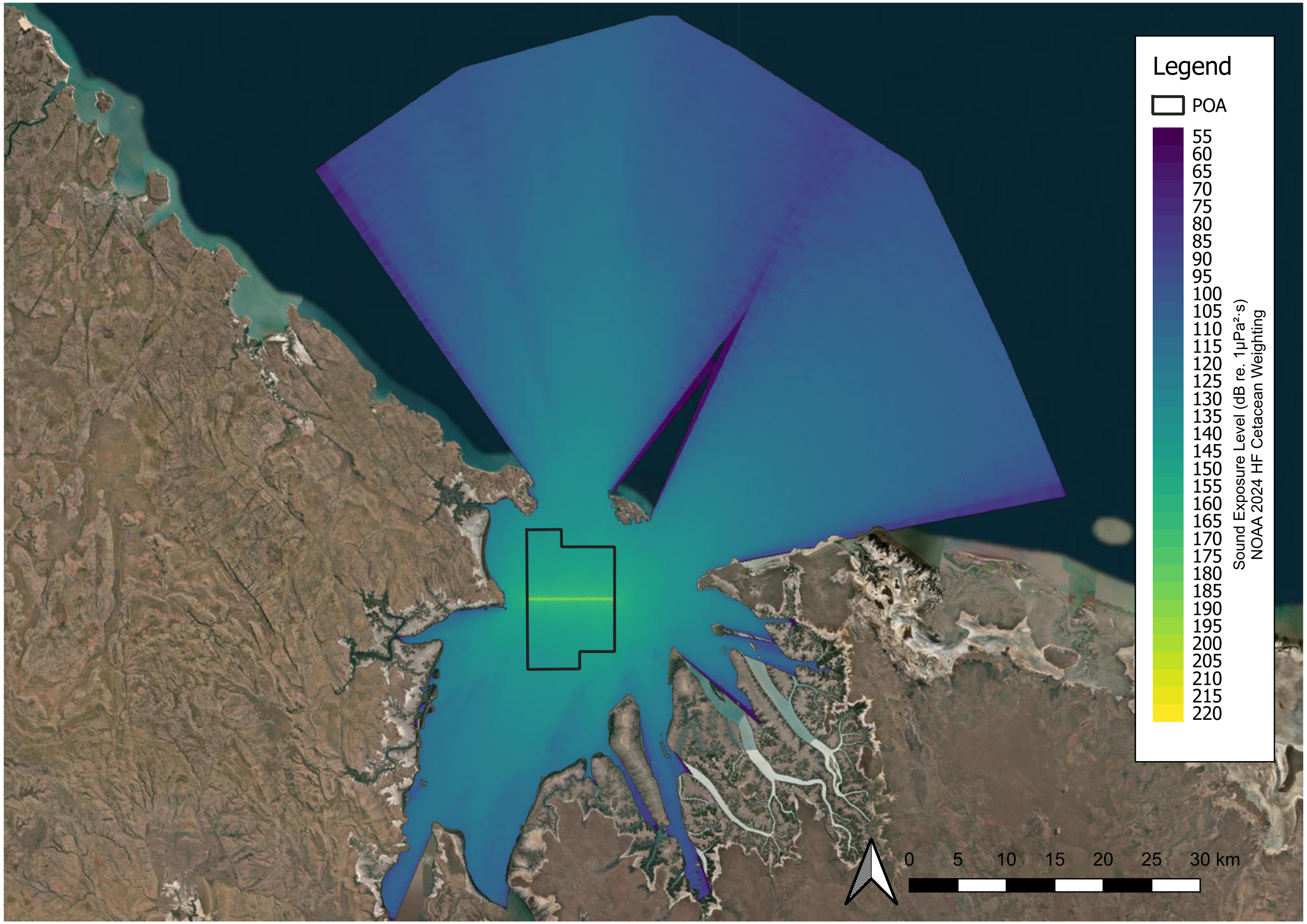


Figure 25 Sound exposure level with TU weighting from the SPV performing an east-west sand loading transect without thrusters.

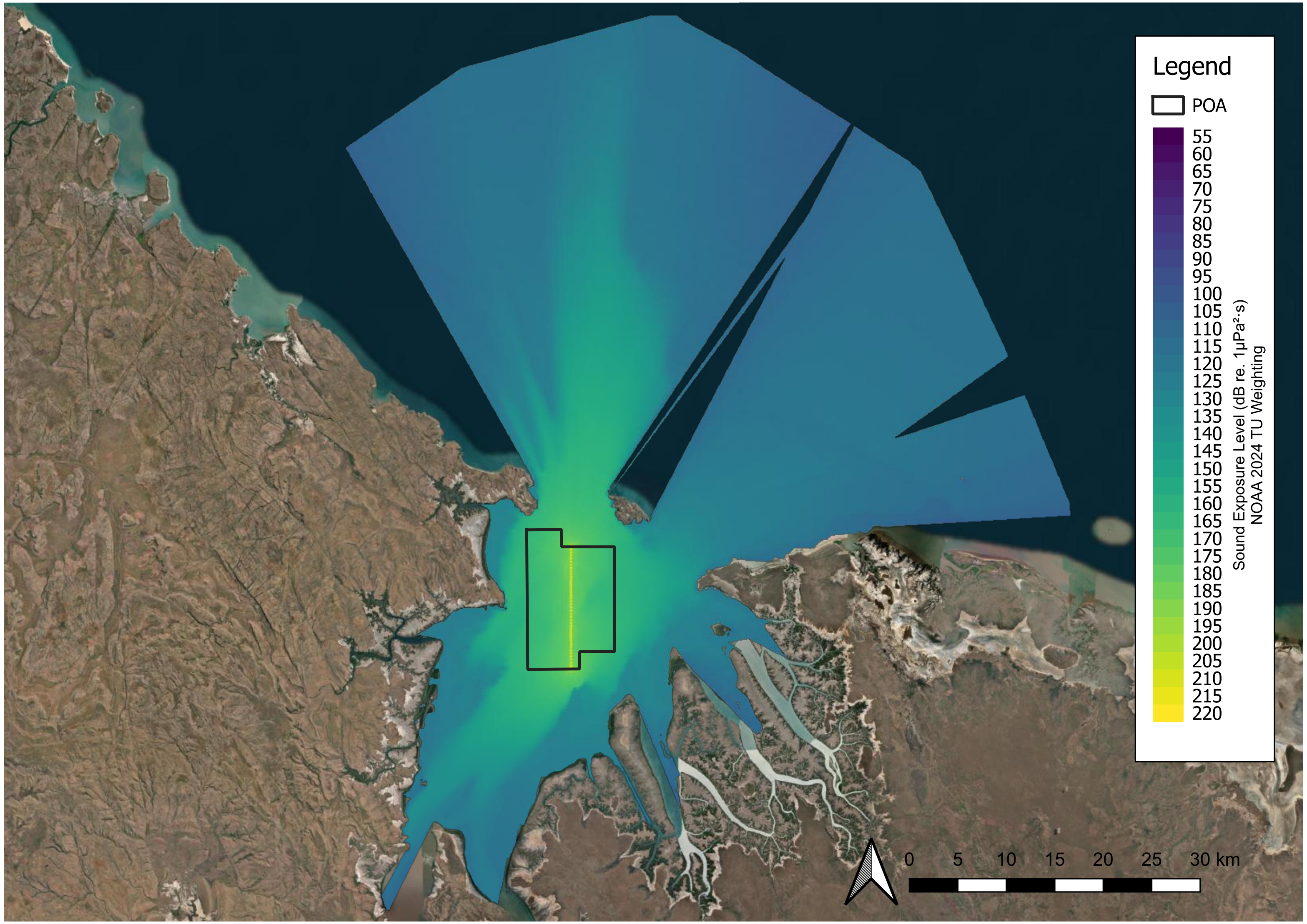


Figure 26 Sound exposure level with TU weighting from the SPV performing a north-south sand loading transect with bow thrusters operating at end of transect.

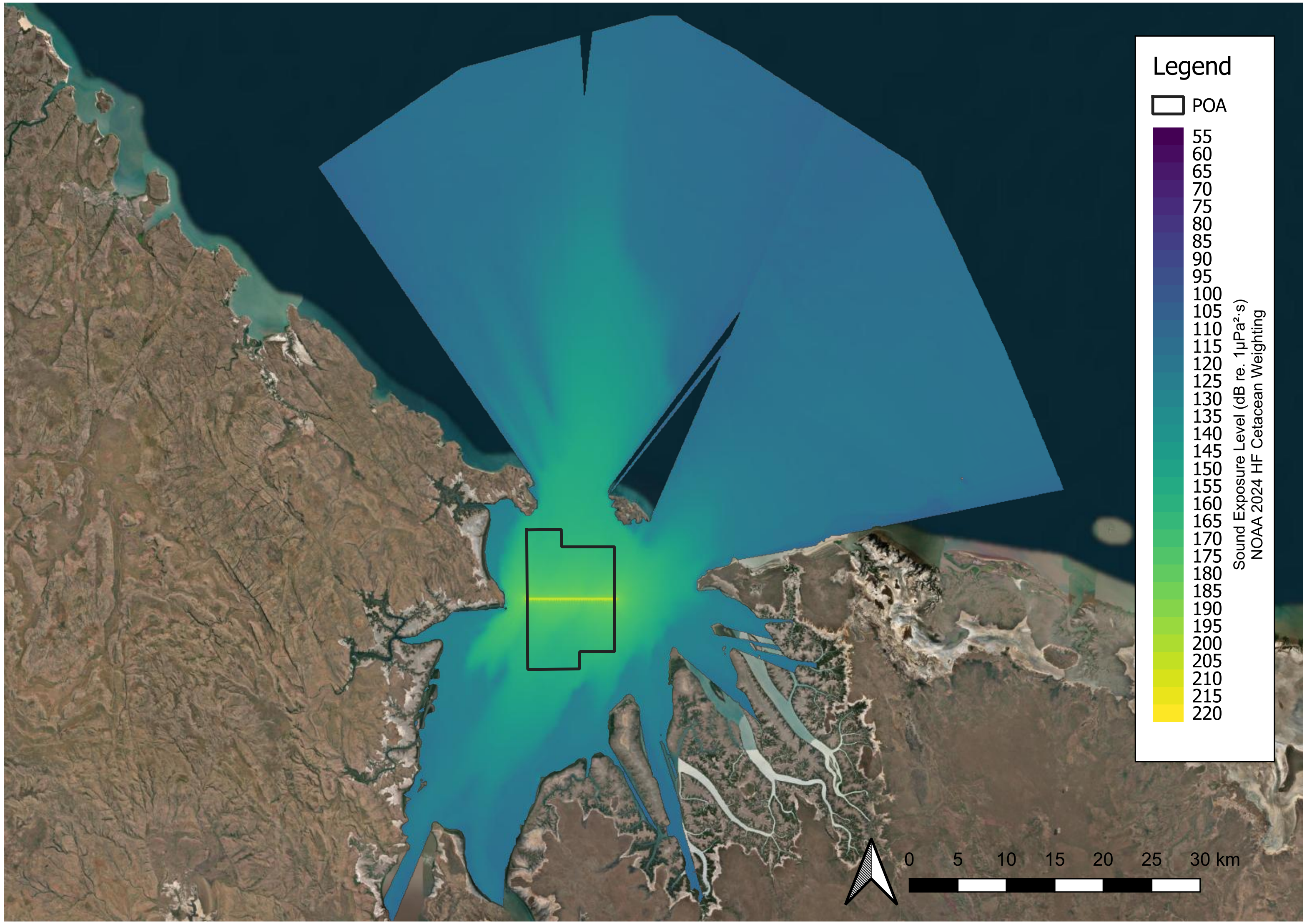


Figure 27 Sound exposure level with TU weighting from the SPV performing an east-west sand loading transect with bow thrusters operating at end of transect.

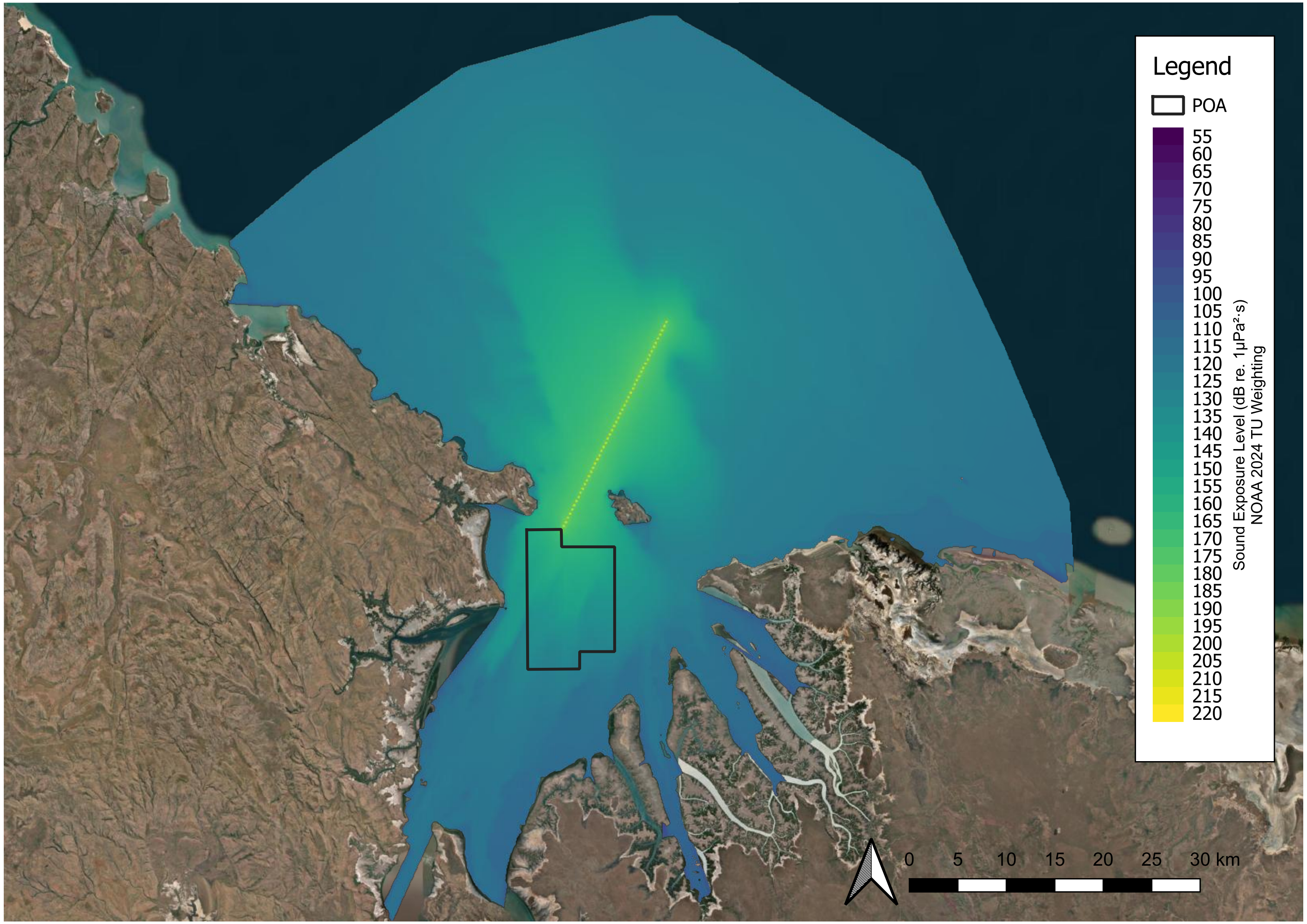


Figure 28 Sound exposure level with TU weighting from the SPV transiting into (and out of) the POA.

Appendix B – Contours showing disturbance region

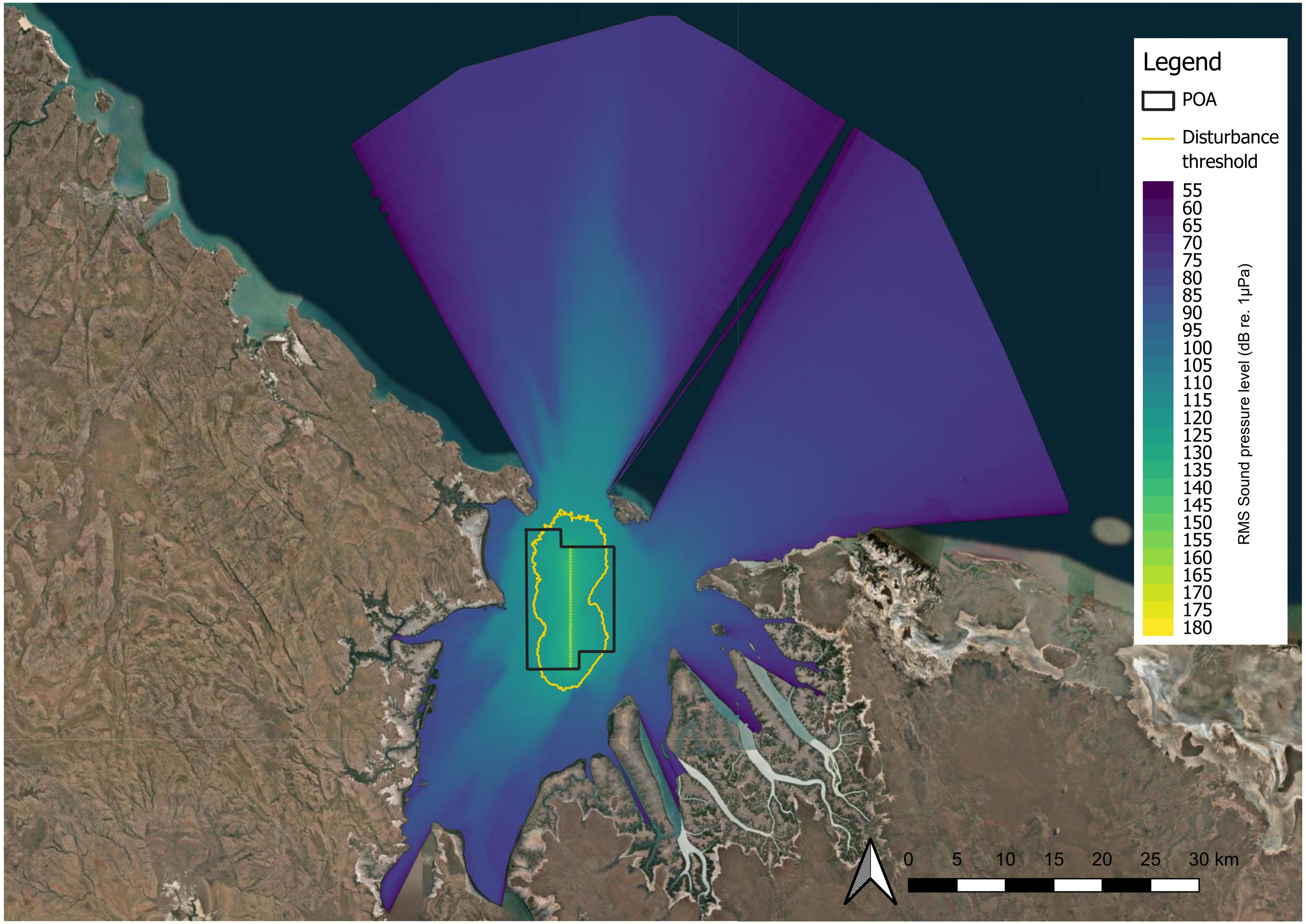


Figure 29 RMS sound pressure levels from the SPV performing a north-without sand loading transect without thrusters. The overlaid contour shows the setback distance for the HF-cetacean disturbance threshold.

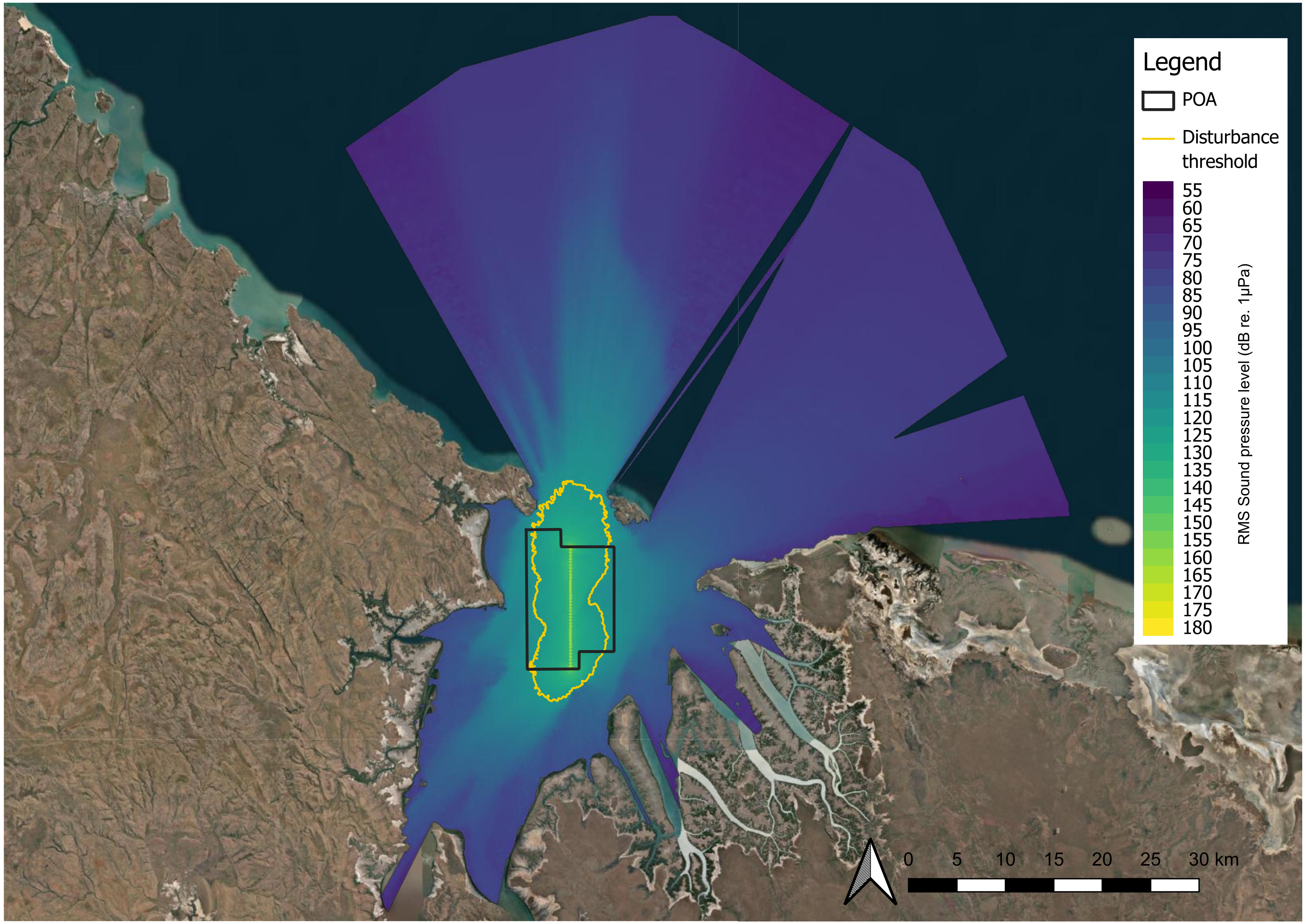


Figure 30 RMS sound pressure levels from the SPV performing a north-without sand loading transect with bow thrusters operating at the end of a transect. The overlaid contour shows the setback distance for the HF-cetacean disturbance threshold.

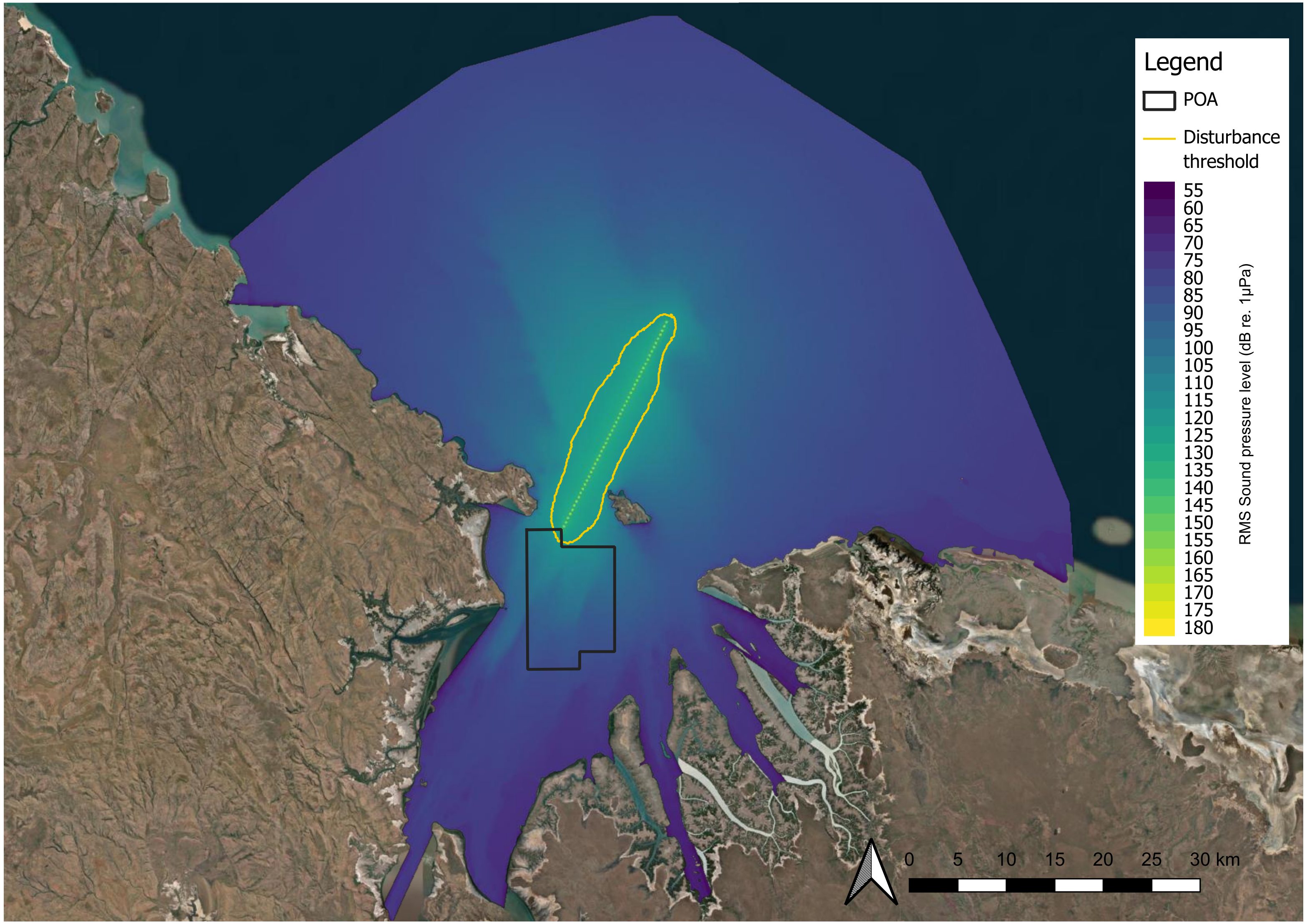


Figure 31 RMS sound pressure levels from the SPV transiting into (and out of) the POA. The overlaid contour shows the setback distance for the HF-cetacean disturbance threshold.

Appendix C – Boskalis capability sheet

CAPABILITY SHEET

MARINE MEGA-FAUNA
OBSERVATION & IMPACT PREVENTION

INTRODUCTION

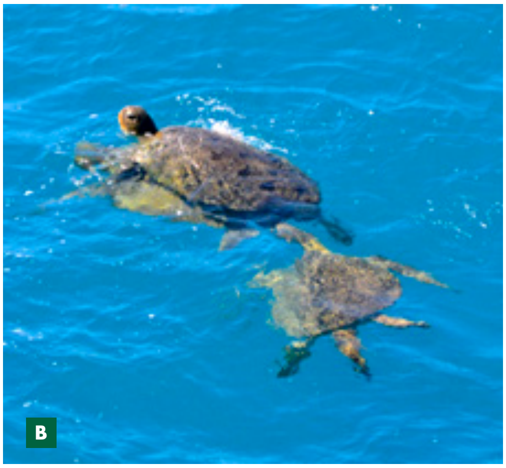
Boskalis' vessels, including dredgers and other work vessels, often operate in areas that host populations of marine mega-fauna (MMF) species, including, depending on the location, marine mammals (whales, dolphins, dugong, manatees and seals), marine turtles, crocodiles and sharks and rays. In certain countries some of these species may be protected under national laws.

MMF observation and impact prevention procedures during vessel operations are therefore a critical component of Boskalis' environmental protection efforts, aimed at preventing and minimizing potential vessel strikes on MMF and potential impacts of vessel-generated underwater noise on MMF.

As part of the company's values, which emphasize sustainability and biodiversity in every project, Boskalis applies extensive mitigation requirements, especially in the presence of important and protected MMF.

MMF observation involves the systematic monitoring for MMF in their natural habitats. Exclusion zones around the working vessel that are appropriate to the MMF species in the area are established, and these are continuously monitored for MMF activity. Avoidance procedures are followed to ensure that the vessel remains clear of MMF during operations. In some jurisdictions exclusion zones and observation and avoidance procedures are specified in guidelines or mandated by law.

A



B

A Humpback whale (*Megaptera novaeangliae*) at Barrow Island, Western Australia
B Mating Sea turtles near Barrow Island, Western Australia
C Short-beaked dolphin (*Delphinus delphis*) observed during MMF observation procedures (source: Gardline)

PRACTICES AND PROTOCOLS

C

In general, as a minimum Boskalis applies the following MMF prac tices and protocols during dredging and other relevant vessel operations:

- Pre-operations Surveys: Before operations begin, surveys are conducted to identify the presence of MMF in the area. This helps in planning the dredging activities to avoid critical habitats or times when MMF is most likely to be present.
- Monitoring During Operations: Trained observers, either on board the vessels or on nearby platforms, monitor the presence of MMF throughout the dredging other relevant vessel operation. The use of both visual and acoustic monitoring techniques allows for the detection of marine life even under poor visibility conditions or underwater.
- Implementing Mitigation Measures: If MMF is/are observed in the vicinity of vessel activities, specific mitigation measures are implemented. These can include changing the vessel's speed and/or direction, pausing operations, reducing vessel noise levels, or adjusting the location or timing of the activities to minimize disturbance.
- Reporting and Documentation: Observations and any mitigation actions taken are meticulously documented and reported to relevant authorities. This data contributes to the understanding of MMF behavior and the impact of dredging and other vessel operations, informing future guidelines and best practices.

TECHNOLOGIES AND TECHNIQUES

MMF observation can employ a variety of technologies to ensure effectiveness and minimize impacts. These technologies are designed to detect the presence of MMF in and around dredging and other marine work sites, enabling timely implementation of mitigation measures. Considering the variation in project requirements across clients and geographical locations, Boskalis adapts its MMF observation technologies accordingly.

D

As outlined above, often a combination of acoustic and visual monitoring is applied.

1. Visual observation of surfacing MMF species. Marine fauna observers (MFOs) use binoculars and thermal imaging cameras. The latter can detect marine mammals and some other MMF based on their body heat, which is particularly useful during low visibility conditions or at night.
2. Passive acoustic monitoring to detect vocalizations of marine mammals. Hydrophones and passive acoustic monitoring systems are used to detect marine mammal vocalizations. This is especially useful for species that are difficult to spot visually. Usually, these systems are mounted on a buoy.

INNOVATIONS – AUTOMATED MMF OBSERVATION

Boskalis is working on an innovation that allows for the automatic detection of certain MMF, and especially marine mammals, using AI technology. The aim of the system is more efficient and reliable MMF observation, with fewer interfaces and increased safety for MFO personnel.

The automated MMF observation system intends to automatically detect MMF and especially marine mammals using a set of visual and acoustic sensors. The data from these sensors is processed real-time through an algorithm using AI technology. This allows for real-time MMF detections and high accuracy species localization and identification. Imagery and data are transmitted in real-time to onshore office(s) and verification of the detections can be done onshore by a qualified MFO. Imagery and data is also backed-up to provide a permanent record of observations and can be further analysed for research and learning purposes.

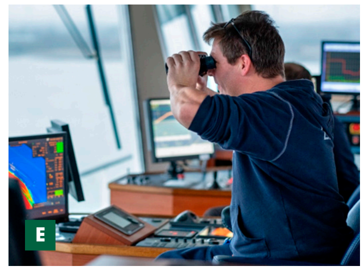
In future when the automatic system is fully proven it can reduce the need for MFOs on site / on vessels, thus improving safety, simplifying logistics and reducing greenhouse gas emissions through a reduced need for auxiliary vessels, as well as a reduced need to travel to and from work sites.

EXPERIENCES / EXAMPLE PROJECTS

Boskalis has extensive experience with MMF observation and impact prevention procedures on its marine projects, and below are some examples.

OFFSHORE WIND PROJECT - CHANGFANG XIDAO, TAIWAN

Between 2021 and 2023, Boskalis installed 62 pre-piled jackets for the 589 MW offshore wind farm Changfang Xidao in Taiwan, an area inhabited by the endangered Chinese White Dolphin (Sousa chinensis). To mitigate the potential impact of underwater noise from piling operations on these marine mammals, Boskalis employed surface-based visual observation and underwater passive acoustic monitoring (PAM) methods. These measures ensured compliance with environmental regulations, aiming to protect the dolphins from potential hearing damage by preventing their proximity to the piling location during operations.



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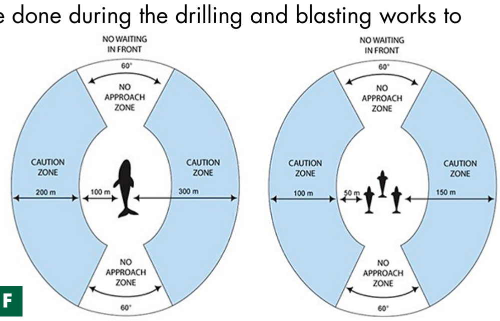
DREDGING PROJECT – KITIMAT, CANADA

Between 2018 and 2021, Boskalis worked on the dredging and remediation of a port basin in Kitimat, Canada, an area inhabited by Humpback Whales (*Megaptera novaeangliae*) and Killer Whales (*Orcinus orca*). The dredging scope involved sailing to and from an offshore disposal area with a Trailing Suction Hopper Dredger (TSHD). To mitigate the potential for vessel strikes in these animals, especially during sailing, 10 MFO's were employed.

Six Observers were stationed around the port basin, two on board of the bridge of the dredger, and another two on smaller vessels patrolling the port and following the dredger to the offshore disposal area. In case of any sightings, the dredging would be paused to avoid and minimize disturbance.

DREDGING PROJECT – DUQM, OMAN

As part of the development of a liquid bulk port facility in Duqm, Oman, Boskalis conducted extensive dredging works with a Cutter Suction Dredger (CSD) and several TSHD's between 2017 and 2019. To protect the local population of Humpback Whales, it was required to have a dedicated MFO on board each of the TSHDs to prevent collisions when the vessels were in transit between the port basin and offshore borrow and disposal areas. Inside the port, observations were done during the drilling and blasting works to remove a small area of rocky material. For this activity, another three MFOs were stationed on board the drilling and blasting barge, on the nearest jetty, and at the entrance to the port basin.



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D Passive Acoustic Monitoring during dredging works, Gabon.
E Trained crew observing from the bridge of the Boskalis dredger Causeway.
F Example of safe distances for whales and dolphins (source: www.dbca.wa.gov.au - Western Australia Department of Biodiversity Conservation & Attractions)

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